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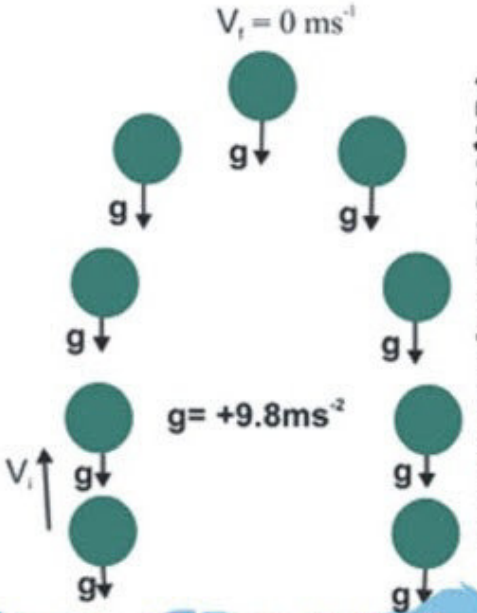
ELECTRODYNAMICS

RATES OF REACTION



STUDY GUIDE

ADMIRE MUGWINYI



VERTICAL PROJECTILE

GRADE

12

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CAPS updated Physical Sciences for grade 12
Study Guide

Admire Mugwinyi

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3 IN 1

(i) **SUMMARIZED** NOTES
(ii) PAST EXAM PAPERS
(iii) MEMORANDA

EXAMINATION TIPS

1. Prepare a personal timetable in the following format:

SUBJECT	14:30 - 15:00	15:00 - 15:30	15:30-16:00	16:30 - 17:00	17:00 - 17:30	17:30 - 18:30
MATHEMATICS						
PHYSICAL SCIENCES						
LIFE ORIENTATION						
ENGLISH						
GEOGRAPHY						

2. Study in a quiet place in order for you to understand
3. Join a study group
4. Practice a lot with past examination questions under examination conditions, and use memoranda to honestly mark your own work
5. When in an examination answer the questions starting with the one easier for you, and remember to answer each question on a new answer sheet
6. Time is precious in the exam room, if you seem to have completely forgotten an answer to a question then don't waste time - leave a gap and move to the next one. Come back to challenging questions after you are done with the ones that are easy to you
7. Remember SUCCESS IN AN EXAMINATION = TIME + ACCURACY

WISH YOU ALL THE BEST AS YOU PREPARE FOR YOUR MATRIC EXAMINATIONS

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TOPIC 1: LINEAR MOMENTUM AND IMPULSE

Linear momentum (p)

Definition Momentum is the product of mass and velocity of an object

- It is given by **p = mv** : Where **p** - momentum (kg.m.s^{-1}); **m** - mass (kg); **v** - velocity (m.s^{-1})
- A net force on an object causes a change in momentum
- If there is no net force on a system its momentum will not change (**p** will be conserved)

Vector nature of momentum

- Momentum is a vector quantity with the same direction as that of the object's velocity
- It is a measure of how easy or difficult it is to stop an object in motion e.g A huge truck is difficult to stop compared to a small car even though they have the same velocity
- The relationship of initial momentum ($\mathbf{p_i}$), final momentum ($\mathbf{p_f}$) and change in momentum($\Delta\mathbf{p}$) is given by: $\Delta\mathbf{p} = \mathbf{p_f} - \mathbf{p_i}$
- The following example illustrates the relationship of $\mathbf{p_i}$, $\mathbf{p_f}$ and $\Delta\mathbf{p}$ using vector diagrams

EXAMPLE 1

Draw momentum vector diagrams of the following situations:

(a) A truck collides head on with a small car with an initial momentum of 40000kg.m.s^{-1} in the forward direction and had a final momentum of 2000kg.m.s^{-1} still moving in the same direction

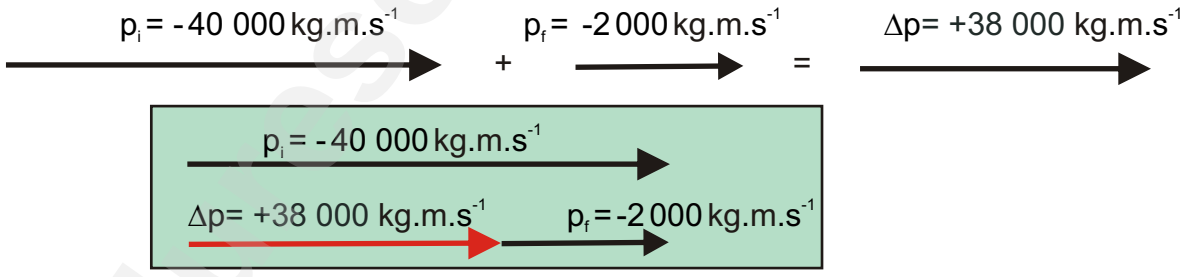
(b) A ball hits a wall with an initial momentum of 0.1kg.m.s^{-1} to the right and had a final momentum of 0.09 kg.m.s^{-1} to the left after the collision

(c) A metal spherical ball was thrown vertically upwards with an initial momentum of 0.1kg.m.s^{-1} which gradually decreases until it becomes zero at maximum height

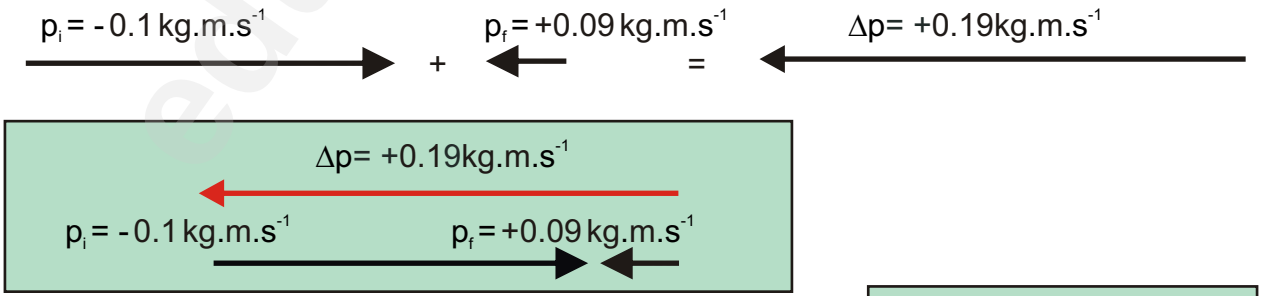
SOLUTION 1

MOTION TO THE LEFT IS POSITIVE, MOTION DOWNWARDS IS POSITIVE

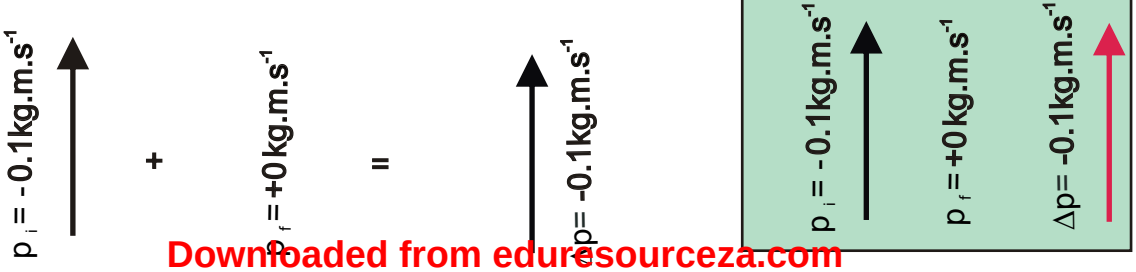
(a)



(b)



(c)



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Newton's Second Law of motion

> The net force acting on an object is equal to the rate of change of momentum

✎Newton's second law is expressed using the following equation below:

$$F_{net} = \frac{\Delta p}{\Delta t}$$

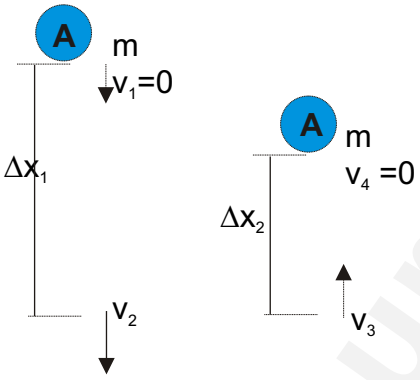
✎It can also be expressed as: $F_{net}\,\Delta t = \Delta p$

Where F_{net} → net force; Δt → change in time (reaction time); Δp → change in momentum; $F_{net}\Delta t$ → impulse

✎The motion of an object and its momentum only changes when a net force is applied
✎In other words a net force causes the change in motion of the object, and hence its momentum changes

Change in momentum in vertical direction

✎Suppose a ball A of mass ***m***kg is released from rest at a certain height h_1 to the ground and rebounded to another height h_2 as shown below:



✎To find change in momentum after collision with the floor let us do Sign Convention
✎**Sign Convention: Upward Motion Is Positive**

Data

Δx_1 = negative (displacement is downwards)
Δx_2 = positive (displacement is upwards)
g = negative (-9.8 ms^{-2})

v_1 = 0 ms^{-1} (released from rest)
v_2 = ?
v_3 = ?
v_4 =0 ms^{-1} (velocity at maximum height)

✎To calculate change in momentum when the ball leaves the ground we use the following equation:

$$\Delta p = m\,(v_f - v_i) \quad \text{where } v_i = v_2 \text{ and } v_f = v_3$$

✎We use equations of motion to find v_2 and v_3
✎Given the data available we should use $v_f^2 = v_i^2 + 2a\Delta x$
✎$v_2^2 = (0)^2 + 2g\Delta x_1$ and $(0)^2 = v_3^2 + 2g\Delta x_2$
✎$v_2 = \sqrt{2g\Delta x_1}$ and $v_3 = -\sqrt{2g\Delta x_2}$
✎$\Delta p = m\,(\sqrt{-2g\Delta x_2} - \sqrt{2g\Delta x_1})$

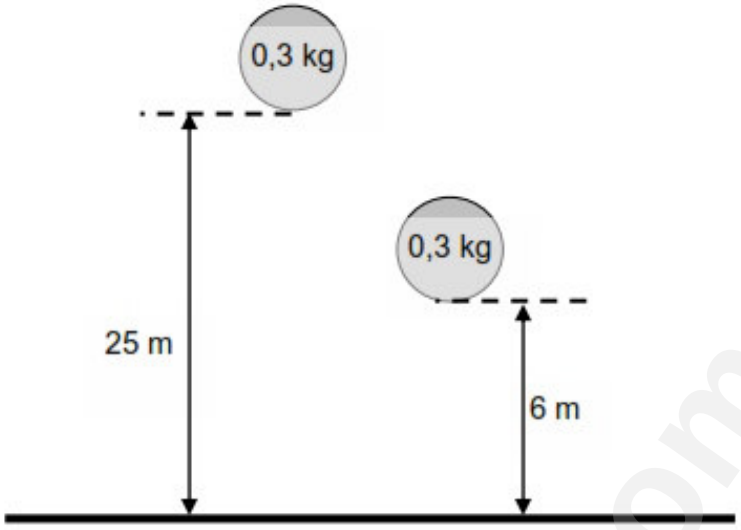
EXAMPLE 1 (FEB 2009/P1/Q5.1 - 5.2)

The roof of a tall building is 25 m above the ground. A rigid ball of mass 0,3 kg falls freely when dropped from the roof. It strikes the concrete floor on the ground with velocity v1. It bounces to a maximum vertical height of 6 m.

The ball was in contact with the floor for 0,9 s. Ignore the effects of friction.

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1.1 Calculate the velocity v1 when the ball first hits the floor. (3)

1.2 Calculate the change in momentum of the ball as a result of the collision. (7)

SOLUTION 1

1.1 **Sign Convention:** Assume downward motion is negative

Data Given

$v_i = 0ms^{-1}$ (from rest)
$a = -9.8ms^{-2}$
$\Delta x = -25m$
$v_f^2 = v_i^2 + 2a\Delta x$
$v_f^2 = (0)^2 + 2(-9.8)(-25)$

$v_f = \pm 22.13ms^{-1}$

Since the ball is falling $v_f = -22.13ms^{-1}$ (downward motion is negative)

Therefore $v_f = -22.13ms^{-1}$ downwards

1.2 Using equation of motion below we can initial velocity:

Sign Convention: Assuming downward motion is negative

Data Given

$v_f = 0ms^{-1}$ (to rest)
$a = -9.8ms^{-2}$
$\Delta x = 6m$

$v_f^2 = v_i^2 + 2a\Delta x$
$(0)^2 = v_i^2 + 2(-9.8)(6)$

$v_i = \pm 10.84ms^{-1}$

Since the ball is falling $v_i = +10.84ms^{-1}$ (downward motion is negative)

Therefore $v_i = 10.84ms^{-1}$ upwards

1.2 (CONTINUATION)

But $\Delta p = pf - pi$

And $P_f = mv_f$
$= (0.3)(10.84)$
$= 3.252$
$P_i = mv_i$
$= (0.3)(-22.13)$
$= -6.639$

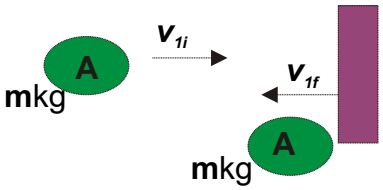
$\Delta p = 3.252 - (-6.639)$
$= +9.89N.s$ upwards

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Change in momentum in horizontal motion

✎Suppose a ball of mass ***m***kg is thrown horizontally to a wall with a velocity v_{1i} and rebounded with a velocity v_{1f}



✎Change in momentum **i**s determined after doing **Sign Convention** (momentum is a vector)

✎It is calculated using the formula:

change in momentum = final momentum - initial momentum

$$\Delta p = m_1v_f - m_1v_i$$

Where Δp - change in momentum v_i - initial velocity

v_f - final velocity m_1 - mass of the ball

EXAMPLE 2

Suppose the ball A in the above diagram had a velocity of $4m.s^{-1}$ and a mass of 0.6kg before it hits a wall, and a velocity of $3m.s^{-1}$ after it rebounds. What is change in momentum of the ball?

SOLUTION 2

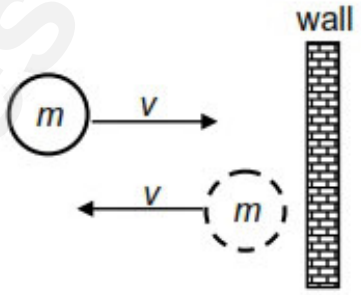
Let our **Sign Convention** be: Motion To The Right Is Positive

$\Delta p = m_1v_f - m_1v_i$

Δp = (0.6)(-3) - (0.6)(4) = -4.2N.s Or 4.2N.s to the left

EXAMPLE 3 (NOV 2010/P1/Q 2.2)

3 A ball of mass m strikes a wall perpendicularly at a speed v. Immediately after the collision the ball moves in the opposite direction at the same speed v, as shown in the diagram below.



Calculate the magnitude of the change in momentum of the ball?

SOLUTION 3

Consider motion to the right to be positive: **Before collision:** $m_1 = m$ $v_1 = v$ **After collision** $m_2 = m$ $v_2 = -v$	$\Delta p = p_f - p_i$ $\Delta p = (m)x(-v) - (mv)$ $= -mv - mv$ $= 2mv$

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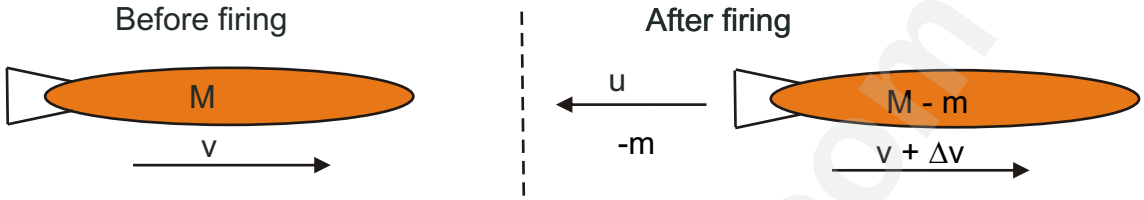
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FURTHER PROBLEMS ON MOMENTUM CHANGE

(a) Increasing velocity

- In previous problems we calculated Δp when the object's mass remained constant
- Suppose a net force acts on an object and its mass decreases whilst its velocity increases in the direction of motion, it is possible to calculate the object's change of momentum in such a situation. One example of such a situation is the 2nd stage rocket engine when it is firing

Rocket engine firing



- A net force driving a rocket forward causes an increase in the velocity of the rocket
- Rocket propulsion is an example of Newton's Third Law which states that: For every action force there is always an equal but opposite reaction force.
- A rocket exert a force on the gases to achieve the relative exit velocity for a given mass of gas
- The gases will exert an equal but opposite force onto the rocket, causing an increase in the velocity of the rocket
- Momentum of the rocket at time **t(s)** is $(M - \mathbf{m})v$
- Momentum of the rocket at time **(t + Δt)(s)** is $(M - \mathbf{m})(v + \Delta v)$
- Momentum of gases at time **t(s)** is $\mathbf{m}v$
- Momentum of gases at time **(t +Δt)(s)** is $\mathbf{m}(v - u)$

NOTE
Velocity of the rocket increased from v to (v + Δv) as its mass decreased from M to (M - m)

Change in momentum of the rocket

$$\Delta p = p_f - p_i$$
$$= (M - m)(v + \Delta v) - (M - m)v$$
$$= \Delta v(M - m)$$

Change in momentum of gas

$$\Delta p = p_f - p_i$$
$$= \mathbf{m}(v - u) - \mathbf{m}v = - \mathbf{m}u$$

- The rocket gains momentum due to its positive sign, however the gas loses momentum due to its negative sign

EXAMPLE 4

A rocket which is in deep space and initially at rest relative to an inertial reference frame, has a mass of 2.55×10^5 kg of which 1.81×10^5 kg is fuel. The rocket engine is then fired for 250s during which 1.2×10^5 kg of fuel is consumed. The speed of the rocket after firing is $v_f = 2.78 \times 10^9 ms^{-1}$ in the forward direction. Calculate the change in momentum of the rocket after 250s.

SOLUTION 4

Sign Convention: Assume forward motion is negative

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Given Data
$M = 2.55 \times 10^5$ kg $\quad v_i = 0 ms^{-1}$
$m_{250} = 1.2 \times 10^5$ kg $\quad \Delta t = 250s$
$v_f = -2.78 \times 10^9 ms^{-1}$

$\Delta p = \Delta v(M - m)$ .....(i)

But $\Delta v = v_f - v_i$
$= (-2.78 \times 10^9) - (0)$
$= -2.78 \times 10^9 ms^{-1}$

Therefore now we can substitute values in equation (i):

$\Delta p = \Delta v(M - m)$
$= (-2.78 \times 10^9)(2.55 \times 10^5 - 1.2 \times 10^5)$
$= -3.75 \times 10^{14}$ N.s
$= 3.75 \times 10^{14}$ N.s , forwards

(B) Decreasing velocity
- Suppose a net force acts on an object and its velocity decreases, we can calculate the object's change of momentum in such a situation
- Example of a decreasing velocity situation is when brakes are applied

Applied brakes
- A change in momentum occurs when a moving car comes to a stop
- Braking force is that net force which decreases velocity and cause a change in momentum of a car in this case
- Momentum changes either when mass changes or when velocity changes
- When brakes are applied it is only velocity which changes
- We use Newton's Second Law to calculate change in momentum when brakes are applied

EXAMPLE 5
A car has a mass of 2000kg and is traveling at a velocity of 20m/s. At a stop sign, the driver applied brakes and stopped it in 30 seconds. Calculate the change in momentum.

SOLUTION 5

Data
m = 2000kg
$v_i = 20$m/s
$v_f = 0$m/s
$\Delta t = 30$s
$\Delta p = ?$
$\Delta p = p_f - p_i$

Initial momentum(p_i) = mv_i
$= 2000 \times 20$
$= 40\,000$ kgm/s

Final momentum (p_f) = mv_f
$= 2000 \times 0$
$= 0$ kgm/s

Change in momentum = Δp
$= p_f - p_i$
$= 0 - 40\,000$
$= -40\,000$ kgm/s
$= 40\,000$ kgm/s in the reverse
(**momentum is being lost**)

(c) When a net force reverses direction of motion of an object
Suppose a net force acts on an object and it reverses its direction of motion, we can calculate the object's change of momentum in that case
- e.g a soccer ball kicked back in the direction it came from

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Law of conservation of linear momentum

It states that:

Momentum of a system is conserved when no net external force act on the system.

✎Net external force causes momentum to change, so if net force is zero momentum in a closed system will remain constant (conserved.)

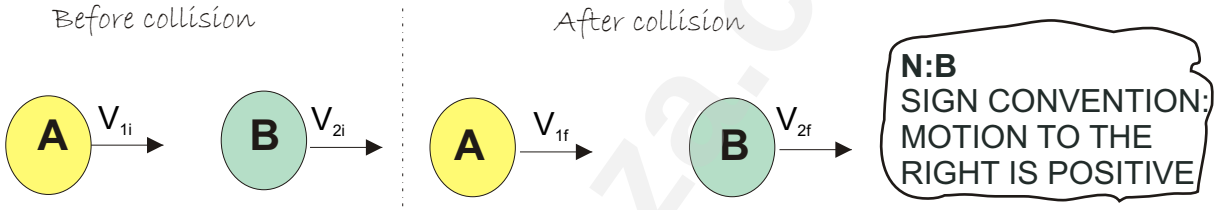
✎N:B If objects are moving either in the same direction or in opposite directions **do Sign Convention first** (velocity is a vector)

✎In the examples below let us take the following **Sign Convention:**
MOTION TO THE RIGHT IS POSITIVE

What is a system? What is an external force?

EXAMPLE 1

✎The following diagram helps to understand the Law of conservation of linear momentum when two bodies A and B move in the same direction before and after collision:



✎The overall equation for the law of conservation of linear momentum in the above diagram is:

$$m_1v_{1i} + m_2v_{2i} = m_1v_{1f} + m_2v_{2f}$$

Following our Sign Convention above

v_{1i} is positive	v_{1i} is positive
v_{2i} is positive	v_{2i} is positive

Suppose ball A and B had velocities of $3m.s^{-1}$ and $2m.s^{-1}$ before collision, and ball A had a velocity of $1.5m.s^{-1}$ then velocity of ball B after collision will be calculated by applying the Law Of Conservation Of Linear Momentum together with our Sign Convention as follows:
(NOTE: mass of ball A is 1kg and mass of ball B is 2kg)

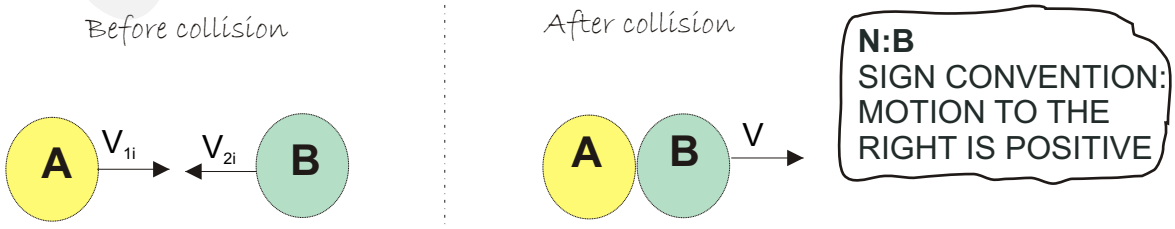
✎Law Of Conservation Of Linear Momentum: $m_1v_{1i} + m_2v_{2i} = m_1v_{1f} + m_2v_{2f}$

✎After using Sign Convention: $v_{1i} = +3m.s^{-1}$ $v_{1f} = +1.5m.s^{-1}$ $m_1 = 1kg$; $m_2 = 2kg$
$v_{2i} = +2m.s^{-1}$ $v_{2f} = ?$

✎Substituting: $(1)(3) + (2)(2) = (1)(1.5) + (2)(v_{2f})$ Therefore $v_{2f} = 2.75m.s^{-1}$ to the right

EXAMPLE 2

✎Suppose ball A and B again moved from opposite directions before collision, collide and stick together and moved in the same direction as shown in the diagram below:



✎Now our overall equation is still: $m_1v_{1i} + m_2v_{2i} = m_1v_{1f} + m_2v_{2f}$

✎But since they stuck together and moved in the same direction after collision then $v_{1f} = v_{2f} = v$ our overall equation will be simplified to $m_1v_{1i} + m_2v_{2i} = (m_1 + m_2)v$

✎Following our Sign Convention above:

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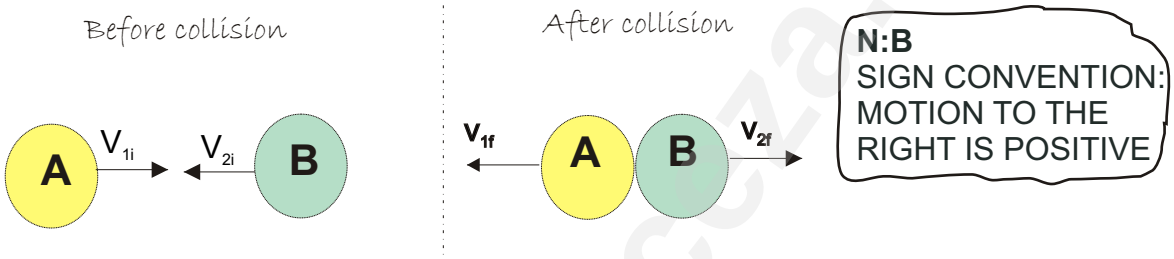
v_{1i} is positive v_{1f} is positive
v_{2i} is **negative** v_{2f} is positive

Suppose ball A and B had velocities of $3m.s^{-1}$ and $2m.s^{-1}$ before collision from opposite directions, and if they collide and stick together and moved in the same directions then their common velocity after collision will be calculated by applying the Law Of Conservation Of Linear Momentum together with our Sign Convention as follows:
(NOTE: mass of ball A is 2kg and mass of ball B is 1kg)

- Law Of Conservation Of Linear Momentum: $m_1v_{1i} + m_2v_{2i} = (m_1 + m_2)v$
- After using Sign Convention: $v_{1i} = +3m.s^{-1}$ $v_{1f} = ?$ $m_1 = 2kg$; $m_2 = 1kg$
  $v_{2i} = -2m.s^{-1}$ $v_{2f} = ?$
- Substituting: $(2)(3) + (1)(-2) = (2+1)v$
- Therefore $v = 1.33\ m.s^{-1}$ to the right

EXAMPLE 3

- Suppose ball A and B again moved from opposite directions before collision, collide and bounced back in different directions as shown in the diagram below:



- Now our overall equation is still: $m_1v_{1i} + m_2v_{2i} = m_1v_{1f} + m_2v_{2f}$
- Following our Sign Convention above:
  v_{1i} is positive v_{1f} is **negative**
  v_{2i} is **negative** v_{2f} is positive

Suppose ball A and B had velocities of $3m.s^{-1}$ and $2m.s^{-1}$ before collision from opposite directions, and if the velocity of A after collision is $1.5m.s^{-1}$ then the velocity of B after collision will be calculated by applying the Law Of Conservation Of Linear Momentum together with our Sign Convention as follows:
(NOTE: mass of ball A is 2kg and mass of ball B is 1kg)
Law Of Conservation Of Linear Momentum: $m_1v_{1i} + m_2v_{2i} = m_1v_{1f} + m_2v_{2f}$

- After using Sign Convention: $v_{1i} = +3m.s^{-1}$ $v_{1f} = -1.5\ m.s^{-1}$ $m_1 = 2kg$; $m_2 = 1kg$
  $v_{2i} = -2m.s^{-1}$ $v_{2f} = ?$

Substituting: $(2)(3) + (1)(-2) = (2)(-1.5) + (1)(v_{2f})$

- Therefore $v_{2f} = 7\ m.s^{-1}$ to the right

DEFINITION OF TERMS:

1. **A Component** - part of the system
2. **A System** - a set of interacting components forming one piece
3. **Internal forces** - forces between two or more components of a system
4. **External forces** - forces between a component of the system and an object Outside the system
5. **Isolated System** - a system which do not interact with external forces, that is - it has no net force acting on it

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Impulse

- Impulse is defined as the product of net force and contact time
- Mathematically impulse is given by:

$$\text{Impulse} = F_{net}\Delta t$$

- Impulse is equivalent to the change in momentum
- The relationship between impulse and momentum is called **Impulse - momentum theorem**
- It is determined using the following equation:

$$F_{net}\Delta t = \Delta p$$

Where

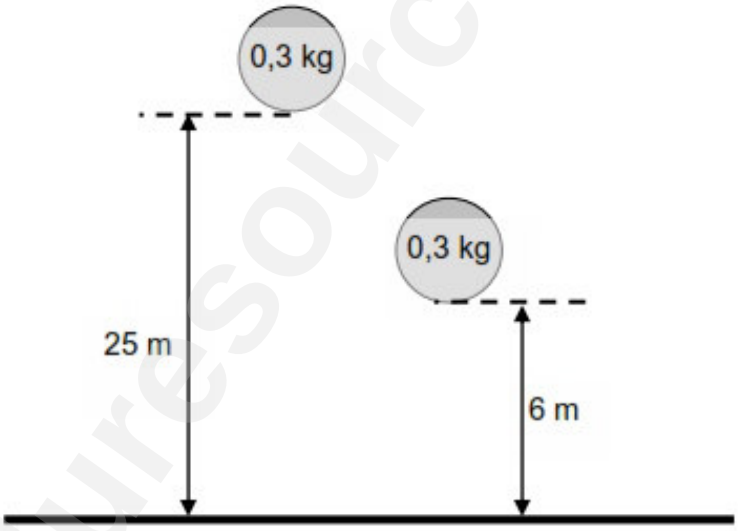
F_{net} → net force
Δt → change in time (reaction time)
Δp → change in momentum
$F_{net}\Delta t$ → impulse

- Impulse is a vector quantity

EXAMPLE 1 (FEB 2009/P1/Q5.3)

The roof of a tall building is 25 m above the ground. A rigid ball of mass 0,3 kg falls freely when dropped from the roof. It strikes the concrete floor on the ground with velocity v1. It bounces to a maximum vertical height of 6 m.

The ball was in contact with the floor for 0,9 s. Ignore the effects of friction.



Calculate the magnitude of the net force exerted on the ball. (3)

SOLUTION 1

Take upward motion as positive:
$F_{net}\Delta t = \Delta p$

$$F_{net} = \frac{\Delta p}{\Delta t} = \frac{+9.89}{0.9} = +10.99\text{N upwards}$$

Take upwards as negative:
$F_{net}\Delta t = \Delta p$

$$F_{net} = \frac{\Delta p}{\Delta t} = \frac{-9.89}{0.9} = -10.99\text{N upwards}$$

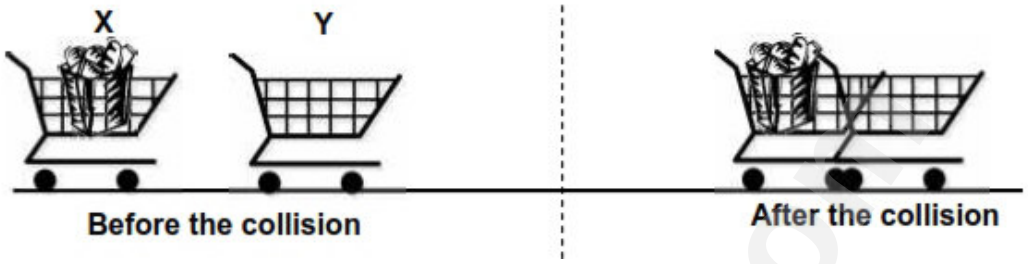
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EXAMPLE 2 (MAR 2011/P1/Q4.3)

Two shopping trolleys, **X** and **Y**, are both moving to the right along the same straight line. The mass of trolley **Y** is 12 kg and its kinetic energy is 37,5 J.

Trolley **X** of mass 30 kg collides with trolley **Y** and they stick together on impact. After the collision, the combined speed of the trolleys is 3,2 $m \cdot s^{-1}$. (Ignore the effects of friction.)



2.1 Calculate the speed of trolley X before the collision. (5)

During the collision, trolley X exerts a force on trolley Y. The collision time is 0,2 s.

2.2 Calculate the magnitude of the force that trolley X exerts on trolley Y. (4)

SOLUTION 2

2.1 $\sum p(\text{before collision}) = \sum p(\text{after collision})$
$(30)v_i + (12)(2.5) = (30 + 12)(3.2)$
$v_i = 3.48 ms^{-1}$

2.2 $F_{net} \Delta t = \Delta p$
$F_{net} (0.2) = 30(3.2 - 3.48)$
$F_{net} = -42N$
Therefore magnitude of $F_{net} = 42N$

APPLICATION OF IMPULSE

(a) Air bags

- When an accident happens the air bag prolongs time taken by the passenger to come to rest
- According to Newton's Second Law Of Motion ($F_{net} \Delta t = \Delta p$), when reaction time increases the net force on the passenger will be reduced (net force is inversely proportional to reaction time)
- Hence severe injuries and death will be minimized

(b) Seat belts, crumple zone, arrestor beds

- The same explanation for air bags applies to seat belts, crumple zone and arrestor beds

Elastic and inelastic collisions

Elastic collisions

- When total kinetic energy before collision equals to total kinetic energy after collision, then we say the collision is elastic
- Total kinetic energy of a system is conserved, that is,

$$\frac{1}{2}M_1v^2_{1i} + \frac{1}{2}m_2v^2_{2i} = \frac{1}{2}m_1v^2_{1f} + \frac{1}{2}m_2v^2_{2f}$$

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Inelastic collisions

✎When total kinetic energy before collision is not equal to total kinetic energy after collision, then we say the collision is inelastic.

✎Total kinetic energy of the system is not conserved, that is,

$$½M_1v^2_{1i} + ½m_2v^2_{2i} \neq ½m_1v^2_{1f} + ½m_2v^2_{2f}$$

EXAMPLE 3

Is the collision between two shopping trolleys in Example 2 elastic or inelastic? Justify your answer by a relevant calculation.

SOLUTION 3

Before collision

Kinetic energy of trolley X

$½ m_xv^2_{xi} = ½ (30)(3.48)^2 = 181.7J$

Kinetic energy of trolley Y

$½ m_yv^2_{yi} = 37.5J$

After collision

Kinetic energy of trolley X

$½ m_xv^2_{xf} = ½ (30)(3.2)^2 = 153.6J$

Kinetic energy of trolley Y

$½ m_yv^2_{yf} = ½ (12)(3.2)^2 = 61.44J$

Total kinetic energy before collision:

$½ m_xv^2_{xi} + ½ m_yv^2_{yi} = 181.7 + 37.5 = 219.2J$

Total kinetic energy after collision :

$½ m_xv^2_{xf} + ½ m_yv^2_{yf} = 153.6 + 61.44 = 215.04J$

Total kinetic energy before collision ≠ Total kinetic energy after collision

$219.2 \neq 215.04$

Therefore the collision is **inelastic**

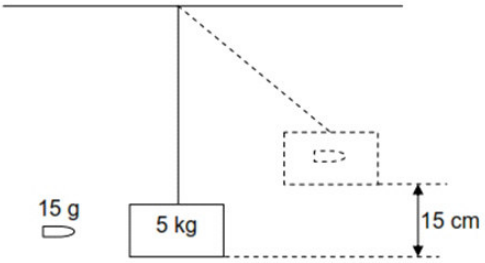
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TASK 1

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QUESTION 1 (FEB 2010/P1/Q4)

During an investigation a police officer fires a bullet of mass 15 g into a stationary wooden block, of mass 5 kg, suspended from a long, strong cord. The bullet remains stuck in the block and the block-bullet system swings to a height of 15 cm above the equilibrium position, as shown below. (Effects of friction and the mass of the cord may be ignored.)



1.1 State the law of conservation of momentum in words. (2)

1.2 Use energy principles to show that the magnitude of the velocity of the block-bullet system is 1,71 ms^{-1} immediately after the bullet struck the block. (3)

1.3 Calculate the magnitude of the velocity of the bullet just before it strikes the block. (4)

1.4 The police officer is pushed slightly backwards by the butt of the rifle, which he is holding against his shoulder, whilst firing the rifle. Use the relevant law of motion to explain why this happens. (3)

[12]

QUESTION 2 (NOV 2011/P1/Q4)

While travelling at 40 m·s-1, the thief's car of mass 1 000 kg, collides head-on with a truck of mass 5 000 kg moving at 20 m·s-1. After the collision, the car and the truck move together. Ignore the effects of friction



2.1 State the law of conservation of linear momentum in words. (2)

2.2 Calculate the velocity of the thief's car immediately after the collision. (6)

2.3 Research has shown that forces greater than 85 000 N during collisions may cause fatal injuries. The collision described above lasts for 0,5 s.

Determine, by means of a calculation, whether the collision above could result in a fatal injury (5)

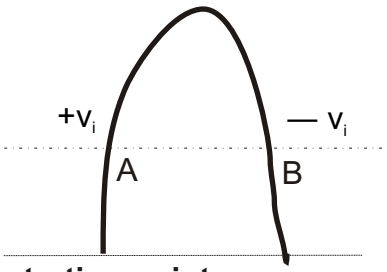
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TOPIC 2: VERTICAL PROJECTILE MOTION

CHARACTERISTICS OF PROJECTILE

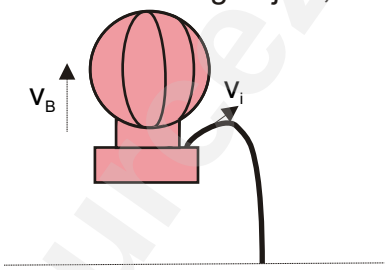
- The only force acting on a projectile in free fall is gravitational force (we assume friction air resistance are negligible)
- Gravitational acceleration is constant in its entire motion, and it always acts downwards whether the projectile is going upwards or downwards
- At maximum height a projectile has a velocity of zero
- The time taken by a projectile to reach maximum height equals to the time it takes from maximum height back to its starting point
- Its upward velocity as it passes through a point is equal in magnitude but different in direction to its downwards velocity as it passes through the same point.



If a projectile was going up with a velocity of $+v_i$ at point A, it must have a velocity of $-v_i$ as it pass point B downwards

- When an object is dropped from another moving object, its initial velocity is equal to the velocity of the moving object

suppose a ball is dropped from a balloon moving vertically upwards with a constant velocity of v_B then the initial velocity of the ball $v_i = v_B$



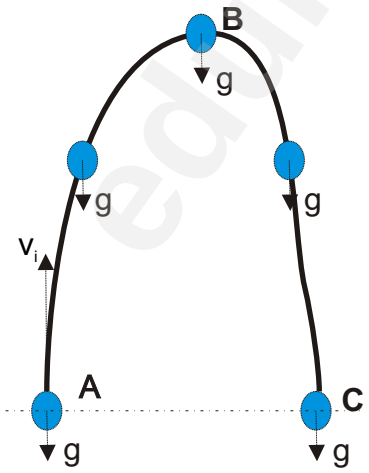
Equations of motion

- There are four equations of motion that we will use in this topic

(i) $v_f = v_i + a\Delta t$ (ii) $v_f^2 = v_i^2 + 2a\Delta x$ (iii) $\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2$ (iv) $\Delta x = \frac{1}{2}(v_i + v_f)\Delta t$

SIGN CONVENTION

- Before doing any vertical projectile motion calculations it is imperative that we must do sign convention



the diagram above shows a projectile thrown upwards, it shows the path it takes until it returns to its original position

- For our sign convention we can either take upward motion as positive or downward motion as positive

Taking upward motion as positive

(a) gravitational acceleration (g)
(i) When a body is going up - g is negative
(ii) When a body is going down - g is negative
(b) Velocity (v)
(i) When a body is going up - v is positive
(ii) When a body is going down - v is negative
(c)Displacement Δx
(i) When displacement is below point of launching a projectile - Δx is negative
(ii) When displacement is above point of launching a projectile - Δx is positive

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WORKED EXAMPLE

A boy throw a ball vertically upwards in the air with a velocity of 3m.s^{-1} and catches it at the point of launching.

1.1 Calculate the maximum height the ball reached above the boy's hand.

1.2 Calculate the time taken by the ball during its entire motion in the air

WORKED SOLUTION

Assume upward motion positive:

Data Given: $v_i = +3m.s^{-1}$, $v_f = 0\ m.s^{-1}$ (maximum height) , $g = -9.8m.s^{-2}$

1.1 Use $v_f^2 = v_i^2 + 2a\Delta x$

Substituting values into the equation we have: $(0)^2 = (+3)^2 + 2(-9.8)\ \Delta x$

Therefore $\Delta x = 0.46m$

1.2 Use $v_f = v_i + a\Delta t$

Substituting values: $(-3) = (3) + (-9.8)\Delta t$

Therefore $\Delta t = 0.61s$

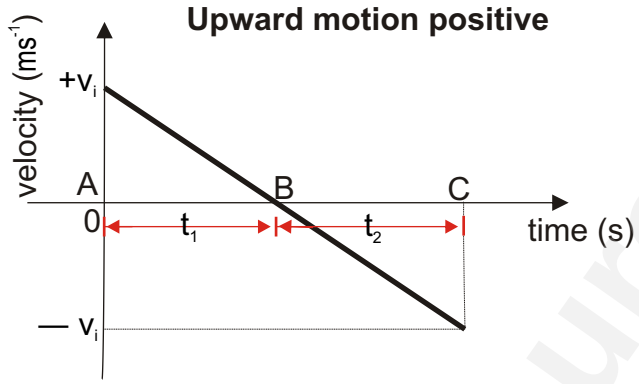
GRAPHS

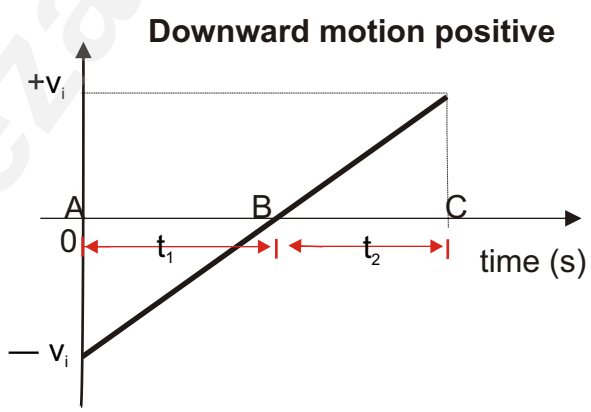
- When drawing vertical projectile motion graphs we use SIGN CONVENTION
- We will use both sign conventions in the examples below to draw graphs (downward motion positive and upward motion positive)

(a) WHEN A BALL IS THROWN VERTICALLY UP AND RETURN TO ITS STARTING POINT

- Suppose a projectile is thrown vertically upwards and then return to its original position, the following are the graphs to show its motion:

(i) Velocity-Time graph

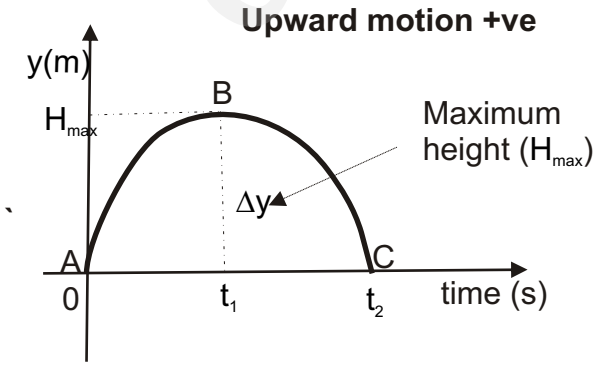




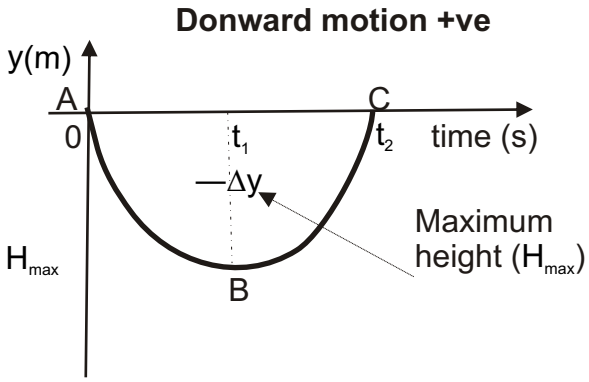
Explaining the velocity - time graph above assuming downward motion positive:

- Time from A (starting point) to B(greatest height) is t_1 seconds, is equal to time from B(greatest height) to C(original position) which is t_2 seconds.
- According to our sign convention initial velocity is positive, so we start drawing our graph from the positive direction
- Velocity of a projectile decreases as it goes up due to air resistance until it becomes zero at maximum height . From maximum height it increases from zero until it reaches the magnitude of its initial velocity in the opposite direction (— v_i)
- The graph is a straight line with a decreasing gradient showing that velocity decreased from a magnitude of v_i m/s in the positive direction (+v_i m/s) to 0 m/s , and then increased from 0m/s to its initial velocity of magnitude v_i in the negative direction (— v_i m/s)

(ii) Position-Time graph



Diag 1



Diag 2

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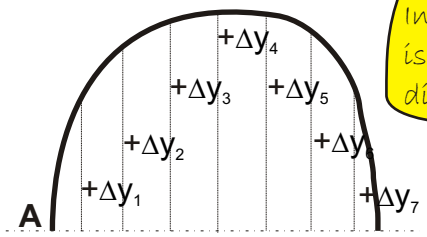
Explaining position - time graph above assuming upward motion is positive:

✎Position - time graph in *Diag 1* above shows the path followed by a projectile, therefore its shape is similar to that of motion of the projectile.

✎At every point above the starting point displacement is positive In *Diag 1*

✎Hence when the position - time graph is plotted it will have the shape of projectile motion in the positive direction.

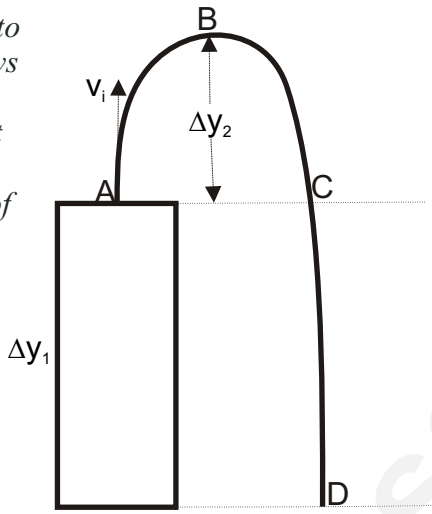
✎Referring again to *Diag 1* we see that displacement increases from zero at A and becomes maximum at B, however from B it decreases until it becomes zero(its point of launch) as shown in the diagram below:



In the diagram on the left, when a projectile is above the point of launch its displacement is positive

A projectile thrown from a cliff

The diagram to the right shows motion of a projectile that was launched from the top of a cliff.



✎Suppose a projectile was thrown from edge of a cliff. And again suppose the time from A to D (time for the whole motion) is t_G and time from A to B (time to reach maximum height) is t_H then to find the initial velocity v_i we should consider the following points:

(i) Displacement cancels at C, therefore the total displacement from A to C is zero (displacement is a vector).Hence displacement for the whole motion becomes $-\Delta y_1$

(ii) Velocity at B(maximum height) is zero

(ii) Velocity at C is $-v_i$

WORKED EXAMPLE

If a projectile is launched from the top of a 20m cliff, and it takes 5s to reach the ground, calculate initial velocity of the projectile. (N:B Use diagram on the left)

SOLUTION

Assume upward motion is positive:

Given Data: $\Delta y_1 = -20m$, $t_G = 5s$, $g = -9.8 m.s^{-2}$

✎Using the equation $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$ we can substitute the values as follows:

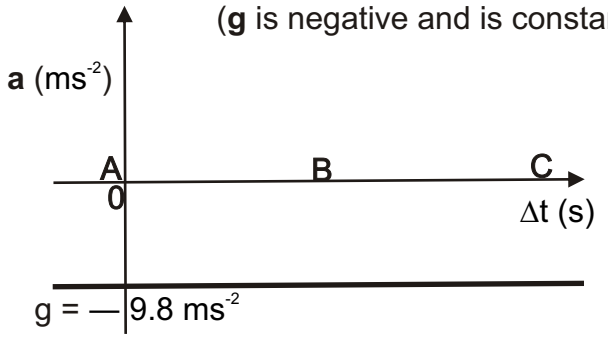
$$-20 = v_i(5) + \frac{1}{2}(-9.8)(5)^2$$

✎We can now find v_i by making it subject of formula

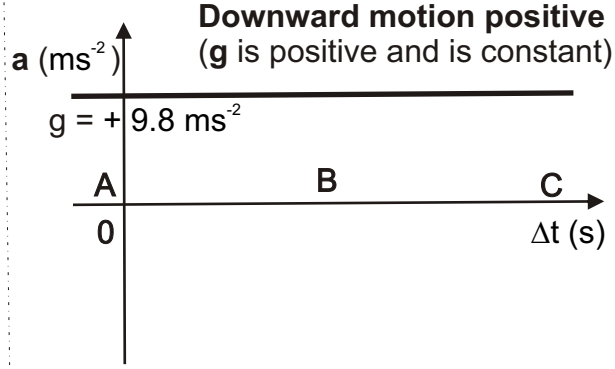
✎ $v_i = 20.5\ m.s^{-1}$

iii) Acceleration - Time graph

Upward motion positive
(**g** is negative and is constant)



Downward motion positive
(**g** is positive and is constant)



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Explaining Acceleration - time graph above assuming upward motion is positive:

✎When a projectile goes up from A to B, gravitational acceleration is negative

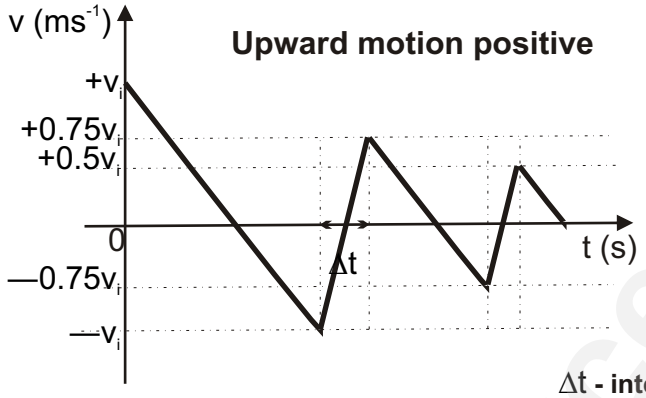
✎As the projectile falls from B to C , gravitational acceleration will still be negative: that's why we have a continuous straight line on the negative (**g** is constant whether the projectile goes up or down)

(b) WHEN A BALL REBOUNDED SEVERAL TIMES UNTIL IT STOPS

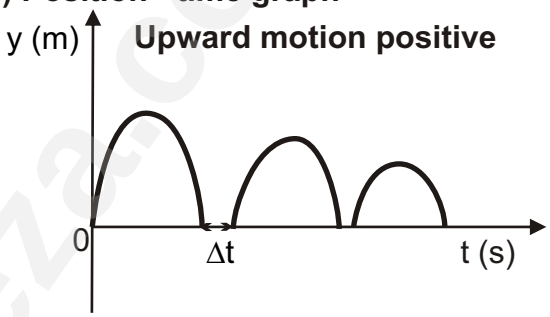
✎A projectile was fired vertically upwards from the ground with an initial velocity v_i and reached its maximum height. It returned to its point of launch where it hit the ground and rebounced with a velocity $0.75v_i$. A drop in velocity from v_i to $0.75v_i$ shows that the collision between the floor and the ball was inelastic, kinetic energy was not conserved. Again it reached another maximum height and fell to the ground where it rebounced with a velocity of $0.5v_i$. Finally it reached another maximum height and fell to the ground where it stopped.

✎We can represent this motion using the following graphs:

(i) Velocity - time graph

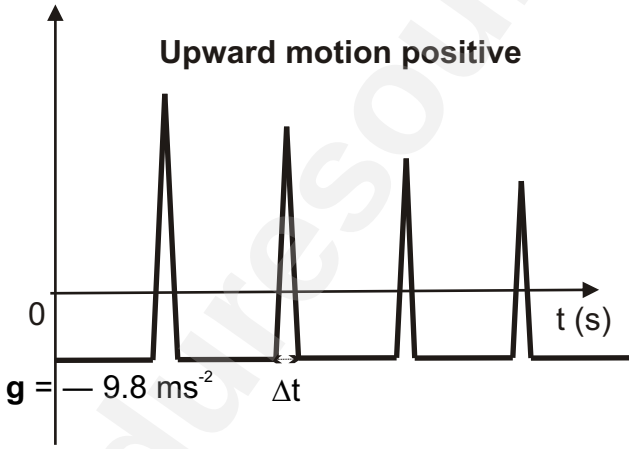


(ii) Position - time graph



Δt - interaction time of the ball with the floor

(ii) Acceleration - Time graph



Acceleration - time graph

✎gravitational acceleration always act vertically downwards

✎The diagram on the left shows an acceleration - time graph that is a straight line except at very short time interval where the ball experiences a huge reaction force from the ground in the upward direction

✎This explains sharp peaks on the graph

✎When the ball is in the air, moving either up or down, its acceleration is a constant value of — 9.8 $m.s^{-2}$ acting vertically downwards until it hits the ground. As soon as the ball loses contact with the ground its acceleration changes direction and becomes much bigger than $9.8 m.s^{-2}$. The huge value of acceleration the ball has after losing contact with the ground is attributed to a huge reaction force from the ground in a very small time interval Δt. However it decreases until it becomes a constant value of — 9.8 $m.s^{-2}$ acting vertically downwards. This happens in each and every bounce of the ball until it eventually stops.

WORKED EXAMPLE

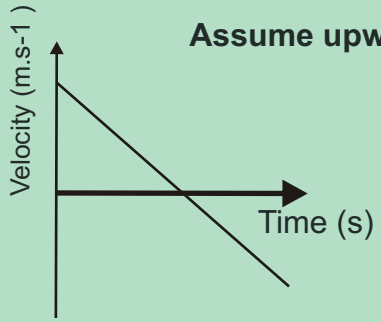
A stone is thrown vertically upwards and returns to the thrower's hand after a while. Draw a velocity-time graph that best represents the motion of the stone.

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WORKED SOLUTION

Assume upward motion positive



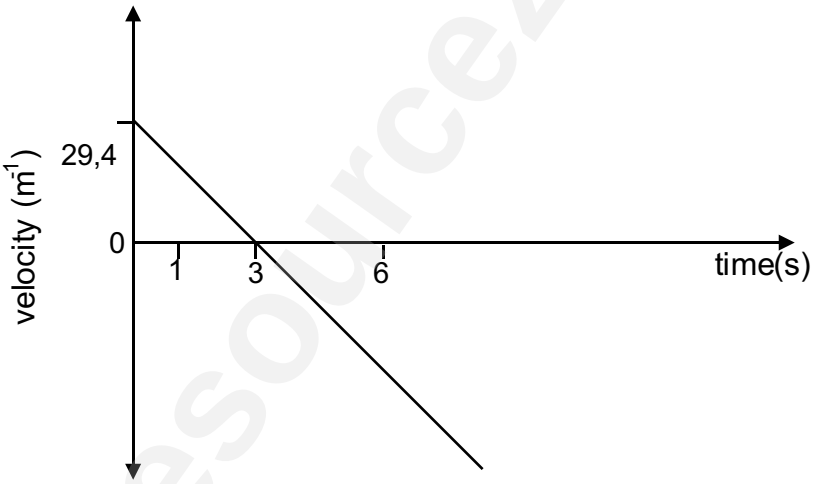
EXAM TYPE WORKED EXAMPLES

QUESTION 1 (NOV 2010/ P1/Q3)

1.1 Use the graph to determine the time that the projectile takes to reach its maximum height. (A calculation is not required.) (1)

1.2 Calculate the maximum height that projectile X reaches above the ground. (4)

1.3 Sketch the position-time graph for projectile X for the period t = 0 s to t = 6 s. USE THE EDGE OF THE CLIFF AS ZERO OF POSITION.



Indicate the following on the graph:

- The time when projectile X reaches its maximum height
- The time when projectile X reaches the edge of the cliff (4)

1.4 One second (1 s) after projectile X is fired, the man's friend fires a second projectile Y upwards at a velocity of 49 m·s -1 FROM THE GROUND BELOW THE CLIFF. The first projectile, X, passes projectile Y 5,23 s after projectile X is fired. (Ignore the effects of friction.)

Calculate the following:

1.4.1 The velocity of projectile X at the instant it passes projectile Y (5)

1.4.2 The velocity of projectile X RELATIVE to projectile Y at the instant it passes projectile Y (5)

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SOLUTION 1

1.1 3 seconds / 3 s

1.2

Assume downward motion positive

From edge of cliff to maximum height:

$v^2_f = v^2_i + 2a\Delta y$

Substituting values into the above equation

$0^2 = 29.4^2 + 2(-9.8)\Delta y$

$\Delta y = 44.1m$

Maximum height above ground:

100 + 44,1 = 144,1 m

Assume upward motion positive

From edge of cliff to maximum height:

$v^2_f = v^2_i + 2a\Delta y$

Substituting values into the above equation

$0^2 = -29.4^2 + 2(9.8)\Delta y$

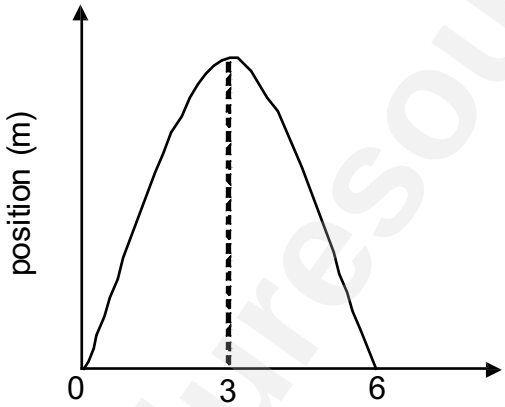
$\Delta y = -44.1m$

Maximum height above ground:

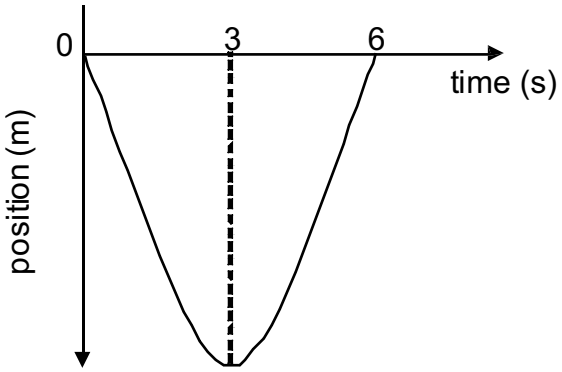
100 + 44,1 = 144,1 m

1.3 Position time graphs

DOWNWARD MOTION POSITIVE



UPWARD MOTION POSITIVE



1.4.1

DOWNWARD MOTION POSITIVE

$v_f = v_i + a\Delta t$

$v_f = 29.4 + (-9.8)(5.23)$
$= -21.85\ ms^{-1}$
$= 21.85\ ms^{-1}$ downwards

UPWARD MOTION POSITIVE

$v_f = v_i + a\Delta t$

$v_f = -29.4 + (9.8)(5.23)$
$= 21.85\ ms^{-1}$
$= 21.85\ ms^{-1}$ downwards

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1.42

UPWARD MOTION POSITIVE	DOWNWARD MOTION POSITIVE
$\Delta t = (5.23 \ \ 1) = 4.23s$	$\Delta t = (5.23 \ \ 1) = 4.23s$
$v_f = v_i + a\Delta t$	$v_f = v_i + a\Delta t$
substitute values:	substitute values:
$v_f = 49 + (-9.8)(4.23)$ $v_f = 7.55\ ms^{-1}$	$v_f = -49 + (9.8)(4.23)$ $v_f = -7.55\ ms^{-1}$ $v_f = 7.55\ ms^{-1}$ upwards
$V_{XY} = V_{XG} + V_{GY}$ $= -21.85 + (-7.55)$ $= -29.40\ ms^{-1}$ $V_{XY} = 29.40\ ms^{-1}$ downwards	$V_{XY} = V_{XG} + V_{GY}$ $= 21.85 + (7.55)$ $= 29.40\ ms^{-1}$ $V_{XY} = 29.40\ ms^{-1}$ downwards

QUESTION 2 (MAR 2010/P1/Q5)

A supervisor, 1,8 m tall, visits a construction site. A brick resting at the edge of a roof 50 m above the ground suddenly falls. At the instant when the brick has fallen 30 m the supervisor sees the brick coming down directly towards him from above.

Ignore the effects of friction and take the downwards motion as positive.

2.1 Calculate the speed of the brick after it has fallen 30 m. (3)

2.2 The average reaction time of a human being is 0,4 s. With the aid of a suitable calculation, determine whether the supervisor will be able to avoid being hit by the brick. (6)
[9]

SOLUTION 2

2.1 Velocity after 30m:

$V^2_f = v^2_i + 2a\Delta y$
$= 0 + 2(9.8)(50 \ \ 20)$
$= 24.25\ ms^{-1}$

2.2 Velocity after a further 18.2m

$v^2_f = v^2_i + 2a\Delta y$
$= 24.25^2 + 2(9.8)(20 - 1.8)$
$= 30.74\ ms^{-1}$

Using $v_f = v_i + a\Delta t$

$30.74 = 24.25 + 9.8t$
$t = 0.66s$

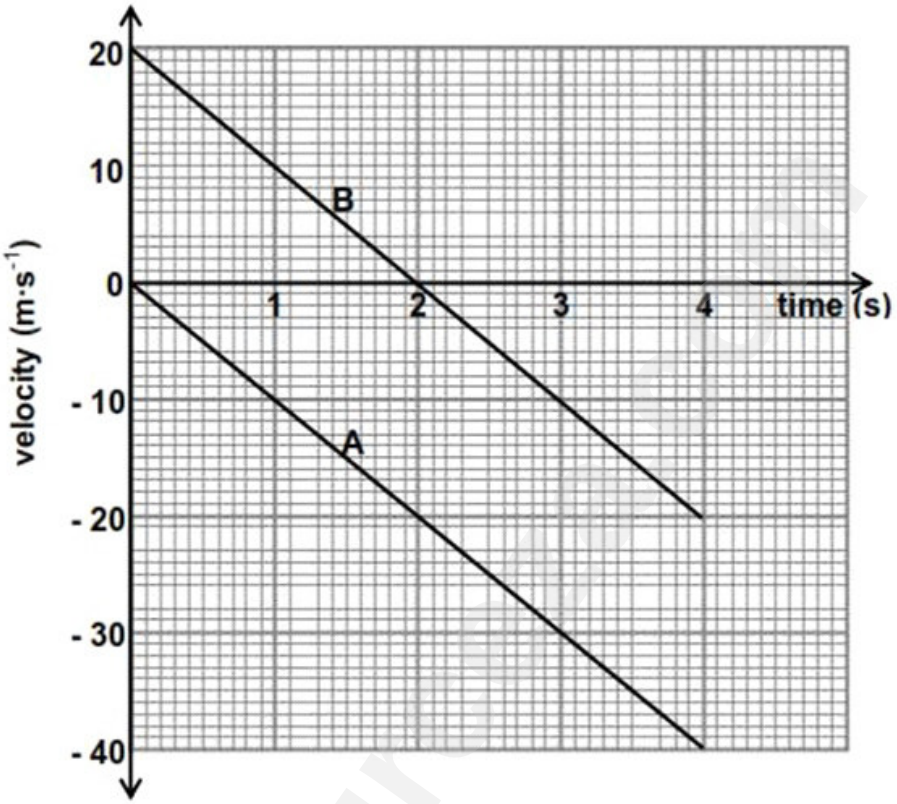
He will not be struck reaction time is shorter than the time for the brick to reach his head.

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QUESTION 3 (FEB 2011/ P1/Q3)

The velocity-time graph shown below represents the motion of two objects, **A** and **B**, released from the same height. Object **A** is released from REST and at the same instant object **B** is PROJECTED vertically upwards. (Ignore the effects of friction.)



3.1 Object A undergoes a *constant acceleration*. Give a reason for this statement by referring to the graph. (No calculations are required.) (2)

3.2 At what time/times is the SPEED of object **B** equal to 10 $m \cdot s^{-1}$? (2)

3.3 What is the velocity of object **A** relative to object **B** at t = 1 s? (3)

3.4 Object **A** strikes the ground after 4 s. USE EQUATIONS OF MOTION to calculate the height from which the objects were released. (3)

3.5 What physical quantity is represented by the area between the graph and the time axis for each of the graphs **A** and **B**? (2)

3.6 Calculate, WITHOUT USING EQUATIONS OF MOTION, the distance between objects **A** and **B** at t = 1 s.

(5)
[17]

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SOLUTION 3

3.1 Gradient of the graph is constant

3.2 At t=1s and t=3s

3.3 $V_{AB} = V_{AC} + V_{CB}$
$= —10 + (—10)$
$= —20\ ms^{-1}$
$= 20\ ms^{-1}$ downwards

3.4 $\Delta y = v_i\Delta + ½a\Delta t^2$
$= (0)(4) + ½(10)(4)^2$ $(g = 10ms^{-2})$
$= 80m$

3.5 Displacement/change in position

3.6 **Distance covered by object B**

$\Delta y = ½\ bh + lb$
$= ½\ (1)(10) + (10)(1)$
$= 15m$

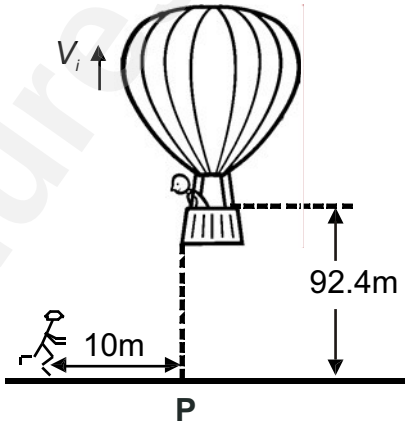
Distance covered by object A

$\Delta y = ½\ bh$
$= \Delta y = ½\ (1)(—10)$
$= —5m$

Distance between A and B = 15 — (—5)
= 20m

QUESTION 4 (NOV 2011/P1/Q3)

A hot-air balloon is moving vertically upwards at a constant speed. A camera is accidentally dropped from the balloon at a height of 92,4 m as shown in the diagram below. The camera strikes the ground after 6 s. Ignore the effects of friction.



4.1 At the instant the camera is dropped, it moves upwards. Give a reason for this observation. (1)

4.2 Calculate the speed v_i at which the balloon is rising when the camera is dropped. (4)

4.3 Draw a sketch graph of velocity versus time for the entire motion of the camera.

Indicate the following on the graph:

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- initial velocity
- time at which it reaches the ground (4)

4.4 If a jogger 10m away from **P** as shown in the above diagram and running at a constant speed of 2 $m \cdot s^{-1}$, sees the camera at the same instant it starts falling from the balloon, will he be able to catch the camera before it strikes the ground?

Use a calculation to show how you arrived at the answer (5)
[14]

SOLUTION 4

4.1 The initial velocity / speed of the camera is the same (as that of the balloon).

4.2

Downward positive:

$\Delta y = v_i \Delta t + \frac{1}{2} \Delta a \Delta t^2$

$92.4 = v_i(6) + \frac{1}{2}(9.8)(6)^2$

v_i **=** $-14 ms^{-1}$

v_i **=** $14 ms^{-1}$ upwards

Downward negative:

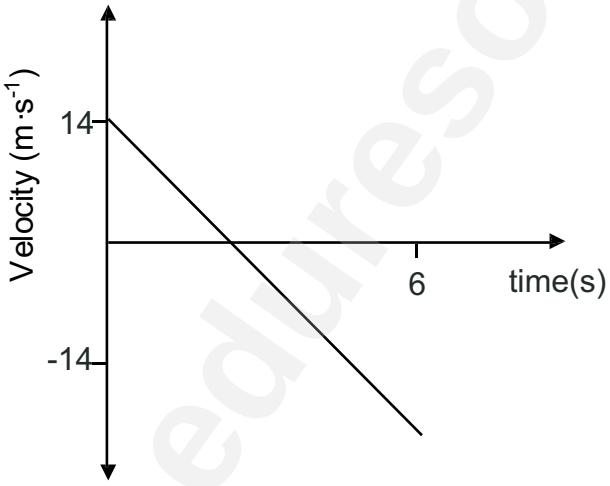
$\Delta y = v_i \Delta t + \frac{1}{2} \Delta a \Delta t^2$

$-92.4 = v_i(6) + \frac{1}{2}(-9.8)(6)^2$

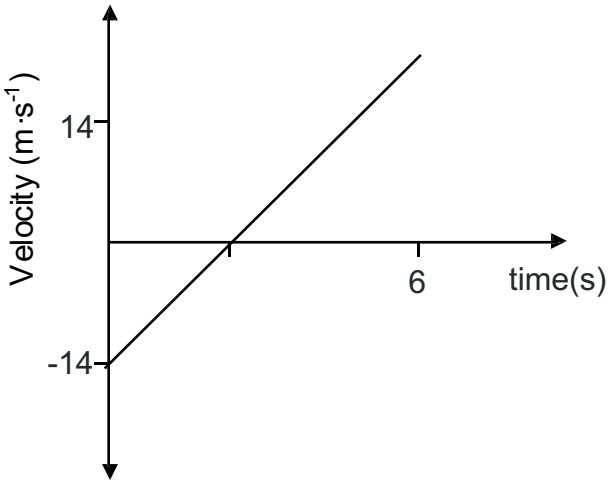
v_i **=** $14 ms^{-1}$ upwards

4.3

UPWARD MOTION POSITIVE



DOWNWARD MOTION POSITIVE



4.4

$\Delta y = v_i \Delta t + \frac{1}{2} \Delta a \Delta t^2$
$10 = (2)\ \Delta t + \frac{1}{2}\ (0)\ \Delta t^2$
$\Delta t = 5s$

Yes. Will catch the camera because time is less than 6s

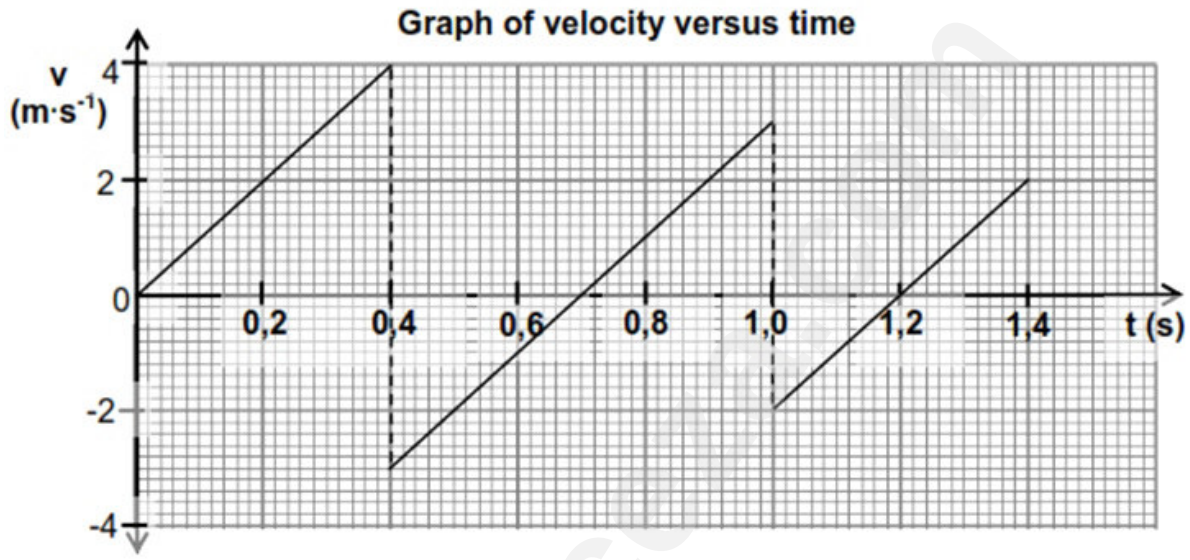
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TASK 2

QUESTION 1 (NOV 2009/P1/Q4)

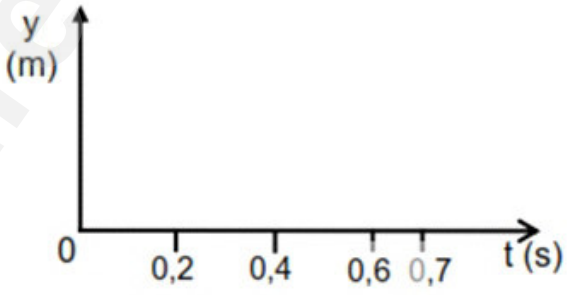
A ball is released from a certain height. The velocity-time graph below represents the motion of the ball as it bounces vertically on a concrete floor. The interaction time of the ball with the floor is negligibly small and is thus ignored.



1.1 Describe the changes, if any, in velocity and acceleration of the ball from t = 0 s to t = 0,4 s. (4)

1.2 Without using the equations of motion, calculate the height from which the ball has been dropped initially. (4)

1.3 Copy the set of axes below into your ANSWER BOOK.



Use the given velocity versus time graph for the motion of the ball to sketch the corresponding position-time graph for the time interval 0 s to 0,7 s. (3)

1.4 Is the first collision of the ball with the floor elastic or inelastic? Give a reason for your answer. (2)

[13]

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TOPIC 3: MATTER AND MATERIALS

ORGANIC MOLECULES

Definition

- These are molecules which contains carbon atoms
- All organic compounds are made up of carbon, which is recycled in various ways such as the earth's air, water, soil and living organisms including human beings

Recycling of carbon

The following are the steps by which carbon is recycled:

1) Combustion and respiration releases carbon dioxide in the air, this way carbon enters the earth's air
2) Plant absorbs carbon dioxide to produce carbohydrates through a process known as **photosynthesis**. The following is the reaction equation for photosynthesis:

Carbon dioxide + water → carbohydrates

3) The carbon that was converted to carbohydrates by plants will be eaten by animals. This way carbon is absorbed by animals. However during excretion animals release that carbon in the form of carbon dioxide back into the air through a process known as **respiration**. The following is the reaction equation for respiration:

Carbohydrates → carbon dioxide + water

4) When animals and plants die they either pass carbon in their bodies to other plants and animals or will remain as fossils which will be used as fuel and undergoes combustion.

Special properties of carbon

Carbon forms a variety of compounds more than all other atoms simply because it has special properties. The following are some of the properties of carbon atoms:

- They can bond with one another to form:
  (i) long carbon - to - carbon chains
  (ii) complex branches
  (iii) single, double or triple bonds
- Electrons that are not involved in carbon - to - carbon bonds are used to bond with other atoms such as bromine or hydrogen
- When the same atoms and bonds are in different orientation, it will also result in different shape and properties in the molecules

DEFINITION OF TERMS

Hydrocarbon

- An organic compound consisting entirely of hydrogen and carbon

Homologous series

- Is a group of organic compounds with the same general formula and chemical properties, but usually the successive compounds differ by -CH_2 group

Saturated hydrocarbons

- These are hydrocarbons composed of entirely single bonds and are saturated with hydrogen atoms

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Unsaturated hydrocarbons

- Hydrocarbons with one or more double or triple bonds between carbon atoms
- Alkenes have double bonds whilst alkynes have triple bonds

General formula

- Indicates the types of atoms in a homologous series and their ratio to one another
- It do not show the actual number of atoms in the compound
- It do not show the bonds between atoms
- Substituting the number of carbon atoms in the general formula will give you molecular formula e.g General formula for alkenes is C_nH_{2n} where n is the number of carbon atoms

Molecular formula

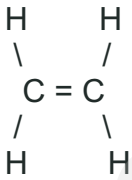
- It shows both the type of atoms and actual number of atoms in a compound
- However it do not show the bonds between atoms
- Suppose you substitute the number of carbon atoms (n) with 2 in the alkene general formula, then the molecular formula become C_2H_4, and the name of the organic compound is ethene.

Condensed structural formula

- It shows all the atoms in a compound, but however it only shows bonds between carbon atoms and do not show bonds between hydrogen atoms
- It show bonds between some atoms
- E.g : condensed structural formula for ethene is $CH_2 = CH_2$

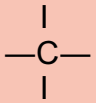
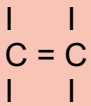
Structural formula

- Shows all the atoms in a compound
- Shows all the bonds between atoms
- A single bond is shown by a single straight line, a double bond by two lines and a tripple bond by three lines
- E.g: structural formula for ethene is



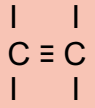
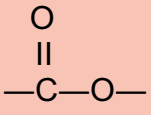
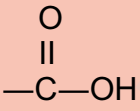
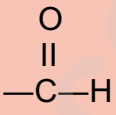
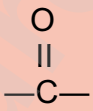
FUNCTIONAL GROUP

- Is defined as a specific group of atoms or bonds within molecules which give the molecule characteristic properties
- Molecules with the same functional group will undergo the same chemical reactions despite difference in the size of the molecules
- The following table shows all the functional groups necessary in your syllabus:

Name	Functional Group
Alkane	
Alkene	

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Name	Functional Group
Alkyne	
Alky hallide	—X (X = F, Cl, Br and I)
Alcohol	— OH
Ester	
Carboxylic acid	
Aldehyde	
Ketone	

isomers

✎Hydrocarbons with the same molecular formula but different structural formula

Examples of isomers

(1) Chain isomers

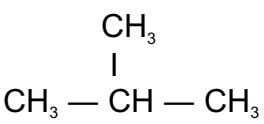
✎Chain isomers have the same molecular formula but different chains, hence different structural formulae

(i) Butane and 2-methylpropane are structural isomers because they have the same molecular formula (C_4H_{10}) but their chains are different, and hence their structural formulae are also different

Butane

$CH_3 — CH_2 — CH_2 — CH_3$

2-methylpropane

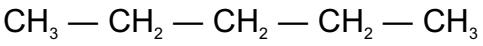


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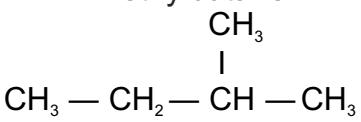
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(ii) Pentane, 2-methylbutane and 2,2 - dimethylpropane are chain isomers, because they all have the same molecular formula (C_5H_{12})

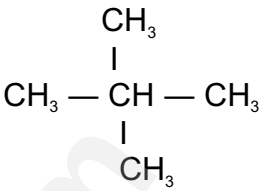
Pentane



2-methylbutane



2,2 -dimethylpropane

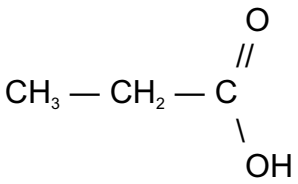


(2) Functional isomers

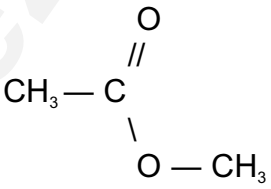
These are isomers with the same molecular formula but different functional groups, and hence different structural formulae.

(i) Propanoic acid (carboxylic acid) and methyl ethanoate (ester) are functional isomers, they have the same molecular formula ($C_3H_6O_2$) but their structural formula are different due to different functional groups

Propanoic acid

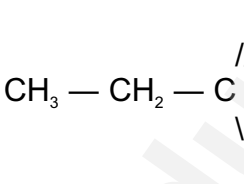


Methyl ethanoate

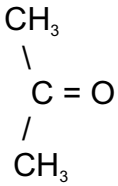


(ii) Propanal (aldehyde) and propanone (ketone) are also functional isomers, they have the same molecular formula (C_3H_6O) but their structural formulae differs due to different functional groups.

Propanal



Propanone



(3) Positional isomers

When organic compounds have the same molecular formula but different position of the same functional group, they will have different structural formulae

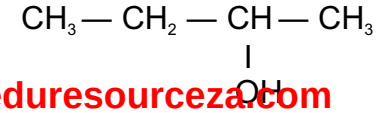
Such compounds are called positional isomers

(i) Butan-1-ol and Butan-2-ol are positional isomers, they have the same molecular formula ($C_4H_{10}OH$) but the position of the -OH group in each case is different.

Butan-1-ol



Butan-2-ol

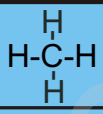
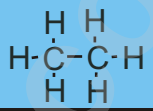
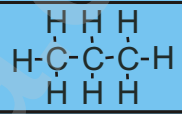
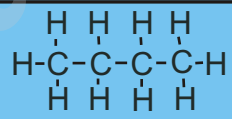
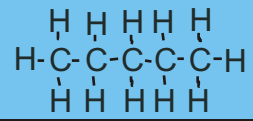
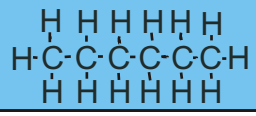


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ALKANES

- These are hydrocarbons with single carbon to carbon bonds (—C—C—)
- For this reason they are called saturated hydrocarbons
- Their general formula is C_nH_{2n+2} ;; where n is 1, 2, 3, ...
- The following is a list of the first six alkanes:

Alkane	Molecular formula	Condensed structural formula	Structural formula
Methane	CH_4	CH_4	
Ethane	C_2H_6	CH_3CH_3	
Propane	C_3H_8	$CH_3CH_2CH_3$	
Butane	C_4H_{10}	$CH_3CH_2CH_2CH_3$	
Pentane	C_5H_{12}	$CH_3CH_2CH_2CH_2CH_3$	
Hexane	C_6H_{14}	$CH_3CH_2CH_2CH_2CH_2CH_3$	

Nomenclature of alkanes

- Identify the parent chain (longest chain of carbon atoms)
- Number the parent chain starting with the end nearest the first alkyl substituent
- Name alkyl substituents and determine their position
- Arrange alkyl substituents in alphabetical order

Example 1

Determine the IUPAC name of the following alkane:

$$CH_3CH_2\underset{\displaystyle CH_2CH_3}{\underset{|}{CH}}CH_2CH_3$$

Solution 1

$$\overset{\displaystyle ③}{CH_3CH_2CHCH_2CH_3}$$
$$\overset{\displaystyle ⑤\quad ④\quad \quad ②\quad ①}{\qquad\quad |\qquad\quad}$$
$$CH_2CH_3$$

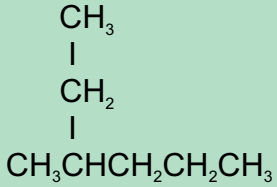
a) Parent name : pentane (5 carbon atoms)
b) Substituents available: 3 - ethyl
c) IUPAC name: 3 - ethylpentane

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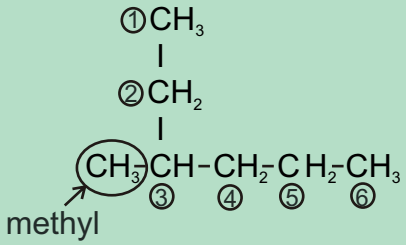
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Example 2

Name the following alkane using the IUPAC system



Solution 2



a) Parent name: hexane
b) Substituents available: 3 - methyl
c) IUPAC name: 3 - methylhexane

Example 3

Given the IUPAC name of the following alkane, determine its formula:

2,2 - methylbutane

Solution 3

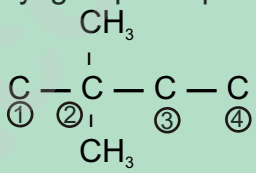
(i) Draw a carbon chain of the parent chain (with four carbon atoms):

C - C - C - C

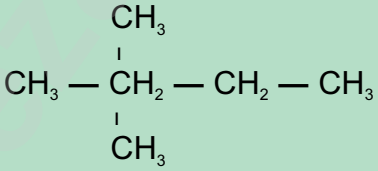
(ii) Number the carbon atoms in the parent chain:

C—C—C—C
① ② ③ ④

(iii) Put both methyl groups on position number 2:



(iv) Balance the number of H atoms



Example 4

Given IUPAC name of the following alkane, determine its formula:

2,4 - dimethylpentane

Solution 4

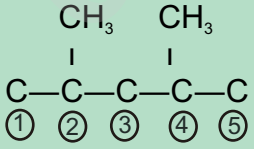
(i) Draw a carbon chain of the parent chain (with five carbon atoms)

C - C - C - C - C

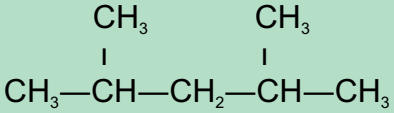
(ii) Number C atoms in the parent chain:

C - C - C - C - C
① ② ③ ④ ⑤

(iii) Put one methyl group on position 2 and another on position 4:



(iv) Balance the number of H atoms:



Example 5

Given IUPAC name of the following alkane, determine its formula:

4-ethyl - 2 - methylhexane

Solution 5

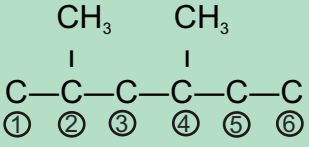
(i) Draw a carbon chain of the parent chain (with six carbon atoms)

C - C - C - C - C - C

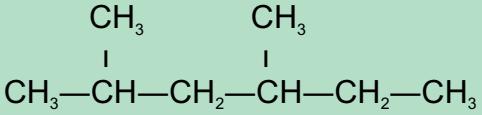
(ii) Number C atoms in the parent chain:

C - C - C - C - C - C
① ② ③ ④ ⑤ ⑥

(iii) Put an ethyl group on position 4 a methyl on position 2:



iv) Balance the number of H atoms:



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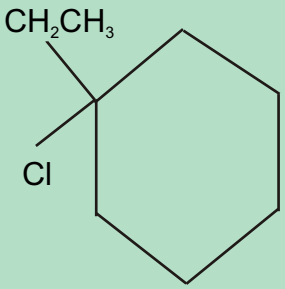
CYCLO - ALKANES

Rules for naming cyclo-alkanes

- The ring is the parent chain even if there is a longer linear chain attached to it
- Number the carbon atoms of the cycloalkane so that the carbons with functional groups or alkyl groups have the lowest possible number (in some complex problems go in the direction that is alphabetical)
- A carbon with multiple substituents should have a lower number than a carbon with only one substituent or functional group
- Name the substituents attached to the parent ring
- Repeated substituents must be grouped using di-; tri-;tetra- etc
- List substituents in alphabetical order ignoring the prefixes e.g an **ethyl** should go before a **methyl**
- If halogens are present, treat them just like alkyl groups

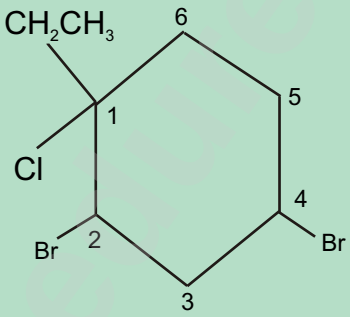
Example 1

Determine the IUPAC name of the following cycloalkane:



Solution 1

a) Parent chain: cyclohexane (6 carbon atoms)
b) Number the parent chain (start with the one with more substitutents than the others)



b) Substituents: 1 - ethyl; 1- chloro; 4 - bromo
c) IUPAC name:
4-bromo-1-chloro-1-ethyl-cyclohexane

Example 2

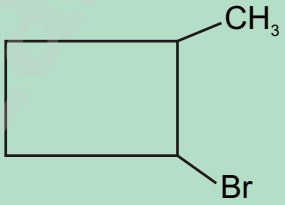
Write the IUPAC name of the following cycloalkane:



Solution 2: cyclohexane (6 carbons)

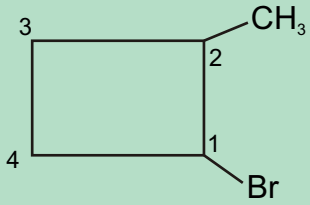
Example 3

Determine the IUPAC name of the following cyclo-alkane:



Solution 3

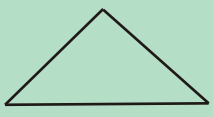
a) Parent chain name: cyclobutane
b) Number the parent chain:



b) Substituents: 1-bromo; 2-methyl
c) IUPAC name :
1-bromo-2-methylcyclobutane

Example 4

Write the IUPAC name of the following cycloalkane:



Solution 4

a) parent name: cyclopropane (3 carbon atoms in the parent chain)
b) Substituents: no substituents
c) IUPAC name: cyclopropane

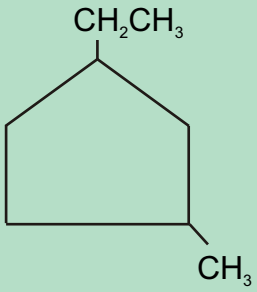
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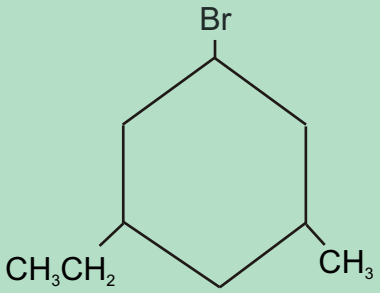
Example 5

Determine the IUPAC names of the following cycloalkanes:

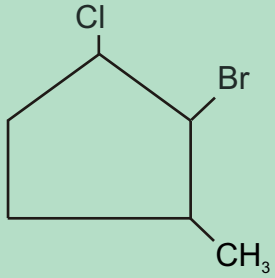
(a)



(b)



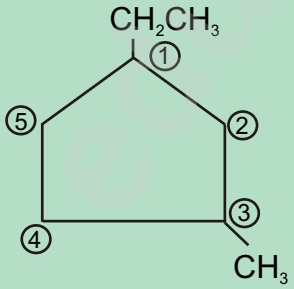
(c)



Solution 5

(a)

(i) Parent name: cyclopentane
(ii) Number the parent chain:

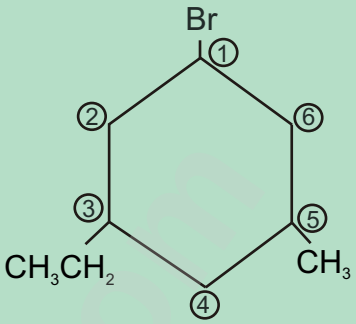


(iii) Substituents available: 1-ethyl; 3-methyl

(iv) IUPAC name:
1-ethyl-3-methylcyclopentane

(b)

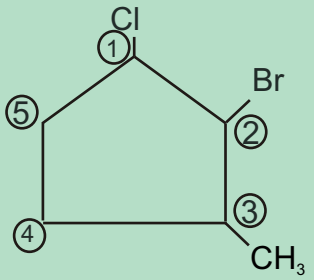
(i) Parent name: cyclopentane
(ii) Number the parent chain:



(iii) Substituents: 1-bromo; 3-ethyl; 5-methyl
(iv) IUPAC name:
1-bromo-3-ethyl-5-methylcyclopentane

(c)

(i) Parent name: cyclopentane
(ii) Number the parent chain:



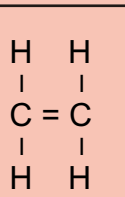
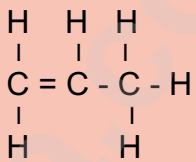
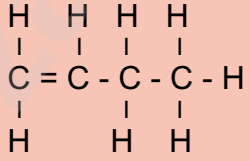
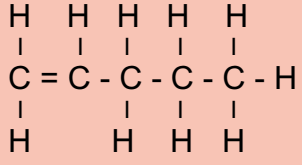
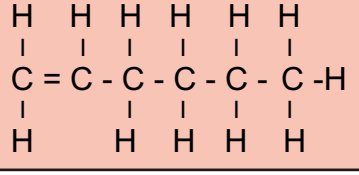
(iii) Substituents: 1-chloro; 2-bromo; 3-methyl
(iv) IUPAC name:
2-bromo-1-chloro-3-methylcyclopentane

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ALKENES

- Hydrocarbons with double carbon - to - carbon bonds
- They are normally called unsaturated hydrocarbons
- Their general formula is C_nH_{2n} ;; where n is 1, 2, 3, ...
- The following is a list of the first six alkenes:

Alkene	Molecular Formula	Condensed structural formula	Structural formula
Ethene	C_2H_4	$CH_2=CH_2$	
prop-1-ene	C_3H_6	$CH_2=CH-CH_3$	
but-1-ene	C_4H_8	$CH_2=CH-CH_2-CH_3$	
pent-1-ene	C_5H_{10}	$CH_2=CH-CH_2-CH_2-CH_3$	
hex-1-ene	C_6H_{12}	$CH_2=CH-CH_2-CH_2-CH_2-CH_3$	

Nomenclature of alkenes

- Select the longest carbon chain that contains a double bond as your parent chain
- Name the compound the same way you would do an alkane but only change suffix **-ane** to **-ene**
- Number the parent chain starting with the end nearer the C to C double bond
- Determine position of the C to C double bond by choosing the smaller of the two numbers on the double - bonded carbon atoms
- Place the number which stands for position of the double bond in front of the suffix (**-ene**)
- The alkene functional group takes precedence over alkyl and halide functional groups.The alcohol functional group takes precedence over the alkene functional group

The same rules for naming alkanes apply

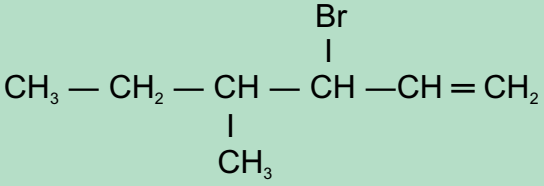
Example 1

Determine IUPAC names of the following alkenes:

(a) $CH_2=CH-CH_2-CH_2-CH_3$

(b) $CH_3-CH=CH-CH_2-CH_3$

(c)

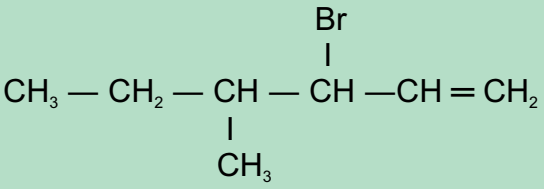


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Example 1
Determine IUPAC names of the following alkenes:

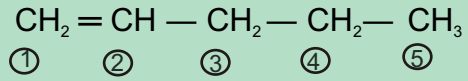
(a) $CH_2 = CH - CH_2 - CH_2 - CH_3$
(b) $CH_3 - CH = CH - CH_2 - CH_3$
(c)



(d)

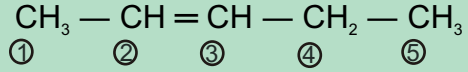


Solution 1
(a)
(i) Number the longest carbon chain with a double bond (start with the end near C=C)



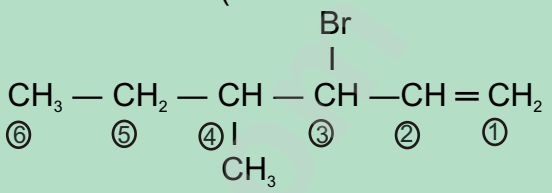
(ii) Parent name: pent - 1 - ene
(iii) Substituents available : no substituents
(iv) IUPAC name: pent - 1 - ene

(b) (i) Number the longest carbon chain with a double bond (start with the end near C=C):



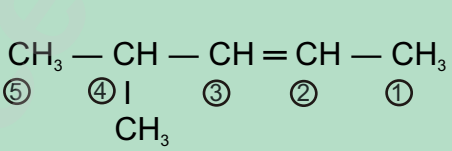
(ii) Parent name: pent-2-ene
(iii) Substituents: no substituents
(iv) IUPAC name: pent-2-ene

(c) (i) Number the longest carbon chain with a double bond (start with the end near C=C)



(ii) Parent name: hex-1-ene
(iii) Substituents available: 4-methyl; 3-bromo
(iv) IUPAC name:
3-bromo-4-methylhex-1-ene

(d)
(i) Number the longest carbon chain with a double bond (start with the end near C=C)

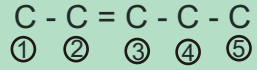


(ii) Parent name: pent-2-ene
(iii) Substituents available: 4-methyl
(iv) IUPAC name: 4-methylpent-2-ene

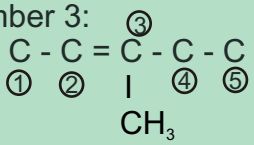
Example 2
Determine formula given IUPAC names of the following alkenes:

(a) 3 - methylpent-2-ene
(b) 2-ethyl-3-methylpent-2-ene
(c) 3-chlobut-1-ene
(d) 2,3 - dimethylbut-1-ene

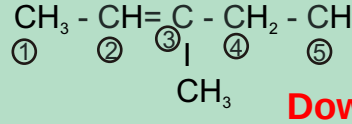
Solution 2
(a) (i) write the parent chain:
C-C=C-C-C
(ii) Number the parent chain



(iii) Add a methyl substituent on the C number 3:



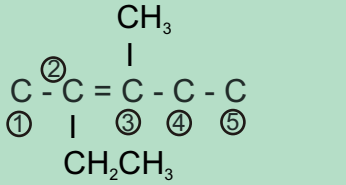
(iv) Balance the number of H atoms:



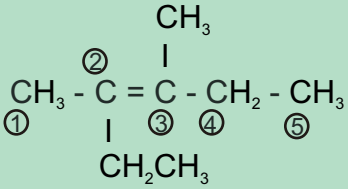
(b) (i) Write the parent chain: C-C=C-C-C
(ii) Number the parent chain:



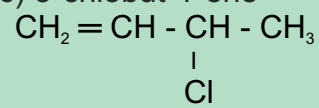
(iv) Add an ethyl group on C number 2 and a methyl on C number 3:



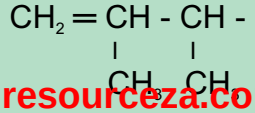
(iv) Balance the number of H atoms:



(c) 3-chlobut-1-ene



(d) 2,3 - dimethylbut-1-ene



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DIENES

- These are alkene compounds with two double bonds
- The position of double bonds in these compounds is important when naming them
- The have a suffix **-diene** instead of **-ene**

Example 1

Determine the IUPAC names of the following dienes:

(a) $H_2C = CH - CH = CH_2$
(b) $H_2C = C = CH_2$
(c) $H_2C = C = CH\text{-}CH_2$

Solution 1

(a) (i) Parent name: butadiene (4 C atoms and 2 double bonds)
(ii) Number the parent chain starting with the end near the C=C:

$H_2C = CH - CH = CH_2$
① ② ③ ④

(iii) Substituents available: none
(iv) Position of double bonds: 1 and 3
(v) IUPAC name: 1,3 - butadiene

(b) (i) Parent name: propadiene (3 C atoms and 2 double bonds)
(ii) Number the parent chain starting with the end near the C=C:

$H_2C = C = CH_2$
① ② ③

(iii) Substituents available: none
(iv) Position of double bonds: 1 and 2
(v) IUPAC name: 1,2 - propadiene

(c) (i) Parent name: butadiene (4 C atoms and 2 double bonds)
(ii) Number the parent chain starting with the end near the C=C:

$H_2C = C = CH\text{-}CH_2$
① ② ③ ④

(iii) Substituents available: none
(iv) Position of double bonds: 1 and 2
(v) IUPAC name: 1,2 - butadiene

CYCLO-ALKENES

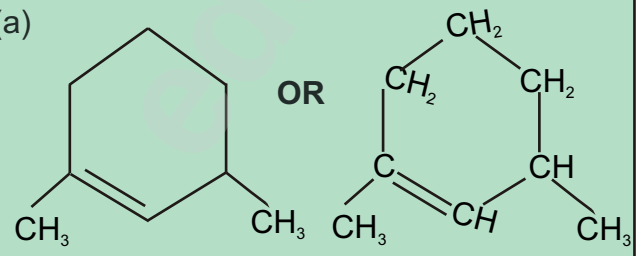
Nomenclature of cyclo-alkenes

- Cycloalkenes are named in the same way we did with open - chain alkenes, except that the numbering always start at one of the C atoms involved in a double bond and continues around a ring through the double bond so as to keep the index numbers as low as possible
- To number the cycloalkene, one C atom of the C=C is given the number 1 and the other C atom of the C=C will be assigned a number 2. Numbering is done to give the alkyl groups the lowest possible numbers.

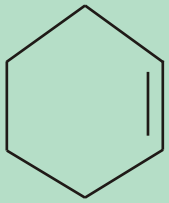
Example 1

Determine the IUPAC names of the following cycloalkenes:

(a)



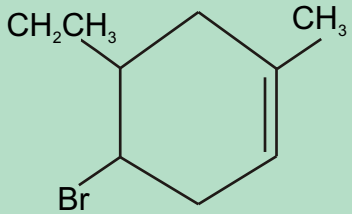
(b)



(c)

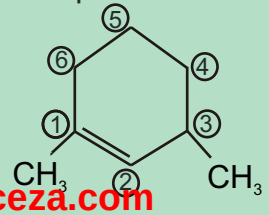


(c)



Solution 1

(a)
(i) Parent name: cyclohexene (6 C atoms)
(ii) Number the parent chain:



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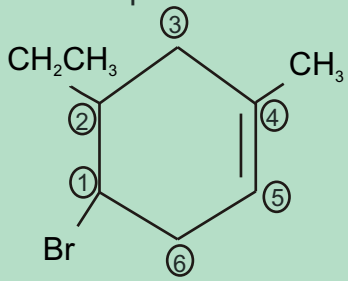
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(iii) Substituents available: 1-methyl; 3-methyl
(iv) IUPAC name: 1,3-dimethylcyclohexene

(b)
(i) Parent name: cyclohexene (6 C atoms)
(ii) Numbering of parent chain: no need since there are substituents
(iii) IUPAC name: cyclohexene

(c)
(i) Parent name: cyclopropene (3 C atoms)
(ii) Numbering of parent chain: no need since there are substituents
(iii) IUPAC name: cyclopropene

(d) (i) Parent name: cyclohexene
(ii) Number the parent chain:



(iii) Substituents available: 1-bromo; 2-ethyl; 4-methyl
(iv) IUPAC name:
1-bromo-2-ethyl-4-methylcyclohexene

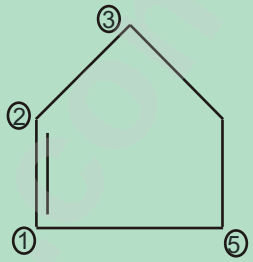
Example 2

Determine the formula of the following cycloalkene given its name:

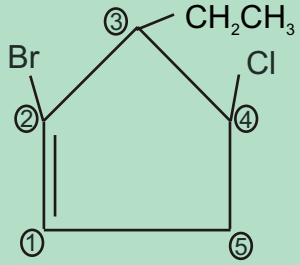
2-bromo-4-chloro-3ethylcyclopentene

Solution 2

(i) Parent name: cyclopentene
(ii) Number the parent chain:



(iii) Attach a bromo alkyl on position 2, a chloro on position 4, and an ethyl on position 3.

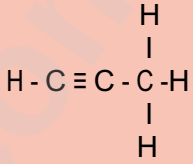
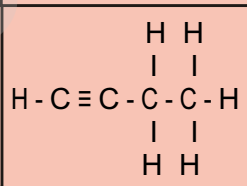
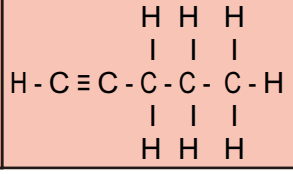


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ALKYNES

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- Hydrocarbons with tripple carbon - to - carbon bonds
- They are normally called unsaturated hydrocarbons
- Their general formula is C_nH_{2n-2} ;; where n is 1, 2, 3, ...
- The following is a list of the first five alkynes:

Alkyne	Molecular formula	Condensed structural formula	Structural formula
Ethyne	C_2H_2	CH≡CH	H - C ≡ C - H
Propyne	C_3H_4	CH≡C - CH_3	
But-1-yne	C_4H_6	CH≡C - CH_2-CH_3	
Pent-1-yne	C_5H_8	CH≡C - CH_2-CH_2- CH_3	

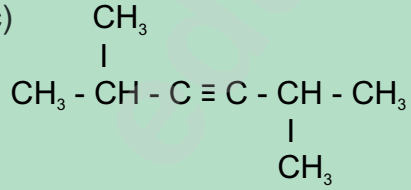
Nomenclature of alkynes

- Rules for naming alkynes are the same with those for alkenes, but the only difference is that alkynes have a tripple bond whereas alkenes have a double bond.

Example 1

Determine the IUPAC of the following alkynes given their formulae:

(a) CH_3 - CH_2 - CH_2 - C ≡ CH
(b) CH_3 - CH_2- C ≡ C - CH_3

(c)


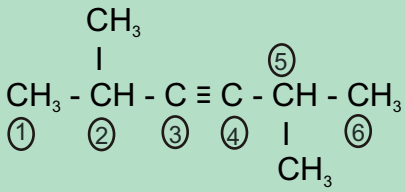
Solution 1

(a) (i) Number the parent chain:

CH_3 - CH_2 - CH_2 - C ≡ CH
⑤ ④ ③ ② ①
(ii) Parent name: pent-1-yne
(iii) Substituents available: none
(iv) IUPAC name: pent-1-yne

(b) (i) Number the parent chain:
CH_3 - CH_2- C ≡ C - CH_3
⑤ ④ ③ ② ①
(ii) Parent name: pent-2-yne
(iv) Substituents available: none
(v) IUPAC name: pent-2-yne

(c) (i) Number the parent chain:



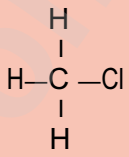
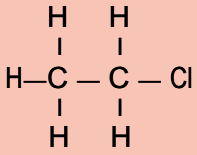
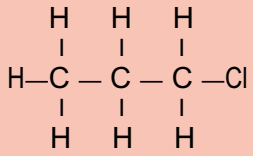
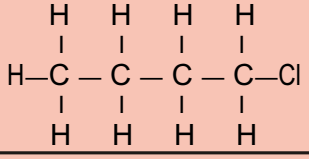
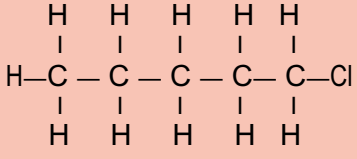
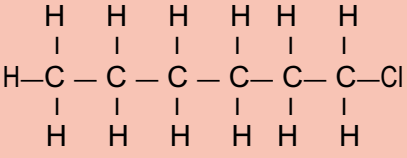
(ii) Parent name: hex-3-yne
(iv) Substituents available: 2-methyl; 5 - methyl
(v) IUPAC name: 2,5-dimethylhex-3-yne

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ALKYL HALIDES

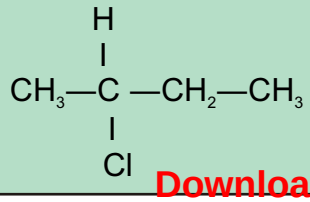
- Alkanes in which one or more H atoms are substituted by a halogen atom (X), where X is either F. Cl. Br or I
- They are normally saturated hydrocarbons
- Their general formula is $C_nH_{2n+1}X$;
  Where n is 1, 2, 3, ...
  X is F, Cl, Br
- The following is a list of the first six alkanes (Where X= Cl):

Alkyl halide	Molecular formula	Condensed structural formula	Structural formula
Methyl chloride	CH_3Cl	CH_3-Cl	
Ethyl chloride	C_2H_5Cl	CH_3-CH_2-Cl	
Propyl chloride	C_3H_7Cl	CH_3-CH_2-CH_2-Cl	
Butyl chloride	C_4H_9Cl	CH_3-CH_2-CH_2-CH_2-Cl	
Pentyl chloride	$C_5H_{11}Cl$	CH_3-CH_2-CH_2-CH_2-CH_2-Cl	
Hexyl chloride	$C_6H_{13}Cl$	CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-Cl	

Nomenclature of alkyl halides

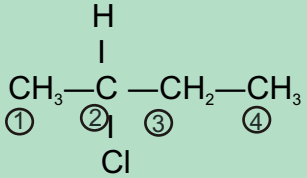
- Identify the parent chain (the longest C chain which contains a halogen)
- Number the chain in a way that will give a halogen the lowest possible number
- Add a suffix **-ane** to the parent chain
- A halogen is treated as a substituent on an alkane chain

Example 1
Determine the IUPAC name for the following alkyl halide:



Solution 1

- Parent name: butane
- Number the parent chain
- Substituents available: 2-chloro
- IUPAC name: 2-chlorobutane



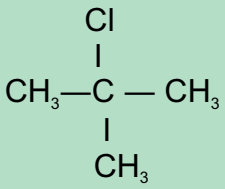
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Example 2

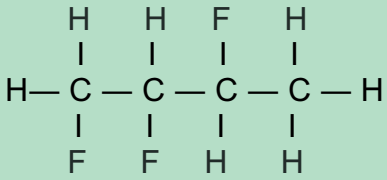
Determine the IUPAC names of the following alkyl halides:

(a)

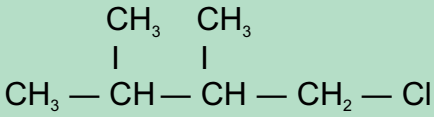


(b) $CH_3 — CH_2 — CH_2 — Cl$

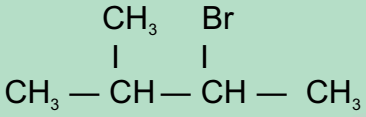
(c)



(d)



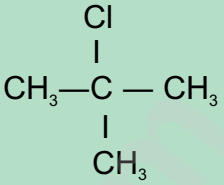
(e)



Solution 2

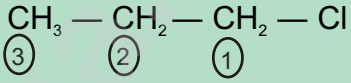
To determine the IUPAC names of the following alkyl halides:

(a) (i) Number the parent chain:



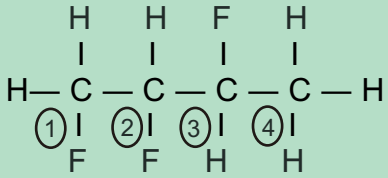
(ii) Parent name: propane
(iii) Substituents available: 2-chloro
(iv) IUPAC name: **2-chloropropane**

(b) (i) Number the parent chain:



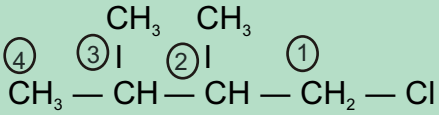
(ii) Parent name: propane
(iii) Substituents available: 1-chloro
(iv) IUPAC name: **1-chloropropane**

(c) (i) Number the parent chain:



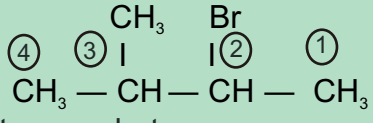
(ii) Parent name: butane
(iii) Substituents available: 1-fluoro; 2-fluoro; 3-fluoro
(iv) IUPAC name: **1,2,3 - fluorobutane**

(d) (i) Number the parent chain:



(ii) Parent name: butane
(iii) Substituents available: 1-chloro; 2-methyl; 3-methyl
(iv) IUPAC name: **1-chloro-2,3-dimethylbutane**

(e) (i) Number the parent chain:



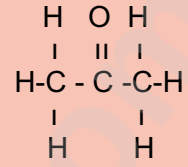
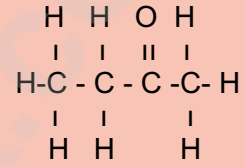
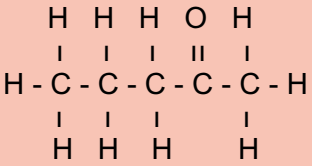
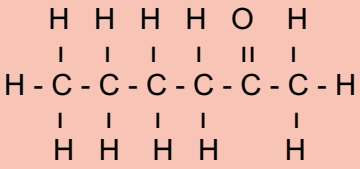
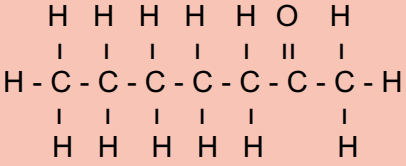
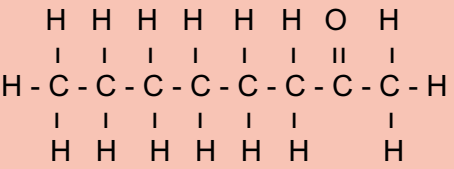
(ii) Parent name: butane
(iii) Substituents available: 2-bromo; 3-methyl
(iv) IUPAC name: **2-bromo-3-methyl- butane**

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KETONES

- Hydrocarbons with a carbonyl carbon attached to two more carbon atoms
- Their general formula is $C_nH_{2n}O$;; where n is 1, 2, 3, ...
- The following is a list of the first eight ketones (Carbonyl is attached to the second carbon):

Ketone	Molecular formula	Condensed structural formula	Structural formula
2- propanone	C_3H_6O	CH_3-CO-CH_3	
2- butanone	C_4H_8O	CH_3-CH_2-CO-CH_3	
2- pentanone	$C_5H_{10}O$	CH_3-CH_2-CH_2-CO-CH_3	
2- hexanone	$C_6H_{12}O$	CH_3-CH_2-CH_2-CH_2-CO-CH_3	
2- heptanone	$C_7H_{14}O$	CH_3-CH_2-CH_2-CH_2-CH_2-CO-CH_3	
2- octanone	$C_8H_{16}O$	CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CO-CH_3	

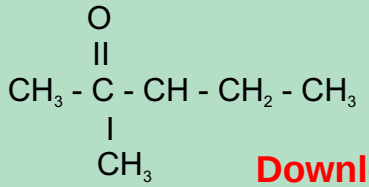
Nomenclature of ketones

- Identify the parent chain (the longest C chain which contains a carbonyl group)
- Number the carbon atoms, starting with the end which is closest to the carbonyl group
- Add a suffix -none to the parent chain

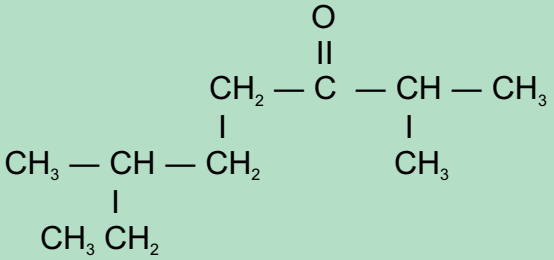
Example 1

Determine the IUPAC names of the following ketones:

(a)



(b)

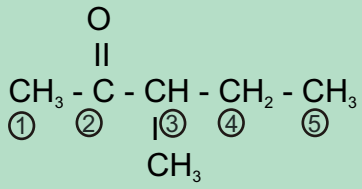


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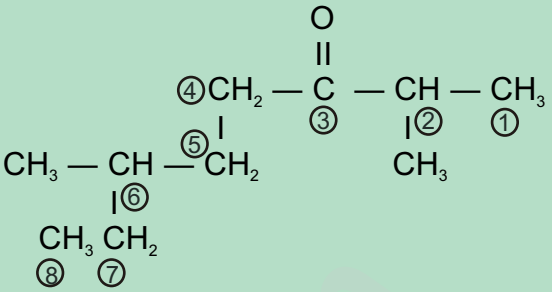
Solution 1

(a) (i) Number the parent chain:



(ii) Parent name: 2-pentanone
(iii) Substituents available: 3-methyl
(iv) IUPAC name: 3-methyl-2-pentanone

(b) (i) Number the parent chain:



(ii) Parent name: 3-octanone
(iii) Substituents available: 2-methyl; 6-methyl
(iv) IUPAC name: 2,6 - dimethyl-3-octanone

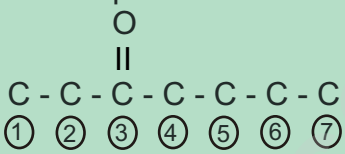
Example 2

Determine the formula given the following IUPAC names of ketones:

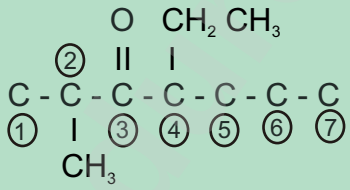
(a) 4 - ethyl - 2- methyl - 3 - heptanone
(b) 1 - bromo - 3 - methyl - 2 - butanone

Solution 2

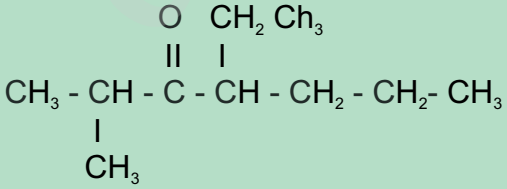
(a) (i) Parent name: 3-heptanone
(ii) Number the parent chain:



(iii) Attach an ethyl group on position 4, a methyl group on position 2:

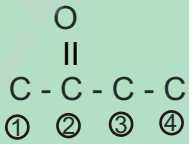


(iii) Balance the number of H atoms:

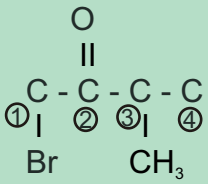


(b)

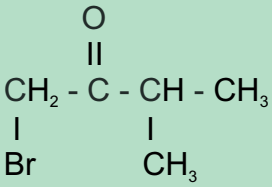
(i) Parent name: 2-butanone
(ii) Number the parent chain:



(iii) Attach a bromo group on position 1 and a methyl on position 3:



(iv) Balance the number of H atoms:

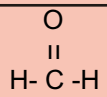
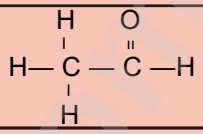
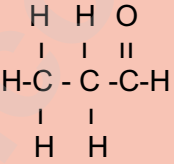
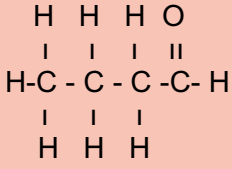
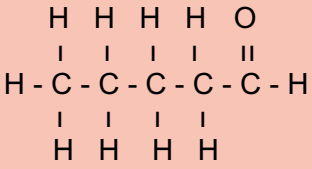
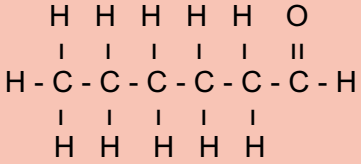
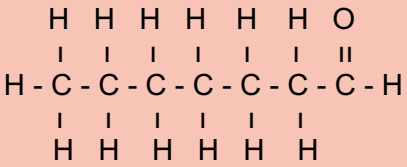
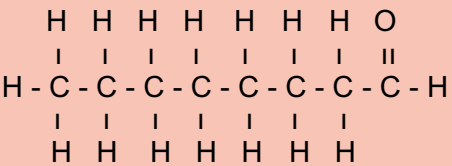


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ALDEHYDES

- Hydrocarbons with a carbonyl carbon attached to at least one carbon atom
- Their general formula is $C_nH_{2n}O$;; where n is 1, 2, 3, ...
- The following is a list of the first eight aldehydes:

Ketone	Molecular formula	Condensed structural formula	Structural formula
Methanal	CH_2O	HCHO	
Ethanal	C_2H_4O	CH_3-CHO	
Propanal	C_3H_6O	CH_3-CH_2-CHO	
Butanal	C_4H_8O	CH_3-CH_2-CH_2-CHO	
Pentanal	$C_5H_{10}O$	CH_3-CH_2-CH_2-CH_2-CHO	
Hexanal	$C_6H_{12}O$	CH_3-CH_2-CH_2-CH_2-CH_2-CHO	
Heptanal	$C_7H_{14}O$	CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CHO	
Octanal	$C_8H_{16}O$	CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CHO	

Nomenclature of aldehydes

- Identify the parent chain (the longest C chain which contains a carbonyl group)
- Number the C atoms in the chain, starting with the end which is closest to the carbonyl group
- Add a suffix **-al** to the parent chain

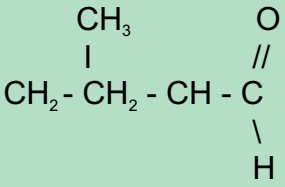
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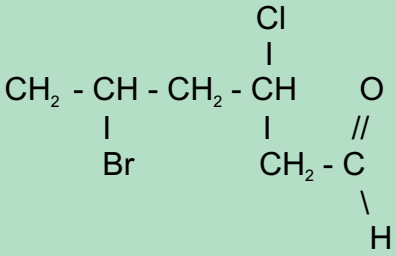
Example 1

Write the IUPAC names of the following aldehydes:

(a)

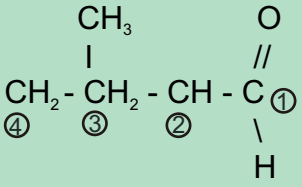


(b)



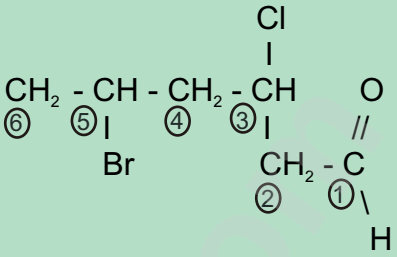
Solution 1

(a) (i) Number the parent chain:



(ii) Parent name: butanal
(iii) Substituents available: 2-methyl
(iii) IUPAC name: 2-methylbutanal

(b) (i) Number the parent chain:



(ii) Parent name: hexanal
(iii) Substituents available:
5-bromo
3-chloro
(iv) IUPAC name:
5 -bromo-3-chlorohexanal

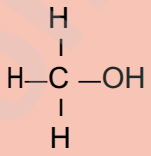
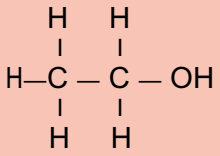
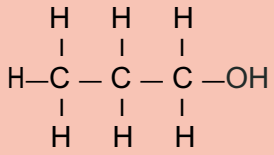
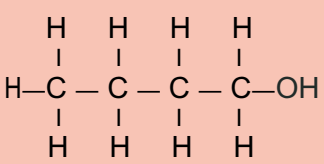
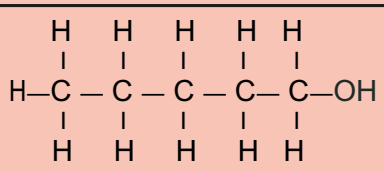
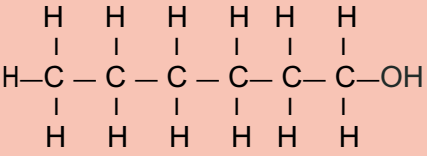
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ALCOHOLS

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- Hydrocarbons with at least one hydroxyl (-OH) group
- They are normally saturated hydrocarbons
- Their general formula is $C_nH_{2n+1}OH$;;
  Where n is 1, 2, 3, ...

- The following is a list of the first six alcohols:

Alcohol	Molecular formula	Condensed structural formula	Structural formula
Methan-1-ol	CH_3OH	CH_3-OH	
Ethan-1-ol	C_2H_5OH	CH_3-CH_2-OH	
Propan-1-ol	C_3H_7OH	CH_3-CH_2-CH_2-OH	
Butan-1-ol	C_4H_9OH	CH_3-CH_2-CH_2-CH_2-OH	
Pentan-1-ol	$C_5H_{11}OH$	CH_3-CH_2-CH_2-CH_2-CH_2-OH	
Hexan-1-ol	$C_6H_{13}OH$	CH_3-CH_2-CH_2-CH_2-CH_2-CH_2-OH	

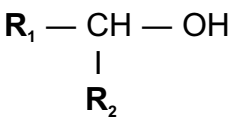
Primary alcohols

- They are in the form of **R** - OH
- The C atom attached to an -OH group is bonded to one other C atom

Example 1

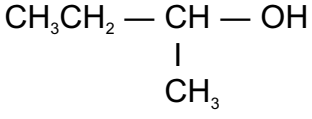
CH_3-CH_2-CH_2-CH_2-OH Butan-1-ol

Secondary alcohols

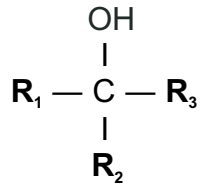
- They are in the form 

- The C atom attached to an -OH group is bonded to two other C atoms

Example 2



Tertiary alcohols

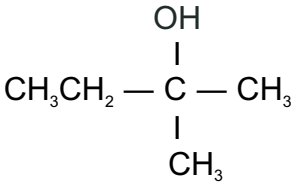
- They are in the form 

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✎ The C atom attached to an -OH group is bonded to three other C atoms

Example 3



NB: R_1 , R_2 and R_3 represents attached H atom or hydrocarbon side chain or any group of atoms

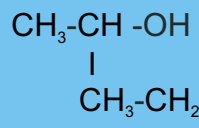
Nomenclature of alcohols

✎Identify the parent chain (the longest C chain which contains an -OH group)
✎Number the C atoms in the chain, starting with the end which is closest to the -OH group
✎-OH group has precedence over alkyl groups
✎Add a suffix **-ol** to the parent chain
✎Position of the -OH must be indicated in the parent chain

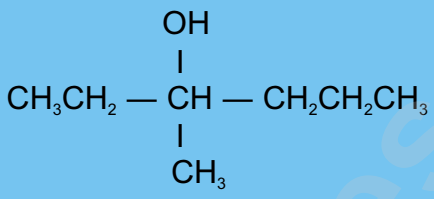
Example 1

Determine the IUPAC names of the following alcohols:

(a)

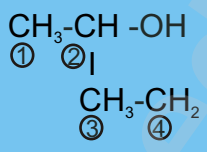


(b)



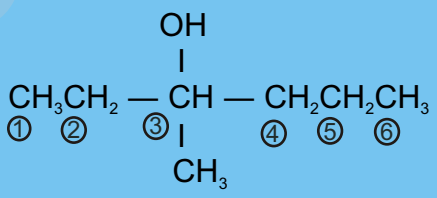
Solution 1

(a) (i) Number the parent chain:



(ii) Parent name: butan-2-ol
(iii) Substituents available: none

(b) (i) Number the parent chain:



(ii) Parent name: hexan-3-ol
(iii) Substituents available: 3-methyl
(iv) IUPAC name: 3-methylhexan-3-ol

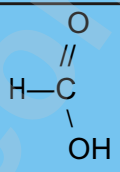
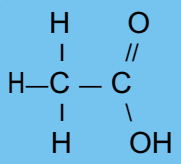
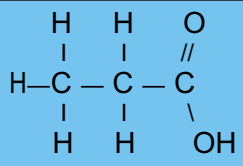
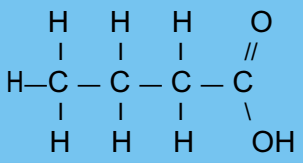
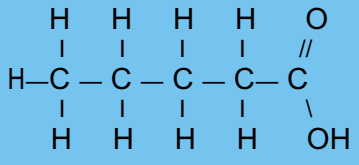
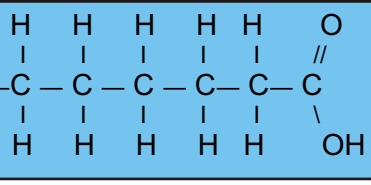
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CARBOXYLIC ACIDS

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- Hydrocarbons with a -COOH functional group
- They are normally unsaturated hydrocarbons
- Their general formula is $C_nH_{2n+1}COOH$;;
  Where n is 0,1, 2, 3, ...

- The following is a list of the first six carboxylic acids :

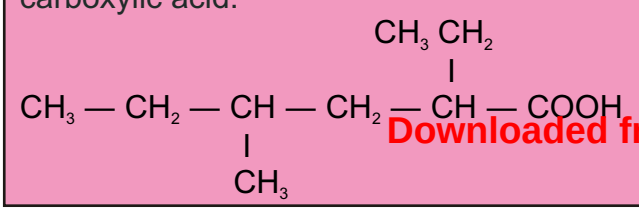
Carboxylic acids	Molecular formula	Condensed structural formula	Structural formula
Methanoic acid	HCOOH	H-CO-OH	
Ethanoic acid	CH_3COOH	CH_3-CO-OH	
Propanoic acid	C_2H_5COOH	CH_3-CH_2-CO-OH	
Butanoic acid	C_3H_7COOH	CH_3-CH_2-CH_2-CO-OH	
Pentanoic acid	C_4H_9COOH	CH_3-CH_2-CH_2-CH_2-CO-OH	
Hexanoic acid	$C_5H_{11}COOH$	CH_3-CH_2-CH_2-CH_2-CH_2-CO-OH	

Nomenclature of carboxylic acids

- Identify the parent chain (the longest C chain which contains a carbonyl group)
- Number the C atoms in the chain, starting with the end which is close to the carbonyl group
- Add a suffix **-oic acide** to the parent chain

Example 1

Determine the IUPAC name for the following carboxylic acid:

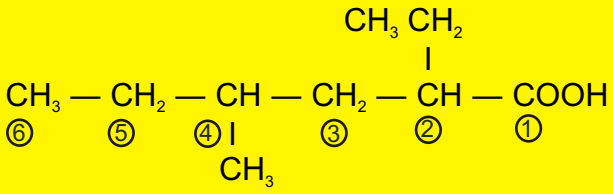


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Solution 1

(i) Number the parent chain:

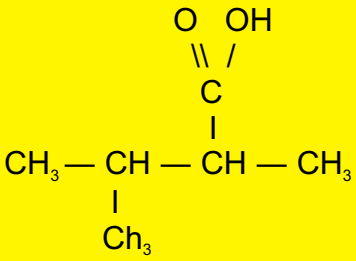


(ii) Parent name: hexanoic acid
(iii) Substituents available: 2-ethyl; 4-methyl
(iv) IUPAC name:

2-ethyl - 4 - methylhexanoic acid

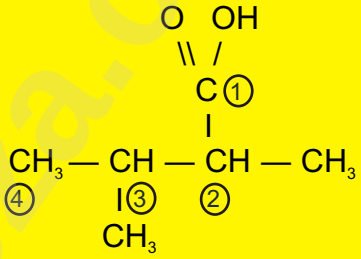
Example 2

Determine the IUPAC name of the following carboxylic acid:



Solution 2

(i) Number the parent chain:



(ii) Parent name: butanoic acid
(iii) Substituents available: 2-methyl; 3-methyl
(iii) IUPAC name:
2,3-dimethylbutanoic acid

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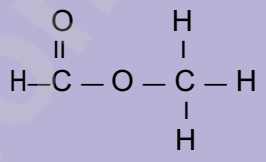
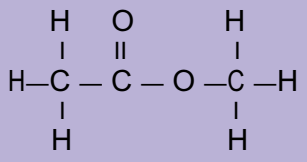
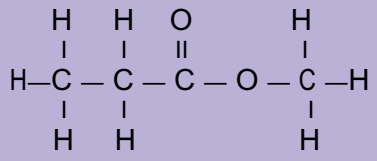
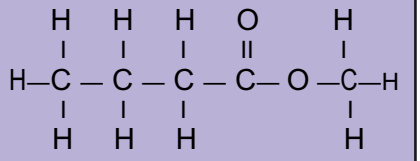
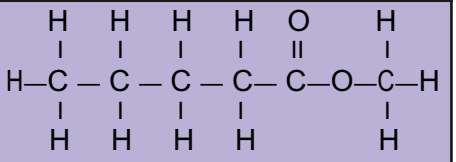
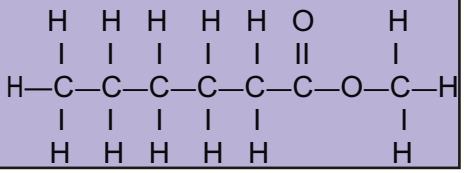
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ESTERS

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- Hydrocarbon in which an **alcoholic alkyl** and an **acid alkyl** are both attached to the oxygen atom
- They are normally unsaturated hydrocarbons
- Their general formula is $C_nH_{2n}O_2$;;
  Where n is 1, 2, 3, ...

- The following is a list of the first six esters (Where the alcoholic alkyl is -methyl):

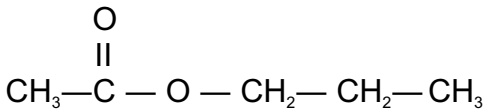
Esters	Molecular formula	Condensed structural formula	Structural formula
Methyl methanoate	$C_2H_4O_2$	H-CO-O-CH_3	
Methyl ethanoate	$C_3H_6O_2$	CH_3-CO-O-CH_3	
Methyl propanoate	$C_4H_8O_2$	CH_3-CH_2-CO-O-CH_3	
Methyl butanoate	$C_5H_{10}O_2$	CH_3-CH_2-CH_2-CO-O-CH_3	
Methyl pentanoate	$C_6H_{12}O_2$	CH_3-CH_2-CH_2-CH_2-CO-O-CH_3I	
Methyl hexanoate	$C_7H_{14}O_2$	CH_3-CH_2-CH_2-CH_2-CH_2-CO-O-CH_3I	

Nomenclature of esters

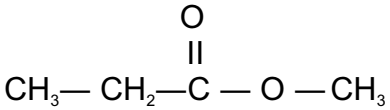
- Name the alkyl group attached to the oxygen first, and that of the acid second
- Replace suffix of the acid part with **-oate** to the parent chain

Example 1
Determine the IUPAC name for the following esters:

a)



(b)



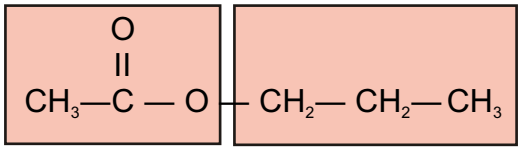
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Solution 1

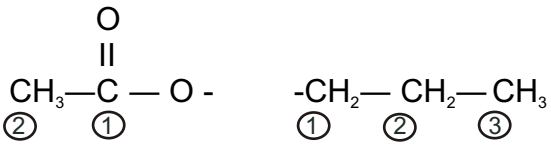
(a)

(i) Split the ester into an alcohol and an acid:



acid part alcohol part

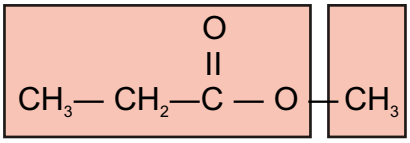
(ii) Number both the acid part and the alcohol part:



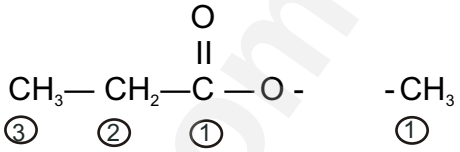
(iii) Parent name: ethanoate (from acid part)
(iv) Substituents available: propyl (from alcohol part)
(v) IUPAC name: propylethanoate

(b)

(i) Split the ester into an alcohol and an acid:



(ii) Number both the acid part and the alcohol part:



(iii) Parent name: propanoate (from acid part)
(iv) Substituents available: methyl (from alcohol part)
(v) IUPAC name: methylpropanoate

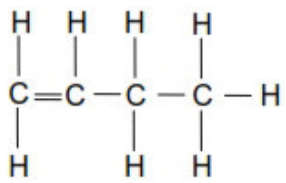
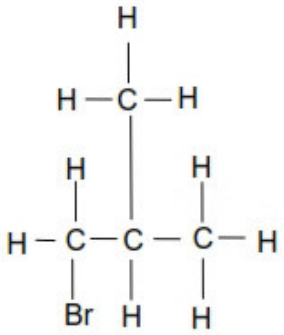
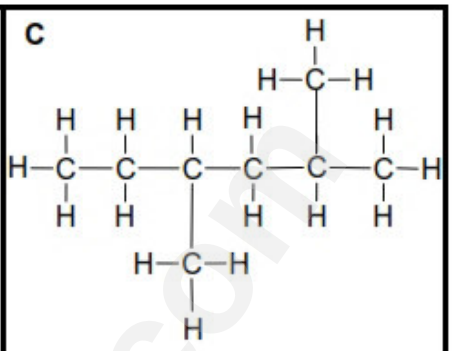
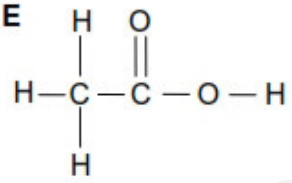
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TASK 3

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QUESTION 1 (NOV 2010/P2/Q3)

The chemical properties of organic compounds are determined by their functional groups. The letters A to F in the table below represent six organic compounds.

A 	**B** 	**C** 
D Methanal	**E** 	**F** Methyl methanoate

1.1 Write down the LETTER that represents the following:

1.1.1 An alkene (1)

1.1.2 An aldehyde (1)

1.2 Write down the IUPAC name of the following:

1.2.1 Compound B (2)

1.2.2 Compound C (2)

1.3 Write down the structural formula of compound D. (2)

1.4 Write down the IUPAC name of the carboxylic acid shown in the table. (2)

1.5 Write down the structural formula of compound F. (2)

[12]

QUESTION 2 (NOV 2011/P2/Q3)

The letters A to F in the table below represent six organic compounds.

2.1 Write down the letter that represents the following:

2.1.1 A ketone (1)

2.1.2 A compound which is an isomer of prop-1-ene (1)

2.2 Write down the IUPAC name of the following:

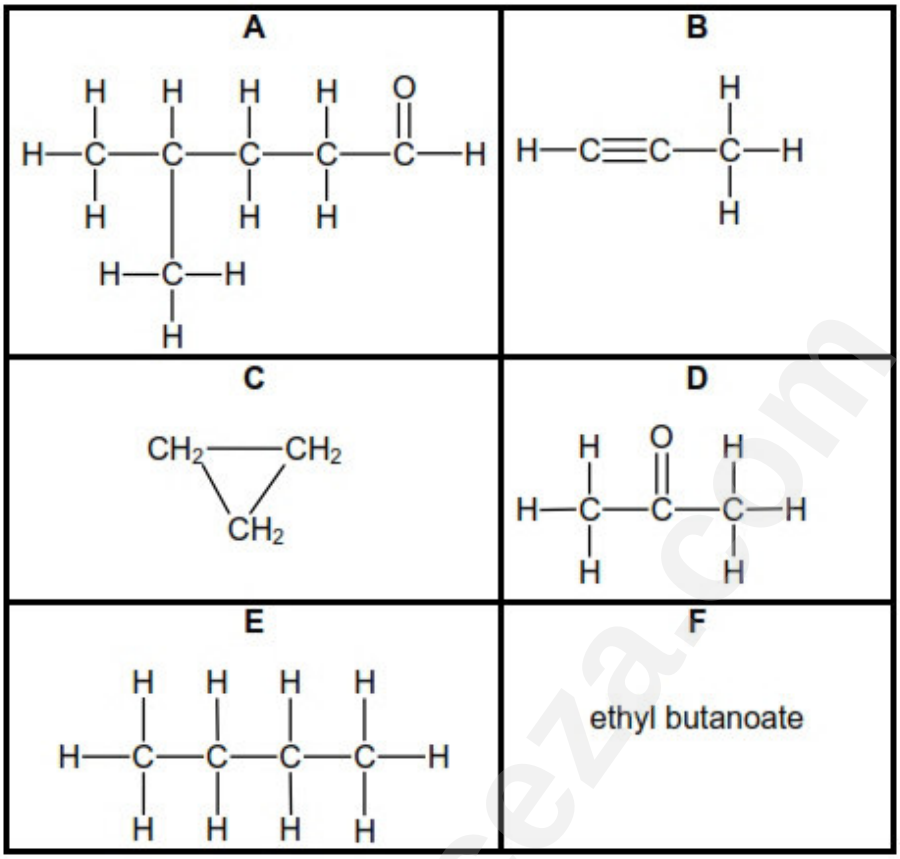
2.2.1 Compound A (2)

2.2.2 Compound B (2)

2.3 Write down the NAME or FORMULA of EACH of the TWO products formed during the complete combustion of compound E. (2)

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2.4 Compound F is the organic product of the reaction between a carboxylic acid and ethanol. Write down the following:

2.4.1 The name of the homologous series to which compound F belongs (1)

2.4.2 The structural formula of the FUNCTIONAL GROUP of carboxylic acids (1)

2.4.3 The IUPAC name of the carboxylic acid from which compound F is prepared (2)

2.4.4 The structural formula of compound F (2)

[14]

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PHYSICAL PROPERTIES OF ORGANIC MOLECULES

✎In this topic we will concentrate on the following physical properties:

Boiling point - temperature at which vapour pressure equals to atmospheric pressure
Melting point - temperature needed to change a solid to liquid
Vapour pressure - pressure exerted on to the wall of a container by produced vapour. High volatile substances have high vapour pressures
Density - mass per unit volume
Flamability - easiness with which a substance can burn
Solubility - easiness with which a substance dissolve into polar solvents. Substances which can form hydrogen bonds with polar solvents (e.g H_2O) have higher solubility than those which do not.

✎We will discuss how these properties are affected by intermolecular forces, chain length, branched chains, number and type of functional group.

(1) Relationship between physical properties and intermolecular forces

✎There are two types of intermolecular forces that are of interest to us in this topic, namely, Hydrogen bonds and Van der Waals forces
✎Hydrogen bonds are strong intermolecular forces whereas Van der Waals are weak intermolecular forces
✎The stronger the intermolecular forces, the higher the energy required to separate the molecules
✎For this reason substances with:

(a) Hydrogen bonds have -

(i) Higher melting points
- Molecules are strongly attracted to each other
- More energy is required to break bonds between their respective molecules, and hence they will have relatively higher melting points

(ii) Higher boiling points
- Molecules are strongly attracted to each other
- More energy is required to break bonds between their respective molecules, and hence they will have relatively higher boiling points

(iii) Higher density
- Molecules are strongly attracted to each other
- Hence they substance becomes more compact, resulting in higher densities

(b) Van der Waal forces have -

(i) Higher vapour pressure
- Molecules are weakly attracted to each other
- Less energy is needed to break the bonds between their respective molecules, and hence will have relatively high vapour pressures

(ii) Stronger smell
- Molecules are weakly attracted to each other
- Less energy is needed to break the bonds between their respective molecules, and hence will have relatively strong smell

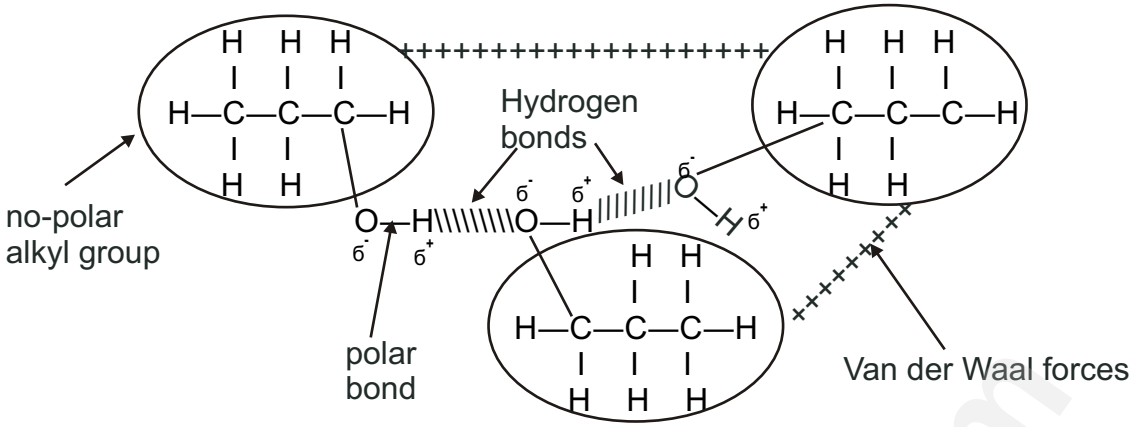
(iii) Higher flammability
- Molecules are weakly attracted to each other
- Less energy is needed to break the bonds between their respective molecules, and hence will be relatively more flammable

Generally substances with higher melting points, higher boiling points and higher density values have lower vapour pressure, weaker smell and are less flammable.

The diagram below shows how hydrogen bonds are formed between Propan-1-ol molecules:

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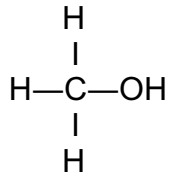
Hydrogen bonds are a strong electrostatic attraction which occurs between the partially negative (δ^-) side of an -OH or -FH in one molecule and the partially positive (δ^+) side of an -OH or -FH in another molecule.

Van der Waal forces are weak electrostatic attraction forces between two or more non-polar alkyl groups as shown in the diagram above

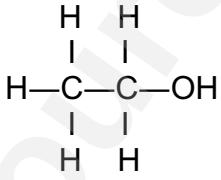
(2) Relationship between physical properties and chain length

✎Consider the following chains of alcohols:

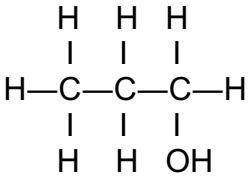
Methanol



Ethanol



Propan-1-ol

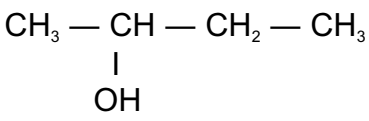


✎The longer the carbon chain will also result in an increase in strength of intermolecular forces between the molecules
✎Length of a carbon chain is determined by the number of carbon atoms, molecular mass, molar mass, or size of the molecules
✎The bigger the number of carbon atoms or molecular mass or molar mass or molecular size is the longer the carbon chain
✎In the above diagram we see that Propan-1-ol has the longest carbon chain, and hence it has stronger hydrogen bonds and Van der Waal forces between its molecules as compared to Methanol and Ethanol (NB: Alcohols have both Van der Waal forces and hydrogen bonds)
✎ The greater the hydrogen bonds and Van der Waal forces between Propan-1-ol molecules, will also result in it having high values of viscosity, melting point and boiling point as compared to Methanol and Ethanol.

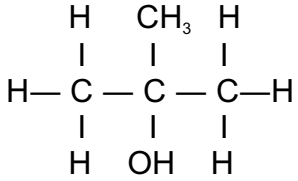
(3) Relationship between physical properties and branched chains

✎ Consider the following alcohols:

Butan-2-ol



2-methylpropan-2-ol



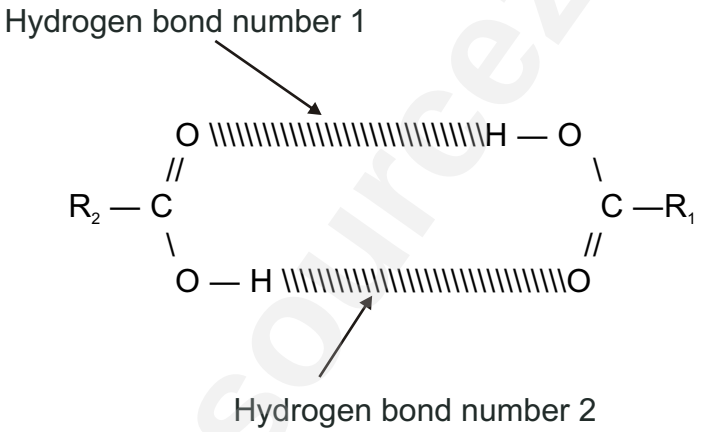
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✎From the above diagram we can see that 2-methylpropan-2-ol is more branched than butan-2-ol
✎More branched chains are said to be more compact or spherical
✎The more branched the molecule is, the smaller the surface area over which intermolecular forces should act
✎Hence it will cause a decrease in strength of intermolecular forces, less energy is required to break bonds and result in a decrease in viscosity, melting points and boiling points
✎Therefore we can safely say that 2-methylpropan-2-ol has lower viscosity, lower melting points, and lower boiling points than butan-2-ol

(4) Relationship between physical properties and number and type of functional group

(i) Carboxylic acids versus alcohols
✎Generally carboxylic acids have relatively higher boiling points, melting points and viscosity values compared to alcohols with the same molecular mass
✎This is simply because carboxylic acids have strongest hydrogen bonding
✎Two alcohol molecules form a single hydrogen bond whereas two carboxylic acids form two hydrogen bonds (dimers), and this is what makes hydrogen bonding in carboxylic acids the strongest.
✎The diagram below shows hydrogen bonding between two carboxylic acid molecules:



(ii) Alcohols versus aldehydes

✎Alcohols experience both weak Van der Waal forces and stronger hydrogen bonds between their molecules
✎Aldehydes experience merely weak Van der Waal forces between their molecules
✎More energy is needed to overcome intermolecular forces between alcohol molecules than is required between respective aldehyde molecules of the same mass
✎As a result alcohols have relatively higher boiling points, melting points and viscosity values than respective aldehydes of the same mass
✎On the other hand aldehydes have lower boiling points, lower melting points and lower viscosity values, high vapor pressure than respective alcohols of the same mass

(iii) Alcohols versus alkanes
✎Forces acting between alkane molecules are merely weak Van der Waal intermolecular forces
✎Forces acting between alcohol molecules are both weak Van der Waal and strong hydrogen bonds
✎More energy is required to overcome intermolecular forces between alcohol molecules than between respective alkane molecules of the same mass
✎Hence alcohols have relatively higher boiling points, melting points and viscosity values than respective alkanes of the same mass

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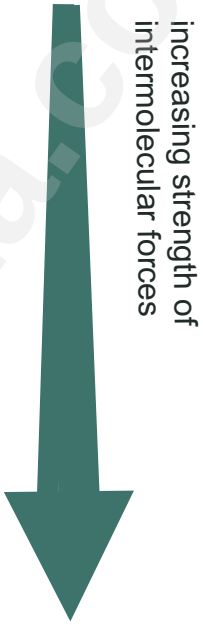
(iv) Carboxylic acids and esters

✎Intermolecular forces between carboxylic molecules are strong hydrogen bonds
✎Intermolecular forces between esters are merely weak Van der Waal forces
✎More energy is required to break hydrogen bonds than is required to break Van der Waal forces
✎Hence carboxylic acids have higher boiling points, higher melting points, high viscosity, low vapour pressure, less flammable than respective esters of the same mass

(iv) General comparison

✎The table below shows the type of intermolecular forces acting on selected organic molecules:

Homologous series	Intermolecular
Alkanes, alkenes and alkynes	Van der Waal
Haloalkanes	Van der Waal
Aldehydes, ketones, esters	Van der Waal
Alcohols	Van der Waal, Hydrogen bonding
Carboxylic acids	Van der Waal, Hydrogen bonding



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TASK 4

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QUESTION 1 (MARCH 2009/P2/Q5)

There are two structural isomers for the organic compound with molecular formula $C_2H_4O_2$.

1.1 Define the term *structural isomer*. (2)

1.2 Write down the structural formula of these two isomers and next to each its IUPAC name. (3 x 2) (6)

1.3 State with reason which ONE of these isomers:

1.3.1 Has the higher boiling point (3)

1.3.2 Has the higher vapour pressure (3)

1.4 Will the vapour pressure of carboxylic acids increase or decrease if the number of carbon atoms in the chain increases? Give a reason for your answer. (3)
[17]

QUESTION 2 (NOV 2010/P2/Q4)

Five alcohols represented by the letters A E are listed in the table below.

A	Methanol	**B**	Ethanol
C	Propan-1-ol	**D**	Butan-2-ol
E	2-methylpropan-2-ol		

2.1 Which ONE of the above alcohols is a SECONDARY alcohol? Write down only the LETTER that represents the alcohol. (1)

2.2 The letter E represents 2-methylpropan-2-ol. For this alcohol, write down the following:

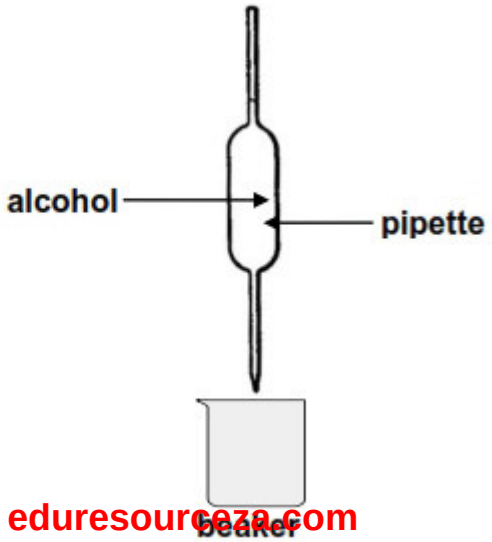
2.2.1 Its structural formula (2)

2.2.2 The LETTER in the table that represents one of its structural isomers (1)

2.3 Viscosity is a measure of a fluid's resistance to flow. Learners conduct an investigation to compare the viscosities of the first three alcohols (A - C) in the table above. They use the appara



stopwatch



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The learners use the stopwatch to measure the time it takes a FIXED VOLUME of each of the alcohols to flow from the pipette. They record this flow time, which is an indication of the viscosity of each alcohol, as given in the table below.

	Alcohol	Flow time (s)
A	Methanol	4,0
B	Ethanol	7,9
C	Propan-1-ol	14,3

2.3.1 Formulate an investigative question for this investigation. (2)

2.3.2 Which ONE of the alcohols (A, B, or C) has the highest viscosity? Use the data in the table to give a reason for the answer. (2)

2.3.3 Refer to the intermolecular forces of the three alcohols (A, B and C) to explain the trend in viscosities as shown in the table. (2)

2.3.4 Lubricants reduce friction. Which one of alcohols, A, B or C, will be the best lubricant? (1)

2.4 Which ONE of 2-methylpropan-2-ol and butan-2-ol has the higher viscosity? (1)

2.5 Refer to intermolecular forces to explain the answer to QUESTION 4.4. (2)

[14]

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(1) Source of fuel

- Alkanes are our most important fossil fuel sources
- Alkanes undergo combustion which is highly exothermic process

$$\text{ALKANE} + O_2 \rightarrow H_2O + Co_2 \qquad \Delta H < 0$$

(2) Production of esters

- An ester is produced from a reaction between an alcohol and a carboxylic acid in the presence of concentrated sulphuric acid catalyst through a process known as condensation
- One example is the production of ethyl ethanoate
- Ethanoic acid reacts with ethanol to produce an ester which is known as ethyl ethanoate
- This reaction is slow and reversible, so in order to reduce the chances of the reversible reaction happening, the ester is distilled immediately after it is formed

$$CH_3COOH + CH_3CH_2OH \rightleftharpoons CH_3COOCH_2CH_3 + H_2O$$

ethanoic acid	ethanol	ethyl ethanoate	water

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(1) Addition reactions

Markovnikov's Rule: When you add a molecule (H-X) across a carbon - carbon double bond, the H atom joins to the carbon atom which already has the more hydrogen atoms attached to it and X will be attached to the carbon atom with more number of alkyl substituents. Where H is a hydrogen atom and X is an atom or group of atoms e.g a halogen or a hydroxyl group.

Addition reaction
An organic reaction where two or more molecules combine to form a single larger molecule

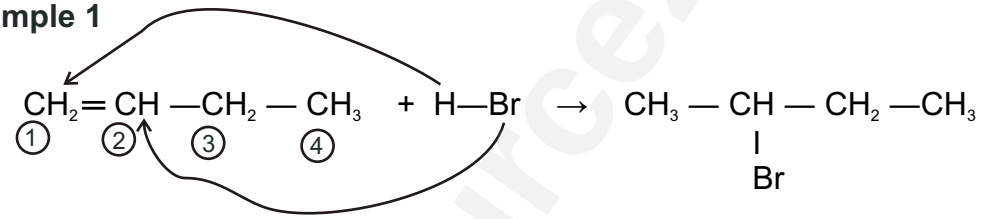
- This kind of reaction occurs only to unsaturated compounds
- Addition reaction is the reverse of elimination reaction
- The following are examples of addition reactions:

(a) Hydrohalogenation

- It is the addition of an (H-X) molecule to an alkene

Where H - hydrogen atom
X - halogen atom

Example 1



- **According to Markovnikov's rule: W**hen the hydrogen halide (HBr) is added to the above alkene its hydrogen atom attached on to the carbon atom number 1 (with more number of H atoms) while the halide atom (Br) will be attached on to the carbon atom number 2 (with more number of alkyl substituents) as shown in the example 1 above.

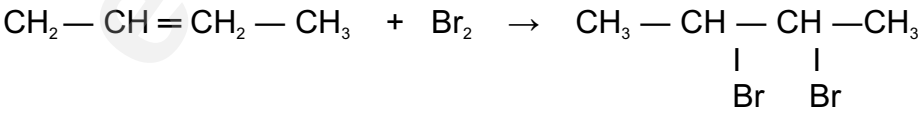
Reaction conditions

- A hydrogen halide should be added to an alkene in the absence of water

(b) Halogenation

- In this reaction a halogen molecule is added to an alkene

Example 2



Reaction conditions

- A halogen molecule (X_2 where X = Cl, Br) is added to an alkene

(c) Hydration

- It is the addition of water to alkenes to form alcohols
- With ethene it is easier to identify which carbon atom will be attached to the H atom because it is symmetrical

Example 2 

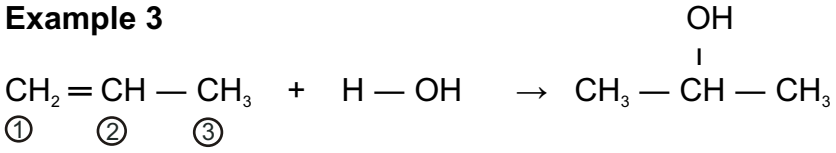
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∴ The H atom can either attach to carbon 1 or carbon 2

However if other alkenes like propene (which are not symetrical) are hydrated, Markovnikov's Rule should be applied to identify which carbon atom will be attached to the H atom

Example 3



The H atom got attached to carbon number 1 which had 2 hydrogen atoms

Reaction conditions

Water in access

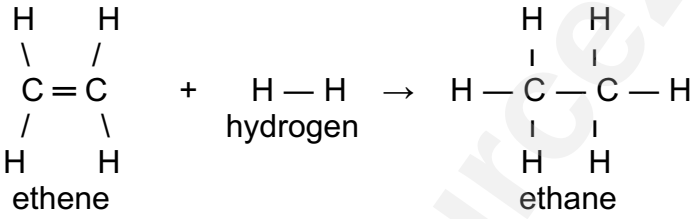
Small amount of HX or other strong acid (H_3PO_4) as a catalyst

Hydrogenation

Hydrogenation is the addition of hydrogen molecule (H_2) to alkenes

In this reaction, two hydrogen atoms are added across the double bond of an alkene which results in a saturated alkane

Example 4



Reaction conditions

Alkene dissolve in a non-polar solvent

A catalyst (Pt, Pd, or Ni) is used in an atmosphere with hydrogen

(2) Elimination reactions

Elimination reaction:

Is a reaction where one or more substituents are removed from a saturated molecule forming unsaturated molecule

Examples of saturated molecules include alkanes, haloalkanes and alcohols

Some of the examples of elimination reactions are dehydrohahogenation, dehydration of alcohols and cracking of hydrocarbon.

(a) Dehydrohalogenation

It is defined as the elimination of both a hydrogen atom and a halogen atom from a haloalkane

It is another method used to prepare alkenes from haloalkanes

Reaction conditions

Apply **heat** under reflux

Use **concentrated** solution of NaOH or KOH in pure ethanol

NB: **Dilute** solution of NaOH / KOH in pure ethanol will result in a **substitution reaction**

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Example 5

$$\underset{\text{bromoethane}}{CH_3 — CH_2Br} \xrightarrow[\Delta]{\text{conc Alc. KOH}} \underset{\text{ethene}}{CH_2 = CH_2} + \underset{\text{potassium bromide}}{KBr} + \underset{\text{water}}{H_2O}$$

✎The major product in this elimination reaction is ethene

Example 6

$$H — \overset{H}{\overset{|}{C}} — \overset{H}{\overset{|}{C}} — CH_3 \xrightarrow[\Delta]{\text{conc Alc. KOH}} H — C = C — CH_3 + KBr + H_2O$$
(H on C bonded to H; H on C bonded to Br)

(Alc. - alcoholic, Δ - heat)

Example 7

$$CH_3 — CHCl — CH — CH_3 \xrightarrow[\Delta]{\text{conc Alc. NaOH}} CH_3 — CH = CH — CH_3 + NaCl + H_2O$$

(b) Dehydration of alcohols

✎The removal of water from an alcohol is called a dehydration reaction

✎This is a process used to make alkenes from alcohols

> **Zaitsev's RULE: If more than one product is being eliminated, the major product is the one where the H atom is removed from the C atom with the least number of H atoms.**

✎Concentrated H_2SO_4 / H_3PO_4 is used during dehydration of alcohols

✎One of the disadvantages of concentrated H_2SO_4 is that it do not produce pure alkenes with some alcohols, rather it oxidises them to carbon dioxide and itself is reduced to sulphur dioxide

Example 8

$$CH_3CH_2CH_2OH \xrightarrow[\Delta]{\text{conc } H_2SO_4 \text{ / conc } H_3PO_4} CH_2 = CH — CH_3 + H_2O$$

Example 9

$$\underset{\text{2-butanol}}{CH_3 — CH_2 — \overset{OH}{\overset{|}{C}}H — CH_3} \rightarrow \underset{\text{2-butene}}{CH_3 — CH = CH — CH_3} + \underset{\text{1-butene}}{CH_3 — CH_2 — CH = CH_2} + \underset{\text{water}}{H_2O}$$

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✎According to Zaitsev's rule, the major product in this reaction is 2-butene

Reaction conditions

✎A concentrated H_2SO_4 / H_3PO_4 catalyst is used
✎Heat alcohol

(c) Cracking of hydrocarbons

✎Cracking is defined as breaking up of large hydrocarbon molecules into smaller molecules
✎Usually large hydrocarbons are less useful than small hydrocarbons
✎Consider crude oil, it must be broken up to produce smaller hydrocarbons like parafin, petrol, diesel etc which are more useful in our day to day lives
✎One possible example is the breaking down of the following hydrocarbon into butene, butane and octane

$$C_{20}H_{42} \rightarrow \underset{\text{butene}}{2C_4H_8} + \underset{\text{butane}}{C_4H_{10}} + \underset{\text{octane}}{C_8H_{18}}$$

Reaction conditions

✎Either use high pressures and temperatures without using a catalyst (thermal cracking)
✎Or use lower temperatures and pressures in the presence of a catalyst (catalytic cracking)

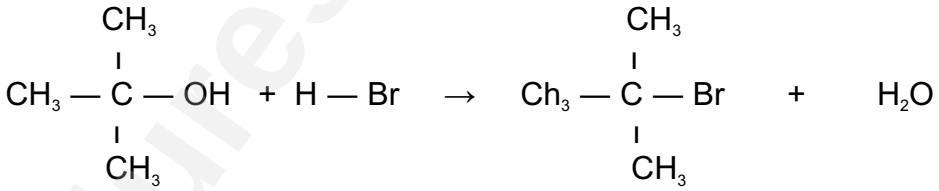
(3) Substitution reactions

✎This is a reaction whereby a functional group in one particular compound is replaced by another group
✎Two types of saturated structures can be inter-converted by substitution
✎A simple example of inter-conversion:

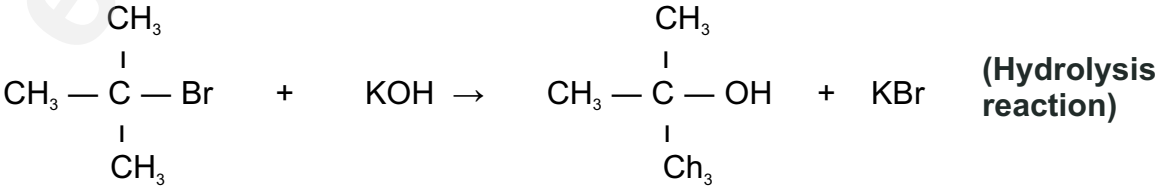
COMPOUND A IS CONVERTED TO **COMPOUND B**, AND **COMPOUND B** WILL ALSO BE ABLE TO BE CONVERTED BACK TO **COMPOUND A**

Example 10

2 - methylpropan-2-ol is converted to **2-bromo - 2 - methylpropane**



2-bromo - 2 - methylpropane is converted back to **2 - methylpropan-2-ol**



✎HX (X= Cl, Br) compounds reacts with alcohols to produce haloalkanes as shown above
✎The reaction works best with tertiary alcohols
✎Primary and secondary alcohols react slowly at high temperatures
✎The reaction of dilute bases (e.g KOH) with haloalkanes to produce alcohols is called **hydrolysis**

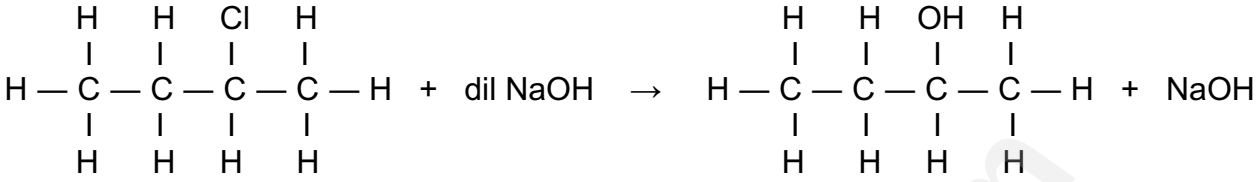
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Hydrolysis

✎Is a substitution reaction which takes place between water or an -OH ion and a haloalkane

Further example of hydrolysis reactions



Reaction conditions

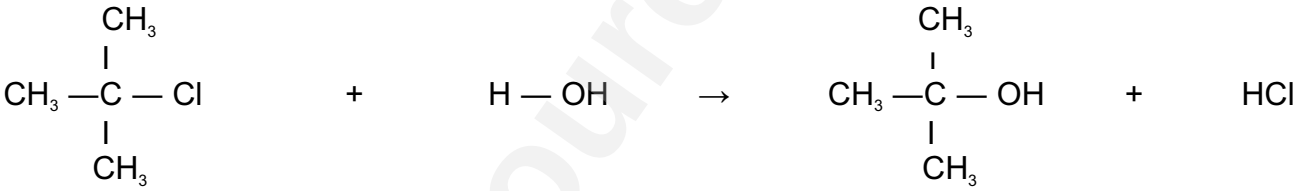
✎Dissolve haloalkane in alcohol (e.g ethanol) before treatment with dilute or aqueous sodium hydroxide

✎Warm the mixture

NB: Most haloalkanes are usually refluxed with an alkali like aqueous sodium hydroxide during a hydrolysis reaction, however there are some haloalkanes molecules which are reactive enough to hydrolyze when just mixed with water bu the reaction proceeds slowly.

Example of hydrolysis with water

Hydrolysis reaction between 2-chloro-2-methylpropane and water is as follows:



2-chloro-2-methylpropane 2 - methylpropan-2-ol

Guidelines on the outcome of a haloalkane reaction (substitution or elimination):

(a) Type of haloalkane

(i) Primary haloalkanes - mainly substitution
(ii) Secondary haloalkanes - substitution and elimination
(iii) Tertiary haloalkane - mainly elimination

(b) Type of solvent used

(i) Water - mainly substitution
(ii) Ethanol - mainly elimination

(c) Concentration of NaOH/KOH

(i) Concentrated NaOH/KOH - eliminaton
(ii) Dilute NaOH/KOH - eliminaton

Haloalkanes from alkanes

✎Halogens directly react with alkanes alkanes in the presence of ultra violet light to form haloalkanes

✎Examples of such reactions include:

(a) Reaction between methane and chlorine: $Cl_2 + CH_4 \rightarrow CH_3Cl + Hcl$

(b) Reaction between bromine and propane: $Br_2 + CH_3CH_2CH_3 \rightarrow CH_3CH_2Br + Hbr$

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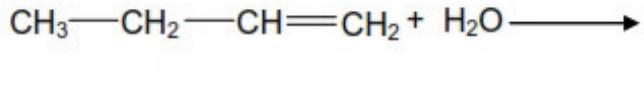
TASK 5

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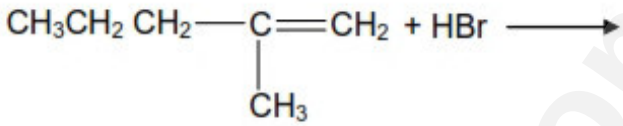
(FEB 2009/P2/Q7)

Most organic compounds can undergo substitution or addition or elimination reactions to produce a variety of organic compounds. Some incomplete organic reactions are represented below.

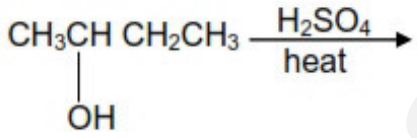
Reaction I



Reaction II



Reaction III



1.1 Name the type of reaction represented by reaction III. (1)

1.2 Both reactions I and II are examples of addition reactions. Name the type of addition that is represented by each reaction. (2)

1.3 Write down the structural formula and IUPAC name of the major product formed in reaction I. (3)

1.4 Reaction I only takes place in the presence of a catalyst. Write down the formula of the catalyst used in reaction I. (1)

1.5 Write down the structural formula and IUPAC name of the major product formed in reaction II. (3)

1.6 To which homologous series does the organic product formed in reaction III belong? (2)

[12]

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ADDITION REACTIONS IMPORTANT IN INDUSTRY

(a) Hydrogenation

✎It involves addition of hydrogen atoms to the double bonds or tripple bonds of a molecule through the use of a catalyst (platinum or palladium)
✎The reaction occurs at lower temperatures and lower pressure

One example of industrial application of hydrogenation is **the processing of vegetable oils and fats.**

✎Hydrogenation convert liquid vegetable oils to solid or semi-solid fats e.g margarine
✎The double bonds in the hydrocarbon chain of these oils or fats converted to a single bonded semi-solids, whose intermolecular forces are much stronger

(b) Addition polymerization reactions

✎Addition polymerization reactions are very important in industry
✎Examples of some of the products that are formed by addition polymerization reactions are polyethylene, polypropylene and polyvinyl chloride (PVC)
✎A polymer is formed when an addition reaction take place between two or more monomers

(c) Production of ethanol

✎As we discussed in previous chapters, alcohols are formed by an addition reaction between alkenes and water
✎Ethanol for instance is formed when ethene is reacted with steam (water) in the following reversible reaction

$$CH_2 = CH_2\ (g) + H_2O = CH_3CH_2OH\ (g)$$

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POLYMERS AND PLASTICS

Polymers

- These are macromolecules produced by chemically combining together many smaller repeating molecules
- Smaller identical units are combined repeatedly to give rise to a polymer
- Some **examples** of polymers are:

plastics
fibers
rubbers

Macromolecule

- A macromolecule is a very large molecule with a high relative molecular mass which is formed by chemically combining smaller different molecules
- Unlike polymers, macromolecules are formed as a result of combining smaller but different units
- As a result, unlike polymers, macromolecule do not have any repeating units
- Some examples of major biological macromolecules are:

Plastics	carbohydrates
Rubbers	nucleic acids
Fibers	proteins

NB: A polymer is a macromolecule because of its larger relative molecular mass, however a macromolecule is not a polymer because it do not consist of repeating smaller units.

Monomer

- Small units that are combined together to form polymers

Types of polymers

- Polymers are divided into natural polymers and synthetic polymers

Examples natural polymers

starch	cellulose	protein
protein	wood	cotton
wool		

Examples of synthetic polymers

plastics e.g wrapping papers, plastic bags etc
fibers e.g windscreens, brakepads
rubber e.g shoe soles,tyres

Classification of synthetic polymers according to process by which they are formed:

(a) Addition polymers
(b) Condensation polymers

(a) ADDITION POLYMERISATION

- This is a process whereby unsaturated monomers (e.g alkenes) are chemically added together to form much bigger saturated polymers
- A larger saturated polymer formed through addition is called an **addition polymer**
- The general reaction in the production of addition polymers is as shown below:

$$n\,(R{-}C{=}C{-}R') \xrightarrow{\text{catalyst}} {-}(-C-CR'-)_n-$$

Where R and R′ are hydrogen atoms, halogen atoms, alkyl groups etc

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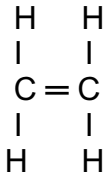
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✎An alkene is the repeating unit in the chain (monomer)

Example

✎Polythene is an example of an addition polymer made from addition reactions between ethene molecules

✎Ethene has a single carbon - to carbon double bond as shown below:



✎The ethene is the monomer of polythene

✎The C = C double bond is fairly strong but can be easily attacked by reactive species such as free radicals

✎**Free radicals** can easily attack one of the bonds in the C = C by taking one of the double bond electrons

✎**A free radical is a molecule with an unpaired electron**

Formation of a free radical

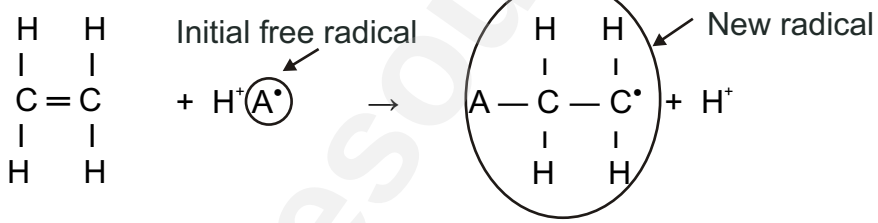
✎ A free radical can be formed when an acid HA is broken either by heat or light energy as shown below: $H-A \rightarrow H^+ + A^-$

✎However the radical A^- is normally represented as $A^\bullet$, it is very unstable and reactive

Steps in production of polyethene

(1) Initiation stage

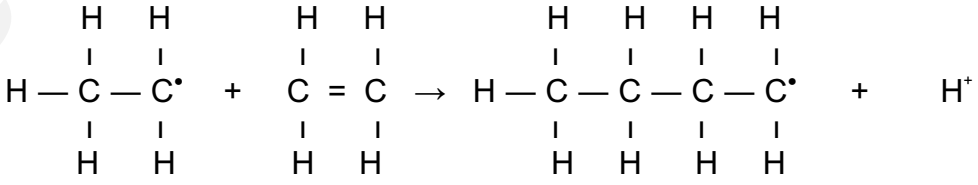
✎ A free radical attacks the double bond of ethene as shown below:

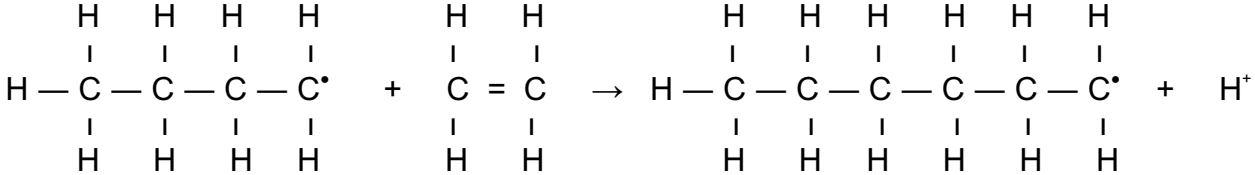


✎When the double bond breaks, one electron from the radical pair with one electron from the broken double bond, and another electron from the broken double bond forms a new radical as shown in the diagram above

(2) Propagation stage

✎Once the new radical is formed, since it has an unpaired electron, it will attack C = C for new ethene molecules to form a new and bigger radical as shown below:





✎The reaction proceed with more bigger radicals being formed until they become long chains

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(3) Termination stage

✎When a large percentage of ethene molecules have been added together to form a very long radical, and when no new radical is being formed, propagation will terminate

✎ At this moment the H^+ will finally add to the very long radical, and a polymer is formed with **n** monomer units as shown below:

$$— (— CH_2 — CH_2 —) — \quad OR \quad — \left[— \underset{H}{\overset{H}{C}} — \underset{H}{\overset{H}{C}} — \right]_n —$$

Where n is number of monomer units

Industrial uses of polythene

Packaging	Pipes	Plastic bags
Toys and moulded objects	Electrical insulation	Squeeze bottles
Films		

Recycling of polythene

✎Polythene has a recycling number 4

✎The following is its recycling code



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(b) CONDENSATION POLYMERS

✎Condensation polymers are formed when an elimination reaction takes place between two or more monomers during polymerization

✎In other words a condensation polymer is the main product formed when some of the atoms of monomer molecules are eliminated as small molecules during polymerization

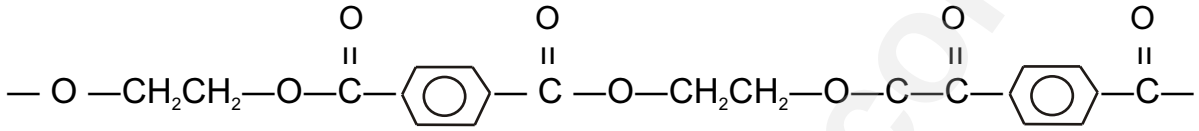
✎A simple example of a small molecule that can be eliminated during condensation polymerization is water.

✎An example of a condensation polymer is a **polyester.**

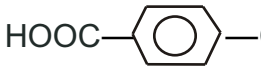
Polyester

✎Polyester is a family of polymers with an ester functional group in their main chain

✎Polyesters are made by reacting an acid with two -COOH groups and an alcohol with two -OH groups. The diagram below shows a polyester:

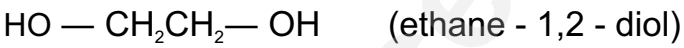


✎The acid part of the above polyester is:



(benzene - 1,4 - dicarboxylic acid)

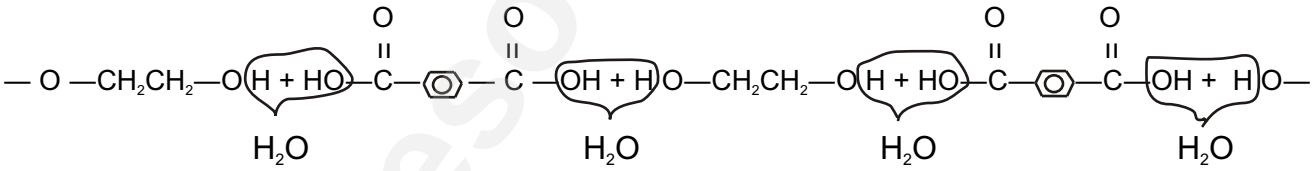
✎The alcohol part of the above polyester is:



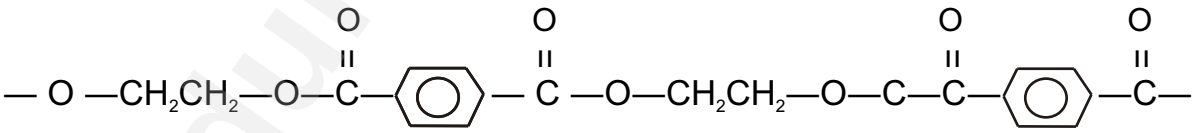
(ethane - 1,2 - diol)

✎The two monomers which forms the above polymer(polyester) are **benzene - 1,4 - dicarboxylic acid** and **ethane - 1,2 - diol**

✎When the two monomers are chemically combined into a very long chain a polyester is formed by eliminating water molecules as shown below:



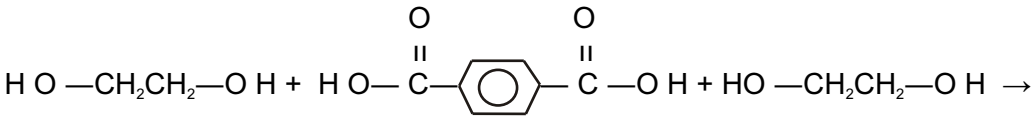
✎After condensation polymerization the end product will be as shown below:

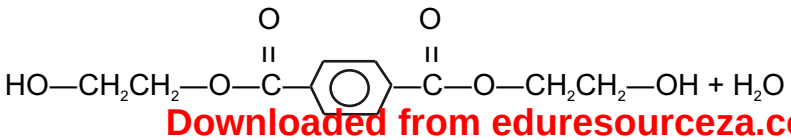


STEPS TO PRODUCE A POLYMER(POLYESTER)

(1) Initiation stage

✎Produce an ester molecule by combining an acid molecule and two molecules of an alcohol as shown below:



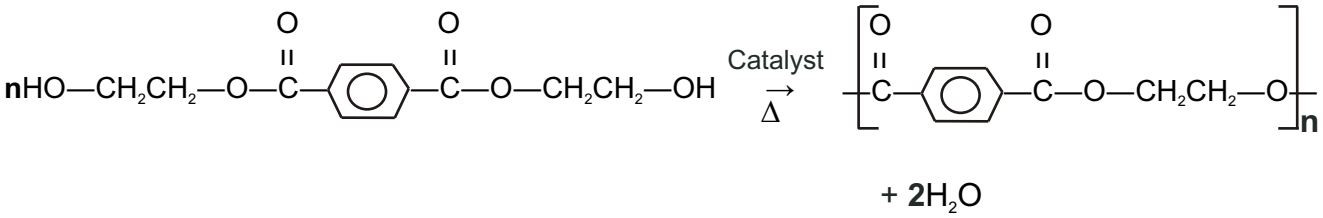


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(2) Polymerization stage

Heat an ester at high temperatures and low pressure in the presence of a catalyst to produce a condensation polymer as shown below:

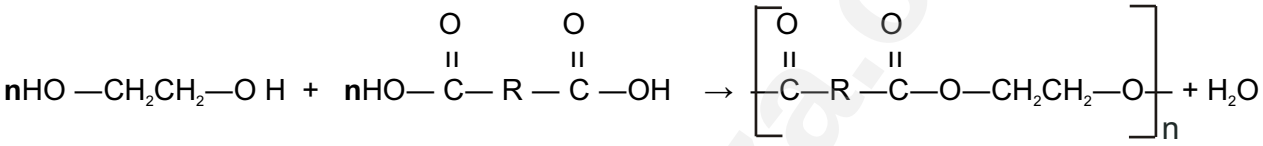


(3) Regeneration stage

During polymerization there will be excess alcohol in the reaction mixture

At this stage excess alcohol that is formed will be removed and regenerated

GENERAL EQUATION FOR ALL POLYESTERS

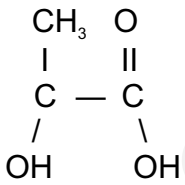


POLYLACTIC ACID

A ploylactic acid is a bio-degradable polyester

Its monomer unit is **lactic acid**

The diagram below shows lactic acid molecule:



Biological materials such as maize are fermented to produce lactic acid

Produced lactic acid is then polymerized by condensation in the presence of a catalyst to form Poly Lactic Acid (PLA)

PLA is more **advantageous** than petroleum polymers

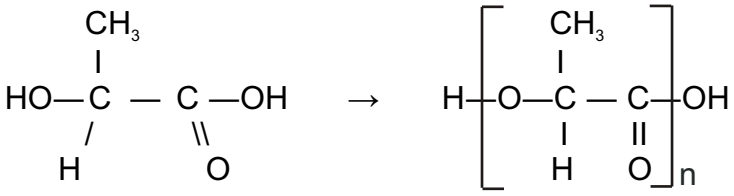
Advantages of PLA polymers

(i) it can decompose and replenish the soil
(ii) reduces environmental pollution
(iii) produces less carbon dioxide when burnt

Uses of PLA polymers

(i) materials used in motor vehicles interior
(ii) Agricultural sheeting
(iii) Household appliances
(iv) Packaging materials

Preparation of PLA using a direct method



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SUMMARY OF ADDITION POLYMERIZATION

Monomer name and structure	Polymer name and structure	Polymer uses
ethene (ethylene) $CH_2=CH_2$	polyethene (polyethylene) $-(-CH_2 - CH_2 -)_n -$	✎water insulation ✎film wrap ✎plastic bags
propene (propylene) $CH_2=CHCH_3$	polypropene (polypropylene) $-(-CH_2 -CHCH_3-)_n -$	✎electrical appliances ✎automotive applications ✎ropes ✎carpets ✎films
chloroethene (vinylchloride) $CH_2=CHCl$	polyvinylchloride (PVC) $-(-CH_2-CHCl-)_n -$	✎ indoor electrical conduits ✎ underground water pipes ✎ electrical sockets ✎ floor tiles
Vinyl acetate $CH_3COOH=CH_2$	polyvinylacetate (PVA) $-(-CH_3COOCH-CH_2-)_n -$	✎adhesives ✎paints

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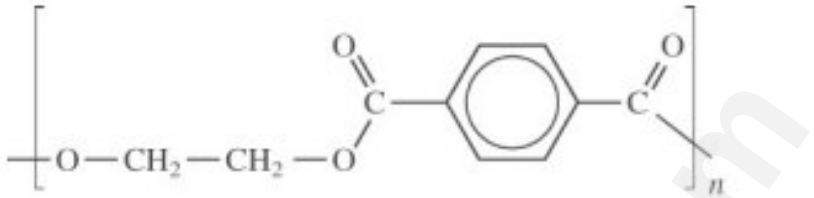
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TASK 6

QUESTION 1 (CHO9_EOC_Questions)

1.1 Here is the structural formula for Dacron, a condensation polyester.

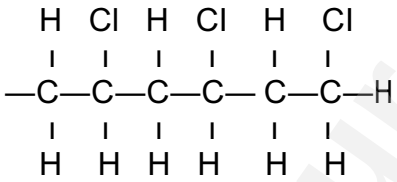


Dacron is formed from two monomers, one with two hydroxyl groups (-OH) and the other with two carboxylic acids (-COOH). Draw the structural formulas for the alcohol and acid monomers used to produce Dacron

1.2 Give two examples each of natural and synthetic polymers

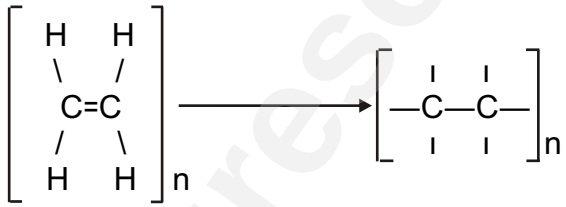
QUESTION 2

2.1 Identify the monomers and the recurring units in the following polymer:

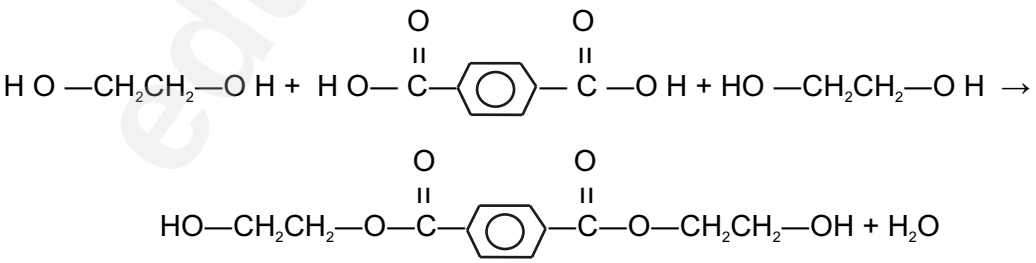


2.2 Identify the type of reactions below:

2.2.1



2.2.2



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TOPIC 4: WORK, ENERGY AND POWER

WORK

- Work is defined as force applied on an object multiplied by distance moved (displacement) in the direction of motion
- Doing work is the process of transferring energy from one object to another
- An object with a lot of energy can also do a lot of work. And when work is done, energy is lost by the object doing work and gained by the object on which work is done
- **Work is done when:**

(i) a force exerted on an object causes it to move
(ii) a force is applied in the direction of motion and there must be displacement

Examples of situations where work is done:
(1) A book falls off a table and free falls to the ground
(2) A rocket accelerates through space
(3) A person pushing a trolley
(4) Stretching a rubber band
(5) Throwing a stone

- **Work is not done when:**

(i) force applied and displacement are at right angles to each other

Examples of situations where work is not done:
(1) A vendor carrying a load on her head
(2) A book on the table

- Work done is expressed using the equation:

$$W = F\Delta x\cos\theta, \quad \text{where}$$

F - force
Δx - displacement
θ - angle

Positive and negative work done

- Force applied (F) and displacement (Δx) are vectors, as a result work done can be positive or negative
- If applied force acts in the same direction as motion then positive work will be done (that is, the object on which work is done gains energy)
- If applied force acts in the opposite direction of motion then negative work will be done (that is, the object loses energy)

ENERGY

- Energy is the capacity to do work

Potential energy (E_P)

- Energy possessed by an object due to its position above the earth's surface
- It is expressed using the equation $E_P = mgh$, where

E_P - potential energy (J)
m - mass (kg)
g - gravitational acceleration (ms^{-2})
h - height above the earth's surface (m)

- An object with a larger potential energy has a greater capacity to do work

Kinetic energy (E_K)

- Energy possessed by an object in motion
- It is expressed using the equation $E_K = \frac{1}{2}mv^2$, where

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E_K - kinetic energy
m - mass of an object (kg)
v - velocity of an object (ms^{-1})

Mechanical energy (E_{mech})

- Mechanical energy is the sum of kinetic energy and potential energy at a single point
- Given two points A and B:

(i) Mechanical energy at A is given by $(E_{mech})_A = (E_K + E_P)_A = mgh_A + \frac{1}{2} mv^2_A$
(ii) Mechanical energy at B is given by $(E_{mech})_B = (E_K + E_P)_B = mgh_B + \frac{1}{2} mv^2_B$

Calculating net force (resultant force)

(a) Objects moving on horizontal surfaces

- The following is a **hypothetical object** going to the right and has three forces acting on it:



- F_{net} is the vector sum of all forces acting on the object parallel to its direction of motion
- Therefore $F_{net} = F_3 + F_2 + F_1$
- **Component of forces** which give us the net force are: $F_3\cos\theta_3$, $F_2\cos\theta_2$ and $F_1\cos\theta_1$
- **SIGN CONVENTION**

$\theta = 0^0$ if direction of force is the same as direction of motion
$\theta = 180^0$ if direction of force is opposite to that of motion

- Using our **Sign Convention** $\theta_3 = 0^0$, $\theta_2 = 0^0$ and $\theta_1 = 180^0$
- Therefore $F_{net} = F_3\cos0^0 + F_2\cos0^0 + F_1\cos180^0$

EXAMPLE 1

Suppose forces acting on the **hypothetical** object **A** above are $F_3 = 50N$, $F_2 = 10N$ and $F_1 = 5N$. Calculate the net force acting on object **A**.

SOLUTION 1

Data Given
$F_3 = 50N$ $F_2 = 10N$ $F_1 = 5N$

But $F_{net} = F_3 + F_2 + F_1$

Using our **Sign Convention**:
$F_{net} = F_3\cos0^0 + F_2\cos0^0 + F_1\cos180^0$
$= (50)\cos0^0 + (10)\cos0^0 + (5)\cos180^0$
$= 50\ (1) + (10)(1) + (5)(-1)$
$= 50 + 10 - 5 = 55N$ to the right

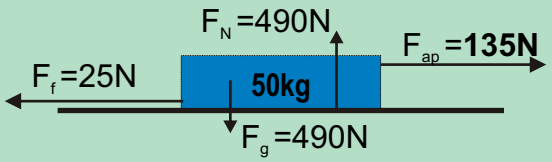
EXAMPLE 2

Suppose a 50kg box was pulled horizontally by a 135N force on a rough surface. If it experiences a force of frictional force of 25N, calculate the net force.



SOLUTION 2

Draw a force diagram:



Collect Data Given
$F_f = 25N$ $F_{ap} = 135N$ $F_N = 490N$ $F_g = 490N$

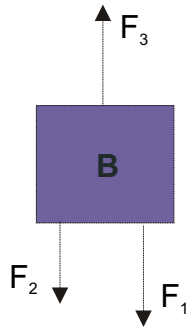
But $F_{net} = F_{ap} + F_f$
Using our **Sign Convention**:
$F_{net} = F_{ap}\cos0^0 + F_f\cos180^0$
$= (135)\cos0^0 + (25)\cos180^0$
$= 135\ (1) + (25)(-1)$
$= 135 - 25 = 110N$ to the right

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(b) Objects moving on vertical surfaces

The following is a **hypothetical object** moving vertically upwards and three forces are acting on it:



$F_{net} = F_3 + F_2 + F_1$

$F_{net} = F_3\cos\theta_3 + F_2\cos\theta_2 + F_1\cos\theta_1$

But $\theta_3 = 0^0$, $\theta_2 = 180^0$ and $\theta_1 = 180^0$

$F_{net} = F_3\cos0^0 + F_2\cos180^0 + F_1\cos180^0$

EXAMPLE 3

If forces acting on object **B** above are $F_3 = 60N$, $F_2 = 15N$ and $F_1 = 10N$. Calculate the net force acting on object **B**.

SOLUTION 3

Data Given

$F_3 = 60N$, $F_2 = 15N$ and $F_1 = 10N$

But $F_{net} = F_3 + F_2 + F_1$

Using our **Sign Convention**:

$F_{net} = F_3\cos0^0 + F_2\cos180^0 + F_1\cos180^0$

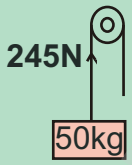
$= (80)\cos0^0 + (15)\cos180^0 + (10)\cos180^0$

$= 80(1) + (15)(-1) + (10)(-1)$

$= 80 - 15 - 10 = 55N$ upwards

EXAMPLE 4

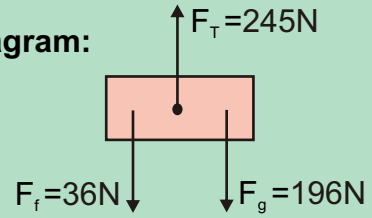
Suppose a pulley system pulled a 20kg box vertically upwards at a constant speed. If tension in the rope is 245N, and the box experiences a air resistance of 36N, calculate the net force acting on the box.



SOLUTION 4

Draw a force diagram:

$F_g = mg$
$\mathbf{g = 9.8 m.s^{-2}}$
$F_g = (20)(9.8)$
$= 196N$



Collect Data Given

$F_T = 245N$ $F_g = 196N$ $F_f = 36N$

But $F_{net} = F_T + F_f + F_g$

Using our **Sign Convention**:

$F_{net} = F_T\cos0^0 + F_g\cos180^0 + F_f\cos180^0$

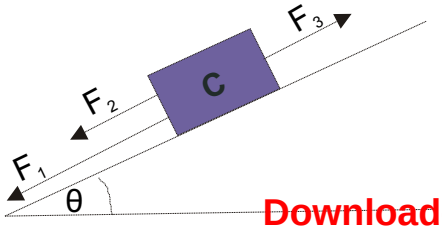
$= (245)\cos0^0 + (196)\cos180^0 + (36)\cos180^0$

$= 245(1) + 196(-1) + 36(-1)$

$= 245 - 196 - 36 = 13N$ upwards

(c) Objects moving on an incline

The following object is moving up the incline and three forces are acting on it:



$F_{net} = F_3 + F_2 + F_1$

$F_{net} = F_3\cos\theta_3 + F_2\cos\theta_2 + F_1\cos\theta_1$

But $\theta_3 = 0^0$, $\theta_2 = 180^0$ and $\theta_1 = 180^0$

$F_{net} = F_3\cos0^0 + F_2\cos180^0 + F_1\cos180^0$

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EXAMPLE 5

If forces acting on object **C** above are F_3 = 160N, F_2 = 75N and F_1 =20N. Calculate the net force acting on object **C**.

SOLUTION 5

Data Given

F_3 = 160N, F_2 = 75N and F_1 =20N

But $F_{net} = F_3 + F_2 + F_1$

Using our **Sign Convention**:

$F_{net} = F_3\cos0^0 + F_2\cos180^0 + F_1\cos180^0$

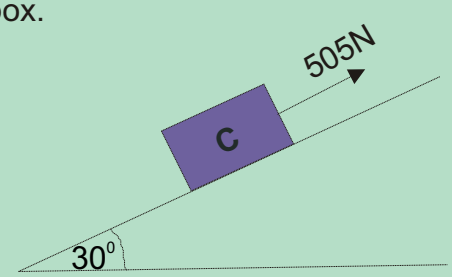
$= (160)\cos0^0 + (75)\cos180^0 + (20)\cos180^0$

$= 160(1) + (75)(-1) + (20)(-1)$

$= 160 - 75 - 20 = 65$N up the slope

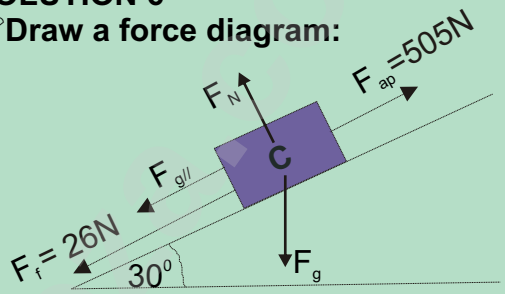
EXAMPLE 6

Suppose a 60kg box was pulled up the inclined plane by a force of 505N as shown in the diagram below. If a frictional force of 26 N acts on the box, calculate the net force acting on the box.



SOLUTION 6

Draw a force diagram:



Collect Data Given

F_{ap} =105N $F_{g//} = mg\sin\theta = 60x9.8\sin30^0 = 294$N

F_f =26N

But $F_{net} = F_{ap} + F_f + F_{g//}$

Using our **Sign Convention**:

$F_{net} = F_{ap}\cos0^0 + F_f\cos180^0 + F_{g//}\cos180^0$

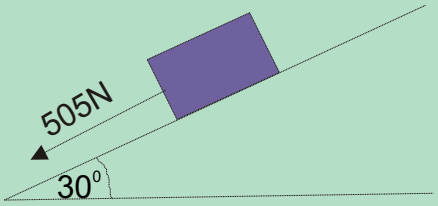
$= (505)\cos0^0 + (26)\cos180^0 + (294)\cos180^0$

$= 505\ (1) + 26(-1) + 294(-1)$

$= 505 - 26 - 294 = 185$N up the slope

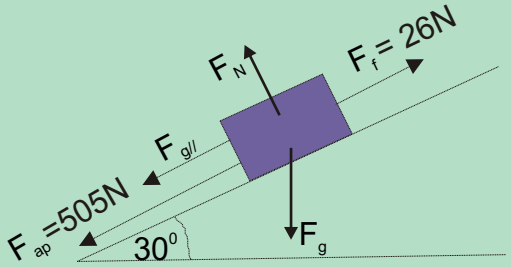
EXAMPLE 7

Suppose a 60kg box was pulled down the inclined plane by a force of 505N as shown in the diagram below. If a frictional force of 26 N acts on the box, calculate the net force acting on the box.



SOLUTION 7

Draw a force diagram:



Collect Data Given

F_{ap} =105N $F_{g//} = mg\sin\theta = 60x9.8\sin30^0 = 294$N

F_f =26N

But $F_{net} = F_{ap} + F_f + F_{g//}$

Using our **Sign Convention**:

$F_{net} = F_{ap}\cos0^0 + F_f\cos180^0 + F_{g//}\cos0^0$

$= (505)\cos0^0 + (26)\cos180^0 + (294)\cos0^0$

$= 505\ (1) + 26(-1) + 294(1)$

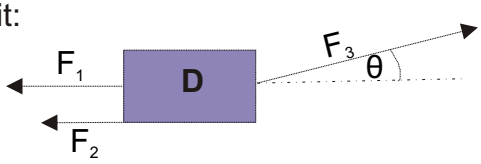
$= 505 - 26 + 294 = 773$ N down the slope

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(d) Objects moving horizontally to the right with some forces at an incline:

The following is a **hypothetical object** moving up an incline and three forces are acting on it:



$F_{net} = F_3 + F_2 + F_1$

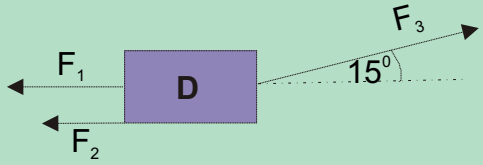
$F_{net} = F_3\cos\theta_3 + F_2\cos\theta_2 + F_1\cos\theta_1$

But $\theta_3 = 0^0$, $\theta_2 = 180^0$ and $\theta_1 = 180^0$

$F_{net} = F_3\cos0^0 + F_2\cos180^0 + F_1\cos180^0$

EXAMPLE 8

If forces acting on object **D** above are $F_3 = 55N$, $F_2 = 17N$ and $F_1 = 13N$. Calculate the net force acting on object **B**.



SOLUTION 8

Data Given

$F_3 = 55N$, $F_2 = 17N$ and $F_1 = 13N$ $\theta = 15^0$

But $F_{net} = F_3 + F_2 + F_1$

Using our **Sign Convention**:

$F_{net} = F_3\cos0^0\cos15^0 + F_2\cos180^0 + F_1\cos180^0$

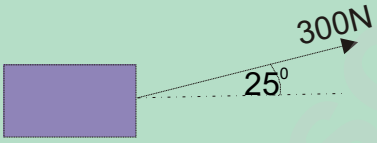
$= (55)\cos0^0\cos15^0 + (17)\cos180^0 + (13)\cos180^0$

$= 55(1)(0.97) + (17)(-1) + (13)(-1)$

$= 53.35 - 17 - 13 = 23.35N$ to the right

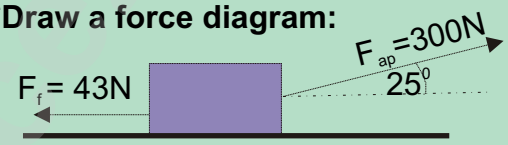
EXAMPLE 9

Suppose a 20kg box is pulled horizontally at an angle as shown in the diagram below. If the applied force is 300N, and the box experiences a frictional force of 43N, calculate the net force acting on the box.



SOLUTION 9

Draw a force diagram:



Collect Data Given

$F_{ap} = 300N$ $F_f = 43N$

But $F_{net} = F_{ap} + F_f$

Using our **Sign Convention**:

$F_{net} = F_{ap}\cos0^0 + F_f\cos180^0$

$= (300)\cos0^0 + (43)\cos180^0$

$= 300\ (1) + 43(-1)$

$= 300 - 43 = 257N$ to the right

WORK NET

Work net is the work done by a net force

It can be expressed as $W_{net} = F_{net} \times \Delta x\cos\theta$

However it also be found by calculating the total work done by all the forces acting on an object in the direction of motion

Work net done on the following **hypothetical object** moved Δx**m** to the right is:

NOTE: At constant velocity $F_{net} = 0$ and hence $W_{net} = 0$



$W_{net} = W_{F1} + W_{F2} + W_{f3}$

$= (F_1\cos\theta_1)\Delta x + (F_2\cos\theta_2)\Delta x + (F_3\cos\theta_3)\Delta x$

$= (F_1\cos180^0)\Delta x + (F_2\cos180^0)\Delta x + (F_3\cos0^0)\Delta x$

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EXAMPLE 10

If a force of 150N is applied to move object E 2**m** to the right in the above diagram, and a frictional force of 13N acts against it, what is the value of net work done on the object? Assume the mass of object E is 15kg.

SOLUTION 10



Given Data: F_{ap}= 150N, F_f= 13N, Δx=2m

$W_{net} = W_{ap} + W_f$

$= (F_{ap}\cos 0^0)\Delta x + (F_f \cos 180^0)\Delta x$

$= (150)(1)(2) + (13)(-1)(2)$

$= (300) + (-26)$

$= 274J$

Work - energy theorem

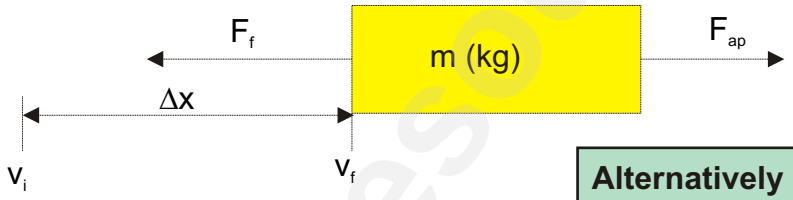
- It states that:
- The net work done on an object is equal to its change in kinetic energy
- Or the work done by a net force on an object is equal to its change in kinetic energy
- It is summarized by the following equation:

$$W_{net} = \Delta E_K$$
$$= E_{Kf} - E_{ki}$$
$$= \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_i^2$$

Application of Work - Energy Theorem

(i) Objects on horizontal surfaces

A net force acting on an object in the diagram below will do a net work by causing a displacement (Δx) in the horizontal direction according to the equation $W_{net} = F_{net} \times \Delta x \cos\theta$. For an object moving horizontally its potential energy is zero, therefore the net work done is only as a result of change in its kinetic energy. Work is done by a net force on the object below when kinetic energy is transferred according to the equation $W_{net} = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_i^2$



Calculating W_{net}

$F_{net} = F_{ap} + F_f$

$= F_{ap}\cos 0^0 + F_f \cos 180^0$

$W_{net} = F_{net} \times \Delta x \cos\theta$.

Alternatively

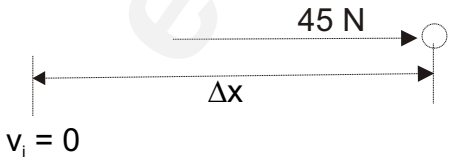
$W_{net} = Wap + W_f$

$= F_{ap}\cos 0^0 \Delta x + F_f \cos 180^0 \Delta x$

EXAMPLE 11

A student wearing a frictionless in - line skates on a horizontal surface is pushed by a friend with a constant force of 45 N. How far must the student be pushed, starting from rest, so that the final kinetic energy is 352 J (Use work - energy theorem).

SOLUTION 11



Data given:

F_{ap} = 45 N

v_i = 0 ms^{-1}

E_{kf} = 352 j

- According to work - energy theorem

$W_{net} = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_i^2$

- Since v_i = 0 (starting from rest) it follows that E_{ki} is zero also. Therefore

$W_{net} = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}m\,(0)^2 = \tfrac{1}{2}mv_f^2$

- But $\tfrac{1}{2}mv_f^2$ = 352 J *(given)*.
- Therefore W_{net} = 352 J
- And $W_{net} = F_{net} \times \Delta x \cos\theta$
- $F_{net} = F_{ap}$ *(sum of all forces)*

$= F_{ap}\cos 0^0 = 45\cos 0^0$

= 45 N, forward

- $352 = 45 \times \Delta x \cos 0^0$
- Δx = 7.82 m

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EXAMPLE 12

The driver of a 1000kg car traveling at a speed of 16.7 m/s applies brakes when he sees a red robot. The car's brakes provide a frictional force of 8000N. Determine the stopping distance of the car by using the work - energy theorem.

SOLUTION 12

Given Data

m = 1000kg

v = 16.7 m/s

F_f = 8000N

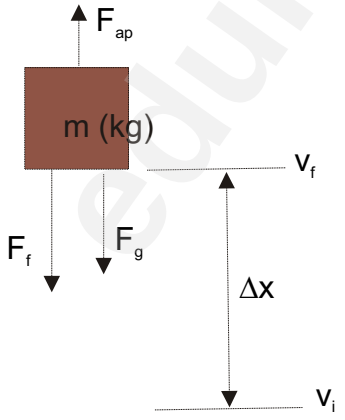


- The work - energy theorem states that $W_{net} = \Delta E_K$
- We can find net work done by adding work done by all forces acting in the direction of motion of the object, in this case only friction is acting on the object
- So $W_{net} = W_f$
  $= (F_f \cos 180^0)\ \Delta x$
  $= 8000 \cos 180^0 \Delta x = 8000(-1)\Delta x$
- But $\Delta E_K = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$
  $= 0 - \frac{1}{2} \times 1000 \times 16.7^2$
  $= -139445$
- Substituting values into the equation $\mathbf{W_{net} = \Delta E_K}$ we will have:
  $8000(-1)\Delta x = -139445$

Therefore $\Delta x = 17.4m$

(ii) Objects on vertical surfaces

A net force acting on an object in the diagram below will do a net work by causing a displacement (Δx) in the vertical direction upwards according to the equation $W_{net} = F_{net} x\ \Delta x \cos\theta$. Since the object is moving vertically upwards its kinetic energy is being transferred to potential energy, $\Delta E_K = \Delta E_P$. Hence net work done on an it is a result of change in its kinetic energy. Work is done by a net force on the object below when kinetic energy is transferred according to the equation $W_{net} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$



Calculating W_{net}

$F_{net} = F_{ap} + F_f + F_g$

$F_{net} = F_{ap} \cos 0^0 + F_f \cos 180^0 + F_g \cos 180^0$

$W_{net} = F_{net} x\ \Delta x \cos\theta$

Alternatively,

$W_{net} = Wap + W_f + Wg$

$= F_{ap} \cos 0^0 \Delta x + F_f \cos 180^0 \Delta x + F_g \cos 180^0 \Delta x$

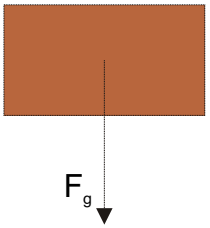
EXAMPLE 13

A brick of mass 1 kg is dropped from a height of 10m. Calculate (a) The work done on the brick at the point it hits the ground assuming that there is no air resistance. (b) Velocity with which hits the ground (Use work - energy theorem)

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SOLUTION 13



a)

- $W_{net} = W_g$
- $W_{net} = F_g \cos 0^0 \Delta x$
- $W_{net} = mg \cos 0^0 \Delta x$
- $W_{net} = 1 \times 9.8 \times 1 \times 10$

$= 9.8$ J

So the work that was done on the brick is 98 J

b)

- Work - energy theorem states that $W_{net} = \Delta E_K$

$W_{net} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

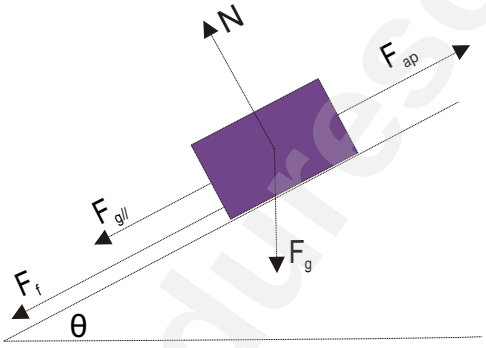
$98 = \frac{1}{2}(1)v_f^2 - \frac{1}{2}(1)(0)^2$

$196 = v_f^2$

$v_f = 14$m/s

(iii) Objects on an inclined plane

A net force acting on an object of mass m (kg) in the diagram below will do a net work by causing a displacement (Δx) on an inclined plane according to the equation $W_{net} = F_{net} x \Delta x \cos\theta$. For an object moving up an incline its kinetic energy is being transferred to potential energy, $\Delta E_K = \Delta E_P$. Hence net work done on an object moving up an incline is a result of change in its kinetic energy. Work is done by a net force on the object below when kinetic energy is transferred according to the equation $W_{net} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$ (velocities at the bottom and top of the incline are v_i and v_f respectively.)



Calculating W_{net} :

$F_{net} = F_{ap} + F_f + F_{g//}$

$= F_{ap} \cos 0^0 + F_f \cos 180^0 + F_{g//} \cos 180^0$

$W_{net} = F_{net} x \Delta x \cos\theta$

Alternatively,

$W_{net} = Wap + W_f + W_{g//}$

$= F_{ap} \cos 0^0 \Delta x + F_f \cos 180^0 \Delta x + F_{g//} \cos 180^0 \Delta x$

NOTE $F_{g//}$ — gravitational force component parallel to the plane ($F_{g//} = mg\sin\theta$)

F_g — gravitational force ($F_{g//} = mg$)

Δx — length of the inclined plane

POINTS TO TAKE NOTE WHEN CALCULATING F_{net} ON AN INCLINE

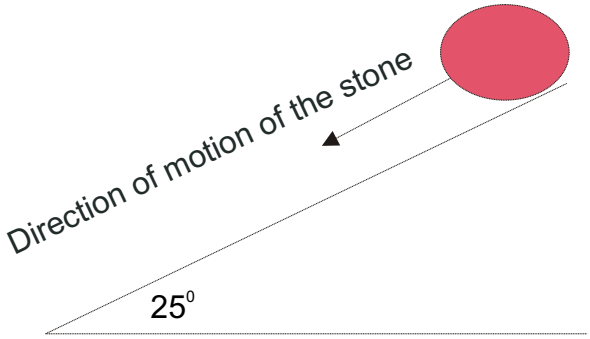
- If a body is released from the top of the inclined plane and it is not mentioned that a force was applied on it, assume the applied force is zero
- If a body is released from rest, its initial velocity is zero

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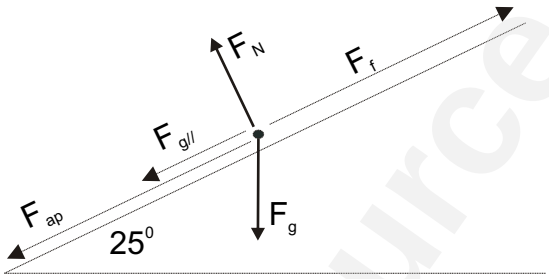
EXAMPLE 14

A stone with a mass of 50kg was rolled from rest at the top of an incline after a force of 60N was applied on it as shown in the diagram below. The frictional force of 30N acted against it while it rolled down a 20m inclined plane. Use the work - energy theorem to determine the velocity of the stone as it reached the bottom of the inclined plane.



SOLUTION 14

Step 1: Draw a free body diagram



Step 2: Determine work net (W_{net})

$W_{net} = W_{ap} + W_{g//} + W_f$

$= F_{ap}\cos 0^0 + F_{g//}\cos 0^0 + F_f\cos 180^0$
$= F_{ap}\cos 0^0 + mg\sin 25^0 \cos 0^0 + F_f\cos 180^0$
$= 60(1) + 50\times 9.8\times \sin 25^0(1) + 30(-1)$
$= 237$ J

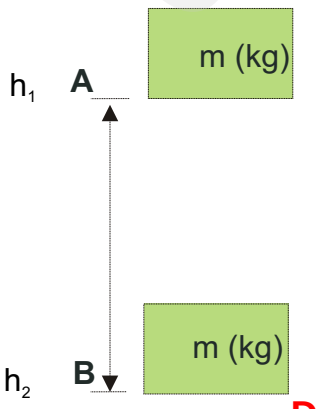
Step 3: Apply work - energy theorem to determine v_f

$W_{net} = \Delta E_k$
$W_{net} = \frac{1}{2}mv_f^2 - \frac{1}{2}m_iv^2$
$237 = \frac{1}{2}(50)v_f^2 - 0$ ($v_i = 0$, was rolled from rest)
$v_f = 3.08\ m.s^{-1}$

Law of conservation of mechanical energy

- It state that mechanical energy in a system is conserved provided that there is no friction or external forces other than gravitational force doing work on the object
- For a free falling object, the conservation of mechanical energy is given by
  $(E_P + E_K)_{\text{at point A}} = (E_P + E_K)_{\text{at point B}}$ where A and B are points through which the object falls freely

(i) Objects moving in vertical plane



At point A
$E_{ki} = 0$ ($v_i = 0$) $E_{pi} = mgh_1$

At point B
$E_{kf} = \frac{1}{2}mv_f^2$ $E_{pf} = 0$ ($h_2 = 0$)

The diagram on the left shows an object falling freely from rest from point A of height h_1 to point B of height h_2.

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Using the Principle Of Conservation Of Mechanical Energy, we will have the following equation:

$(E_{ki} + E_{pi})$ at A = $(E_{kf} + E_{pf})$ at B

$(0 + mgh_1) = (½mv_f^2 + 0)$

$mgh_1 = ½mv_f^2$

The Law of Conservation of E_{mech} can be reduced to:

$\Delta E_p + \Delta E_k = 0$

Therefore $\Delta E_k = - \Delta E_p$

It means that all the potential energy (mgh_1) has been converted to kinetic energy ($½mv_f^2$).

EXAMPLE 15

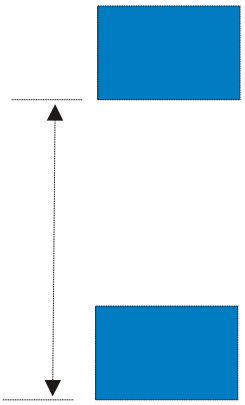
A brick of mass 1 kg is dropped from a height of 10m. Using the Principal of conservation of mechanical energy, calculate the work done on the brick at the point it hits the ground assuming that there is no air resistance.

SOLUTION 15

Data

m = 1kg h_1= 10m

h_2 = 0m



$E_{ki} = 0$ ($v_i = 0$) $E_{pi} = mgh_1$

$E_{kf} = ½mv_f^2$ $E_{pf} = 0$ ($h_2 = 0$)

WHEN DO WE USE THE PRINCIPAL OF CONSERVATION OF MECHANICAL ENERGY?

When mechanical energy of an object at a single point equals to either potential energy ($E_p = mgh$) or kinetic energy($E_k = ½mv^2$)

This way potential energy will be transferred to kinetic energy or vise versa

$(E_{ki} + E_{pi})$ at TOP = $(E_{kf} + E_{pf})$ at BOTTOM

$0 + mgh_1 = ½mv_f^2 + 0$

$mgh_1 = ½mv_f^2$

(All potential energy is converted to kinetic energy as the brick hits the ground)

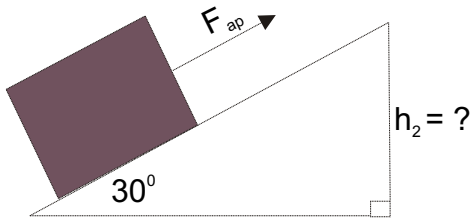
Therefore Work done on the brick = $\Delta E_p = \Delta E_k$

But $\Delta E_p = mgh_1$ and $\Delta E_k = \Delta ½mv_f^2$

So Work done on the brick = $mgh_1 = 1 \times 9.8 \times 10 = 98$ J

EXAMPLE 16

A box with a mass of 2kg was pushed up a frictionless surface ramp with a velocity of 2m/s and stopped at the top as shown on the diagram below. The ramp is 10m long, use the principal of conservation of mechanical energy to calculate the vertical height h_2 of the ramp.



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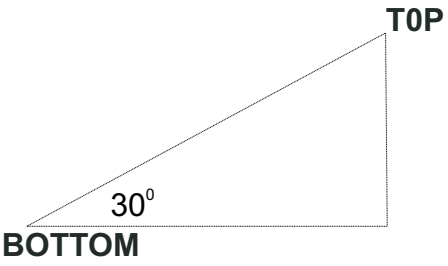
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SOLUTION 16

$v_f = 0$, $h_2 = ?$

$E_{pf} = mgh_2$

$E_{kf} = ½mv_f^2 = 0$



$h_1 = 0$

$E_{pi} = mgh_1 = 0$

$E_{ki} = ½mv_i^2$

$(E_{ki} + E_{pi})$ at the BOTTOM = $(E_{kf} + E_{pf})$ at the TOP

$½mv_i^2 + 0 = ½mv_f^2 + mgh_2$

$½(2)(2)^2 + 0 = ½(2)(0)^2 + 2 \times 9.8 \times h_2$

$4 = 0 + 19.6h_2$

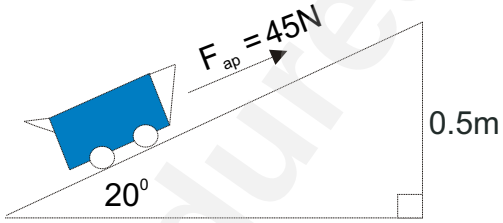
Therefore $h_2 = 0.20$ m

LIMITATIONS OF THE PRINCIPAL OF CONSERVATION OF MECHANICAL ENERGY

- Suppose friction is considered when an object is falling, then the principal of conservation of mechanical energy will not apply
- In this case work done by friction (W_f) will add to the initial mechanical energy as follows :
  $(E_{ki} + E_{pi})$ at the starting point + $W_f = (E_{kf} + E_{pf})$ at the end point
- Suppose motion started at point A and ended at point B, then A is the starting point and B is the end point.
- We can re-write the above equation as:
- $(E_{ki} + E_{pi})$ at A + $W_f = (E_{kf} + E_{pf})$ at B
- In other words mechanical energy at A and work done against friction combined together were transformed to mechanical energy at B

EXAMPLE 17

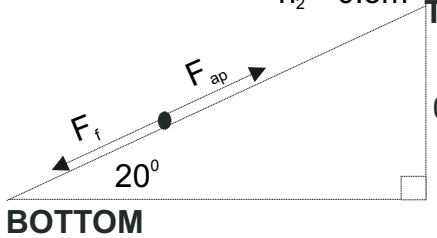
A trolley with grocery was pushed with a certain velocity v_i up an incline by a woman applying a force of 45N for a distance of 3m. Force of friction against the trolley was 35N,determine initial velocity of the trolley if it comes to rest at the top of the ramp. N:B Mass of trolley and grocery is 100kg.



SOLUTION 17

$E_{pf} = mgh_f$ $E_{kf} = 0$

$h_2 = 0.5$m



$h_1 = 0$ $E_{pi} = 0$

$E_{ki} = ½mv_i^2$

- $(E_{ki} + E_{pi})$ at A + $W_f + W_{ap} = (E_{kf} + E_{pf})$ at B
- $(½mv_i^2 + 0) + F_f \Delta x \cos 180^0 + F_{ap} \Delta x \cos 0^0 = (0 + mgh_f)$
- $(½x100xv_i^2 + 0) - 35x3 + 45x3 = (0 + 100x9.8x0.5)$
- $(½x100xv_i^2 + 0) - 30 = (0 + 100x9.8x0.5)$
- $50\ v_i^2 - 30 = 490$
- $v_i = 3.22$ m/s

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POWER

Definition

- Power is the rate at which work is done
- It can also be defined as energy expended

Power calculations when work is done

- When work is done by an object, power is given by:

$$\text{Power} = \frac{\text{Work done by the applied}}{\text{Time taken}}$$

- This formula applies whether an object is moving horizontally, vertically or on an inclined plane

Power at constant velocity

- If a force causes an object to move at constant velocity, average power or instantaneous power is given by:

$$P = F_{ap}\ v$$

Where F_{ap} - Force applied
v - velocity of an object

EXAMPLE 18

A constant force of 2kN pulls a crate along a level floor a distance of 10m in 50s. What is the power used?

SOLUTION 18

Data given:

F_{ap} = 2kN D = 10m Δt = 50s

$$P = \frac{W_{ap}}{\Delta t}$$

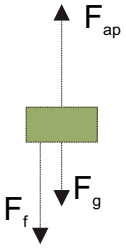
But $W_{ap} = F_{ap} \times D$
$= 2000 \times 10$
$= 20\ 000J$

Therefore $P = \frac{20000}{50} = 400\ W$

EXAMPLE 19

A hoist operated by an electric motor has a mass of 500kg. It raises a load of 300kg vertically at a steady speed of 0.2 m/s. Frictional resistance can be taken to be constant at 1200N. What is the power required? (1.81kW)

SOLUTION 19



- At constant velocity $F_{net} = 0$
- $F_{net} = F_{ap} + F_f + F_g$
- Therefore $F_{net} = F_{ap}\cos 0^0 + F_f \cos 180^0 + F_g \cos 180^0$
- $0 = F_{ap}(1) + F_f(-1) + F_g(-1)$
- $0 = F_{ap} + (1200)(-1) + (7840)(-1)$
- $F_{ap} = 1200 + 7840 = 9040N$
- $P = F_{ap} \times v = 9040 \times 0.2 = 1.81kW$

Data given:
F_f = 1200N
F_g = mg = 800 x 9.8 = 7840N

m = 500 + 300

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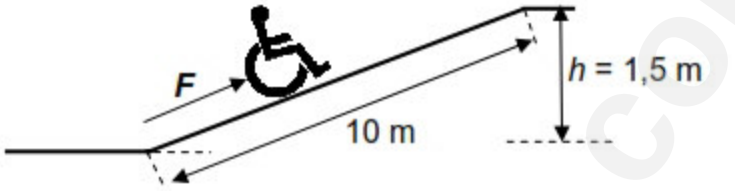
TASK 7

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QUESTION 1 (NOV 2009/P1/Q5)

John applies a force F to help his friend in a wheelchair to move up a ramp of length 10 m and a vertical height of 1,5 m, as shown in the diagram below. The combined mass of his friend and the wheelchair is 120 kg. The frictional force between the wheels of the wheelchair and the surface of the ramp is 50 N. The rotational effects of the wheels of the wheelchair may be ignored.

The wheelchair moves up the ramp at constant velocity.



1.1 What is the magnitude of the net force acting on the wheelchair as it moves up the ramp? Give a reason for your answer. (2)

1.2 What is the magnitude of the net work done on the wheelchair on reaching the top of the ramp? (1)

1.3 Calculate the following:

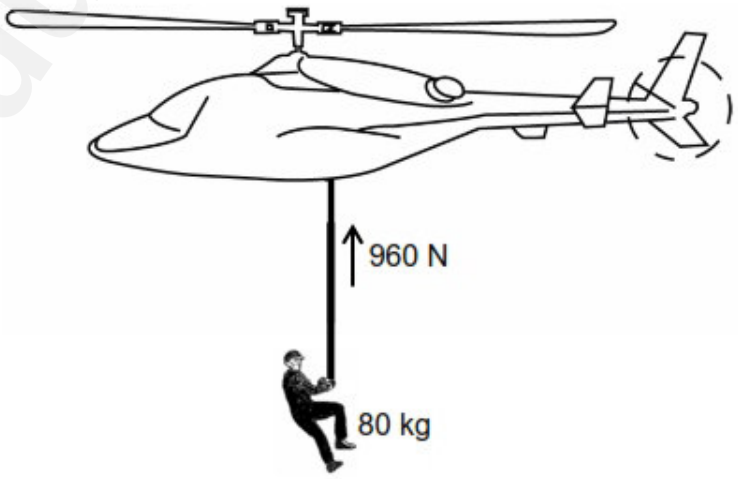
1.3.1 Work done on the wheelchair by force F (5)

1.3.2 The magnitude of force F exerted on the wheelchair by John (4)

[12]

QUESTION 2 (NOV 2011/P1/Q5)

A rescue helicopter is stationary (hovers) above a soldier. The soldier of mass 80 kg is lifted vertically upwards through a height of 20 m by a cable at a CONSTANT SPEED of 4 m·s-1. The tension in the cable is 960 N. Assume that there is no sideways motion during the lift. Air friction is not to be ignored.



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2.1 State the work-energy theorem in words. (2)

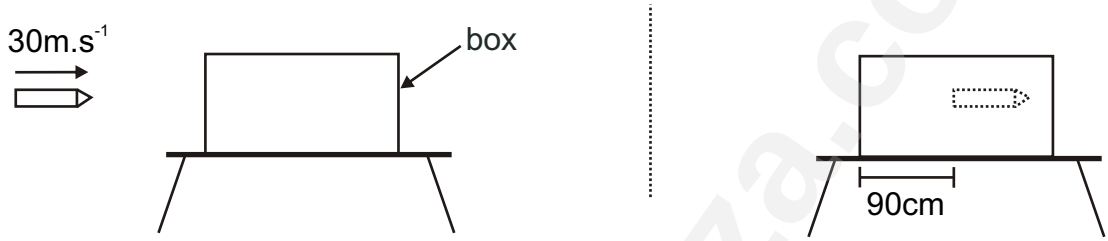
2.2 Draw a labelled free-body diagram showing ALL the forces acting on the soldier while being lifted upwards. (3)

2.3 Write down the name of a non-contact force that acts on the soldier during the upward lift. (1)

2.4 Use the WORK-ENERGY THEOREM to calculate the work done on the soldier by friction after moving through the height of 20 m. (5)

QUESTION 3

A bullet of mass 80g is moving at a speed of 30m.s^{-1}. It strikes a wooden block on the table of mass 4.5kg and penetrates into the block for a displacement of 90cm before it comes to rest.



3.1 Draw a free body diagram showing all the forces acting on the block as the bullet penetrates (3)

3.2 Use the work - energy theorem to calculate the net force exerted on the bullet as it is brought to rest. (5)

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TOPIC 5: DOPPLER EFFECT

DOPPLER EFFECT

✎Is the apparent change in the frequency of a wave motion when there is relative motion between the source of the waves and the observer

Every day examples

(a) Suppose you are standing on the road side, then an ambulance or police car with a siren approaches and passes you. Perceived pitch of the sound of a siren as it approaches increases, and drops as it passes you.

(b) As one approaches a ringing bell, the perceived pitch of sound increases but however it becomes lower as one pass the bell

Pitch and frequency

✎Frequency is the number of complete waves which passes through a given point in one second

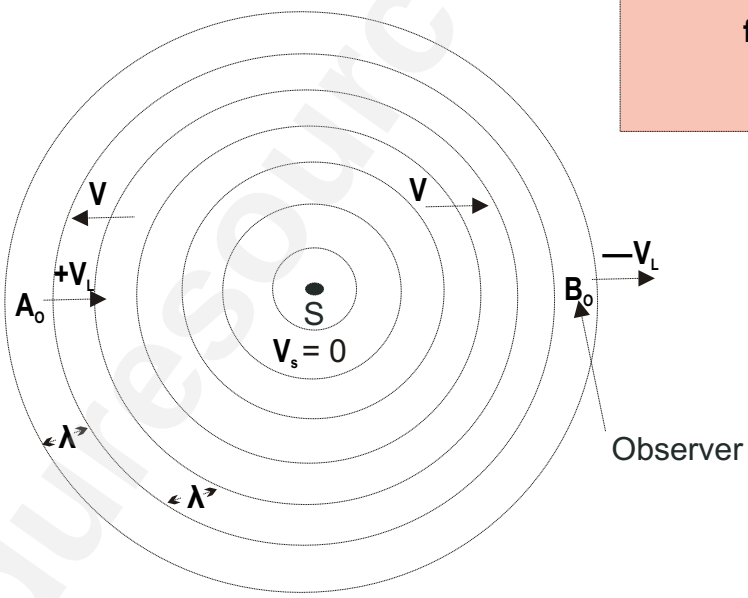
✎However pitch is a measure of the degree of loudness of a sound wave

✎Sound waves with low frequency have low pitch whilst those with high frequency have high pitch

Stationary sound source and moving listener

DOPPLER EFFECT EQUATION

$$f_L = \frac{v \pm v_L}{v \pm v_s} \cdot f_s$$



✎When a stationary sound source emits waves, a stationary listener at any point will perceive waves as if they are moving with the same wavelength and the same frequency ($f = \frac{v}{\lambda}$)

(a) Listener moving towards a stationary sound source ($V_s = 0$, V_L = +ve)

✎Suppose a sound source is stationary and an observer A_o is moving towards it, then the spacing between waves (λ) remains constant but number of waves that the observer intercepts per second (f_L) increases

✎The frequency f_L increases because the listener traverses more waves per unit time than a stationary listener

✎According to the Doppler effect equation, mathematically for f_L to have a bigger value V_L should be positive

✎Hence

$$f_L = \frac{v + v_L}{v} \cdot f_s$$

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✎The listener intercepts more waves per unit time than a stationary listener because he/she is moving in the opposite direction of the waves
✎It is for this reason why the apparent change of frequency as heard by the listener becomes bigger

(b) Listener moving away from a stationary sound source ($V_s = 0$, V_L = —ve)

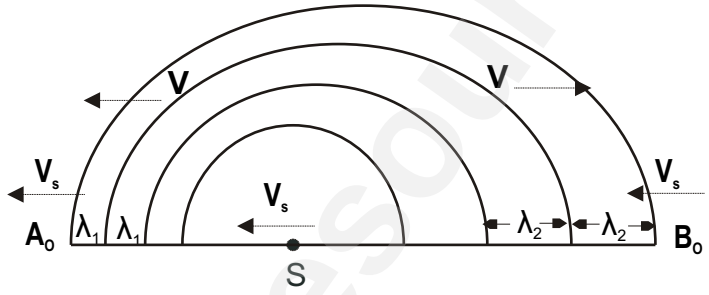
✎Suppose a sound source is stationary and an observer B_0 is moving away from it, then the spacing between waves (λ) remains constant but number of waves that the observer intercepts per second (f_L) decreases
✎The frequency f_L decreases because the listener traverses few waves per unit time than a stationary listener
✎The listener will intercept few waves per unit time since he/she is moving in the same direction as the waves
✎As a result the apparent change in frequency as heard by the listener becomes smaller
✎According to the Doppler effect equation, mathematically for f_L to have a smaller value V_L should be negative
✎Hence

$$f_L = \frac{v - v_L}{v} \cdot f_s$$

Moving sound source and stationary listener ($V_L = 0$)

(a) Sound source moving towards a stationary listener ($V_L = 0$, V_s = —ve)

✎When a sound source move towards a stationary listener A_0, waves are closer together (compression) in front of the sound source as shown in the diagram below
✎Therefore waves which passes the listener A_0 per unit time increases and hence an increased frequency (f_L) and decreased wavelength (λ_1)



✎ According to the Doppler effect equation, mathematically for f_L to have a bigger value V_s should be negative
✎Hence

$$f_L = \frac{v}{v - v_s} \cdot f_s$$

✎The diagram to the left shows a pattern of waves as the sound source move towards a stationary listener A_0

(b) Sound source moving away from the listener ($V_L = 0$, V_s = +ve)

✎When a sound source move away from a stationary listener B_0, waves are further apart (rarefaction) behind the sound source as shown in the diagram above
✎Therefore waves which passes the listener B_0 per unit time decreases and hence a decreased frequency (f_L) and increased wavelength (λ_2)
✎ According to the Doppler effect equation, mathematically for f_L to have a bigger value V_s should be positive
✎Hence

$$f_L = \frac{v}{v + v_s} \cdot f_s$$

✎The diagram above shows a pattern of waves as the sound source move away from stationary listener B_0

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EXAMPLE 1

A police car is moving towards you. You recall that the pitch of its sirene is 700Hz, but you hear the sirene at 800Hz. How fast is the police car approaching?

SOLUTION 1

$$f_L = f_s \cdot \frac{v \pm v_L}{v \pm v_s}$$

$$f_L = f_s \cdot \frac{v}{v - v_s}$$

$$800 = 700 \cdot \frac{340 + 0}{340 - v_s}$$

$$800(340) - 800(v_s) = 700(340)$$

$$v_s = 42.5\ m.s^{-1}$$

EXAMPLE 2

A man is driving his car whilst playing a radio at 90Hz on the highway. If the car speed is 85km.h^{-1}, what is the frequency heard by a person on the ground behind the car?

SOLUTION 2

$$f_L = f_s \cdot \frac{v \pm v_L}{v \pm v_s}$$

$$f_L = f_s \cdot \frac{v}{v + v_s}$$

$$85km.h^{-1} = \frac{85x1000}{60 \times 60} = 23.6\ m.s^{-1}$$

$$f_L = 90 \cdot \frac{340 - 0}{340 + 23.6}$$

$$f_L = 84.1Hz$$

EXAMPLE 3

A man is running at 23m.s^{-1} towards a boy standing by the road side. What frequency does the man hear if the boy starts singing at 350Hz?

SOLUTION 3

$$f_L = f_s \cdot \frac{v \pm v_L}{v \pm v_s}$$

$$f_L = f_s \cdot \frac{v + v_L}{v}$$

$$= 350 \cdot \frac{340 + 23}{340 - 0}$$

$$= 373.68\ Hz$$

EXAMPLE 4

A man is running at 23m.s^{-1} away from a boy standing by the road side. What frequency does the man hear if the boy starts singing at 350Hz?

SOLUTION 4

$$f_L = f_s \cdot \frac{v \pm v_L}{v \pm v_s}$$

$$f_L = f_s \cdot \frac{v - v_L}{v}$$

$$f_L = 350 \cdot \frac{340 - 23}{340 + 0}$$

$$f_L = 326.32Hz$$

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EXAMPLE 5

A bat moving towards a stationery insect at a velocity of 10 $m.s^{-1}$, it produces a frequency of 80 000Hz. Calculate the frequency detected by the bat as it approaches the insect . Assume the speed of ultrasound waves in air is 340 $m.s^{-1}$

SOLUTION 5

$$f_L = f_s \cdot \frac{v \pm v_L}{v \pm v_s}$$

$$f_L = f_s \cdot \frac{v}{v - v_s}$$

$$f_L = 80\,000 \cdot \frac{340 + 0}{340 - 10}$$

f_L = 82424.24Hz .....(i)

$$f_L = f_s \cdot \frac{v}{v + v_s} \quad .....(ii)$$

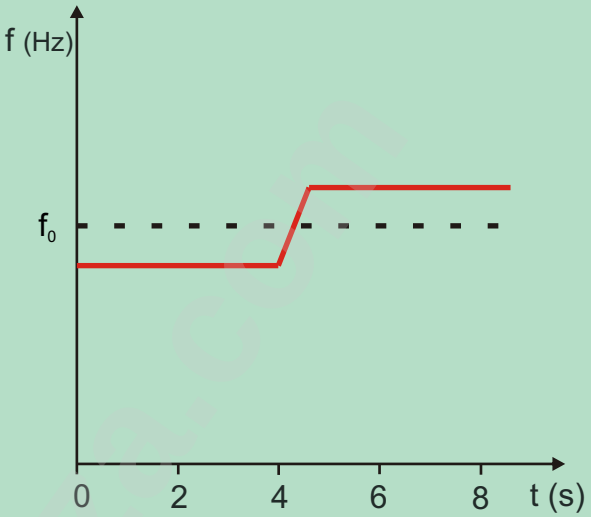
Substitute (i) into (ii)

$$f_L = 82424.24 \cdot \frac{340 + 10}{340 - 0}$$

f_L= 84848.48Hz

EXAMPLE 6

IA stationary man is listening to a sound that is emitted at a frequency f_0 by a moving source as shown in the diagram below:



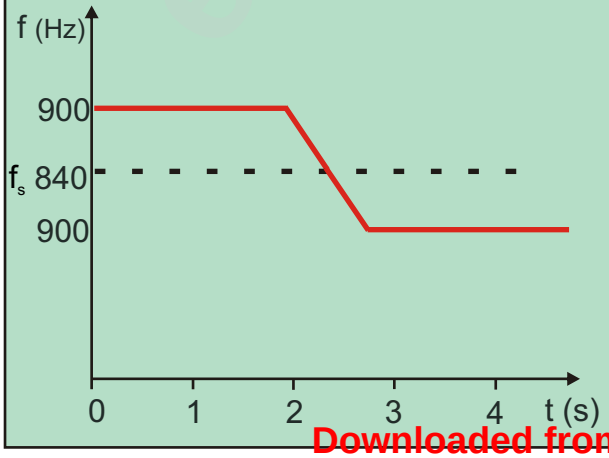
Use the graph to describe the motion of the sound source.

SOLUTION 6

The sound source moved away from the man until t = 4s. It then reverses and moved toward the man but it did not reach him

EXAMPLE 7

A boy is stationary and is listening to a moving sound source which emits a sound of frequency f_0 as shown in the diagram below:



7.1 Is the source moving towards or away from the observer in the first 2s?
7.2 Calculate v_s

SOLUTION 7

7.1 Towards
7.2

$$f_L = f_s \cdot \frac{v \pm v_L}{v \pm v_s}$$

Use the Doppler effect equation to form two simultaneous equations

$$900 = 840 \cdot \frac{340 + 0}{340 - v_s} \quad .....(i)$$

$$824 = 840 \cdot \frac{340 - 0}{340 + v_s} \quad .....(ii)$$

If we substitute (i) into (ii) then

v_s = 14.99 $m.s^{-1}$

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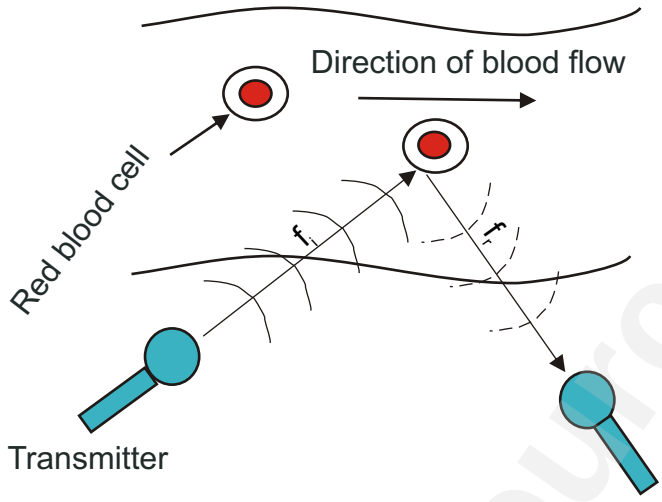
Principle of operation in Doppler effect

- A stationary transmitter shoots waves at a moving object.
- The waves hit the object and bounce back.
- The transmitter (now a receiver) detects the frequency of the returned waves.
- Based on the amount of Doppler shift, the speed of the object can be determined.

Applications of the Doppler effect

(a) Medicine

- Doppler effect is used to monitor blood flow through vessels in the body
- A transmitter sends out ultra sounds of high frequency into the heart
- Transmitted waves are reflected by blood cells moving through the heart and blood vessels
- Frequency of reflected waves is detected by a receiver
- A frequency shift as a result of the movement of these cells results can be measured
- This shift helps to determine the speed and direction of blood flow in the heart to provide information on blood clots, blocked arteries, and fetus developing in the womb



f_i - frequency of an incident wave
f_r - frequency of a reflected wave

The diagram on the left is a cross section of a blood vessel

(b) Measure vehicle speeds

- Waves are sent by a transmitter pointing at the car with a certain frequency
- Incident waves strike the vehicle and bounce back towards the receiver
- An over - speeding car will have reflected waves with a higher frequency
- Speed of the car is determined by calculating the difference between emitted frequency and reflected frequency

(c) Redshift

- Is a phenomenon whereby light observed when a light source moves away from an observer is apparently shifted towards lower frequency or red (red has lower frequency on the electromagnetic spectrum)

Visible Radiation

Red Orange Yellow Green Blue Indigo Violet

increasing frequency/Decreasing wavelength

- In the universe, light emitted from many stars is shifted toward the red due to the movement of the source of light
- These redshifts by the stars in the universe proves that stars are moving away from the earth, and hence it further proves that the universe is expanding
- Uses of redshift:
  (i) to measure velocity of astronomical bodies
  (ii) to measure car speeds

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EXAM TYPE WORKED EXAMPLES

QUESTION 1 (NOV 2009/P1/UNUSED/Q7)

The siren of a police car produces a sound of frequency 420 Hz. A man sitting next to the road notices that the pitch of the sound changes as the car moves towards and then away from him.

1.1 Write down the name of the above phenomenon. (1)

1.2 Assume that the speed of sound in air is 340 $m \cdot s^{-1}$. Calculate the frequency of the sound of the siren observed by the man, when the car is moving towards him at a speed of 16 $m \cdot s^{-1}$. (4)

1.3 The police car moves away from the man at constant velocity, then slows down and finally comes to rest.

1.3.1 How will the observed frequency **compare** with the original frequency of the siren when the police car moves away from the man at constant velocity? Write only GREATER THAN, SMALLER THAN or EQUAL TO. (2)

1.3.2 How will the observed frequency **change** as the car slows down whilst moving away? Write only INCREASES, DECREASES or REMAINS THE SAME. (2)

[9]

SOLUTION 1

1.1 Doppler effect

1.2 Car approaching

$$f_L = \left(\frac{v \pm v_L}{v \pm v_s}\right) \times f_s \quad \text{OR} \quad f_L = \left(\frac{v}{v - v_s}\right) \times f_L$$

$$= \left(\frac{340}{340 - 16}\right) \times (420)$$

$f_L = 440.74 Hz$

1.3.1 Smaller than

1.3.2 increases

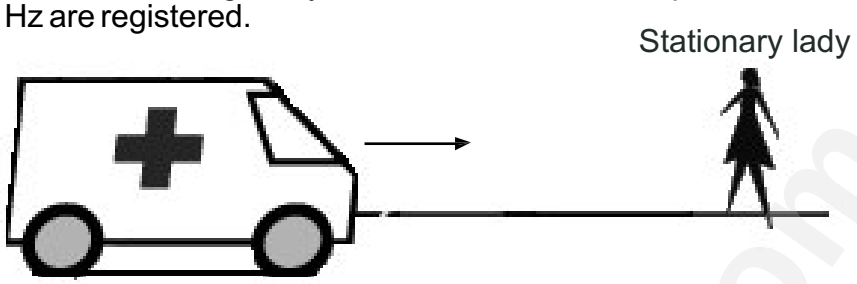
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QUESTION 2 (NOV 2008/P1/Q8)

An ambulance travelling down a road at constant speed emits sound waves from its siren. A lady stands on the side of the road with a detector which registers sound waves at a frequency of 445 Hz as the ambulance approaches her.

After passing her, and moving away at the same constant speed, sound waves of frequency 380 Hz are registered.



Assume that the speed of sound in air is 343 $m.s^{-1}$

2.1 Name the phenomenon that describes the change in the frequency observed by the lady. (1)

2.2 Calculate:

2.2.1 The speed at which the ambulance is moving (7)

2.2.2 The frequency at which the siren emits the sound waves (3)

[11]

SOLUTION 2

2.1 Doppler effect

2.2.1 $f_L = \left(\frac{v \pm v_L}{v \pm v_s}\right) x\ f_s$

approaching : $f_L = \left(\frac{v}{v - v_s}\right) x\ f_s$

moving away : $f_L = \left(\frac{v}{v + v_s}\right) x\ f_s$

Ambulance approaching:

$$445 = f_s\left(\frac{343}{343 - v_s}\right)$$

$445(343 - v_s) = 343\ f_s$ .....(i)

Ambulance moving away:

$$380 = f_s\left(\frac{343}{343 + v_s}\right)$$

$380(343 + v_s) = 343 f_s$ .....(ii)

Substitute equation (i) into equation (ii)

$445(343 - v_s) = 380(343 + v_s)$

Simplify the above equation and you get:

$V_s = 27.02\ m.s^{-1}$

2.2.2

$$445 = f_s\left(\frac{343 \pm 0}{343 - v_s}\right)$$

$445(343 - 27.02) = 343 f_s$

$f_s = 409.94Hz$

OR

$$380 = f_s\ x\left(\frac{343 \pm 0}{343 + v_s}\right)$$

$380(343 + 27.02) = 343\ f_s$

$f_s = 409.94Hz$

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QUESTION 3 (FEB 2009/P1/Q9)

Dolphins use ultrasound to scan their environment.

When a dolphin is 100 m from a rock, it emits ultrasound waves of frequency 250 kHz whilst swimming at 20 $m \cdot s^{-1}$ towards the rock. Assume that the speed of sound in water is 1 500ms^{-1}

3.1 Calculate the frequency of the sound waves detected by a detector on the rock. (4)

3.2 When the dolphin is 50 m from the rock, another ultrasound wave of 250 kHz is emitted.

How will the frequency of the detected sound waves compare with the answer calculated in QUESTION 7.1?

Write down only HIGHER, LOWER or REMAINS THE SAME. Explain your answer. (2)

[6]

SOLUTION 3

3.1 $f_L = \left(\frac{v \pm v_L}{v \pm v_s} \right) x\ f_s$

$f_L = \left(\frac{1500 \pm 0}{1500 - 20} \right) x\ (250x10^{-3})$

$= 253.38 \times 10^3$

3.2 Remains the same
The detected frequency is independent of the distance between the source and observer

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TASK 8

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QUESTION 1 (FEB 2010/P1/Q7)

An ambulance with its siren on, moves away at constant velocity from a person standing next to the road. The person measures a frequency which is 90% of the frequency of the sound emitted by the siren of the ambulance.

1.1 Name the phenomenon observed. (1)

1.2 If the speed of sound in air is 340 m·s-1, calculate the speed of the ambulance. (5)
[6]

QUESTION 2 (NOV 2010/P1/Q6)

The siren of a burglar alarm system has a frequency of 960 Hz. During a patrol, a security officer, travelling in his car, hears the siren of the alarm of a house and approaches the house at constant velocity. A detector in his car registers the frequency of the sound as 1 000 Hz.

2.1 Name the phenomenon that explains the change in the observed frequency. (1)

2.2 Calculate the speed at which the patrol car approaches the house. Use the speed of sound in air as 340 m·s-1. (4)

2.3 If the patrol car had approached the house at a higher speed, how would the detected frequency have compared to the first observed frequency of 1 000 Hz? Write down only HIGHER THAN, LOWER THAN or EQUAL TO. (1)
[6]

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TOPIC 6: RATE AND EXTENT OF REACTIONS

RATE OF A REACTION

✎Is defined as:

changes in concentration per unit time of products or reactants

✎It describes the speed with which products are converted to reactants and vice versa
✎If reactants forms products faster then we say the rate of reaction is high
✎If products decompose faster to form products then we can as well say the rate of reaction is high
✎Mathematically rate of reaction is given by:

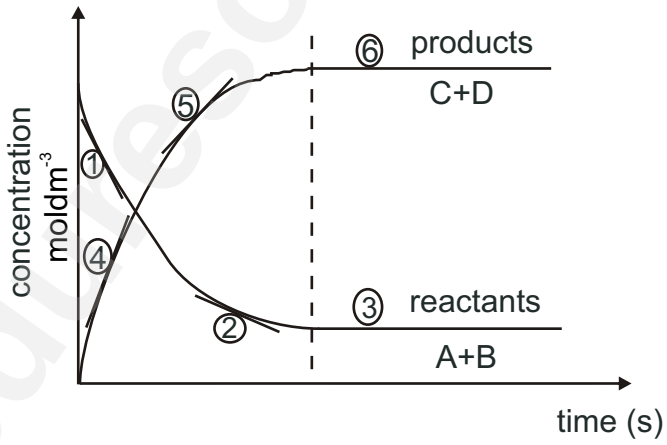
$$\text{Rate of reaction} = \frac{\text{Change in concentration of reactants}}{\text{Change in time}}$$ = gradient of **conc**-time graph

Or

$$\text{Rate of reaction} = \frac{\text{Change in concentration of products}}{\text{Change in time}}$$ = gradient of **conc**-time graph

✎Suppose we have a hypothetical equation $A + B \rightarrow C + D$
✎Reaction rate is determined by how fast A and B are used up in a given unit time or how fast C and D are being formed in a given unit time.
✎We can use the concentration - time graph below to represent rate of reaction for the hypothetical reaction above:

Concentration - time graph



N:B The greater the **gradient** on a concentration - time graph, the higher the rate of reaction

INTERPRETATION OF CONCENTRATION - TIME GRAPH

Change in concentration of reactants
✎Gradient at point 1 > gradient at point 2 > point 3
✎This tells us that reactants are being used up faster at the beginning of the reaction, and the speed at which they are used up decreases with time until the reaction stops at point 3
✎Note that gradient at point 3 is zero (a horizontal straight line)
✎So the rate of reaction decreases as reactants are used up in a chemical reaction with time

Change in concentration of products
✎Gradient at point 4 > gradient at point 5 > gradient at point 6
✎This tells us that products are being formed faster at the beginning of the reaction, and the

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speed at which they are formed decreases with time until the reaction stops at point 6
- Note that gradient at point 6 is zero (a horizontal straight line)
- So the rate of reaction decreases as products are formed in a chemical reaction with time

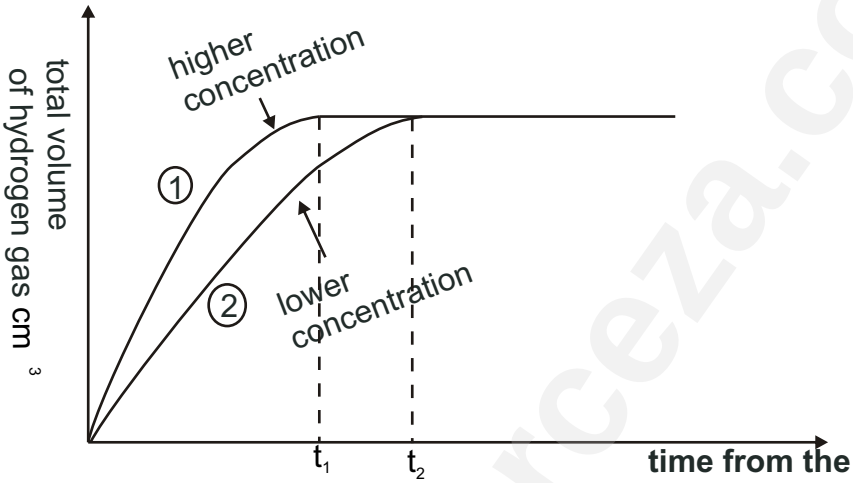
FACTORS AFFECTING RATE OF REACTION

The following is a list of **factors affecting rate of reaction**:
Surface area (solid), Concentration (solution), Pressure (gas), Catalyst and Temperature

Changing factors affecting rate of reaction
Any change of these factors will cause a change in the rate of reaction as shown in graphs below:

(1) CHANGES IN CONCENTRATION

concentration - time graph



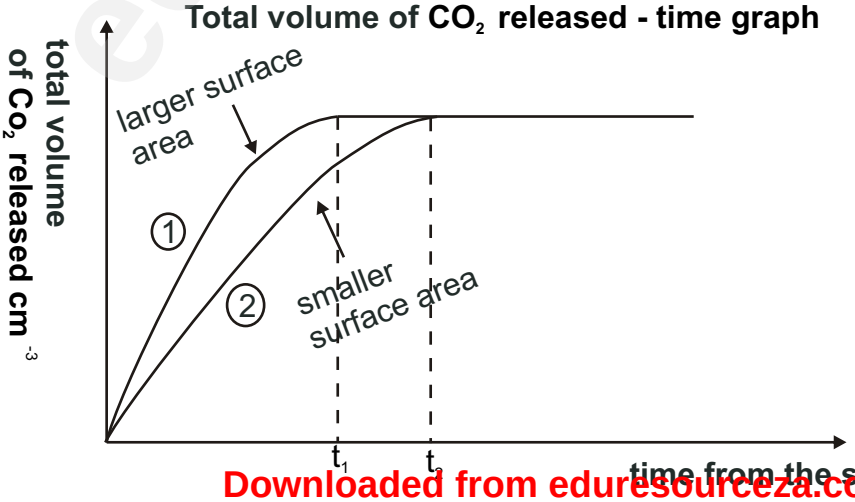
- Gradient of the concentration - time graph is the rate of reaction
- The steeper the gradient means high rate of rate of reaction
- A horizontal line means reaction has stopped

Graph 1 above is the reaction of **Mg** powder and highly concentrated **HCl**, and graph 2 is the reaction of the same amount of Mg powder and less concentrated HCl. The volume of H_2 measured at constant time intervals determines rates of reaction for the two reactions.

INTERPRETING CONCENTRATION - TIME GRAPHS ABOVE
- Graph 1 has a steeper gradient than graph 2
- Therefore rate of reaction in graph 1 is higher than that in graph 2
- The higher rate of reaction in graph 1 shows that higher concentration was used
- The lower rate of reaction in graph 2 shows that lower concentration was used
- Reaction 1 reaches completion earlier at t_1 than reaction 2 which stops later at t_2
- Both reactions will eventually reach completion, but reaction 1 is faster than reaction 2
- Since the **number of moles used in both reactions is the same**, the final volume of **H_2** in each reaction is the same

(2) CHANGES IN SURFACE AREA

Total volume of CO_2 released - time graph



- Gradient of the volume of CO_2 released - time graph is the rate of reaction
- The steeper the gradient means high rate of rate of reaction
- A horizontal line means reaction has stopped

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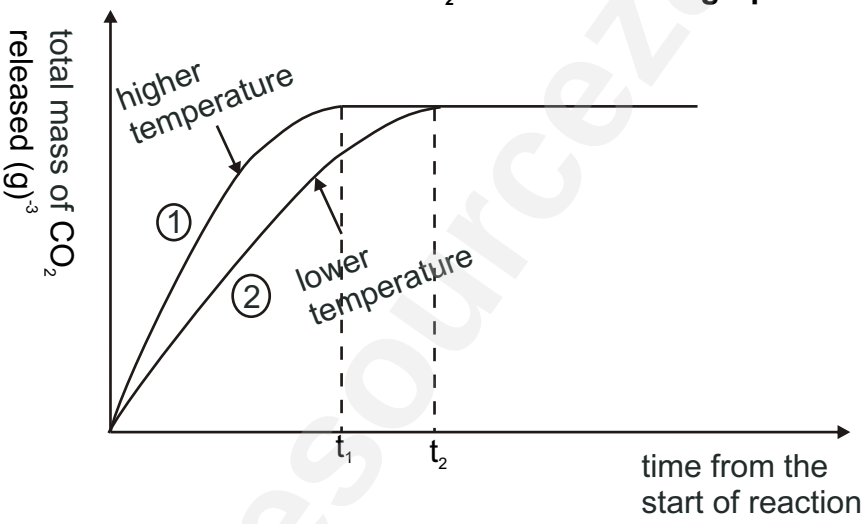
Consider graph 1 above to be the reaction between hydrochloric acid and POWDERED antacid tablet, and graph 2 to be the reaction of hydrochloric acid with SOLID antacid tablet. The volume of CO_2 measured at constant time intervals determines rates of reaction for the two reactions.

INTERPRETATION OF CHANGES IN SURFACE AREA

- Graph 1 has a steeper gradient than graph 2
- Therefore rate of reaction in graph 1 is higher than that in graph 2
- The higher rate of reaction in graph 1 shows that antacid tablets with larger surface were used
- The lower rate of reaction in graph 2 shows that antacid tablets with smaller surface were used
- Reaction in graph 1 reaches completion earlier at t_1 than reaction in graph 2 which stops later at t_2
- Reaction in graph 1 is faster than reaction in graph 2
- Since the **number of moles used in both reactions is the same**, the final volume of CO_2 released in each reaction is the same

(3) CHANGES IN TEMPERATURE

Total mass of CO_2 released - time graph



- Gradient of total mass of CO_2 released - time graph is the rate of reaction
- The steeper the gradient means high rate of rate of reaction
- A horizontal line means reaction has stopped

Consider graph 1 above to be the reaction between hydrochloric acid and POWDERED antacid tablet at **higher temperatures**, and graph 2 to be the reaction of hydrochloric acid and the same POWDERED antacid tablet at **lower temperatures**. The mass of CO_2 measured at constant time intervals determines rates of reaction for the two reactions.

INTERPRETATION OF CHANGES IN TEMPERATURE

- Graph 1 has a steeper gradient than graph 2
- Therefore rate of reaction in graph 1 is higher than that in graph 2
- The higher rate of reaction in graph 1 shows that higher temperature was used
- The lower rate of reaction in graph 2 shows that lower temperature was used
- Reaction in graph 1 reaches completion earlier at t_1 than reaction in graph 2 which stops later at t_2
- Reaction in graph 1 is faster than reaction in graph 2
- Since the **number of moles used in both reactions is the same**, the final mass of CO_2 released in each reaction is the same

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COLLISION THEORY

✎A chemical reaction will only take place when the reactant molecules **collide effectively**
✎A collision is effective when:

(i) particles collide with the correct orientation
(ii) there is enough energy for the particles to react
(iii) there is greater number of collisions per second

EXPLAINING FACTORS AFFECTING RATE OF REACTION

(1) Surface area

✎When a solid is reduced into smaller particles we say its surface has increased
✎When surface are is increased:

- the number of particles in contact with other reactants will be increased
- the number of collisions per second will also increase
- hence chances of effective collisions to occur is very higher
- and this will also increase the rate of reaction

(2) Concentration

✎Concentration is the number of particles which occupies a unit volume
✎When concentration is increased:

- the number of particles in a given volume will also increase
- the number of collisions per second will eventually increase
- hence chances of effective collisions to occur is very higher
- and this will result in an increase in the rate of reaction

(3) Temperature

✎When temperature is increased:

- average kinetic energy will increase
- number of collisions per second will also increase
- hence chances of effective collisions to occur is higher
- and this will result in an increase in the rate of reaction

(4) Catalyst

✎Is a substance which speed up the rate of reaction but itself is not used up during the course of the reaction
✎When a catalyst is used:

- it lowers activation energy
- therefore more particles will have enough kinetic energy to react
- hence chances of effective collisions are very high
- and this will result in an increase in the rate of reaction

DEPENDANT, INDEPENDENT AND CONTROL VARIABLE

A dependant variable

✎A variable which changes as we change other variables in an experiment
✎In an experiment a dependant variable is the one whose value is changed by the value of an independent variable
✎e.g If we are required to measure volume of gas evolved over a period time, then volume is a **dependant variable**
✎Usually a dependant variable goes on the y-axis

Independent variable

✎A variable which is not changed by other variables in an experiment
✎In an experiment an independent variable is the one whose value you choose to change in an experiment
✎e.g If we are required to measure volume of gas evolved over a period time, then time is an **independent variable**
✎It usually goes on the x-axis

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Control variable

✎A variable which is kept constant throughout the experiment
✎This variable is kept constant so that we may have a fair comparison between the independent and dependant variables
✎e.g Suppose we are required to measure volume of gas evolved over a period time if the mass of one variable is kept constant, then mass is a control **variable**

Investigative question

✎Is a question intended to find facts and is normally designed to find information
✎Suppose we are investigating the relationship between surface area and rate of reaction, a possible investigative question will be:

How does surface area affect rate of reaction

OR

What is the relationship between rate of reaction and surface area

Hypothesis

✎Is an intelligent guess about the relationship between two or more variables
✎Suppose we are investigating the relationship between surface area and rate of reaction, a possible hypothesis will be:

Rate of reaction increases with an increase in surface area

OR

Rate of reaction decreases with a decrease in surface area

✎A hypothesis is done **before conducting an experiment,** so it is yet to be proved after conducting the experiment in the **conclusion**

Conclusion

✎Is an answer to the investigative question
✎It evaluates and your hypothesis whether it is right or wrong
✎When writing a conclusion you can either accept or reject your hypothesis
✎Suppose we are investigating the relationship between surface area and rate of reaction, a possible conclusion will be:

I accept my hypothesis, rate of reaction increases with an increase in surface area

MEASURING RATES OF REACTION

✎Reaction rates are either measured by measuring the rate at which reactants are used up or products are formed

Experimental techniques to measure reaction rate

Rate of reaction can be measured by measuring volume of gas evolved, turbidity, change of colour, and change of mass.

(a) Measuring of gas volumes evolved

✎volume of gas evolved should be measured using a measuring cylinder
✎volume should be recorded at regular time intervals and plot a graph
✎The faster the gas is released is also the higher the rate of reaction
✎The slower the gas is released is also the lower the rate of reaction
✎since **volume** depends on time it is a **dependant variable**, so it should be on they y-axis
✎**time** do not depend on **volume** therefore it is an **independent variable**, and must be on the x-axis

$$\text{Rate of reaction} = \frac{\text{volume of gas evolved}}{\text{time taken}}$$

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(b) Measuring turbidity

- Some reactions are studied by measuring the time required for the reaction mixture to become so turbid until it ceases to allow light to pass through it
- Change in turbidity must be noted after regular time intervals
- One good example is the reaction between sodium thiosulphate and hydrochloric acid
- Turbidity in this reaction mixture is a yellowish - cloudy appearance which is caused by small particles of sulphur particles suspended according to the following reaction

$$Na_2S_2O_3 + HCl \rightarrow 2NaCl + SO_2 + H_2O + S$$

- The faster the reaction mixture becomes turbid is also the higher the rate of reaction
- The slower the reaction mixture becomes turbid is also the lower the rate of reaction

(c) Change of colour

- If one of the reactants is coloured then a calorimeter can be used to determine change in colour intensity
- Change in colour must be noted at regular time intervals
- The faster the change in colour is also the higher the rate of reaction
- The slower the change in colour is also the lower the rate of reaction

(d) Change of mass

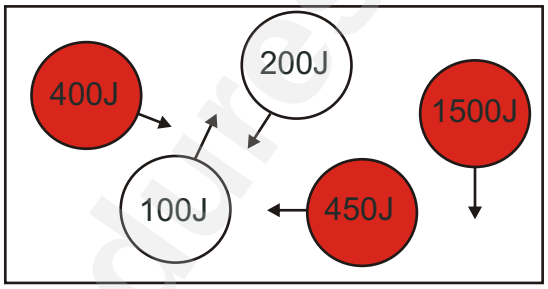
- Mass of either a solid, liquid or gas is measured using a balance
- Mass should be recorded at regular time intervals and plotted on a graph
- Mass readings should be on the y-axis while time should be on the x-axis

$$\text{Rate of reaction} = \frac{\text{mass of reactants/products}}{\text{time taken}}$$

- The faster the change in mass is also the higher the rate of reaction
- The slower the change in mass is also the lower the rate of reaction

Activation energy

- Minimum amount of energy required for a chemical reaction to take place
- Suppose we have five molecules in a reaction mixture as shown by the diagram below:



- Suppose the activation energy in the reaction mixture is 400J, then only three molecules will be involved in effective collisions and take part in the chemical reaction
- For a collision to be effective, molecules should have average kinetic energy equal to or greater than activation energy
- Particles with correct orientation and do not have sufficient kinetic energy will not take part in a chemical reaction

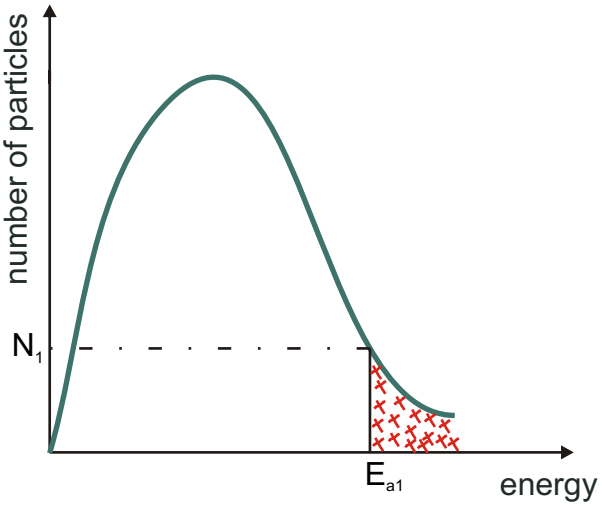
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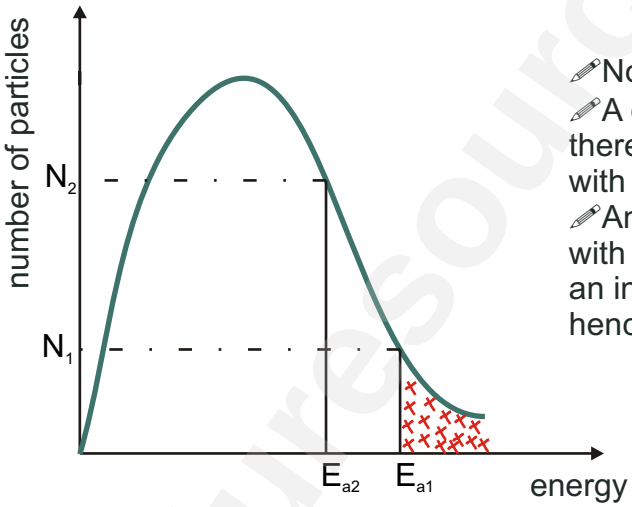
Maxwell - Boltzman Distribution curve

(1) ADDING A CATALYST

Before a catalyst is added a fewer number of molecules (N_1) had enough energy to react as shown in the diagram below:



After a catalyst was added, it lowered activation energy from E_{a1} to E_{a2} and as a result the number of particles with sufficient energy to react also increased from N_1 to N_2 as shown in the diagram below:

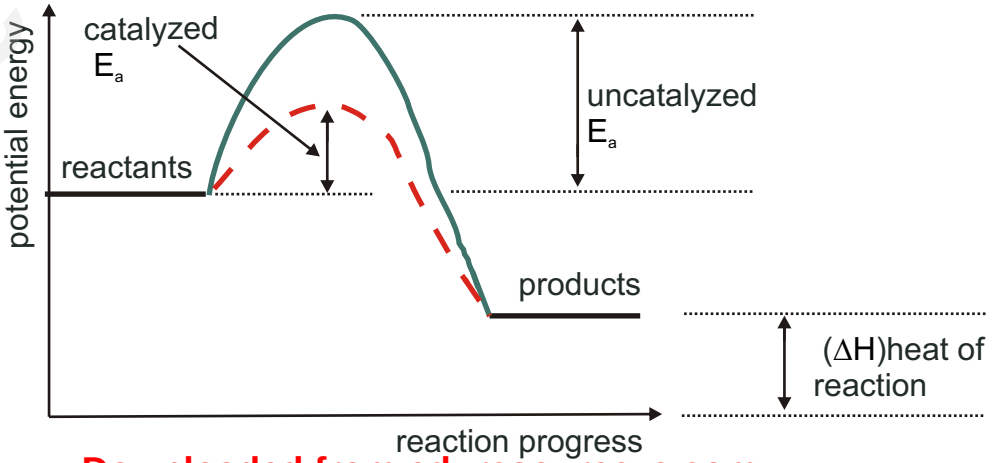


Note that $E_{a1} > E_{a2}$

A catalyst lowered activation energy and thereby increased the number of molecules with enough energy to react

An increase in the number of molecules with sufficient energy to react will result in an increase in effective collisions, and hence an increase in the rate of reaction

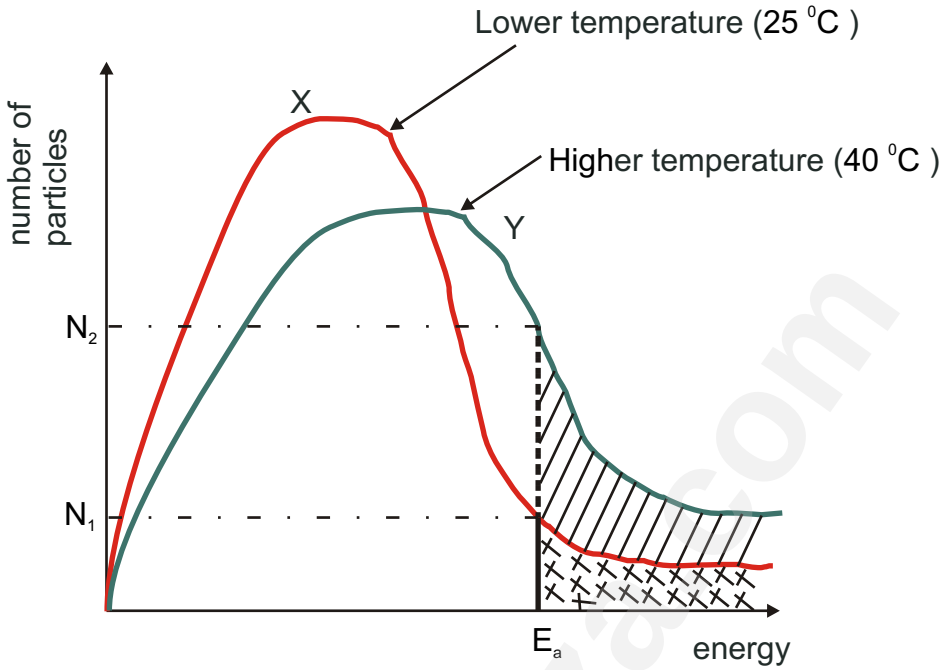
A catalyst react with reactants in such a way that the reaction will follow an alternative path of lower activation as shown below by a potential energy - reaction progress graph :



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(2) INCREASING TEMPERATURE



- Curve X has fewer number of molecules N_1 with activation energy (E_a) at a temperature of 25 °C in the above diagram
- When temperature is increased to 40 °C , the number of molecules with sufficient energy will increase from N_1 on curve X to N_2 on curve Y
- So at higher temperature (under curve Y) a bigger fraction of the molecules have more kinetic energy, leading to more effective collisions, and hence an increase in the rate of reaction

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EXAM TYPE WORKED EXAMPLES

QUESTION 1 (FEB 2009/P2/Q8)

Antacids are used to relieve indigestion. Indigestion is the condition when the stomach produces too much acid resulting in an uncomfortable and painful feeling. A certain antacid tablet dissolves in water and reacts with the acid in the stomach to release carbon dioxide gas.

1.1 Name the type of chemical reaction that explains why antacids bring relief from indigestion. (1)

1.2 A group of learners wants to investigate the effect of temperature on the rate of dissolution of this antacid tablet in water.

Design an investigation that the group of learners can conduct by answering the questions below.

1.2.1 State an investigative question. (2)

1.2.2 State a hypothesis for this investigation. (2)

1.2.3 Write down a procedure that can be followed in this investigation to test your hypothesis using some or all of the apparatus/chemicals listed below:

- Thermometer
- Stopwatch
- Hot plate
- Beaker
- Measuring cylinder
- Spatula/Teaspoon
- Water
- Antacid tablet (4)

1.2.4 Draw a table that can be used to record the results. Indicate the relevant headings of the rows and columns in the table. No values (numerical data) are required. (4)

1.3 Is it better to take the antacid tablet with warm water or with cold water? Give a reason for your answer. (2)

[15]

SOLUTION 1

1.1 Neutralisation/acid-base reaction (1)

1.2.1 What is the relationship between temperature and the reaction rate of an antacid tablet with water?

OR

What happens with the reaction rate of the antacid tablet with water when the temperature changes (increases) (decreases)?

OR

How does temperature influence the time of dissolution of an antacid tablet in water?

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1.2.2 The reaction rate (of an antacid tablet with water) will increase/decrease with increase/decrease in temperature.
OR
The higher/lower the temperature the faster/slower the rate of dissolution/reaction.

1.2.3 1. Use the measuring cylinder and measure a fixed volume of water and transfer it to the beaker.

2. Record the temperature of the water.

3. Add one antacid tablet to the water and measure the time it takes to dissolve/react completely.

4. Rinse the solution down the sink and repeat the experiment at least two more different temperatures.

5. Repeat steps 1 to 4 for accuracy/compensate for experimental error.

1.2.4

Temperature (°C)	Time (s)		Average time (s)
	Trial 1	Trial 2	

1.3

1.3 Warm water.
The rate at which it will bring relieve will be faster at a higher temperature

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QUESTION 2 (NOV 2009/P2/UNUSED/Q7)

The active ingredient in a certain antacid tablet is the carbonate ion (CO_3^{2-}(aq)). This ion reacts with the hydrochloric acid in your stomach according to the following reaction:

CO_3^{2-} (aq) + 2HCl(aq) $\rightarrow$ $2Cl^-$ (aq) + H_2O(l) + CO_2(g)

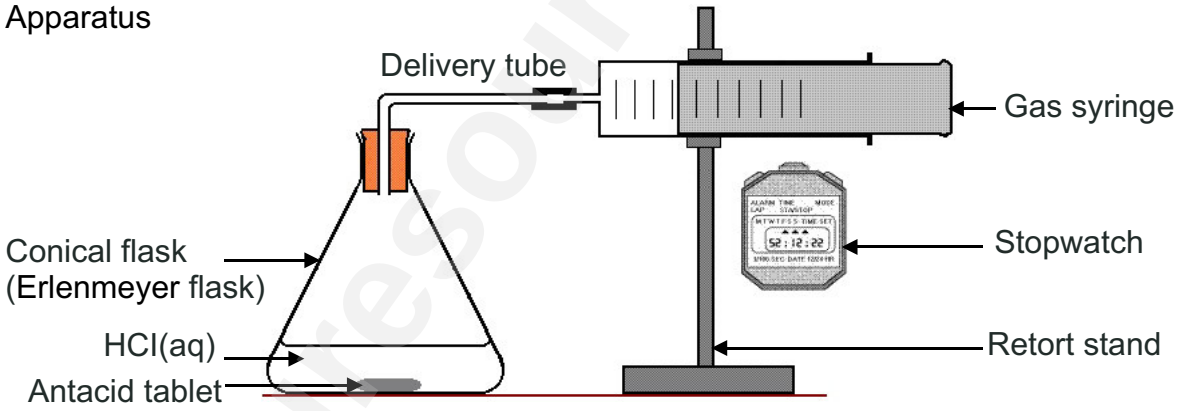
The formation of CO_2 gas is an indication that some of the acid has been neutralised and this brings relief from indigestion.

A group of learners use two of these antacid tablets to investigate **one of the factors that influence the reaction rate**. They follow the method and use the apparatus given below, to conduct the investigation.

Method:

1. Place one antacid tablet in a conical (Erlenmeyer) flask and add 20cm^3 HCl(aq)
2. Simultaneously start the stopwatch and close the flask with the rubber stopper that is at the end of the delivery tube attached to the gas syringe.
3. Measure the volume of the CO_2 gas formed in intervals of 30 seconds.
4. Repeat 1 to 3 above, but grind the second antacid tablet to a fine powder prior to the reaction

Apparatus



2.1 Define the term *reaction rate*. (2)

2.2 Write down an investigative question for this investigation. (2)

2.3 State THREE variables that must be controlled during this investigation. (3)

2.4 Apart from the apparatus illustrated on page 9, the learners need at least TWO other pieces of apparatus to conduct the investigation.

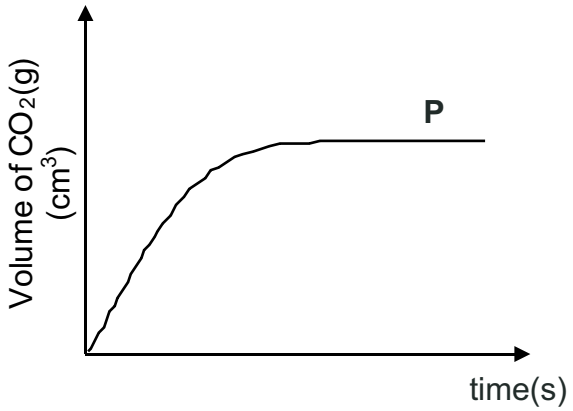
Write down the NAMES of the two pieces of apparatus, as well as the PURPOSE of each, in your ANSWER BOOK. (4)

2.5 The learners measure the volume of CO_2 gas formed at 30-second intervals in Step 3 of the method. Write down the NAME of the apparatus that they used for measuring the volume of the CO_2 . (1)

2.6 Consider the sketch graph below for the reaction of hydrochloric acid with the SOLID antacid tablet.

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Redraw the above sketch graph in your ANSWER BOOK. On the same set of axes, sketch the curve Q that was obtained for the reaction of the POWDERED antacid tablet with hydrochloric acid.

Clearly label the curves P and Q on the re-drawn sketch graph. (3)

2.7 The instruction on an antacid packet recommends that antacid tablets must be chewed for faster relief. Explain how chewing the tablets bring about faster relief. (2)

[17]

SOLUTION 2

2.1 The change in concentration of reactants/products per unit time
OR/OF
The rate of change of concentration of reactants/products
OR/OF
The change in amount of reactants/products per unit time

2.2 What is the relationship between reaction rate and surface area (of an antacid tablet)?
OR/OF
What is the relationship between the volume of CO2(g) formed per unit time and surface area (of an antacid tablet)?

2.3 Concentration of acid
Mass of antacid
Temperature of acid

2.4 Any two pieces of apparatus with purpose:
- Thermometerr

Measure temperature
- Pestle and mortar/any apparatus that can be used for grinding tablet

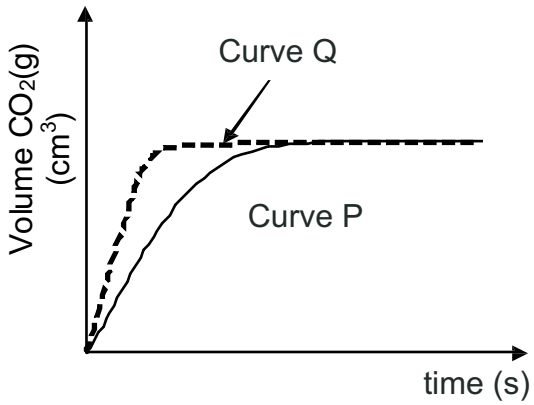
Grind antacid tablet to a powder
- Triple beam/mass meter

Measure the mass of the antacid

2.5 (Gas) syringe

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2.7 Chewing tablet increases its surface area that results in a faster rate of reaction

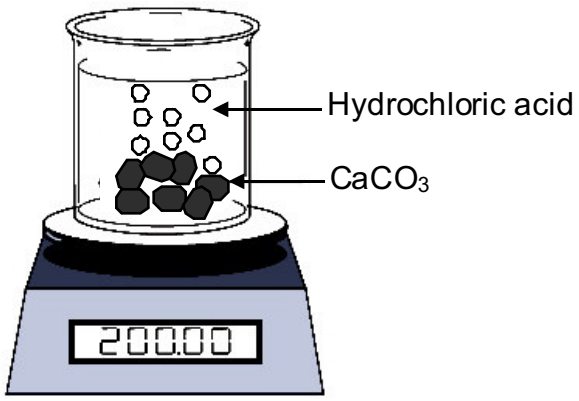
QUESTION 3 (MAR 2010/P2/Q9)

A certain mass of calcium carbonate chunks is added to a hydrochloric acid solution in an open beaker on a scale as shown below. The equation for the reaction is as follows:

$CaCO_3$ (s) + 2HCℓ(aq) → $CaCℓ_2$ (aq) + $H_2O(ℓ)$ + CO_2 (g)

Co_2 (g) is allowed to escape from the beaker. The data in the table below was obtained for a time interval of 8 minutes.

Time (min)	Mass of beaker and contents (g)
0	200,00
1	197,50
2	195,45
3	193,55
4	191,70
5	189,90
6	188,15
7	186,45
8	184,80



3.1 'Rate' in science refers to something that happens in a certain time. Explain the term *reaction rate.* (2)

3.2 Calculate the change in mass of the beaker and its contents during the 8 minutes. (1)

3.3 Use your answer in QUESTION 3.2 to show that the average reaction rate during the 8 minutes is 1,9 $g \cdot min^{-1}$. (2)

3.4 Calculate the mass of calcium carbonate consumed during the 8 minutes. (5)

3.5 Use the collision theory to explain how the rate of the above reaction will change when powdered calcium carbonate is used instead of calcium carbonate chunks. (3)

[13]

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SOLUTION 3

3.1 The change in amount/mass/volume of products formed per unit time.
OR
The change in amount/mass/volume of reactants used per unit time.

3.2 Change in mass = 200 - 184,8
+ = 15,2 g

3.3 Rate of reaction = $\frac{\text{mass change}}{\text{time change}}$

$= \frac{15.2}{8}$

$= 1.9 g.min^{-1}$ (CO_2 produced)

3.4

OPTION 1

mol(CO_2) formed:

$n = \frac{m}{M} = \frac{200 - 184.8}{44} = 0.35$ mol CO_2

Mol $CaCO_3$ consumed:

$n(CaCO_3) = n(CO_2) = 0.35$ mol (ratio)

Therefore, $m(CaCO_3) = nM = (035)(100)$

$= 35g$ (34.54g)

OPTION 2

From balanced equation

100g $CaCO_3$ forms 44g Co_2

$m(CO_2)$ formed = 200 - 184.8g = 15.2g

$m(CaCO_3) = \frac{100 \times 15.2}{44} = 35g$ (34.54g)

9.5 Powder - large surface area
More effective collisions per unit time/ more molecules colliding with the correct orientation
Increase in rate of reaction

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TASK 9

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QUESTION 1 (NOV 2010/P2/Q6.)

1.1 The collision theory explains why chemical reactions occur and why they take place at different rates.

Some of the terms used in the collision theory and reaction rate are given below.

surface area;	catalyst;	effective collision;	activated complex;
concentration;	temperature;	heat of reaction;	activation energy

Give ONE term for each of the following descriptions by choosing a term from the list above. Write down only the term next to the question number (6.1.1 6.1.6) in the ANSWER BOOK.

1.1.1 A chemical substance that speeds up the rate of a chemical reaction by lowering the net activation energy (1)

1.1.2 A collision in which the reacting particles have sufficient kinetic energy and the correct orientation (1)

1.1.3 The factor responsible for increasing the rate of a reaction when a solid is broken up into smaller pieces (1)

1.1.4 The temporary unstable state that is formed during the course of a chemical reaction (1)

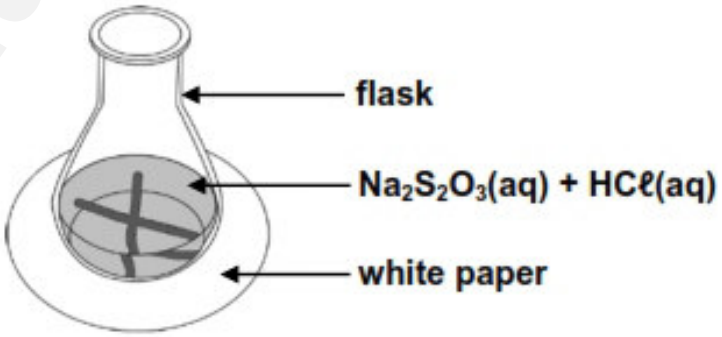
1.1.5 A measure of the average kinetic energy of the particles in a gas (1)

1.1.6 The net amount of energy released or absorbed during a chemical reaction (1)

1.2 Learners use hydrochloric acid and a sodium thiosulphate ($Na_2S_2O_3$) solution to investigate the relationship between rate of reaction and temperature. The reaction that takes place is represented by the following equation:

$$Na_2S_2O_3(aq) + 2HC\ell(aq) \rightarrow 2NaC\ell(aq) + S(s) + H_2O(\ell) + SO_2(g)$$

They add 5 cm3 dilute hydrochloric acid solution to 50 cm3 sodium thiosulphate solution in a flask placed over a cross drawn on a sheet of white paper, as shown in the diagram below. The temperature of the mixture is
30 °C.



They measure the time it takes for the cross to become invisible. The experiment is repeated with the temperature of the mixture at 40 °C, 50 °C and 60 °C respectively.

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1.2.1 Write down a possible hypothesis for this investigation. (2)

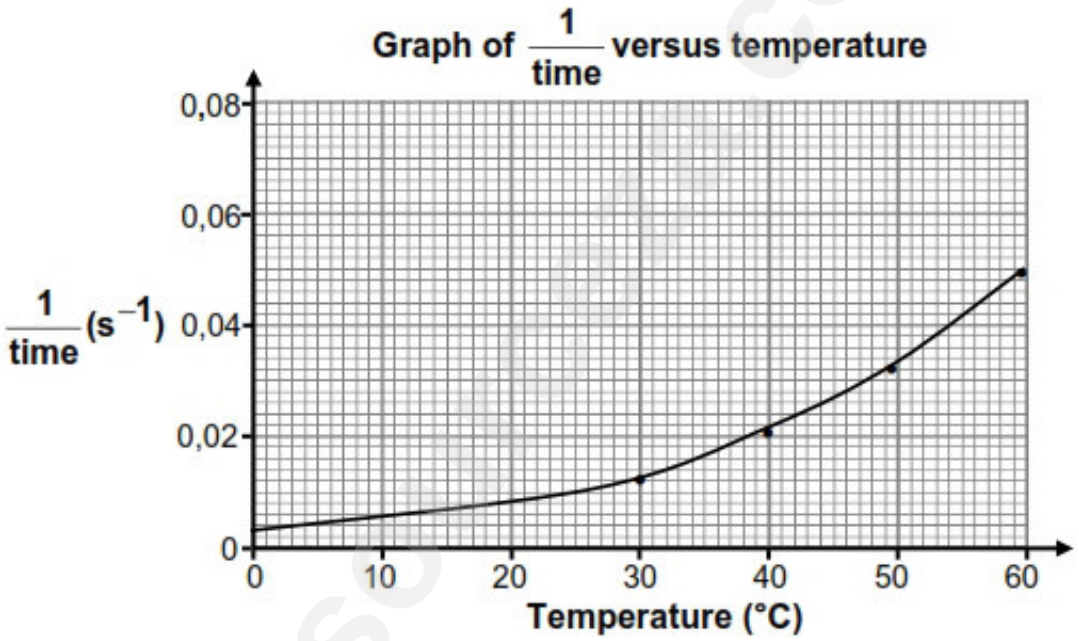
1.2.2 Write down the NAME or FORMULA of the product that requires the need to work in a well-ventilated room. (1)

1.2.3 Apart from the volume of the reactants, state ONE other variable that must be kept constant during this investigation. (1)

1.2.4 Write down the NAME or FORMULA of the product that causes the cross to become invisible. (1)

1.2.5 Why is it advisable that the same learner observes the time that it takes for the cross to become invisible? (1)

The graph shown below is obtained from the results.



1.2.6 What is represented by $\frac{1}{\text{time}}$ on the vertical axis? (1)

1.2.7 What conclusion can be drawn from the results obtained? (2)

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TOPIC 7 CHEMICAL EQUILIBRIUM

OPEN AND CLOSED SYSTEMS

Closed system
A system whereby reactants and products do not have interaction with the environment.

Open system
A system whereby reactants and products interact with the environment

DYNAMIC EQUILIBRIUM

This is when the rate of forward reaction is equal to the rate of the reverse reaction

Le Chartelier's Principle
- It states that: Any disturbance that is introduced into a system in equilibrium will cause a shift in the position of equilibrium in a direction that will oppose the disturbance.
- A disturbance can be a change in temperature, pressure or concentration

Application of Le Chartelier's Principle and factors affecting position of equilibrium

(a) Changes in Concentration
Suppose we have the following reaction equation for a system in equilibrium:

$$A + B \rightleftharpoons C + D$$

If more of A is added into the system, then concentration of A in the system will increase. The increase in concentration of A becomes a DISTURBANCE to a system's equilibrium. Hence according to Le Chartelier's principle, the position of equilibrium will shift in favour of the forward DIRECTION which will oppose this disturbance. So B will react with excess of A to produce C and D. This way excess of A will be converted to products (C and D) until the system attains a new equilibrium.

(b) Changes in pressure
Suppose we have a slightly different reaction equation:

$$A + 2B \rightleftharpoons C + 3D$$

When pressure is increased in a system in equilibrium, volume of the system will decrease. The decrease in volume is a disturbance to the system's equilibrium. According to Le Chartelier's Principle, to oppose this disturbance, the position of equilibrium will shift in favour of the direction that will decrease pressure. Pressure increases with collisions against walls of the container. More molecules have more collisions on the walls than fewer molecules. So the system can lower pressure by favouring direction that can produce fewer number of molecules until a new equilibrium is reached. Therefore in the above example, when pressure is increased the position of equilibrium will shift in favour of the reverse reaction with 3 molecules.

(c) Changes in temperature
- When temperature is increased in any equilibrium system, according to Le Chartelier's Principle, an endothermic reaction will always be favoured until a new equilibrium position is reached. In other words, when temperature is increased, position of equilibrium will shift in favour of the reaction which lowers temperature of the surroundings. An endothermic reaction is favoured because it lowers temperature of the surroundings.
- When temperatured is decreased in any equilibrium system, according to Le Chartelier's Principle, an exothermic reaction will always be favoured until a new equilibrium position is reached. In other words, when temperature is decreased, position of equilibrium will shift in favour of the reaction which increases temperature of the surroundings. An exothermic reaction is favoured because it increases temperature of the surroundings.

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Suppose we have the following reaction equation:

(i) Exothermic reactions

$A + B \rightleftharpoons C + D \quad \Delta H < 0$

The reaction above is called an EXOTHERMIC REACTION because the system becomes hotter($\Delta H < 0$) as the forward reaction occurs in a closed container. However it does not mean that an exothermic reaction is the only one in the system. There is also an endothermic reaction, but in the reverse direction.

✎ When temperature is increased in this system, the endothermic reaction will be favoured according to Le Chartelier's Principle. And hence C and D will decompose to form A and B. Therefore more reactants will be formed when temperature is increased in a system with an exothermic as its forward reaction.

✎When temperature is decreased in this system, the exothermic reaction will be favoured according to Le Chartelier's Principle. And hence A and B will react to form C and D. Therefore more products will be formed when temperature is decreased in a system with an exothermic as its forward reaction.

(ii) Endothermic reactions

$A + B \rightleftharpoons C + D \quad \Delta H > 0$

A reaction above is called an ENDOTHERMIC REACTION because the system becomes colder ($\Delta H > 0$) as the forward reaction occurs in a closed container. However it does not mean that an endothermic reaction is the only one in the system. There is also an exothermic reaction, but in the reverse direction.

✎ When temperature is increased in this system, the endothermic reaction will be favoured according to Le Chartelier's Principle. And hence A and B will combine to form C and D. Therefore more products will be formed when temperature is increased in a system with an endothermic as its forward reaction.

✎When temperature is decreased in this system, the exothermic reaction will be favoured according to Le Chartelier's Principle. And hence C and D will decompose to form A and B. Therefore more reactants will be formed when temperature is decreased in a system with an endothermic as its forward reaction.

Use of a catalyst

✎A catalyst only increases the rate at which equilibrium is reached but it does not shift the position of equilibrium.

Equilibrium Constant (Kc)

Example 1: Determine Kc expressions given the following equilibrium systems:

(i) $A(g) + 3B(g) \rightleftharpoons 2C(g) + D(g)$ (ii) $X_2(g) + Y_2(g) \rightleftharpoons 2YX(g)$

(iii) $CaCO_3(s) + 2HCl(aq) \rightleftharpoons CaCl_2(s) + H_2O(l) + CO_2(g)$

Solution 1:

(i) $K_c = \frac{[C]^2[D]}{[A][B]^3}$ (ii) $K_c = \frac{[YX]^2}{[X_2][Y_2]}$ (iii) $K_c = \frac{[CaCl_2][H_2O][CO_2]}{[CaCO_3][HCl]^2} = [CO_2]$

concentration of solids or liquids equals to 1. That's why $K_c = [CO_2]$

Factors which influence the value of Kc

✎Temperature is the only factor which affect the value of Kc

✎Other factors such as change in concentration, change in pressure, use of a catalyst can on affect the rate of reaction but cannot affect the value of Kc

Direction of reaction when calculating Kc

✎It is determined using Le Chartelier's principle

✎However the following tips are useful to quickly determine direction of reaction

(i) When initially there are reactants in the container and no products, then the reaction must favour the direction that forms products (forward reaction is favoured)

(ii) When initially there are both reactants and products in the container, then the reaction can favour any direction (forward or backwards)

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CALCULATION OF Kc USING A TABLE - METHOD

✎This method works best when:
(i) Given number of moles (initial moles, change in mole or moles at equilibrium)
(ii) Given concentration (initial concentrations, change in concentrations or concentrations at equilibrium for **some reactants or products**)
(iii) Given mass (initial mass, mass reacted/produced or mass at equilibrium)
N:B If the concentrations at equilibrium **for all reactants and products** involved are given, then there is no need to use the table. The purpose of the table is to determine concentrations at equilibrium for all reactants and products which are needed to calculate Kc.

Example 2
The following reaction took place in a closed system:

$A(g) + 2B(g) \rightleftharpoons C(g) + 4D(g)$

Initially in the system there were 2 moles of A and 1 mole of B injected in a closed container of 2 dm^{-3}. At equilibrium it was found that there was 0.8 mol of D left. Calculate Kc.

Solution 2

Mol reacted/produced = x × Mol ratio

STEP 1 : Draw the table in terms of x

	A(g)	2B(g)	⇌ C(g)	4D(g)
Mol ratio	1	2	1	4
Initial mol	2	1	0	0
Mol reacted /produced	-X	-2X	+X	+4X
Mol at equilib	2-X	1-2X	0 + X	0+4X = 0.8
Conc at equilib				

✎ 0+ 4x = 0.8; therefore x = 0.2
✎ Substitute x in the above table as follows

N:B Mol at equilibrium = initial moles + moles reacted/produced

STEP 2 : Fill in the actual values:

	A(g)	2B(g)	⇌ C(g)	4D(g)
Mol ratio				
Initial mol	2	1	0	0
Mol reacted/ produced	— 0.2	— 0.6	0.2	0.8
Mol at equilib	1.8	0.4	0.2	0.8
Conc at equil **C = n/V**	0.9	0.2	0.1	0.4

Direction of reaction determines sign for Moles reacted/formed in the table. Moles reacted are negative when reactant/product is used up, and positive when reactant/prodcut is being formed.

✎ Now that we have all concentrations at equilibrium, we can calculate our Kc using the following expression:

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$$K_c = \frac{[C][D]^4}{[A][B]^2} = \frac{(0.1)(0.4)^4}{(0.9)(0.2)^2} = 0.0711$$

N:B There are no products initially, therefore the equilibrium can ONLY shifts to the right

Example 3

Hydrogen iodide is formed during a reversible reaction when hydrogen and iodine react at 424.5 ^{0}C. Initially there is 1.2 mol of H_2 , 0.9mol of I_2 and 1.9mol of HI in a closed container of 2d.m^{-3}. At equilibrium it was found that there was 0.12mol of I_2 left. Calculate K_c

Solution 3

STEP 1: Draw the table in terms of x:

Mol reacted/produced = *x* x Mol ratio

	$H_2(g)$	$I_2(g)$	$\rightleftharpoons$	$2HI(g)$
Mole ratio	1	1		2
Initial mol	1.2	0.9		1.9
Mol reacted /produced	+x	+x		-2x
Mol at equilibrium	1.2+x	0.9+x		1.9-2x = 0.12
Conc at equilib				

- 1.9 - 2x = 0.12 ; therefore x = 0.89
- Substitute x in the above table as follows

N:B Mol at equilibrium = initial moles + moles reacted/produced

STEP 2: Fill in the actual values:

	$H_2(g)$	$I_2(g)$	$\rightleftharpoons$	$2HI(g)$
Mole ratio	1	1		2
Initial mol	1.2	0.9		1.9
Mol reacted /produced	+0.89	+0.89		-1.78
Mol at equilibrium	2.09	1.79		0.12
Conc at equilib **C= n/V**	1.04	0.89		0.06

Direction of reaction determines sign for Moles reacted/formed in the table. Moles reacted are negative when reactant/product is used up, and positive when reactant/prodcut is being formed.

- Now that we have all concentrations at equilibrium, we can calculate Kc using the following expression:

$$K_c = \frac{[HI]^2}{[H_2][I_2]} = \frac{(0.06)^2}{(1.04)(0.89)} = 3.89 \times 10^{-03}$$

N:B We solved this problem assuming the equilibrium position shifted to the left, but we will still be correct even if we assume that the equilibrium shifted to the right. In that case mol reacted for H_2 will be **-x**, for I_2 will be **-x** and for HI will be **+2x**. So when it is mentioned that **initially products have a certain number of moles** then you can assume either the equilibrium shifted to the left or to the right (unless the equilibrium shift is given)

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Example 4

Hydrogen iodide is formed during a reversible reaction when hydrogen and iodine react at 424.5 ^{0}C. Initially there is 1.2 M of H_2 and 0.9 M of I_2 in a closed container. At equilibrium it was found that there was 0.12 M of I_2 left. Calculate K_c

Solution 4

STEP 1: Draw the table in terms of x:

	$H_2(g)$	$I_2(g)$	$\rightleftharpoons$ $2HI(g)$
Initial concentrations	1.2	0.9	0
Change in concentration	-x	-x	+2x
Equilibrium Concentration (In terms of x)	1.2-x	0.9-x = 0.12	0 + 2x

STEP 2: Fill in the missing values:

	$H_2(g)$	$I_2(g)$	$2HI(g)$
Initial concentrations	1.2	0.9	0
Change in concentration	-x	-x	+2x
Equilibrium Concentration (In terms of x)	1.2-x	0.9-x = 0.12	0 + 2x
Equilibrium Concentration (Numerical)	0.42	0.12	1.56

Having all concentrations at equilibrium, we can now calculate our Kc using the following expression:

$$K_c = \frac{[HI]^2}{[H_2][I_2]} = \frac{(1.56)^2}{(0.42)(0.12)} = 48.29$$

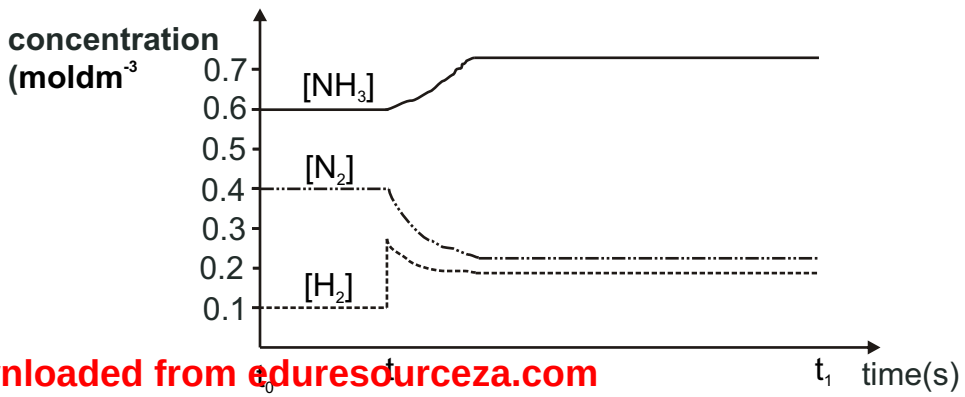
CALCULATING Kc FROM GRAPHS

(i) Concentration - time graphs

Given a concentration - time graph it is possible to determine the value of Kc

Example 5

Calculate the value of Kc from t_0 to t_1 using the concentration - time graph on the right.



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Solution 5

STEP 1: **Write a balanced equation for the reaction:**

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

STEP 2: Write a Kc expression for the above reaction:

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

STEP 3: Read values of concentration at equilibrium from t_0 to t_1.

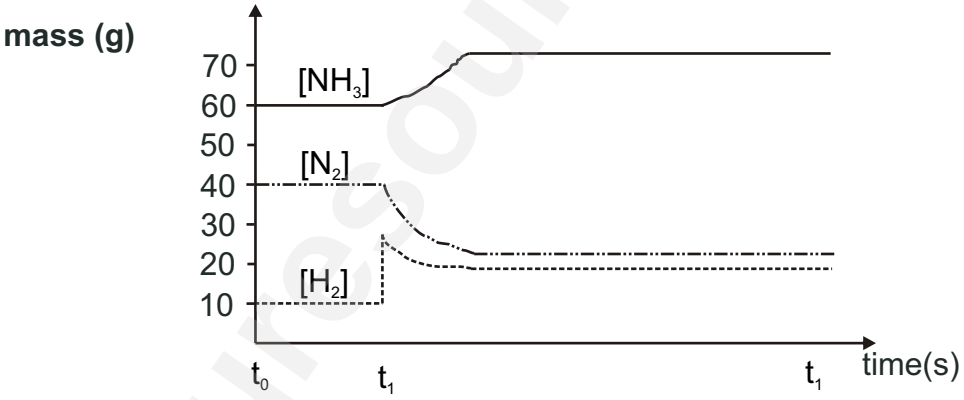
From the graph we can see that $[NH_3] = 0.6\ mol.dm^{-3}$
$[N_2] = 0.4\ mol.dm^{-3}$
$[H_2] = 0.1\ mol.dm^{-3}$

STEP 4: Since we have concentrations at equilibrium from the graph, we can now calculate the value of Kc by simply substituting values in the Kc expression in STEP 2.

$$K_c = \frac{(0.6)^2}{(0.4)(0.1)^3} = 900$$

Example 6

Given the graph below, calculate the Kc value between t_0 to t_1 if volume of the container is $1.5\ dm^3$



Solution 6

STEP 1: Write down the Kc expression for the reaction:

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

STEP 2: Calculate the number of moles for NH_3, N_2 and H_2 at equilibrium:

$m_{NH3\ at\ equilibrium} = 60g$
$m_{N2\ at\ equilibrium} = 40g$
$m_{H2\ at\ equilibrium} = 10g$

$Mr\ (NH_3) = 17gmol^{-1}$ $Mr(N_2) = 28gmol^{-1}$ $Mr(H_2) = 2\ g.mol^{-1}$

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$n_{NH3\ at\ equilibrium} = \frac{60}{17} = 3.5mol$

$n_{N2\ at\ equilibrium} = \frac{40}{28} = 1.4mol$

$n_{H2\ at\ equilibrium} = \frac{10}{2} = 5mol$

STEP 3: Calculate concentrations at equilibrium:

$[NH_3]_{at\ equilib} = \frac{n}{V} = \frac{3.5}{1.5} = 2.33\ mol.dm^{-3}$

$[N_2]_{at\ equilib} = \frac{n}{V} = \frac{1.4}{1.5} = 0.93\ mol.dm^{-3}$

$[H_2]_{at\ equilib} = \frac{n}{V} = \frac{5}{1.5} = 3.33\ mol.dm^{-3}$

STEP 4: Substitute values of concentration at equilibrium into the Kc expression to determine the value of Kc:

$$K_c = \frac{(2.33)^2}{(0.93)(3.33)^3} = 0.16$$

PROFITABILITY AND MAGNITUDE OF Kc

(i) Kc is large

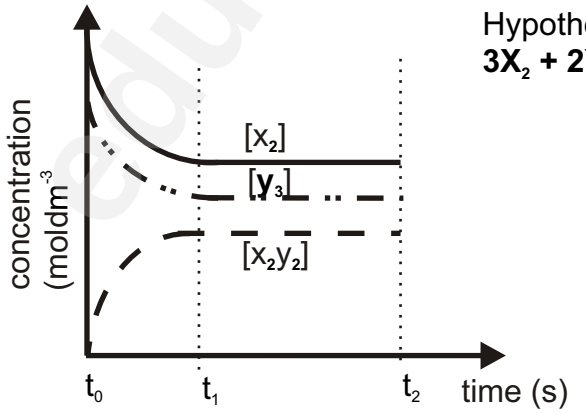
- The value of Kc is great when Kc > 1
- The reaction is profitable if the value of Kc is large

(ii) Kc is small

- The value of Kc is small when Kc < 1
- The reaction is said to be unprofitable if Kc is small

CHANGES IN CONCENTRATION VERSUS TIME

Concentration versus - time graph



Hypothetical reaction for the graph on the left is:
$3X_2 + 2Y_3 = 3X_2Y_2$

- Changes in concentrations from t_0 to t_1:

(i) [x_2] decreases
(ii) [y_3] decreases
(iii) [x_2y_2] increases

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N:B Forward reaction is faster than reverse reaction

✎Changes in concentrations from t_1 to t_2
(i) $[x_2]$ no change
(ii) $[\mathbf{y_3}]$ no change
(iii) $[x_2y_2]$ no change

From t_1 to t_2 change in concentration of reactants = change of concentration of products = 0. Equilibrium is reached when there is no change in concentration for both reactants and products, and it is represented by a horizontal line in the graph above

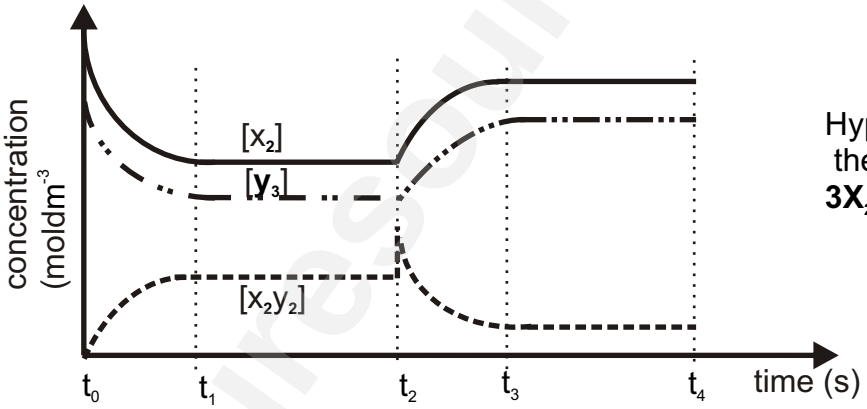
N:B Rate of forward reaction is equal to rate of forward reaction

Facts about reversible reactions:
(1) Forward reaction is faster than reverse reaction if there is net increase in concentration of products and net decrease in concentration of reactants
(2) Forward reaction is slower than reverse reaction if there is net increase in concentration of reactants and net decrease in concentration of products
(3) Rate of forward reaction is equal to the rate of reverse reaction if there is no change in concentrations of both products and reactants (equilibrium)

(A) APPLICATION OF Le Chatelier's PRINCIPLE WHEN CONCENTRATION CHANGES

Interpreting concentration - time graphs using words

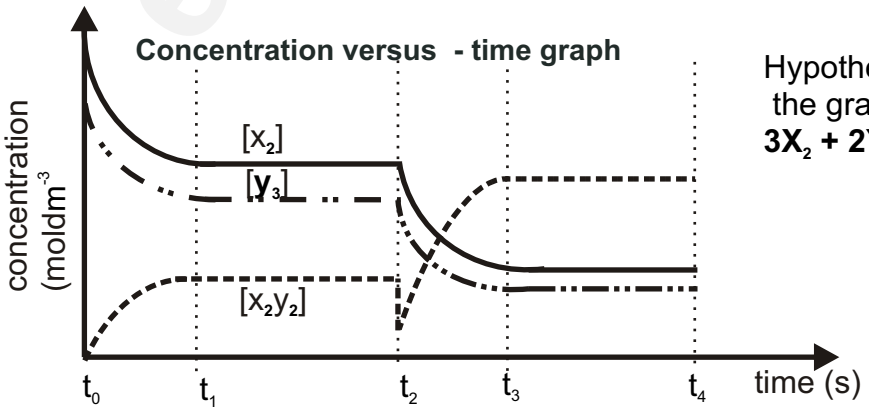
Concentration versus - time graph



Hypothetical reaction for the graph on the left is:
$\mathbf{3X_2 + 2Y_3 = 3X_2Y_2}$

✎**When concentration of X_2Y_2 is increased at t_2 :** more of X_2Y_2 will decompose to form X_2 and Y_3. Therefore according to Le Chartelier's principle an increase in concentration of X_2Y_2 at t_2 will shift the position of equilibrium to **favour the reverse reaction**

Concentration versus - time graph



Hypothetical reaction for the graph on the left is:
$\mathbf{3X_2 + 2Y_3 = 3X_2Y_2}$

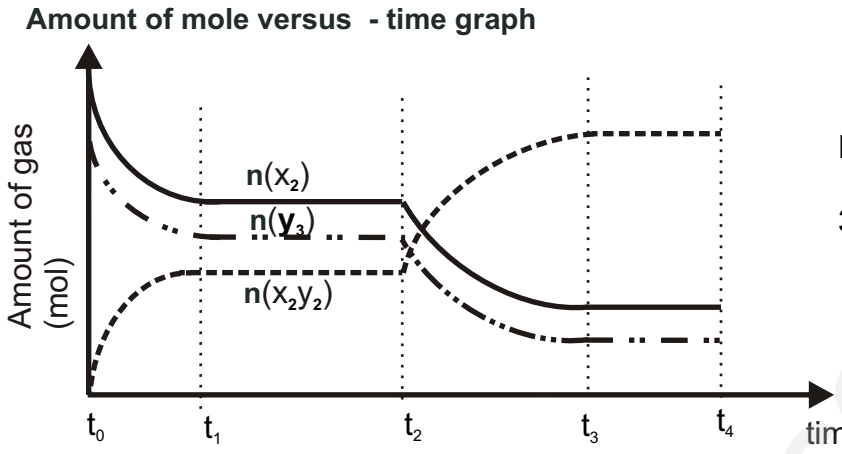
✎Again according to Le Chartelier's principle, decrease in concentration of X_2Y_2 at t_2 will favour the foward reaction

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(B) APPLICATION OF Le Chartelier's PRINCIPLE WHEN TEMPERATURE CHANGES

Interpreting an amount of moles - time graph using words



Hypothetical reaction for the graph on the left is:
$3X_2 + 2Y_3 = 3X_2Y_2$

If temperature is increased at t_2 then:

- Looking at changes in number of moles from t_2 to t_3 we see that:

(i) **n**(x_2) decreases
(ii) **n**($\mathbf{y_3}$) decreases
(iii) **n**(x_2y_2) increases

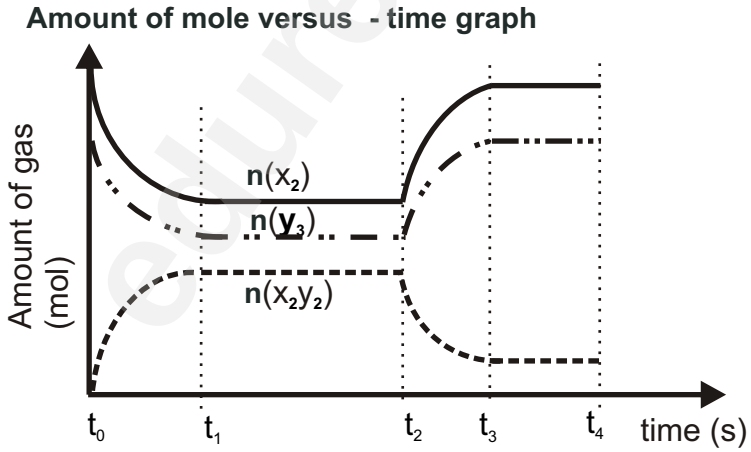
- Therefore it is clear that when temperature was increased the position of equilibrium shifted to favour the forward reaction (more products are formed)
- So according to Le Chartelier's principle, the **forward reaction is endothermic**

If temperature is decreased at t_2 then:

- Looking at changes in number of moles from t_2 to t_3 we see that:

(i) **n**(x_2) increases
(ii) **n**($\mathbf{y_3}$) increases
(iii) **n**(x_2y_2) decreases

- Therefore it is clear that when temperature was decreased the position of equilibrium shifted to favour the reverse reaction (more reactants are formed)
- So according to Le Chartelier's principle, the **reverse reaction is exothermic**



Hypothetical reaction for the graph on the left is:
$3X_2 + 2Y_3 = 3X_2Y_2$

From t_1 to t_2 and t_3 to t_4 change in number of moles of reactants = change of number of moles of products = 0. Equilibrium is reached when there is no change in number of moles for both reactants and products, and it is represented by horizontal lines in the graph above

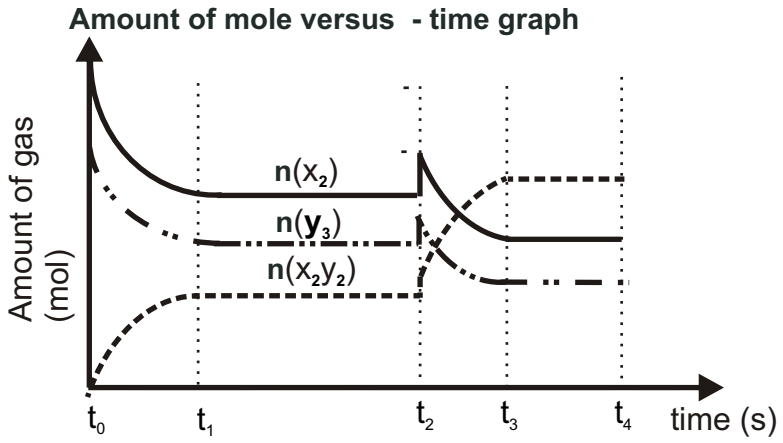
N:B Between t_1 to t_2 and t_3 to t_4 Rate of forward reaction is equal to rate of forward reaction

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(B) APPLICATION OF Le Chartelier's PRINCIPLE WHEN PRESSURE CHANGES

Interpreting an amount of moles - time graph using words



Hypothetical reaction for the graph on the left is:
$3X_2 + 2Y_3 = 3X_2Y_2$

Increase in pressure increases ALL the number of moles/concentrations at t_2

If pressure is increased at t_2 then ALL the number of moles will increase

●Looking at changes in number of moles from t_1 to t_2 we see that:

(i) $n(x_2) + n(y_3) = 5$

(ii) $n(x_2y_2) = 3$

● So $[n(x_2) + n(y_3)] > [n(x_2y_2)]$ **<=>** n(reactants) > n(products)

●Therefore it is clear from the graph above that when pressure was increased the position of equilibrium shifted in the forward reaction so as to decrease pressure of the system

●So according to Le Chartelier's principle, the **forward reaction (with fewer number of moles) will decrease pressure of the system**

If pressure is decreased at t_2 then ALL the number of moles will decrease:

●Looking at changes in number of moles from t_2 to t_3 we see that:

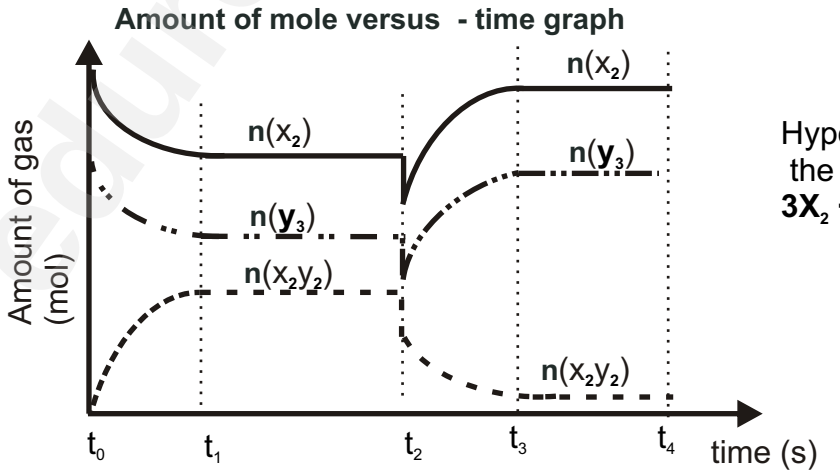
(i) $n(x_2) + n(y_3) = 5$

(ii) $n(x_2y_2) = 3$

● So $[n(x_2) + n(y_3)] > [n(x_2y_2)]$ **<=>** n(reactants) > n(products)

●Therefore it is clear from the graph below that when pressure was decreased the position of equilibrium shifted in the reverse reaction so as to increase pressure of the system

●So according to Le Chartelier's principle, the **reverse reaction (with more number of moles) will increase pressure of the system**



Hypothetical reaction for the graph on the left is:
$3X_2 + 2Y_3 = 3X_2Y_2$

From t_1 to t_2 and t_3 to t_4 change in number of moles of reactants = change of number of moles of products = 0. Equilibrium is reached when there is no change in number of moles for both reactants and products, and it is represented by a horizontal line in the graph above

N:B Between t_1 to t_2 and t_3 to t_4 Rate of forward reaction is equal to rate of forward reaction

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EXAM TYPE WORKED EXAMPLES

QUESTION 1 (FEB 2009/P2/Q9)

Smog refers to a very unpleasant condition of pollution in certain urban environments. It is produced largely by the action of sunlight on car exhaust gases. Two groups of compounds emitted from car exhausts, that contribute to the formation of smog, are nitrogen oxides and unburned hydrocarbons.

Nitric oxide (NO(g)) forms in internal combustion engines by the direct combination of nitrogen and oxygen according to the following reversible reaction:

$$N_2(g) + O_2(g) \rightleftharpoons 2\ NO(g) \qquad \Delta H = +90{,}4\ kJ$$

In air, nitric oxide is rapidly oxidised to nitrogen dioxide (NO_2 (g)) that initiates the reactions responsible for the formation of smog. Nitrogen dioxide acts as catalyst for the formation of ozone, a key component of smog.

Although an essential UV screen in the upper atmosphere, ozone is an undesirable pollutant in the lower atmosphere. It is extremely reactive and toxic, and breathing air containing appreciable amounts of ozone can be dangerous for asthma sufferers, sports people and the elderly.

1.1 Before the Olympic Games in Beijing, authorities were extremely concerned about the levels of smog in the city.
Explain why high smog levels are especially dangerous for sports people. (2)

1.2 Suggest TWO ways of reducing NO(g) in urban areas. (2)

The questions below refer to the reaction in the passage above.

1.3 Explain why the formation of NO(g) is favoured in internal combustion engines where temperatures are as high as 2 400 K. (2)

1.4 During a research experiment carried out by initially adding 1 mol of O_2(g) and 1 mol of N_2 (g) in a 2 dm3 closed container at 300 K, it was found that the concentration of the NO(g) present in the container at equilibrium was 0,1 mol·dm-3.

Calculate the equilibrium constant (Kc) for the reaction at this temperature. (7)

1.5 How will the amount of NO(g) at equilibrium be affected if:

1.5.1 The pressure is increased by decreasing the volume (2)

1.5.2 A catalyst is added (1)

1.6 Draw the potential energy diagram for the above reaction. Indicate the heat of reaction and the activation energy for the catalysed reaction on the diagram. (5)

[21]

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SOLUTION 1

1.1 During exercise more air is breathed and more toxic ozone/nitrogen dioxide will be inhaled, resulting in lung problems/poor performance due to oxygen deficiency.

1.2 Supply more and safe public transport to decrease cars on road.

1.3 The high temperature will favour the forward 9 endothermic reaction and more NO(g) is formed.

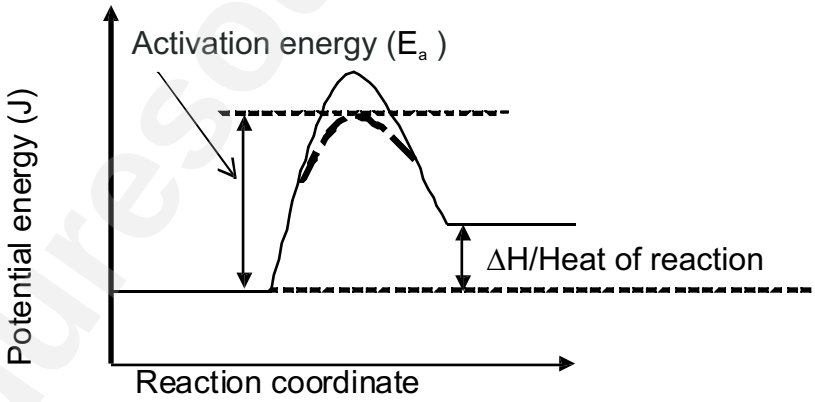
1.4

	N_2	O_2	NO
Molar ratio	1	1	2
Initial quantity (mol)	1	1	0 9
Change (mol)	0,1	0,1	0,2
Quantity at equilibrium (mol)	0,9	0,9	0,2
Concentration ($mol \cdot dm^{-3}$)	0,45	0,45	0,1

$$K_c = \frac{[NO]^2}{[N_2][O_2]} = \frac{(0.1)^2}{(0.45)(0.45)} = 0.049 = 0.05$$

1.5 1.5.1 No effect
1.5.2 No effect

1.6



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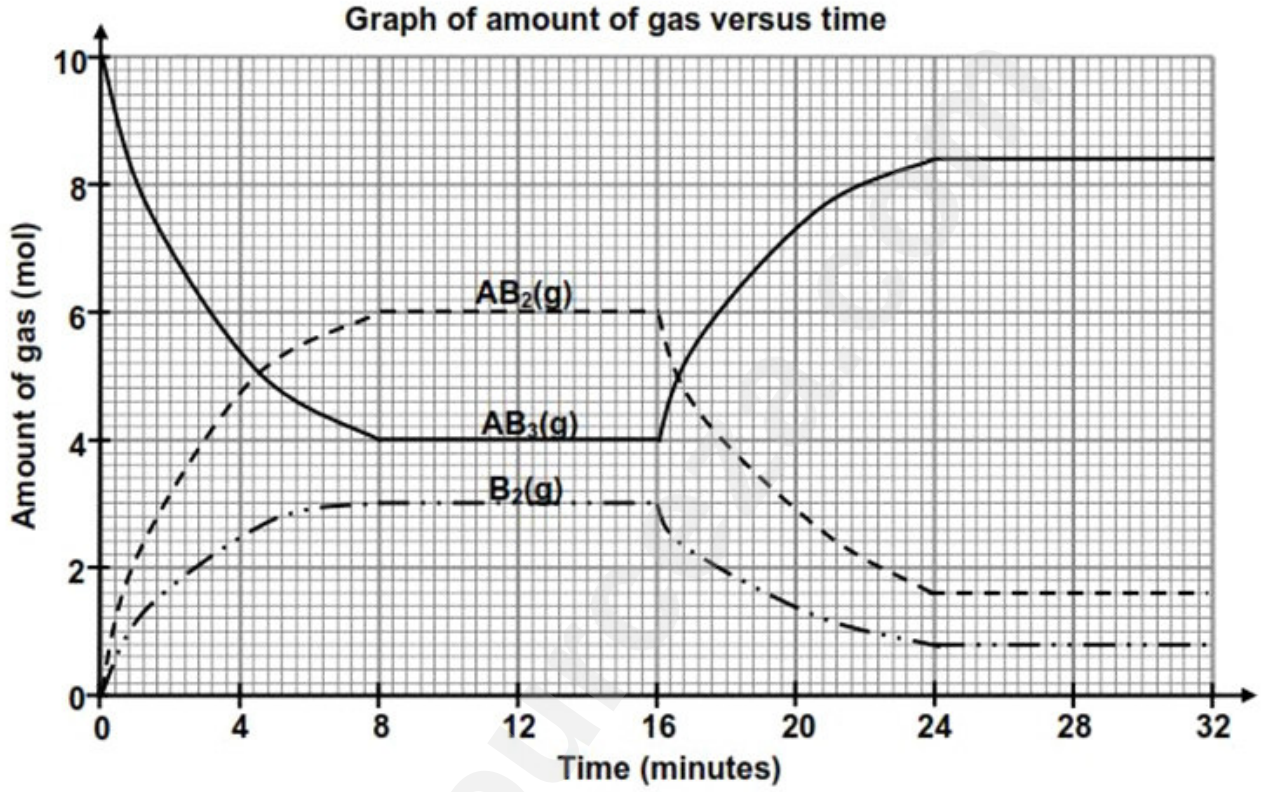
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QUESTION 2 (NOV 2009/P2/Q8)

The following equation represents a hypothetical reaction that reaches equilibrium in a 2dm^3 closed container at 500 °C after 8 minutes.

$$AB_3\,(g) \rightleftharpoons 2AB_2(g) + B_2(g)$$

The course of the reaction is illustrated in the graph below.



8.1 Use the information in the graph to calculate the value of the equilibrium constant at 500 °C. (7)

8.2 The temperature is increased to 600 °C at the 16th minute.

8.2.1 Is the forward reaction endothermic or exothermic?
Use Le Chatelier's principle to explain your answer. (3)

8.2.2 How does the equilibrium constant between t = 8 minutes and t = 16 minutes compare to that between t = 24 minutes and t = 32 minutes? Write down only GREATER THAN, SMALLER THAN or EQUAL TO. (1)

8.3 The volume of the container is decreased from 2 dm^3 to 1 dm^3 after 32 minutes, while keeping the temperature constant at 600 °C. How will each of the following be affected?

8.3.1 The value of Kc (1)

8.3.2 The number of moles of AB_3 (g). Use Le Chatelier's principle to explain your answer. (4)

[16]

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SOLUTION 2

2.1

$[AB_2] = \frac{n}{V} = \frac{6}{2} = 3moldm^{-3}$

$[AB_3] = \frac{n}{V} = \frac{4}{2} = 2moldm^{-3}$

$[B_2] = \frac{n}{V} = \frac{3}{2} = 1.5moldm^{-3}$

$$K_c = \frac{[AB_2]^2[B_2]}{[AB_3]^2}$$

$$= \frac{(3)^2(1.5)}{(2)^2} = 3.38$$

2.2.1 Exothermic

An increase in temperature favours the reverse reaction (according to Le Chatelier), an increase in temperature favours the reaction which decreases the temperature/endothermic reaction.

2.2.2 Smaller than

2.3.1 Remains the same

2.3.2 Increases

-When the volume is decreased at constant temperature, the pressure on the system increases.

Stress on the system is relieved by decreasing pressure, the reverse reaction (decrease in number of moles) is favoured.

QUESTION 3 (FEB 2010/P2/Q8)

Combustion in air at high temperatures produces oxides of nitrogen of which nitrogen dioxide (NO_2 (g)), is the most common. Natural sources of nitrogen dioxide include lightning and the activity of some soil bacteria. These natural sources are small compared to emissions caused by human activity.

NO_2 can irritate the lungs and cause respiratory infection. When No_2 (g) dissolves in rainwater in air it forms nitric acid which contributes to acid rain.

3.1 State TWO human activities that contribute to high nitrogen dioxide levels in the atmosphere. (2)

3.2 Write a balanced equation to show how nitric acid forms from nitrogen dioxide in air. (3)

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3.3 High levels of nitrogen dioxide in the atmosphere can result in damage to crops and eventually food shortages. Briefly state how high levels of nitrogen dioxide can damage crops. (1)

3.4 Nitric acid can cause corrosion of copper cables whilst hydrochloric acid does no harm to copper cables. Refer to the relative strengths of the oxidising agents involved to explain this phenomenon. (3)

3.5 2 mol of NO_2 (g) and an unknown amount of N_2O_4 (g) are sealed in a 2 dm3 container, that is fitted with a plunger, at a certain temperature. The following reaction takes place:

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

At equilibrium it is found that the NO_2 concentration is 0,4 mol·dm-3. The equilibrium constant at this temperature is 2.

3.5.1 Calculate the initial amount (in mol) of N_2O_4 (g) that was sealed in the container. (9)

The plunger is now pushed into the container causing the pressure of the enclosed gas to increase by decreasing the volume.

3.5.2 How will this change influence the amount of nitrogen dioxide at equilibrium? Only write down INCREASES, DECREASES or REMAINS THE SAME. (1)

3.5.3 Use Le Chatelier's principle to explain your answer to QUESTION 8.5.2. (2)
[21]

SOLUTION 3

3.1 Any two :
- Burning of fuel when cars are used - exhaust gases contains oxides of nitrogen.
- Burning of coal (generation of electricity)/nitrogen containing compounds/organic waste.
- Factories and other industrial plants that emits nitrogen oxides into the atmosphere as waste.

3.2 $4NO_2(g) + O_2(g) + 2H_2O(l) \rightarrow 4HNO_3(aq)$ bal
OR
$3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(aq) + NO(g)$

3.3 NO_2 (g) dissolves in rainwater to form acid rain that burns/destroys crops.

3.4 NO_3^- (aq) is a strong oxidising agent and oxidise Cu (to Cu^{2+}).
H^++(aq) is not a strong enough oxidising agent and cannot oxidise Cu to Cu^{2+}.

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3.5.1

	$2NO_2$	N_2O_4
Initial number of mole (mol)	2	x
Number of moles used/formed (mol)	-1,2	+0,6
Number of moles at equilibrium (mol)	0,8	x + 0,6
Equilibrium concentration ($mol \cdot dm^{-3}$)	0.4	$\frac{x + 0,6}{2}$

$$Kc = \frac{[N2O4\,]}{[NO\,2\,]^2}$$

$$2 = \frac{\frac{X + 0.6}{2}}{(0.4)^2}$$

Therefore x = 0.04mol

3.5.2 Decreases

3.5.3 When the pressure is increased the system will try to decrease the pressure. The forward reaction (2 mol to 1 mol) is favoured

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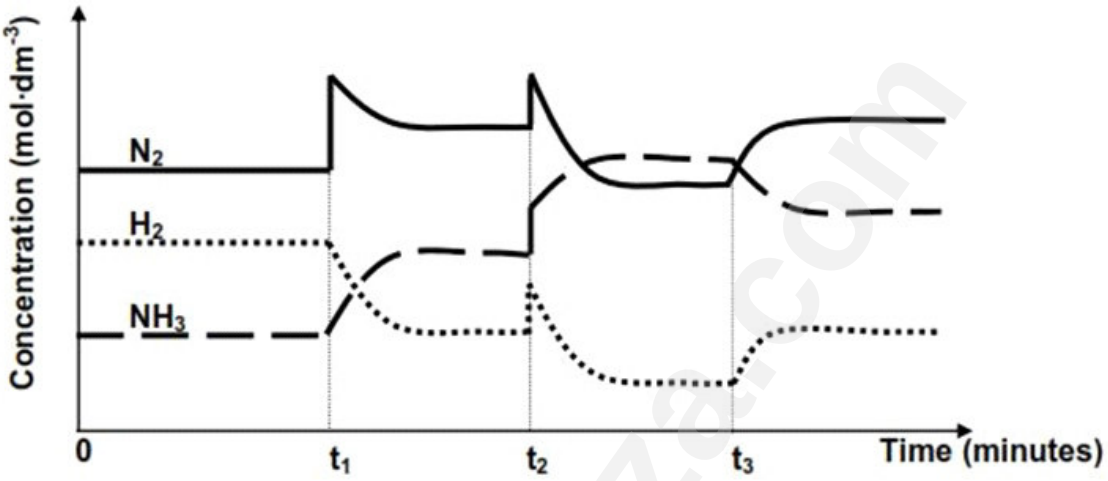
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QUESTION 4 (FEB 2009/P1/Q7.3-7.6)

4.1 Write down a balanced equation for the preparation of ammonium nitrate from nitric acid. (3)

A fertiliser company produces ammonia on a large scale at a temperature of 450 °C. The balanced equation below represents the reaction that takes place in a sealed container.



To meet an increased demand for fertiliser, the management of the company instructs their engineer to make the necessary adjustments to increase the yield of ammonia.

In a trial run on a small scale in the laboratory, the engineer makes adjustments to the TEMPERATURE, PRESSURE and CONCENTRATION of the equilibrium mixture. The graphs below represent the results obtained.

4.2 Identify the changes made to the equilibrium mixture at each of the following times:

4.2.1 t_1 (2)

4.2.2 t_2 (2)

4.2.3 t_3 (2)

4.3 At which of the above time(s) did the change made to the reaction mixture lead to a higher yield of ammonia? Write down only **t_1** and/or **t_2** and/or **t_3**. (2)

4.4 The engineer now injects 5 mol N_2 and 5 mol H_2 into a 5 dm^3 sealed empty container. Equilibrium is reached at 450 °C. Upon analysis of the equilibrium mixture, he finds that the mass of NH_3 is 20,4 g.

Calculate the value of the equilibrium constant (K_c) at 450 °C . (9)

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SOLUTION 4

4.1 $HNO_3 + NH_3 \rightarrow NH_4NO_3$ Bal

4.2

4.2.1 The concentration of nitrogen is increased

4.2.2 The pressure on the system is increased

4.2.3 The temperature is increased

4.3 t_1 and t_2

4.4 $n(NH_3) = \frac{m}{M} = \frac{20.4}{17} = 1.2mol$

	N_2	H_2	NH_3
Molar ratio	1	3	2
Initial quantity (mol)	5	5	0
Change (mol)	0,6	1,8	1,2
Quantity at equilibrium (mol)	4,4 ✓	3,2 ✓	1,2 ✓✓
Concentration ($mol \cdot dm^{-3}$)	0,88	0,64	0,24

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{(0.24)^2}{(0.88)(0.64)^3} = 0.25$$

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TASK 10

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QUESTION 1 (NOV 2011/P2/Q7)

1.1 The industrial preparation of hydrogen gas is represented by the equation below.

$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H > 0$

The reaction reaches equilibrium at 1 000 °C in a closed container.

1.1.1 State Le Chatelier's principle. (3)
1.1.2 How will an increase in pressure at 1 000 °C (by decreasing the volume) affect the yield of hydrogen gas? Write down only INCREASES, DECREASES OR NO EFFECT. Explain the answer. (3)
1.1.3 Give TWO reasons why high temperatures are used for this reaction. (2)

1.2 Study the reversible reaction represented by the balanced equation below.

$$H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g)$$

Initially x moles of $H_2(g)$ is mixed with 0,3 moles of $CO_2(g)$ in a sealed 10 dm3 container. When equilibrium is reached at a certain temperature, it is found that 0,2 moles of $H_2O(g)$ is present.

The equilibrium constant (Kc) for the reaction at this temperature is 4.

1.2.1 Calculate the initial number of moles of $H_2(g)$, x, that was in the container. (8)
1.2.2 The reaction is now carried out at a much higher temperature. It is found that Kc decreases at this higher temperature.

Is this reaction exothermic or endothermic? Explain the answer. (3)
[19]

QUESTION 2 (NOV 2010/P2/Q7.4-7.5)

The reaction below represents the catalysed step in the contact process:

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H < 0$

2.1 The reaction takes place in a closed container and reaches equilibrium at 427 °C. How will a HIGHER temperature affect each of the following?Write down only INCREASES, DECREASES or REMAINS THE SAME.

2.1.1 The rate of production of $SO_3(g)$ (2)
2.1.2 The yield of $SO_3(g)$ (2)

2.2 The reaction is investigated on a small scale in the laboratory. Initially 4 mol of $SO_2(g)$ and an unknown mass, x, of $O_2(g)$ are sealed in a 2 dm^3 flask and allowed to reach equilibrium at a certain temperature.
At equilibrium it is found that the concentration of $SO_3(g)$ present in the flask is 1,5 $mol \cdot dm^{-3}$. Calculate the mass of $O_2(g)$ initially present in the flask if the equilibrium constant (Kc) at this temperature is 4,5. [9]

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TOPIC 8 ACIDS AND BASES

ACID - BASE REACTIONS

Properties of acids
- sour to taste
- change litmus paper from blue to red
- conduct electricity in aqueous solution

Naturally occurring acids
- citric acid (lemons and citrus fruits)
- vinegar
- lactic acid (milk)
- ascorbic acid/ Vitamin C (fruits and vegetables)
- tartaric acid (grapes)

Properties of bases
- bitter to taste
- change red litmus paper to blue
- feels soapy or slippery when touched
- conduct electricity in aqueous solution

Naturally occurring bases
- methylamine (rotting fish)
- sodium hydroxide
- limestone
- lime
- sodium hydrogen carbonate
- calcium oxide

Arrhenius Theory of acids and bases
- **Acid** - a substance which produces H^+ ions in an aqueous solution
- **Base** - a substance which produces OH^- ions in aqueous solution

Bronstead and Lowry Theory of acids and bases
- **Acid** - a substance which donates a proton
- **Base** - a substance which accepts a prooton

Conjugate acid - base pairs
- each time a Bronstead acid donates a H^+-ion it forms a conjugate base
- each time a Bronstead base accepts a H^+-ion it forms a conjugate acid
- suppose we have a hypothetical acid (HA) reacting with NaOH as shown below:

$$\underset{\text{acid}}{HA} + \underset{\text{base}}{NaOH} \rightarrow \underset{\text{base}}{NaA} + \underset{\text{acid}}{H_2O}$$

An acid donate a proton forming a conjugate base according to the following half reaction

$$\underset{\text{acid}}{HA} + Na^+ \rightarrow \underset{\text{base}}{NaA} + H^+$$

A base accepts a proton forming a conjugate base according to the following half reaction

$$\underset{\text{base}}{NaOH} + H^+ \rightarrow \underset{\text{acid}}{H_2O} + Na^+$$

Examples of acid-base conjugate pairs

(1) HCl (acid) and Cl^- (base) [acid - base conjugate pair]

$$\underset{\text{acid}}{HCl} + NH_3 \rightarrow NH_4 + \underset{\text{base}}{Cl^-}$$

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(2) H_3O^+ (acid) and H_2O (base) [acid - base pair]

$$HCl + \underset{\text{Base}}{H_2O} \rightleftharpoons \underset{\text{acid}}{H_3O^+} + Cl^-$$

Reactions of acids and bases

Actions of dilute acids on:

(a) Metals

When dilute acids reacts with metals, hydrogen gas is revolved along with the formation of a salt according to the word equation below:

dilute acid + metal → salt + hydrogen

e.g

$$2HCl(l) + Ca(s) \rightarrow CaCl_2(s) + H_2(g)$$

(b) Metal carbonates

- Metal carbonates are bases
- They are used in antacid tablets
- One compound in antacid tablets is magnesium carbonate, which helps to neutralize excess acid in the stomach
- The reaction between dilute acid and a metal carbonate is given by the following word equation:

dilute acid + metal carbonate → salt + water + carbon dioxide

e.g

$$2HNO_3(l) + Na_2CO_3(s) \rightarrow 2NaNO_3(s) + H_2O(l) + CO_2(g)$$

(c) Metal hydrogen carbonates

- Metal hydrogen carbonates are bases
- They are used to neutralize acids e.g baking soda ($NaHCO_3$) is used to neutralize acid in bee stings
- When dilute acids reacts with metal hydrogen carbonates, they will form a salt, water and carbon dioxide according to the following word equation:

dilute acid + metal carbonates → salt + water + carbon dioxide

e.g

$$HCl + NaHCO_3 \rightarrow NaCl + H_2O + CO_2$$

(d) Metal oxides

- Metal oxides are bases
- They are used to neutralize acids e.g CaO (lime) is used by farmers to neutralize acidic soils
- When a metal oxide reacts with a dilute acid, a salt and water are formed

dilute acid + metal oxide → salt + water

e.g

$$CaO + HCl \rightarrow CaCl_2 + H_2O$$

(e) Metal hydroxides

- Metal hydroxides reacts with dilute acids to form a salt and water

Metal hydroxide + dilute acid → salt + water

Hazardous nature of acids and bases

- acids and bases are corrosive and are able to destroy body tissue

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✎When water is poured into an acid it may cause violent spitting of hot acid all over you. It is safe to add acid to water, rather than adding water to acid
✎Acid and bases can damage the environment. Disposal of batteries which contain acid should be done after neutralization
✎Acid and bases may cause fire hazards

Action of dilute bases on aqueous metal ions

✎When dilute acids are mixed with aqueous metal ions, metal hydroxide precipitates will be formed
✎Suppose a solution of any soluble transition metal compound is mixed with dilute base in solution, there will be a **displacement reaction**
✎**A displacement reaction** is when one metal displaces another metal from its compound
✎Cations in bases are more reactive than transition elements, and for this reason they will be able to displace transition elements from their compounds to form insoluble metal hydroxide precipitates
✎A **precipitate** is a solid that forms out of a solution

Example 1

Suppose (a) dilute sodium hydroxide (NaOH) react with Cu^{2+}, Fe^{3+} in aqueous solution and
(b) dilute calcium hydroxide ($Ca(OH)_2$) react with Zn^{2+} in aqueous solution

Which metal hydroxide precipitates will be formed in each case?

Solution 1

precipitate

(a) $2NaOH(aq) + Cu^{2+}(aq) \rightarrow Cu(OH)_2(s) + 2Na^+(aq)$
$3NaOH(aq) + Fe^{3+}(aq) \rightarrow Fe(OH)_3(s) + 3Na^+(aq)$

(b) $Ca(OH)_2(aq) + Zn^{2+}(aq) \rightarrow Zn(OH)_2(s) + Ca^{2+}(aq)$

The temperature change in a neutralization process

✎Neutralization is an exothermic reaction
✎Therefore the reaction releases heat energy to the surroundings
✎Change in concentration of acid is directly proportional to temperature change
✎So if we increase concentration of the acid, temperature will also increases in a direct proportion until the point of neutralization (the highest temperature), and after this point temperature will decrease

What is pH?

✎Is a measure of hydrogen ion concentration of a solution
✎Solutions with a high concentration of H^+ ions have a low pH, and solutions with a low concentration of H^+ ions have a high pH
✎Mathematically pH is expressed as:

$$pH = -\log_{10}[H^+]$$

Where $[H^+]$ - concentration of H^+ ions

Approximate pH of salts in salt hydrolysis

✎**Salt hydrolysis -** is a reaction of a cation or an anion or both with water which splits the water molecule into its separate ions (H^+ and OH^-)
✎Salt hydrolysis affect pH of the solution
✎We will split salt hydrolysis into two namely (a) cation hydrolysis and (b) anion hydrolysis

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Cation hydrolysis

✎When a cation undergo hydrolysis it split the water molecule by bonding to the OH^- ion in water, and hence the H^+ ion will be liberated resulting in an acidic solution

✎Therefore in general, cations undergo hydrolysis to form acidic solution with pH < 7

Examples:

(a) $Al^{3+}(aq) + 2H_2O(l) \rightleftharpoons H^+(aq) + Al(OH)_3(aq)$

(b) $Fe^{3+}(aq) + 2H_2O(l) \rightleftharpoons H^+(aq) + Fe(OH)_3(aq)$

(c) $Nh_4^+(aq) + H_2O(l) \rightleftharpoons H^+(aq) + NH_4OH(aq)$

Anion hydrolysis

✎When an anion undergoes hydrolysis it split the water molecule by bonding to the H^+ ion in water, and hence the OH^- ion will be liberated resulting in an basic solution

✎Therefore in general, anions undergo hydrolysis to form basic solutions with pH > 7

✎Not all anions hydrolyze in water

✎Anion hydrolysis reaction do not occur if the anion is a strong acid (since strong acids dissociates completely in water) e.g Cl^-, Br^-, I^-, NO_3^-, ClO_4^- etc cannot undergo significant anion hydrolysis

✎Anions which hydrolyze are conjugate bases of weak acids

✎Conjugate bases of weak acids are weak bases and will raise pH of the solution

Examples

(a) $CH_3COO^-(aq) + H_2O(l) \rightleftharpoons CH_3COOH(aq) + OH^-(aq)$

(b) $F^-(aq) + H_2O(l) \rightleftharpoons HF(aq) + OH^-(aq)$

(c) $CN^-(aq) + H_2O(l) \rightleftharpoons HCN(aq) + OH^-(aq)$

Neutralization reactions

✎A neutralization reaction is a reaction between an acid and a base to produce a salt and water

Examples of such reactions

(a) HCl (hydrochloric acid) + $NaHCO_3$ (sodium hydrogen carbonate) → $NaCl$ (sodium chloride) + H_2CO_3 (carbonic acid)

(b) H_2SO_4 (sulphuric acid) + $2NH_4OH$ (ammonium hydroxide) → $(NH_4)_2SO_4$ (ammonium sulphate) + $2H_2O$ (water)

(c) HCl (hydrochloric acid) + KOH (potassium hydroxide) → KCl (potassium chloride) + H_2O (water)

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How do indicators work?

- pH of the solution determines the change in colour of the indicator
- pH ranges for different indicators are used to determine colour changes of acid-base solutions
- In a given pH range an acid is on the left whilst a base is on the right, low pH numbers are on the left while high pH numbers are on the right

pH ranges of indicators

- The following are pH ranges of indicators:

(a) Methyl orange

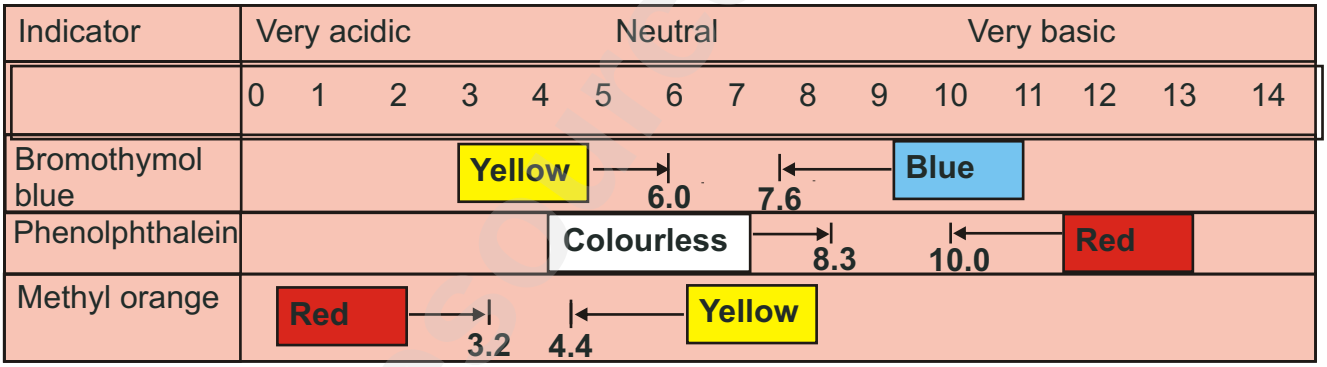
Red pH 3.2 ↔ pH 4.4 Yellow

(b) Bromothymol blue

Yellow pH 6.0 ↔ pH 7.6 Blue

(c) Phenolphthalein

Colourless pH 8.3 ↔ pH 10 Red



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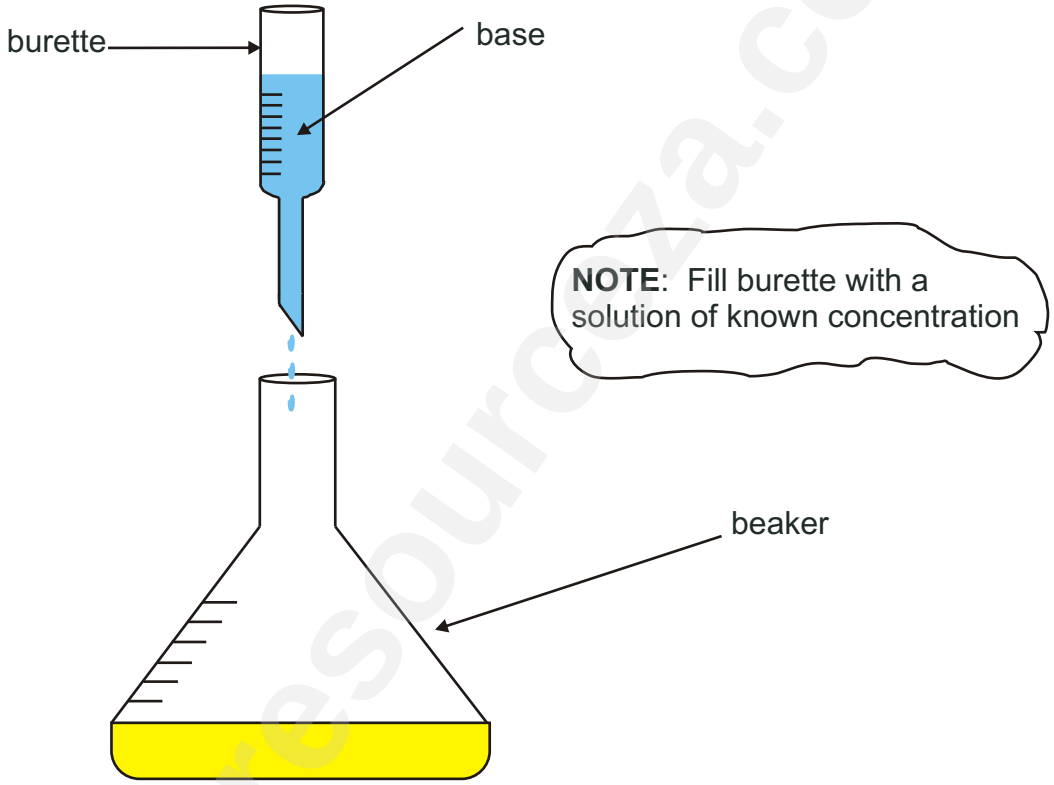
ACID - BASE TITRATIONS

Acid - base titration is a technique which uses neutralization reaction to determine an unknown property of one solution given a known property of another solution
Suppose we want to determine unknown concentration of a base, then we will gradually add a base into an acid until they neutralize each other at end-point

To conduct a titration experiment

Apparatus

(1) A burette
If we want to determine unknown concentration of an acid, then fill burette with a base
If we want to determine unknown concentration of a base, then fill burette with an acid



(2) Beaker of flask
Fill beaker or flask with a solution of **known volume** and **unknown concentration**

(3) Indicator
Put several drops of chosen indicator into a beaker where there is a solution of unknown concentration

Procedure
(a) Add several drops of indicator into the beaker
(b) Gently release the basic solution from the burette into the beaker containing an acidic solution and indicator
(c) Keep on dripping the base until you see a colour change at end - point

End - point
The point when the amount of base added completely react with the amount of acid
In other words at end-point the number of moles of H^+ ions in an acid equals to the number of moles of OH^- in a base
Therefore at endpoint concentration of H_3O^+ ions equals concentration of OH^- ions

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At end-point:

$$\frac{C_1V_1}{C_2V_2} = \left(\frac{n_1}{n_2}\right) \leftarrow \text{molar ratio}$$

$$n_2 C_1 V_1 = C_2 V_2 n_1 \text{ (molar ratio is } n_1:n_2)$$

Where C_1 - concentration of solution 1
V_1 - volume of solution 1
C_2 - concentration of solution 2
V_2 - volume of solution 2
n_2 - moles of solution 2
n_1 - moles of solution 1

If molar ratio is 1:1 then $C_1V_1 = C_2V_2$

DEFINITION OF SOME TERMS

(1) Standard solution
A solution of known concentration

(2) Molar Concentration
Number of moles dissolved in one litre (1 dm^3)

Titration calculations

Example 2

A titration was performed between HCl and NaOH. 50 ml of HCl required 25ml of 1.00M NaOH to reach end point. Calculate the concentration of HCl given their reaction equation below:

$$HCl + NaOH \rightarrow NaCl + H_2O$$

Solution 2

Given Data
n_{NaOH} = 1mol
C_{NaOH} = 1moldm^{-3}
V_{NaOH} = 0.025 dm^3 (25ml/1000)

n_{HCl} = 1mol
C_{HCl} = ?
V_{HCl} = 0.050 dm^3 (50ml/1000)

According to the balanced equation in the reaction between HCl and NaOH molar ratio between HCl and NaOH is 1:1 , at end point

Using the end-point equation:

$$n_2 C_1 V_1 = C_2 V_2 n_1$$

$$n_{NaOH}\, C_{HCl}\, V_{HCl} = n_{HCl}\, C_{NaOH}\, V_{NaOH}$$

$$(1)\ (C_{HCl})\ (0.050) = (1)\ (1)\ (0.025)$$

$$(C_{HCl}) = \frac{0.025}{0.050}$$

$$= 0.5 \text{ moldm}^{-3}$$

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Example 3

If 11.6 ml of 3.0 M sulphuric acid are required to neutralize the sodium hydroxide in 25ml of NaOH solution. What is the molarity of the NaOH solution.

Solution 3

Write a balanced equation for the reaction:

$H_2SO4\,(aq) + 2NaOH(aq) \rightarrow 2H_2O\,(l) + Na_2SO_4(aq)$

Data Given

$n_{NaOH} = 2mol$
$C_{NaOH} = ?$
$V_{NaOH} = 0.025\ dm^3$ (25ml/1000)

$n_{H2SO4} = 1mol$
$C_{H2SO4} = 3\ moldm^{-3}$
$V_{H2SO4} = 0.0116\ dm^3$ (11.6ml/1000)

Write the equation:

$$n_{NaOH}\, C_{H2SO4}\, V_{H2SO4} = n_{H2SO4}\, C_{NaOH}\, V_{NaOH}$$

Substitute given values into the equation:

$$(2)\ (3)\ (0.0116) = (1)\ (C_{NaOH})\ (0.025)$$

Simplify:

$$C_{NaOH} = \frac{0.0348}{0.0125}$$

$$= 2.8\ M$$

COMMON STRONG AND WEAK ACIDS AND BASES

The following is a list of common strong and weak acids and bases:

COMMON STRONG AND WEAK ACIDS

Strong acids

1. HCl (hydrochloric acid)
2. HNO_3 (nitric acid)
3. H_2SO_4 (sulphuric acid)
4. HBr (hydrobromic acid)
5. HI (hydroiodic acid)
6. $HClO_4$ (perchloric acid)

Weak acids

1. CH_3COOH (acetic acid)
2. HCOOH (formic acid)
3. HF (hydrofluoric acid)
4. HCN (hydrocyanic acid)
5. HNO_2 (nitrous acid)
6. HSO_4^- (hydrogen sulphate ion)

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COMMON STRONG AND WEAK BASES

Strong bases	Weak bases
1. NaOH (sodium hydroxide)	1. NH_3 (ammonia)
2. KOH (potassium hydroxide)	2. CH_3NH_2 (methylamine)
3. $Ba(OH)_2$ (barium hydroxide)	3. C_5H_5N (pyridine)
	4. NH_4OH (ammonium hydroxide)

pH scale

- pH scale measures how acidic or basic a substance is
- It is based on whether a substance decreases or increases the concentration of H^+ ions in a solution
- Acids tend to increase H^+ ion concentration in a solution (H^+ ion donor)
- Bases tend to decrease H^+ ion concentration in a solution (H^+ ion acceptor)
- Acids have a pH less than 7, bases have a pH greater than 7 and neutral compounds have a pH equal to 7
- pH values are measured using an indicator
- To calculate pH, the following formula is used:

$$pH = -\log_{10}[H^+]$$

Calculation of pH values of strong acids and strong bases

Calculating pH of strong acids

- Strong acids dissociate completely in water
- e.g HBr dissociate completely in water to form H^+ and Br^-
- For 1mole of HBr, there will be 1 mole of H^+

Example 4
Calculate the pH of a 0.025M solution of hydrochloric acid

Solution 4

- Dissociation equation for HCl is given as:

$HCl \rightarrow H^+ + Cl^-$

- From the ionization equation above 1 mole of HCl forms 1 mole of H^+
- It also follows that concentration of HCl which dissociated is equal to concentration of H^+ formed

Therefore:

0.025 M of HCl forms 0.025M of H^+

Using the pH equation

.$pH = -\log_{10}[H^+]$

$= -\log_{10}(0.025)$
$= -(-1.602)$
$= 1.602$

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Example 5

Calculate the pH of a 0.032 M solution of sulphuric acid

Solution 5

✎Dissociation equation for H_2SO_4 is given as:

$H_2SO_4 = 2H^+ + SO_4^{2-}$

✎From the ionization equation above 1 mole of H_2SO_4 forms 2 moles of H^+
✎It also follows that concentration of H_2SO_4 which dissociated is twice the concentration of H^+ formed

Therefore:

0.032 M of H_2SO_4 forms 2x0.032M of H^+

$[H^+]$ formed = 2x0.032M = 0.064M

Using the pH equation

$pH = -\log_{10}[H^+]$

$= -\log(0.064)$
$= -(-1.602)$
$= -(-1.193)$
$= 1.193$

Calculating pH of strong bases

✎When calculating pH of bases, we need to first determine the **pOH** if concentration of OH^- ions is known
✎The formula to calculate pOH is as follows:

$$pOH = -\log_{10}[OH^-]$$

✎pOH is related to pH using the following equation:

$$pH = 14 - pOH$$

✎A strong base dissociates completely in water to form OH^- ions and metal ions
✎If the metal ion and OH^- ion in the strong base are in the ratio 1:1, then for every 1 mole of the base there will be 1 mole of OH^- ions
✎Again a 1M strong base in aqueous solution will produce 1M of the OH^- ions

Example 6

Calculate pH of a 0.05M solution of NaOH

Solution 6

✎Write the dissociation equation for NaOH in water:

$NaOH \rightarrow Na^+ + OH^-$

✎For every 1 mole of NaOH which dissociates there will be 1 mole of OH^- formed
✎For every 0.05M of NaOH which dissociates there will be 0.05M of OH^- formed

Therefore:
$[OH^-] = 0.05\ moldm^{-3}$

Having $[OH^-]$ ions we can calculate pOH:

$pOH = -\log_{10}[OH^-]$
$= -\log_{10}[0.05]$
$= -(-1.3)$
$= 1.3$

To find pH we use the following relationship:
$pH = 14 - pOH$
$= 14 - 1.3$
$= 12.7$

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Example 7

Calculate the pH of a solution containing 1.2345×10^{-4} M $Ca(OH)_2$

Solution 7

$Ca(OH)_2 \rightarrow Ca^{2+} + 2OH^-$

$Ca(OH)_2 \rightarrow Ca^{2+} + 2OH^-$

$[Ca(OH)_2] : [OH^-]$

1 : 2

Therefore:

$[OH^-] = 2 \times 1.2345 \times 10^{-4}$ M $= 2.468 \times 10^{-4}$ M

$pOH = -\log(2.468 \times 10^{-4})$

$= 3.61$

But $pH = 14 - pOH$

$= 14 - 3.61$

$= 10.39$

AUTO-IONIZATION OF WATER (K_w)

- K_w is an equilibrium constant for the dissociation of water at room temperature (25 ^{0}C) and pressure (1 atm)
- Water molecules behaves both as an acid and a base
- Suppose we have two water molecules, one is acting as an acid and another one is acting as a base
- The acidic water molecule donate a H^+ ion to the basic water molecule as shown below:

$$H_2O + H_2O \rightarrow H_3O^+ + OH^-$$

- Since this happens very fast, the H_3O^+ ions and OH^- ions combines to form water molecules again
- Eventually the reaction becomes a reversible one until it reaches equilibrium as shown below:

$$2H_2O \rightleftharpoons H_3O^+ + OH^-$$

- Now we can write our equilibrium constant (K_w)

$$K_w = \frac{[H_3O^+][OH^-]}{[H_2O]}$$

- Since only few water molecules dissociate to form H_3O^+ ions and OH^- ions, the concentration of water is said to be constant
- But however [constant] = 1
- Therefore:

$$K_w = [H_3O^+][OH^-]$$

- But normally $[H_3O^+]$ is considered to be $[H^+]$ since it is acidic
- Therefore:

$$K_w = [H^+][OH^-]$$

- Concentration of H_3O^+ ions ($[H^+]$) in pure water at room temperature = 1.0×10^{-7} moldm^{-3}
- At equilibrium $[H^+] = [OH^-]$
- Therefore:

$$K_w = (1.0 \times 10^{-7})(1.0 \times 10^{-7}) = 1.0 \times 10^{-14} \text{ mol}^2\text{dm}^{-6}$$

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To find pK_w of water at room temperature:

$$pK_w = -\log_{10}[k_w]$$
$$= -\log_{10}(1 \times 10^{-14})$$
$$= 14$$

To find pH of water at room temperature:

Since $[H^+] = [OH^-] = x$

$K_w = [H^+][OH^-] = x^2 = 1 \times 10^{-14}$

$x = [H^+] = \sqrt{1x10^{-14}}$

$= 1x10^{-7}$

Therefore:

$pH = \log_{10}[H^+]$

$= -\log_{10}(1x10^{-7})$
$= -(-7)$
$= 7$

Example 8

What is the hydroxide ion concentration in a water solution that is $4.0x10^{-5}M$ H_3O^+

Solution 8

$K_w = 1x10^{-14} = [H_3O^+][OH^-]$

$1x10^{-14} = (4x10^{-5})[OH^-]$

$[OH^-] = \frac{1x10^{-14}}{4x10^{-5}} = 2.5x10^{-10}M$

Example 9

What is the pH of 40ml of 0.127 $moldm^{-3}$ NaOH solution if it is required to neutralize 0.187$moldm^{-3}$ CH_3COOH (aq) during a titration experiment. Assume the temperature is 25 ^0C

Solution 9

Given Data
$V_{NaOH} = 40ml$
$C_{NaOH} = 0.127moldm^{-3}$
$C_{acetic\ acid} = 0.187$

At 25^0C we now that $K_w = 1x10^{-14}$
But $K_w = [H_3O^+][OH^-] = 1x10^{-14}$

Since NaOH is a strong base, $[NaOH] = [OH^-]$

$=0.127moldm^{-3}$

$1x10^{-14} = [H_3O^+](0.127)$

$[H_3O^+] = \frac{1x10^{-14}}{0.127} = 7.87 \times 10^{-14}$

$pH = -\log_{10}[H_3O^+] = -\log_{10}(7.87 \times 10^{-14})$

$= -(-13.10) = 13.1$

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Distinguishing strong acids and concentrated acids, concentrated and dilute acids

- A strong acid is an acid which completely dissociates in water into its separate ions
- A concentrated acid is not always a strong acid, it is possible to have either a concentrated weak acid or a concentrated strong acid
- Again a dilute acid is not always a weak acid, it is possible to have either a dilute weak acid or a dilute strong acid
- Strength of an acid depends on the degree of dissociation of the acid molecules in water to form ions
- Strong acid dissociates in water completely whereas weak acids dissociates partially
- Acid concentration is determined by the number of moles of acid in one dm^3 of water
- The greater the number of moles of acid in water, is the more concentrated the acid will be
- The less the number of moles of acid in water, the more diluted the acid will be

Relationship between Ka and Kb values

- The strongest acids have large Ka values and small pKa values
- As acid strength increases, pKa value decreases
- pKa is expressed as:

$$pKa = -\log_{10}[Ka]$$

- The strongest bases have large Kb values and small pKb values
- As base strength increases, pKb decreases
- pKb is expressed as:

$$pKb = -\log_{10}[Kb]$$

- The conjugate base of a string acid has a very small Kb value. The strength of an acid's conjugate base decreases with increasing strength of the acid
- The conjugate acid of a strong base has a very small Ka value. The strength of a base's conjugate acid decreases with increasing strength (and Kb) of the base
- The relationship between Ka and Kb is represented by the following expression:

$$K_a \times K_b = [H_3O^+][OH^-] = K_w = 1.0 \times 10^{-14} \text{ at } 25\ ^0C$$

In general:

Stronger acids have weak conjugate bases, and stronger bases have weak conjugate acids

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Comparison of weak and strong acids based on pH, conductivity and reaction rate

Property	Strong acids	Weak acids
pH	Relatively lower pH (higher H+ ions concentration in solution)	Relatively high pH (less H+ ions concentration in solution)
Conductivity	High conductivity (more H+ ions to carry charge)	low conductivity (fewer H+ ions to carry charge)
Reaction rate	high rate of reaction with active metals and carbonates (more H+ ions in solutions, more effective collisions between H+ and reactant particles)	lower reaction rate with active metals and carbonates (fewer H+ ions in solutions, fewer effective collisions between H+ and reactant particles)

Comparison of weak and strong bases based on pH, conductivity and reaction rate

Property	Strong acids	Weak acids
pH	Relatively high pH (lower H+ ions concentration in solution)	Relatively lower pH (higher H+ ions concentration in solution)
Conductivity	High conductivity (more OH— ions to carry charge)	low conductivity (fewer OH— ions to carry charge)
Reaction rate	high rate of reaction with active metals and carbonates (more OH— ions in solutions, more effective collisions between OH— and reactant particles)	lower reaction rate with active metals and carbonates (fewer OH— ions in solutions, fewer effective collisions between OH— and reactant particles)

N:B

pH of strong acids - since weak acids ionize completely in water,[H^+] ions is equal to [Strong acid]
pH of weak acids - since weak acids do not ionize completely in water, [H^+] ions is not equal to [Weak acid]

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APPLICATION OF ACIDS AND BASES IN THE CHLOR-ALKALI INDUSTRY

- Chlor-alkali industry involves electrolysis of brine
- Brine is a solution of sodium chloride (NaCl) and water (H_2O)
- Products of electrolysis depends on the method used

Products separated during electrolysis

- When brine is electrolyzed, and products are separated , chlorine (Cl_2), sodium hydroxide (NaOH) and hydrogen (H_2) are formed
- Chlorine is obtained at the anode while hydrogen is obtained at the cathode
- The following are reactions involved during electrolysis of brine:

$$Cl^-(g) \rightarrow Cl_2(g) + 2\bar{e}$$
$$2H_2O + 2\,\bar{e} \rightarrow H_2(g) + OH^-(aq)$$

Overall reaction:

$$2NaCl + H_2O \rightarrow 2NaOH + Cl_2(g) + H_2(g)$$

2NaCl	+	H_2O	→	2NaOH	+ $Cl_2(g)$ +	$H_2(g)$
sodium chloride		water		sodium hydroxide	chlorine	hydrogen

Products not separated during electrolysis

- In the case that the products are mixed during electrolysis **sodium hypochlorite** or **sodium chlorate** will be produced depending on temperature

At lower temperatures (below 60 ^{0}C)

- sodium hypochlorite is produced
- chlorine disproportionates at this temperature to form chloride and hypochlorite ions as shown below:

$$Cl_2 + 2OH^- \rightarrow Cl^- + ClO^- + H_2O$$

- with Na^+ ions in solution NaClO (sodium hypochlorite) is formed as shown below;

$$Cl_2(g) + 2NaOH \rightarrow NaCl + NaClO + H_2O$$

At higher temperatures (above 60 ^{0}C)

- sodium chlorate is formed
- chlorine disproportionates at this temperature to form a chloride and cholrate ions as shown below:

$$3Cl_2(g) + 6\,OH^-(aq) \rightarrow 5Cl^-(aq) + ClO_3^-(aq) + 3\,H_2O\,(l)$$

- with Na^+ ions in solution $NaClO_3$ (sodium hypochlorite) is formed as shown below;

$$3Cl_2(g) + 2NaOH \rightarrow {}_5\,NaCl + NaClO_3 + 3H_2O$$

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USES OF PRODUCTS OF CHLOR-ALKALI PROCESS

Chlor-Alkali Process Product	Uses
Chlorine	disinfectant
	plastics
	hydrochloric acid
	bleaches
	drugs
	pesticides
Sodium hydroxide	soaps
	detergents
	food products processing
	paper manufacturing
	remove pollutants from water
	aluminium refining
	drain cleaner
	artificial fibres
	bleaches
sodium hypochlorite	bleaching
	stain remover
	disinfectants
	deodorizing
	water treatment
sodium chlorate	chlorine dioxide
	pulp bleaching
	herbicides

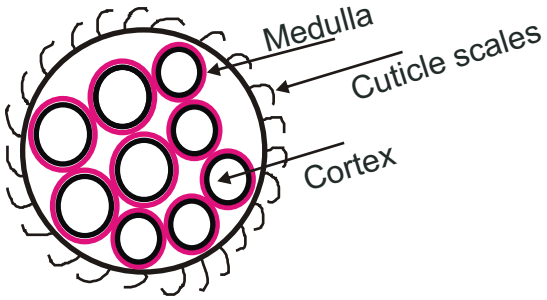
APPLICATION OF ACIDS AND BASES IN CHEMISTRY OF HAIR

WHAT IS pH OF HAIR?

- pH of natural hair is in the average of 4.5 to 5.5
- In other words natural hair is acidic
- Products applied on the hair can change the pH of hair either to make it more acidic or basic
- Examples of these products are shampoos and conditioners

STRUCTURE OF HAIR

- Keratin is the essential component of hair
- It is a protein formed by a combination of amino acids
- It consists of three layers namely Medulla, Cortex and Cuticle scales as shown below:

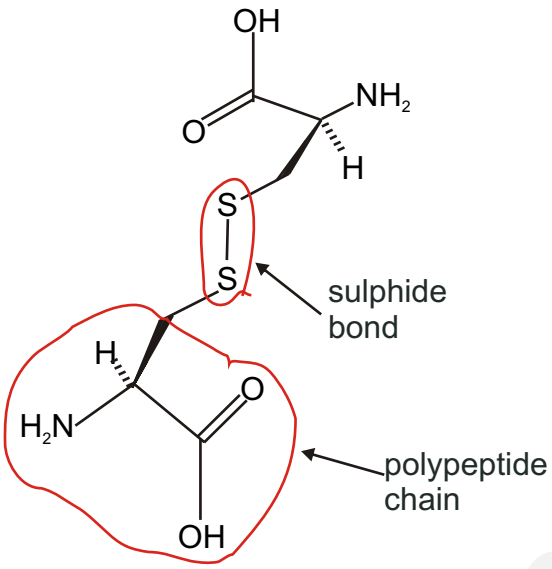


The diagram on the left is a cross-sectional structure of a hair strand

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STRUCTURAL FORMULA FOR KERATIN



- A lower pH will make the hair's cuticle contract and lie flat
- When cuticles lie flat they protect delicate inner hair protein molecules (cortex), and hence the hair becomes much healthy and shiny
- However alkaline products with very high pH lift the cuticles and expose the delicate inner hair protein thereby causing it to harden and break

WHAT IS PERMANENT WAVING LOTION?

- Is a chemical used to break and reform disulphide bonds of the hair
- The hair is washed and wrapped on a perm rod and permanent waving lotion is applied with a strong base
- This solution is involved in a chemical reaction that break disulphide bonds to soften the inner structure of the hair by reduction
- We know from grade 11 that Reduction is the gain of hydrogen or lose of oxygen
- Reduction during permanent waving is caused by gaining of hydrogen
- Special reducing agents are used which donates hydrogen to the sulphur atoms in a disulphide bond
- When disulphide bond is broken polypeptides chains will be separated
- To combine the separated polypeptide chains, a reducing agent used must be **neutralized**
- The common neutralizer used is hydrogen peroxide (H_2O_2)
- During neutralization Sulphur atoms loses hydrogen atoms through oxidation reaction
- An overal neutralization reaction between H_2O_2 and a reducing agent is given by:

$$H_2O_2 + 2H^+ \rightarrow 2H_2O$$

- When H^+ ions are removed from their bonds with Sulphur atoms, it will result in the formation of a new disulphide bonds around the perm rods
- Eventually straight hair will be turned into a curl

WHAT ARE HAIR RELAXERS?

- A hair relaxer is a type of lotion or cream used by people with curly textured hair which makes hair easy to straighten
- Hair relaxers make use of the same chemical reactions as that of the permanent wave lotion, however the only difference is that hair is combed straight and is not wrapped around a perm rod
- Hair straightening compounds have a high pH and hence are strong bases

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Hydrogen Peroxide (H_2O_2) Relaxers

✎ The process used with permanent waving lotion is the same process used with H_2O_2 Relaxers

✎The difference though is that permanent waving lotion creates a curl whilst H_2O_2 Relaxers remove a curl

Hydroxide (OH—) Relaxers

✎These ones are unlike unto hydrogen peroxide relaxers in the sense that they remove only one sulphur atom from the disulphied bond

✎Hydroxide relaxers cause pH of hair to increase, even after hair is washed

✎In order to balance pH a shampoo or any other neutralizing lotion is used to neutralizes excess hydroxide ions to lower the pH of hair and scalp

Negative effects of hair relaxers if misused

✎Hair breakage
✎Hair thinning
✎Lack of hair growth
✎Scalp irritation
✎Scalp damage
✎Hair loss

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TASK 11

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QUESTION 1

1.1 Identify the acid-base conjugate pairs in the following reactions:

1.1.1 $HCO_3^-(aq) + H_3O^+(aq) == CO_2(g) + H_2O(l) + H_2O(l)$

1.1.2 $H_2SO_4(aq) + HNO_3(aq) == HSO_4^-(aq) + NO_2^+(aq) + H_2O(l)$

1.2 Calculate the pH of the following solutions:

1.2.1 $0.001\ moldm^{-3}$ HCl

1.2.2 $0.002\ moldm^{-3}$ KOH

1.3 Calculate the molarity of the following solutions:

1.3.1 HCl , pH = 3.

1.3.2 NaOH, pH = 11.

2.1 Calculate the concentration of H_3O^+ and OH^- in a 0.10M HCl and $Ba(OH)_2$ solutions.

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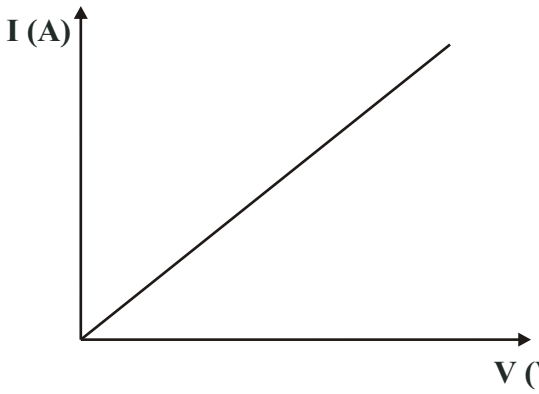
OHM'S LAW

✎The current through a conductor is directly proportional to the potential difference across its ends at constant temperature

✎It is given by :

$$V = IR$$

✎The following graph shows the relationship between voltage and current according to Ohm's Law:

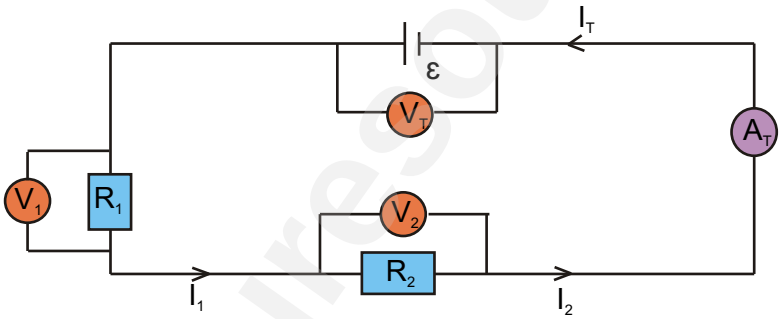


✎Resistance is given by the gradient of the **I - V** graph

SERIES CIRCUITS

✎A circuit is said to be in series if all the resistors are arranged in a chain, so that current has only one path to take.

✎The following is a hypothetical series circuit:



✎In a series circuit:

(i) current across each resistor equals to total current:

$$I_T = I_1 = I_2$$

(ii) resistance of all resistors adds up to the total resistance:

$$R_T = R_1 + R_2$$

(iii) voltage across all resistors adds up to the total voltage:

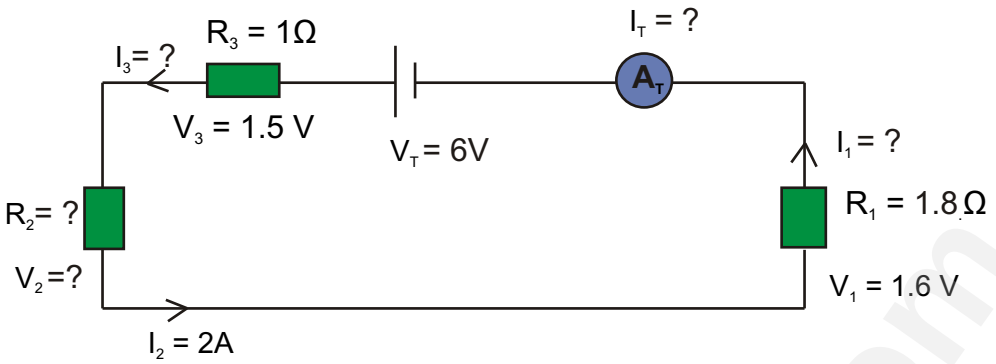
$$V_T = V_1 + V_2$$

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Example 1

Determine missing values in the following circuit diagram:



NB: Assume total resistance (R_T) is 4.5 Ω

Solution 1

Given data
R_T = 4.5 Ω
R_3 = 1 Ω
I_2 = 2A
R_1 = 1.8 Ω
V_T = 6V

$I_T = I_1 = I_2 = I_3$

Therefore **I_T = 2A; I_3 = 2A; I_1 = 2A**

$R_T = R_1 + R_2 + R_3$

Therefore $4.5 = 1.8 + 1 + R_2$

$R_2 = 4.5 - 2.8$
R_2 = 1.7 Ω

$V_T = V_1 + V_2 + V_3$

But according to Ohm's Law:

$V_1 = I_1 \times R_1$
$= 2 \times 1.8$
$= 3.6$ V

$V_3 = I_3 \times R_3$
$= 2 \times 1$
$= 2$ V

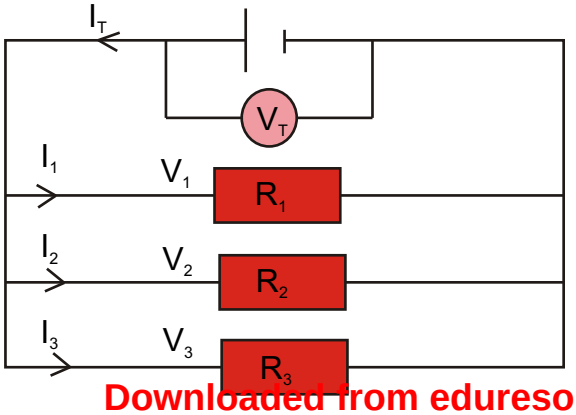
Substituting in the above equation:

$6 = 3.6 + V_2 + 2$

Therefore $V_2 = 6 - 3.6 - 2$
V_2 = 0.4 V

PARALLEL CIRCUITS

The following is a hypothetical parallel circuit:



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In a parallel circuit:

(i) voltage across each resistor equals to the total voltage :

$$V_T = V_1 = V_2 = V_3$$

(ii) The sum of individual current which passes through resistors adds up to the total current:

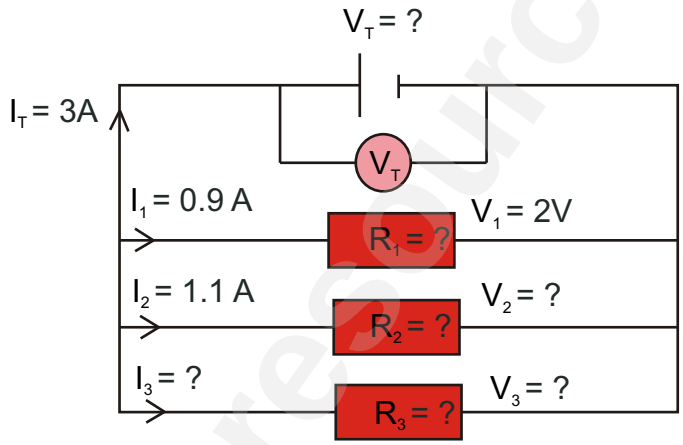
$$I_T = I_1 + I_2 + I_3$$

(iii) Resistance of individual resistors adds up to the total resistance:

$$R_T = R_1 + R_2 + R_3$$

Example 2

Determine the missing values in the parallel circuit below:



Solution 2

Given Data

$V_1 = 2V$
$I_T = 3A$
$I_1 = 0.9A$
$I_2 = 1.1A$

Since voltage of individual resistors in a parallel circuit is equal to total voltage:
$V_T = 2V$
$V_2 = 2V$
$V_3 = 2V$

To find individual current (I_3) we use this equation:
$I_T = I_1 + I_2 + I_3$

Substitution:

$3 = 0.9 + 1.1 + I_3$

$I_3 = 3 - 2$
$= 1A$

To find individual resistances we use Ohm's law:

$V_1 = I_1R_1$ (Ohm's Law)

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$R_1 = \frac{2}{0.9}$

$R_1 = 2.22\,\Omega$

$V_2 = I_2 R_2$

$2 = 1.1\, R_2$

$R_2 = \frac{2}{1.1}$

$R_2 = 1.81\,\Omega$

$V_3 = I_3 R_3$

$2 = 1\, R_3$

$R_3 = \frac{2}{1}$

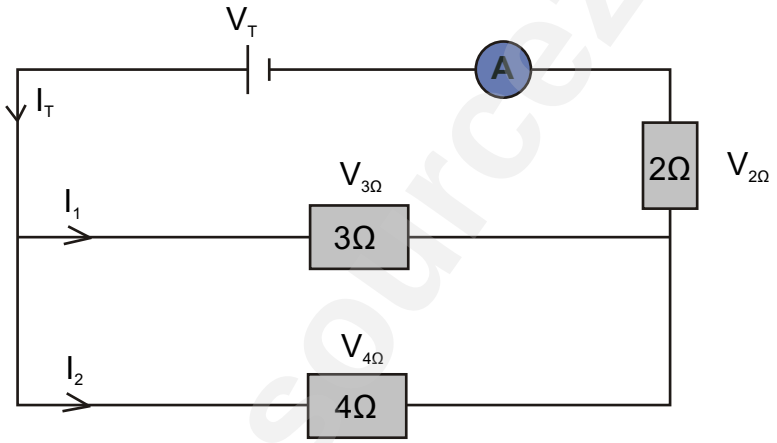
$R_3 = 2\Omega$

COMBINED SERIES AND PARALLEL CIRCUITS

- Sometimes series and parallel circuits are combined to form one circuit
- One example is a circuit shown below:

Example 3

Determine the missing values in the following electric circuit:



Solution 3

Total resistance in the circuit:

$R_T = R_P + R_{2\Omega}$

To determine R_P :

$\frac{1}{R_P} = \frac{1}{R_3} + \frac{1}{R_4}$

$\frac{1}{R_P} = \frac{1}{3} + \frac{1}{4}$

$\frac{1}{R_P} = \frac{7}{12}$

$R_P = \frac{12}{7}$

$R_P = 1.71\Omega$

Substituting into the equation:

$R_T = 1.7 + 2$

$R_T = 3.7\Omega$

$I_T = \frac{V_T}{R_T} = \frac{6}{3.7} = 1.62\ A$

$V_{2\Omega} = I_{2\,\Omega} \times R_{2\Omega}$

$= 1.62 \times 2$

$= 3.24\ V$

$V_{3\Omega} = I_{3\Omega} \times R_{3\Omega}$ ..... (i)

$\leftrightarrow$

$V_{3\Omega} = V_T\ \ V_{2\Omega}$

$= 6\ \ 3.24$

$= 2.76\ V$

Substituting back into equation (i)

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$2.76 = I_{3\Omega} \times 3$

$I_{3\Omega} = \frac{2.76}{3} = 0.92\ A$

$V_{4\Omega} = I_{4\Omega} \times R_{4\Omega}$
$2.76 = I_{4\Omega} \times 4$

$I_{4\Omega} = \frac{2.76}{4} = 0.69\ A$

INTERNAL RESISTANCE

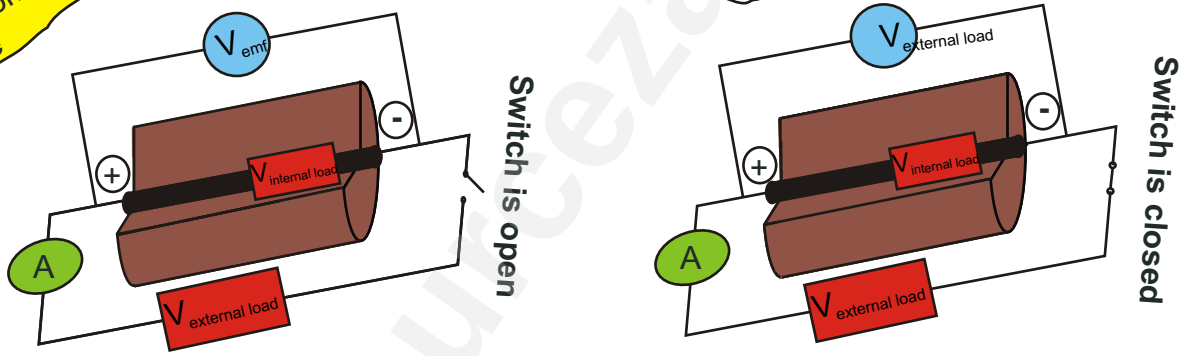
✎**emf** (voltage across the battery when the switch is open) is always greater than voltage of the external circuit (voltage across the battery when the switch is closed)

✎The difference between total voltage of the external circuit and emf of a battery will give us voltage of internal resistance:

$\text{emf} - V_{\text{external load}} = V_{\text{internal resistance}}$

emf* = *terminal voltage *when there is no load (or switch is open)*

e.m.f : electromotive force



✎Real batteries have resistance just like any other component in the circuit

✎Their resistance is called **Internal resistance,** which is defined as resistance that the charges experiences as they pass through the battery as illustrated in the diagram above

✎Voltage across internal resistance of the battery is only used to drive charge in the battery, and is not being used in the external load

✎As a result the voltage reading across the battery when the switch is closed becomes less than the emf

✎ The emf is the work done to move a charge through both the external circuit and the battery, and it is given by the following formula:

$V_{emf} = V_{\text{external load}} + V_{\text{internal resistance}}$ Or $V_{emf} = IR_{\text{external load}} + Ir$

✎Internal resistance of a battery is treated just like another resistor in series in the circuit

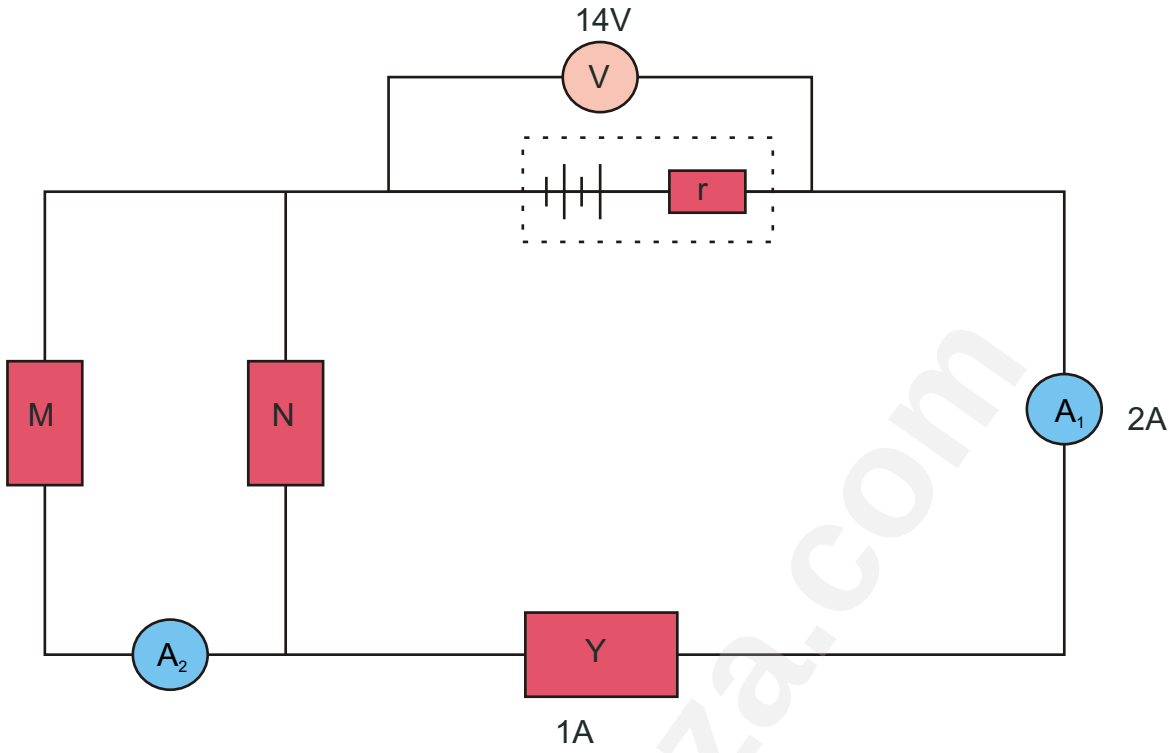
Voltage - work done to move a charge from one point to another in a conductor
Current - the amount of charge passing through a given point per unit time in a conductor
Resistance - the opposition to the flow of charge by cations in a conductor

Example 4 (March 2010 Q 11)

The circuit diagram below shows a battery, with an internal resistance r, connected to three resistors, M, N, and Y. The resistance of N is 2Ω and the reading on ammeter A_2 is 1A. (The resistance of the ammeters and the connecting wires may be ignored.)

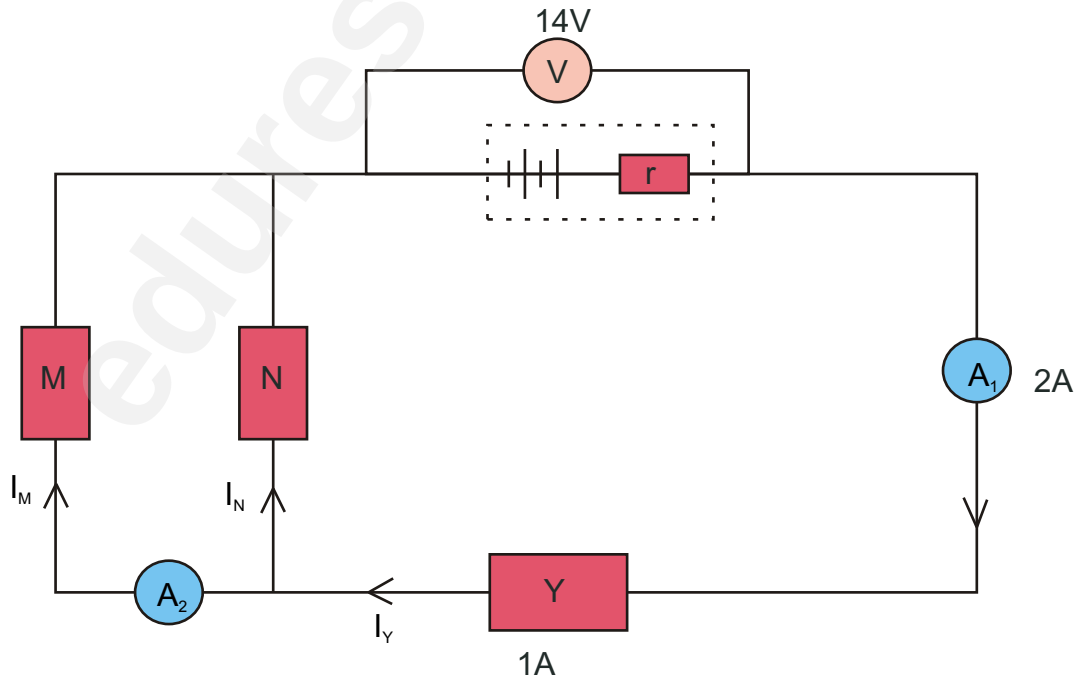
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1.1 State Ohm's Law in words (2)
1.2 How does the resistance of M compare with that of N? Explain how you arrived at the answer (2)
1.3 If the emf of the battery is 17V, calculate the internal resistance of the battery (5)
1.4 Calculate the potential difference across resistor N (3)
1.5 Calculate the resistance of Y (4)

Solution 4



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1.1 The current through a conductor is directly proportional to the potential difference across its ends at constant temperature

1.2 Equal
2A divides equally at T (and since I_M = 1A it follows that I_N = 1A)

$I \alpha \frac{1}{R}$ Therefore $R_M = R_N$

1.3 emf = IR + Ir
17 = 14 + Ir
Ir = 3V

But $Ir = V_{internal\ load} = 3$

Therefore $r = \frac{V_{internal\ load}}{I}$

$= \frac{3}{2}$

$= 1.5\Omega$

1.4

$V_N = I R_N$
$= (1)(2)$
$= 2\ V$

1.5

$V_Y = 14 - 2$
$= 12\ V$

$V_Y = I R_Y$
$12 = (2) R_Y$

$R_Y = 6\ \Omega$

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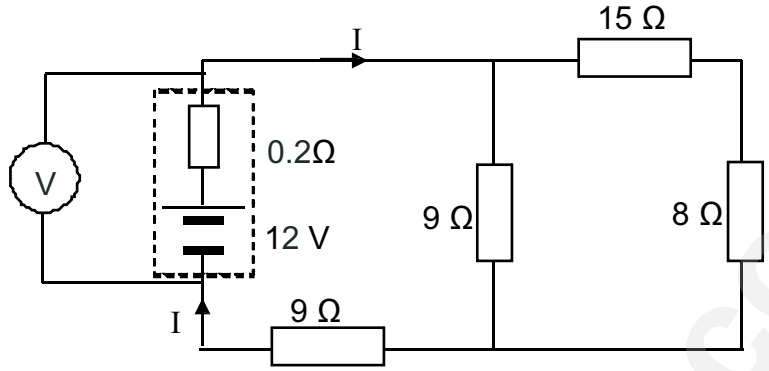
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EXAM TYPE WORKED EXAMPLES

QUESTION 1 (FEB 2009/P1/Q12)

The battery in the circuit below has an emf of 12 V and an internal resistance of 0,2 Ω. The resistance of the connecting wires can be ignored.



1.1 Calculate the current, I, that flows through the battery. (6)

1.2 How will the reading on the voltmeter be affected if the 9 Ω resistor is removed and replaced with a conducting wire of negligible resistance?

Explain your answer. (4)
[10]

SOLUTION 1

1.1

$$\frac{1}{R_e} = \frac{1}{r_1} + \frac{1}{r_2} = \frac{1}{9} + \frac{1}{23}$$

$$R_e = 6{,}47\ \Omega$$

$$R_{tot} = 6{,}47 + 2 + 0{,}2 = 8{,}67\ \Omega$$

$$I = \frac{V}{R} = \frac{12}{8.67} = 1.41A$$

1.2 Decreases

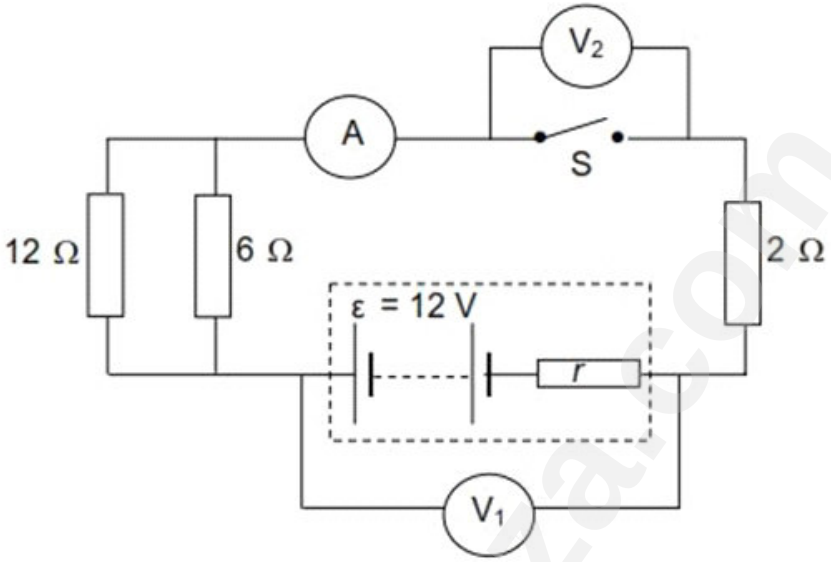
- Effective resistance of circuit decreases (No current through 15 Ω and 8 Ω resistances)
- Current increases
- Ir (lost volts) increases
- Vexternal decreases

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QUESTION 2 (NOV 2009/P1/Q12)

2.1 The battery in the circuit diagram below has an EMF of 12 V and an unknown internal resistance *r*. Voltmeter V_1 is connected across the battery and voltmeter V_2 is connected across the switch S. The resistance of the connecting wires and the ammeter is negligible.



2.1.1 Write down the respective readings on voltmeters V_1 and V_2 when switch S is open. (2)

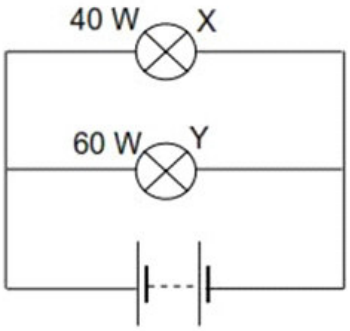
Switch S is now closed. The reading on voltmeter V_1 changes to 9 V.

2.1.2 What will the new reading on V_2 be? (1)

2.1.3 Calculate the total **external** resistance of the circuit. (4)

2.1.4 Calculate the internal resistance, *r*, of the battery. (5)

2.2 The circuit below shows two light bulbs, X and Y, connected in parallel to a battery with negligible internal resistance.



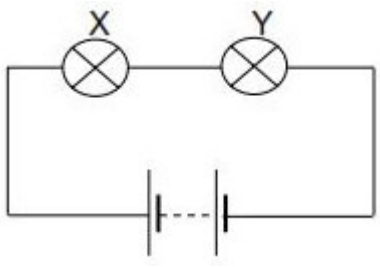
The bulbs are marked 40 W and 60 W respectively. Bulb Y glows brighter than bulb X.

2.2.1 How does the resistance of bulb Y compare to that of bulb X? Use an appropriate equation (or relationship) to explain your answer. (3)

During an experiment a learner connects these two bulbs in series to the same power supply as shown below. He observes that bulb X now glows brighter than bulb Y.

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2.2.2 Use an appropriate equation (or relationship) to explain why bulb X now glows brighter than bulb Y. (3)

[18]

SOLUTION 2

2.1.1 $V_1 = 12V$
$V_2 = 12V$

2.1.2 $V_2 = 0V$

2.1.3 $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$ Therefore $\frac{1}{R_P} = \frac{1}{12} + \frac{1}{6} \leftrightarrow R_p = 4\Omega$

$R_{(total)} = 4 + 2 = 6\Omega$

2.1.4 $R = \frac{V}{I}$ Therefore $6 = \frac{9}{I} \leftrightarrow I = 1.5A$

$Emf = IR + Ir$

$12 = 9 + (1.5)r$

$r = 2\Omega$

2.2.1 In parallel:

$P_Y > P_X$ (given)

$V_V = V_X$ (V is constant parallel)

Therefore $\frac{V^2}{R_Y} > \frac{V^2}{R_X}$

$\leftrightarrow R_Y < R_X$

2.2.2 In series

$I_Y = I_X$ (I is the same)

$I^2R_Y < I^2R_X$

$P \alpha R$ (I is constant)

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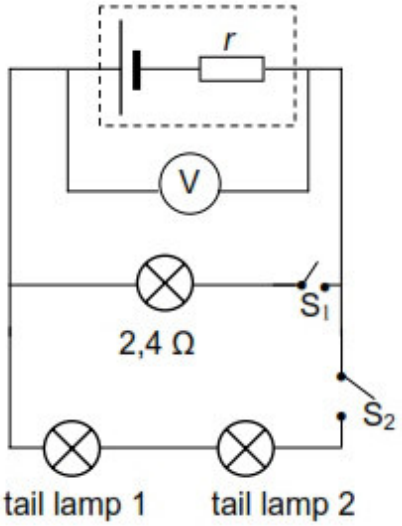
TASK 12

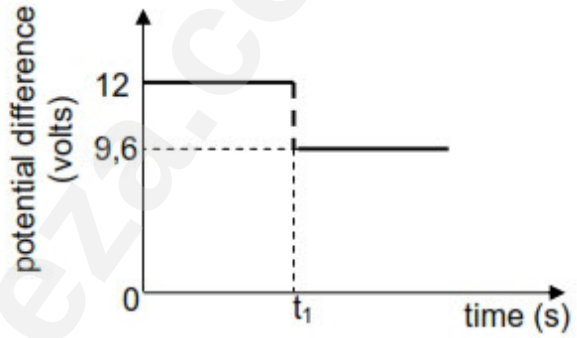
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QUESTION 1 (NOV 2011/P1/Q10)

The headlamp and two IDENTICAL tail lamps of a scooter are connected in parallel to a battery with unknown internal resistance as shown in the simplified circuit diagram below. The headlamp has a resistance of 2,4 Ω and is controlled by switch S1. The tail lamps are controlled by switch S2. The resistance of the connecting wires may be ignored.

The graph alongside shows the potential difference across the terminals of the battery before and after switch S1 is closed (whilst switch S2 is open). Switch S1 is closed at time t1.





1.1 Use the graph to determine the emf of the battery. (1)

1.2 WITH ONLY SWITCH S1 CLOSED, calculate the following:

1.2.1 Current through the headlamp (3)
1.2.2 Internal resistance, r, of the battery (3)
1.3 BOTH SWITCHES S1 AND S2 ARE NOW CLOSED. The battery delivers a current of 6 A during this period.

Calculate the resistance of each tail lamp. (5)

1.4 How will the reading on the voltmeter be affected if the headlamp burns out? (Both switches S1 and S2 are still closed.)

Write down only INCREASES, DECREASES or REMAINS THE SAME.

Give an explanation. (3)
[15]

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TOPIC 10: ELECTRODYNAMICS

ELECTRODYNAMICS

Electrical Machines (Generators, Motors)

- A generator is a machine which convert mechanical energy to electrical energy
- A motor is a machine which convert electrical energy to mechanical energy

Induced Current And Faraday's Law

- When a coil is rotated in a magnetic field, current is induced
- This can be explained using Faraday's Law which states that:

> "Induced e.m.f is directly proportional to the rate of change of the magnetic flux, Φ"

- Mathematically it is stated as:

$$\varepsilon = \frac{-N\Delta\Phi}{\Delta t}$$

Where Φ - magnetic flux (Tm^2)
B - strength of magnetic field (T)
A - area of conductor (m^2)
θ - angle between magnetic field (B) and the normal

$$\Phi = B\cos\theta$$

- As the coil changes orientation with respect to the magnetic field, the amount of magnetic flux through the area of the loop changes, and an emf is induced in the coil

Basic Principle Of An AC Generator

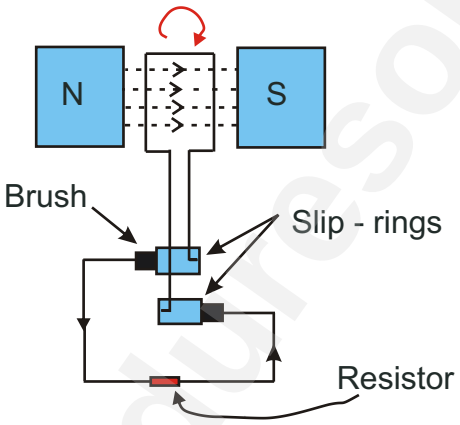


Fig 1. The diagram to the left shows an A.C generator

- In an AC generator, a coil is mechanically rotated in a magnetic field as shown above .
- According to Faraday's Law: (i) the rotating coil continually cut magnetic field lines.
(ii) This will change magnetic flux through the coil and thereby generates voltage (emf)
(iii) The induced emf causes a current to flow if the conductor circuit is closed

D.C Generators

- The principle of operation of A.C generators is the same as that of D.C generators
- However the main difference is that an A.C generator has slip - rings to the ends of the winding while a D.C generator has split - ring / commutator
- The slip - rings are touchable by fixed brushes to take off the A.C current
- The commutator is also connected to the opposite ends of the rotor's winding, and it is touched by fixed brushes just like slip - rings
- A split - ring commutator causes the current change direction every half - rotation,

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whereas a slip - ring commutator maintains a connection between the moving rotor and the stationary rotor

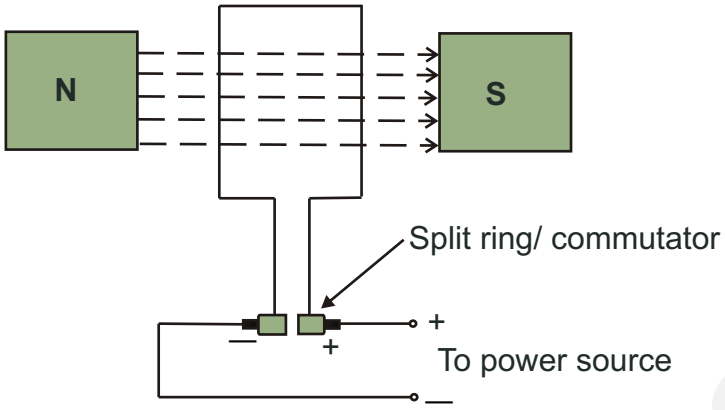
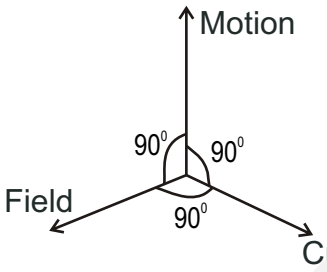


Fig 2. The diagram on the left shows a D.C generator.

Direction of current for generators (AC and DC)

- To determine direction of current we need to use Fleming's Right Hand Rule
- The following are the directions of field, motion, current according to Fleming's Right Hand Rule:

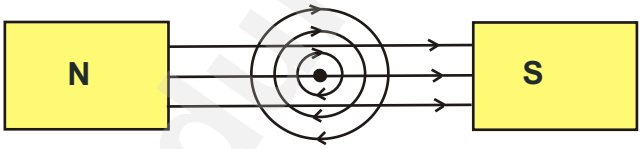


NB: We can use our fingers on the Right Hand to determine directions for field, motion and current.

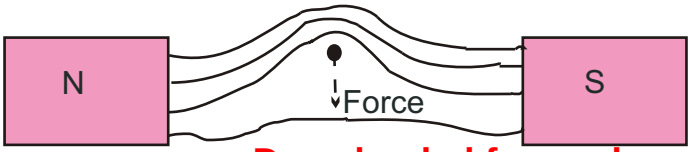
- Field - First finger
- Motion - Thumb
- Current - Second finger

A current carrying coil in a magnetic field

- When a current - carrying conductor is placed in a magnetic field it will turn
- The following is an explanation as to why it turns:
- A current carrying wire is surrounded by its own magnetic field as shown below:



- Above the wire, the field of a magnet and that of a wire are both going in the same direction
- As a result magnetic fields above the wire add up, making a resultant strong field
- However below the wire, the field of a magnet and that of a wire are going in different directions
- For this cause the fields cancel each other out to some extent making a resultant weaker field
- The diagram below shows the new magnetic field pattern after a current - carrying coil is placed in the magnetic field:



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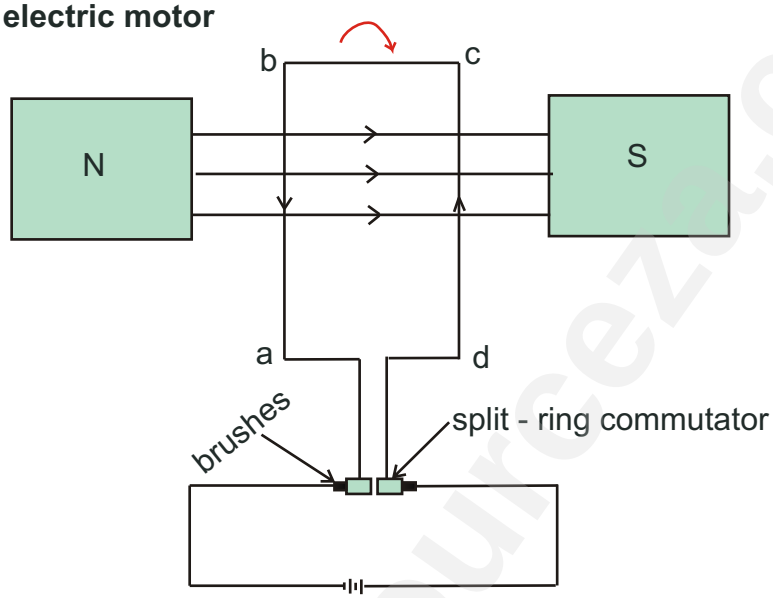
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- The resultant field above the wire is stronger as shown by lines which are close together
- Below the wire the resultant field is weaker as shown by lines which are further apart
- Since the resultant field is much stronger at the top, the force will push the wire downwards towards the weaker field
- As the magnetic fields continues to exert forces on the wire, a torque will be created which will ensure continuous rotation of the wire.

Basic operation of an electric motor

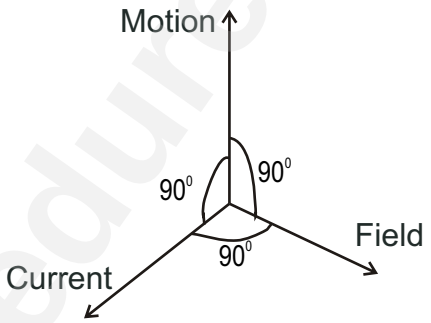
- A simple DC motor has a coil of wire that can rotate in a magnetic field
- The current in a coil is supplied via two brushes which make moving contact with a split ring
- The forces exerted on a current carrying conductor create a torque on the coil

Simple electric motor



Direction of current for motors (DC)

- To determine direction of current we need to use Fleming's Left Hand Rule as shown below:



NB: We can use our fingers on the Left Hand to determine directions for field, motion and current.

- Field - First finger
- Motion - Thumb
- Current - Second finger

Examples of uses of AC and DC generators

- Electroplating
- Battery charging
- For excitation of alternators
- Welding
- Supply power for offices, hostels, hospitals

Examples of the uses of motors

- Used in household appliances which requires speed such as sewing machines, grinders,

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- Used in wind screen wipers, fans and hair blowers
- Used in trains

Advantages of AC current

- More power - more power is generated from AC than DC
- Long distance transmission - power can be transmitted over long distances with AC than DC
- Conversion - It is easy to convert AC to DC by using transformers
- Flexibility of use in the home - It is better to use AC in homes because it can be stepped up or down using transformers
- Economics of production - AC motor can yield higher power output than DC motors and are simpler in function than DC motors

Expressions for the current and voltage in an AC circuit

- The value of current or voltage at any specific time is called the instantaneous current or voltage
- It is calculated using the following equations:

$$I = I_{max} \sin(2\pi ft + \Phi)$$
$$V = V_{max} \sin(2\pi ft)$$

Where:

I = instantaneous current
V = instantaneous voltage
I_{max} = maximum current
V_{max} = maximum voltage
f = frequency of the AC current
t = time at which the instantaneous current or voltage is being calculated

The Root Mean Square (Current and Voltage)

Current (I_{rms})

- The root mean square current is given by:

$$I_{rms} = \frac{I_{max}}{\sqrt{2}}$$

Voltage (V_{rms})

- Root mean square voltage is given by:

$$V_{rms} = \frac{V_{max}}{\sqrt{2}}$$

Importance of rms values

- Unlike DC, AC current and voltage are variable quantities (consecutive positives and negatives). In order to come up with comparable values of AC to DC, we need to calculate the rms. Therefore the rms value, not the peak value, is the equivalent DC value that gives the same average power. Now using the rms values makes the power easy to calculate, and hence electricity users will be able to know their bills based on the power they consume.

- When using DC source, power is given by:

$$P = VI = \frac{V^2}{R}$$

- However when using an AC source, power is given by:

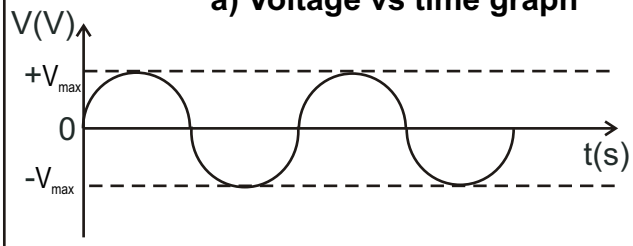
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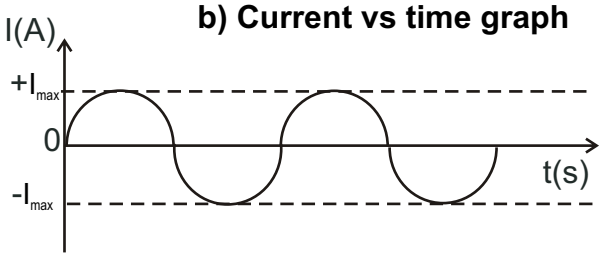
$P_{average} = V_{rms} I_{rms} = \frac{V^2_{rms}}{R}$ Or $P_{average} = \frac{1}{2} V_{max} I_{max}$

A.C GRAPHS

a) Voltage vs time graph

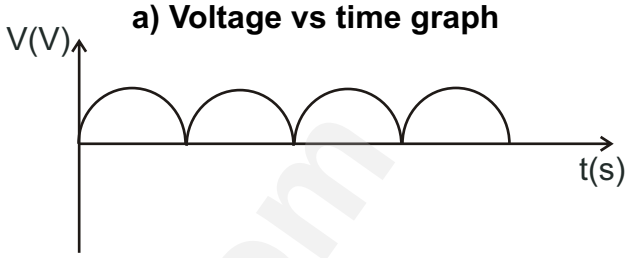


b) Current vs time graph

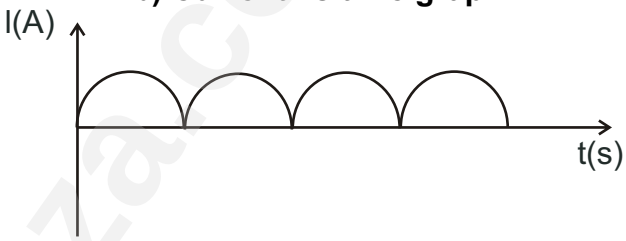


D.C GRAPHS

a) Voltage vs time graph



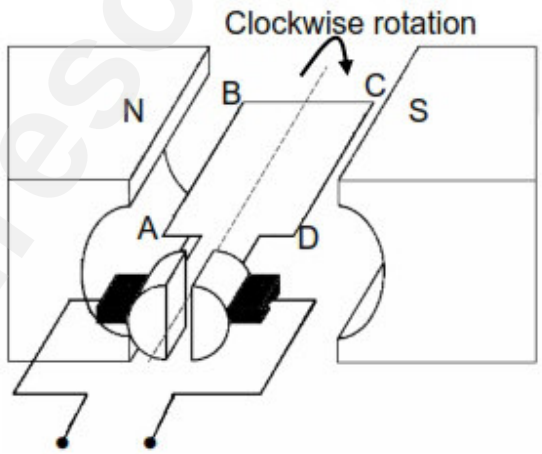
b) Current vs time graph



EXAM TYPE WORKED EXAMPLES

QUESTION 1 (FEB 2009/P1/Q13)

1.1 Electric motors are used in pumps, fans and compressors. Electric motors can be either AC or DC. The diagram below illustrates one of these types of electric motors.



1.1.1 What type of electric motor (AC or DC) diagram? is illustrated in the

Give a reason for your answer. (2)

1.1.2 If the loop turns in a clockwise direction, in current in section AB of the loop flowing in Write down from A to B, or from B to A only.
what direction is the above diagram? (1)

The motor in the diagram is now changed to operate as a generator.

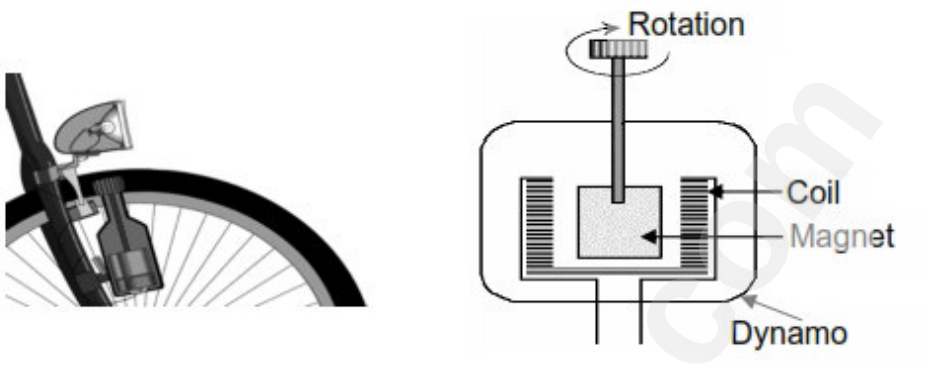
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1.1.3 On what principle does a generator operate? (1)

1.1.4 Draw a sketch graph of the potential difference versus time for this generator while it is functioning. (2)

1.2 The diagram below shows a dynamo attached to the wheel of a bicycle. When riding a bicycle, the wheel rotates a magnet near a coil.

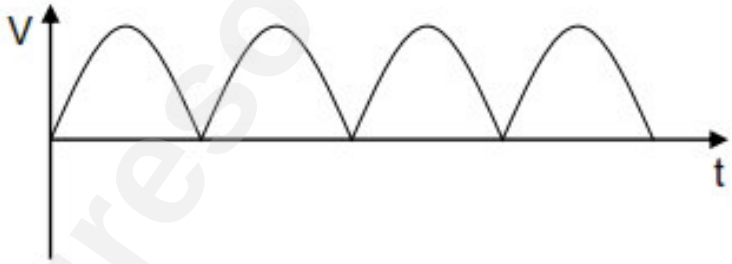


Explain how a current is induced in the coil. (2)
[8]

SOLUTION 1

1.1.1 DC A splitring-commutator is used to ensure that the current in the loop remains in the same direction through the complete cycle.
1.1.2 B to A
1.1.3 Electromagnetic induction

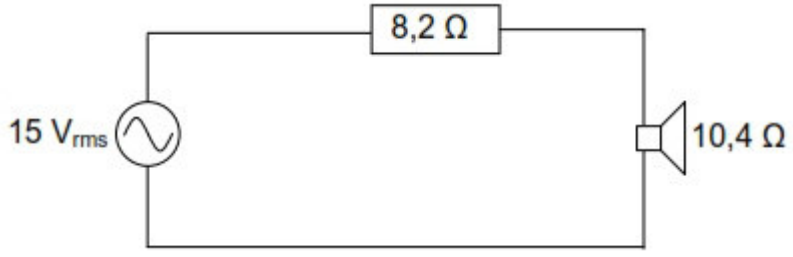
1.1.4



1.2 When the magnet rotates the changing magnetic flux cuts through the windings of the coil and induces a current in the coil.

QUESTION 2 (FEB 2009/P1/Q14)

2.1 In the circuit below the AC source delivers alternating voltages at audio frequency to the speaker.



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2.1.1 What is the peak voltage that the source can deliver? (2)

2.1.2 Calculate the average power delivered to the speaker. (6)

2.2 Alternating current is generated at power stations.

Name TWO advantages of AC transmission over long distances. (2)
[10]

SOLUTION 2

2.1.1 $V_{rms} = \frac{V_{max}}{\sqrt{2}}$ Therefore $V_{max} = 15(\sqrt{2}) = 21.21$

1.1.2 $R_{total} = 8.2 + 10.4 = 18.6\Omega$

$$I = \frac{V}{R} = \frac{15}{18.6} = 0.81A$$

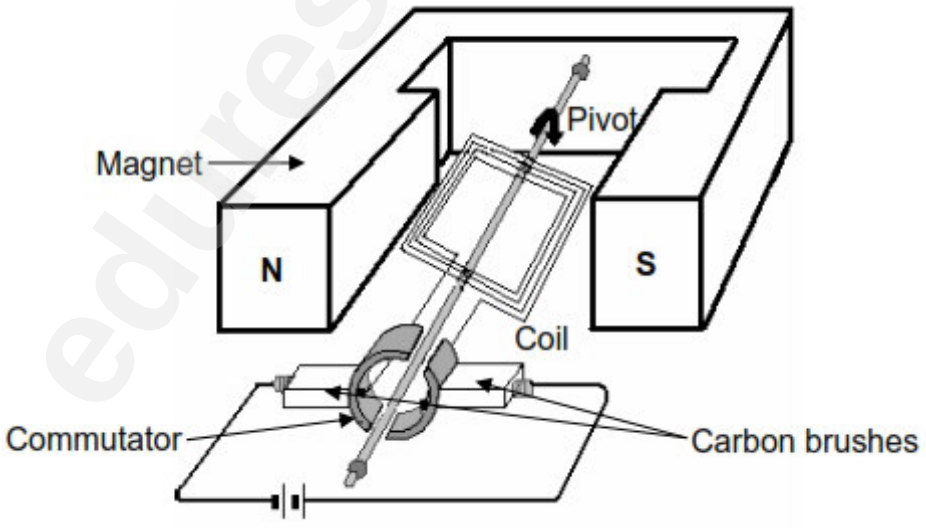
$$P = I^2R = (0.81)^2(10.4) = 6.76W$$

2.2 - With alternating current long distance transmission may be at high voltage and low current, less loss in energy and therefore more energy available for use.

- AC allows power stations to be relatively remote from users, so users are isolated from environmental affects of the stations. This remote delivery may save energy elsewhere (e.g. goods transport and commuting).

QUESTION 3 (NOV 2009/P1/Q13)

The diagram below represents a simplified sketch of an electric DC motor.



3.1 Name the component which ensures continuous rotation of the coil of this electric motor. (1)

3.2 Name the part of the motor which becomes an electromagnet when the current flows in the motor. (1)

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3.3 When the electric motor is connected to a 12 V DC supply, it draws a current of 1,2 A. The motor is now used to lift an object of mass 1,6 kg through a vertical height of 0,8 m at constant speed in 3 s.

Is all the electrical energy converted to the gain in potential energy of the object? Support your answer with relevant calculations. (7)
[9]

SOLUTION 3

13.1 (Splitring) commutator

13.2 Coil

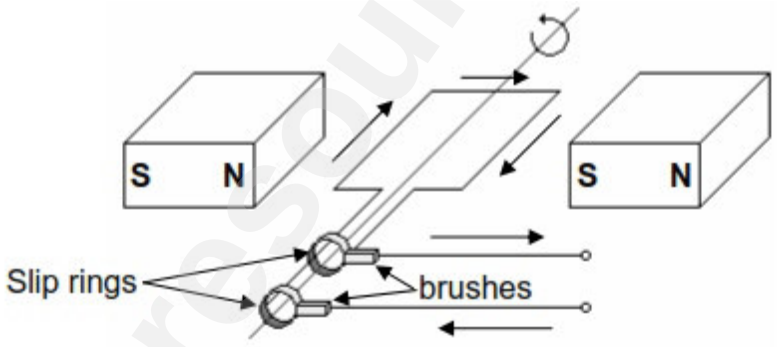
13.3 No

OR
E(electrical) > E(mechanical)

W(electrical) = VI Δ t = (12)(1,2)(3) = 43,2 J
Ep = mgΔy = (1,6)(9,8)(0,8) = 12,544 J

QUESTION 4 (FEB 2010/P1/Q12)

4.1 A simplified sketch of a generator is shown below.



4.1.1 Is the output voltage AC or DC? Give a reason for your answer. (2)

4.1.2 State TWO effects on the output voltage if the coil is made to turn faster. (2)

4.1.3 What is the position of the coil relative to the magnetic field when the output voltage is a maximum? (1)

4.2 In South Africa, the major source of electricity is coal-driven generators. Recently society has become concerned about fossil fuels (like coal) as the primary source of electrical energy. Some business people have proposed that government should invest in windmills as an alternative source of energy.

State ONE advantage and ONE disadvantage of using windmills over coal-driven generators in supplying energy. (2)
[7]

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SOLUTION 4

4.1.1 AC - alternating current
- A separate slip ring connected to each wire.

4.1.2 - Increase in peak (or rms) voltage
- Increase in frequency

4.1.3 The plane of the coil is parallel to the magnetic field.

4.2 **Advantage:**
- Less environmental pollution (noise, gases, etc.)

Disadvantage:
- Will not operate in absence of wind.
- Many windmills needed to generate sufficient electricity unsightly appearance in environment.

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TASK 13

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QUESTION 1 (NOV 2011/P1/Q11)

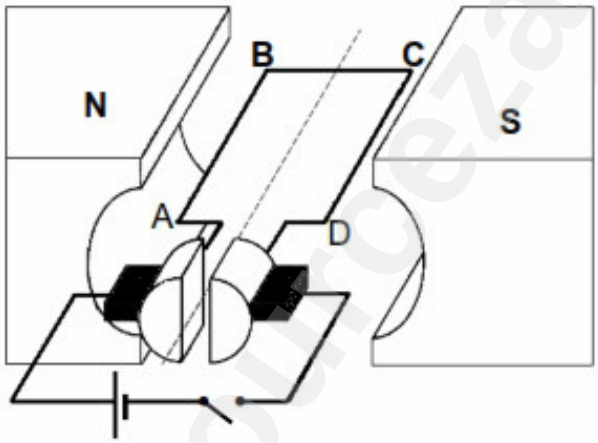
Diesel-electric trains make use of electric motors as well as generators.

1.1 The table below compares a motor and a generator in terms of the type of energy conversion and the underlying principle on which each operates. Complete the table by writing down only the question number (1.1.1 - 1.1.4) in the ANSWER BOOK and next to each number the answer.

	TYPE OF ENERGY CONVERSION	PRINCIPLE OF OPERATION
Motor	1.1.1	1.1.3
Generator	1.1.2	1.1.4

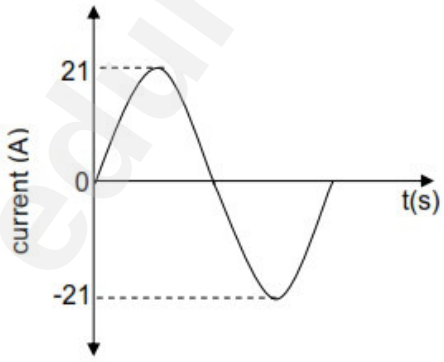
(4)

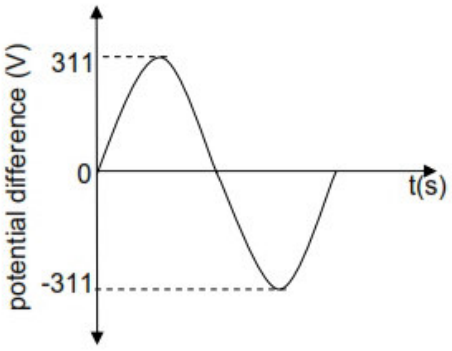
The simplified diagram below represents an electric motor.



1.2 Give a reason why the section of the coil labelled BC in the above diagram does not experience a magnetic force whilst the coil is in the position as shown. (2)

1.3 Graphs of the current and potential difference outputs of an AC generator are shown below.





Calculate the average power output of this generator. (6)

[12]

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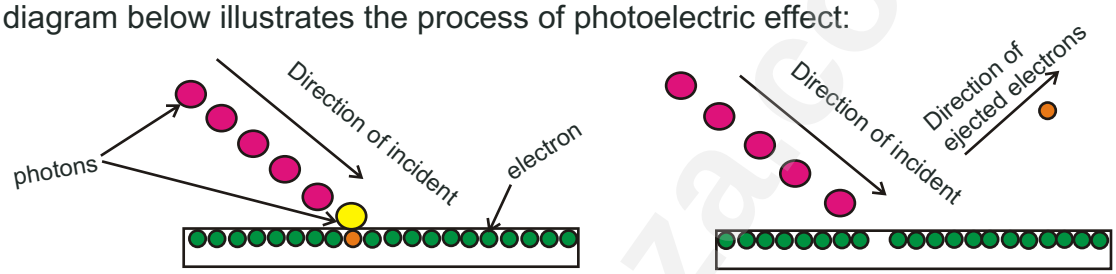
TOPIC 11: OPTICAL PHENOMENA AND PROPERTIES OF MATTER

WAVE - PARTICLE DUALITY

- It states that electromagnetic radiation behave like a stream of particles in some cases while exhibiting wave-like properties in others
- Light is one of electromagnetic radiations and it exhibits some properties which shows that it is a wave (e.g reflection, refraction, interference etc), but in some instances it exhibits some properties which shows that it is a stream of particles (e.g photoelectric effect.)

PHOTOELECTRIC EFFECT

- **Definition:** is the process that occurs when light shines on a metal and it ejects electrons
- This process is quite significant since it establishes the quantum theory and it illustrates the particle nature of light
- The diagram below illustrates the process of photoelectric effect:



According to the particle - nature of light: when light is shone on the surface of a metal, the light beam will be a stream of particles.

- Each particle is known as a photon
- A photon is a discrete bundle of light energy (or any electromagnetic radiation), it is always in motion, and in a vacuum it have a constant speed of light.
- In the above diagram we see that an electron was emitted after a photon transferred all its energy to it
- And this electron is called a **photo-electron**
- Note that the photon which transferred its energy to an electron just disappeared - a photon always ceases to exist whenever it give up its energy (because a photon is a bundle of energy.)

Emission of photo-electrons

- A photo-electron is emitted after an electron on the metal surface absorbs energy from a photon
- Energy of a photon is given by

$$E = hf$$

where
E - energy of a photon
h - plank's constant
f - frequency of a photon

- However not every photon has sufficient energy to eject an electron from the surface of a metal
- Frequency of a photon plays a bigger role in the emission of photo - electrons, a photon with a frequency greater or equal to threshold frequency would have sufficient energy to eject a single electron, producing the photoelectric effect.

Threshold frequency/cut - off frequency, f_0

- It is the frequency of light that has the same energy (hf) as the work function
- A photon with frequency greater or equal to threshold frequency have energy that is enough to eject an electron from the surface of a metal
- Again no photo-electrons are emitted if the frequency of light falls below some cut off frequency
- Threshold frequency differ with different materials

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✎Threshold frequency corresponds to a maximum wavelength

Work function

✎It is the minimum energy required to eject an electron from the surface of a metal
✎It is given by :

$$W_0 = hf_0$$

Where

W_0 = work function
h = plank constant
f_0 = threshold frequency

✎Work function differs with different materials
✎Electrons gains energy by interacting with photons
✎If a photon has energy less than the work function, it will not be able to eject electrons from the metal surface
✎If a photon has energy that is at least equal to the work function, the photon energy can be transferred to an electron and the electron will have enough energy to escape from the surface of the metal
✎Photons with energy equal to work function will eject an electron from the metal surface, but however the electron will not have enough energy to gain kinetic energy
✎Photons with energy greater than work function will eject an electron from the metal surface, but however the electron will gain kinetic energy and escape into the air.

Photo-electric equation

(1) $hf < W_0$
✎No photo-electron will be ejected

(2) $hf = W_0$
✎Photo-electrons will be ejected
✎Since all the energy of a photon is used to liberate an electron, there is no excess energy to move the electrons
✎Hence the electron have negligible kinetic energy to escape into the air
✎The equation which describe this is given below:

$$W_0 = hf_0$$

(3) $hf > W_0$
✎Photo-electrons will be ejected
✎Since energy of a photon is greater than the energy needed to liberate an electron from the metal surface, it means that the excess energy will move the electrons
✎Hence the electrons will have maximum kinetic energy to escape into the air will
✎The equation which describe this is given below:

$$KE_{max} = E - W_0$$

Or $$E = KE_{max} + W_0$$

Where $E = hf$ and $W_0 = hf_0$

$$KE_{max} = \tfrac{1}{2}mv^2_{max}$$

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FREQUENCY AND INTENSITY OF PHOTONS

Intensity of photons (at constant frequency)

✎An increase in intensity of the incident radiation will result in an **increase in the number of electrons** ejected per second
✎The rate at which photo-electrons are emitted is directly proportional to the intensity of incident photons provided frequency is kept constant
✎ If the frequency of the incident radiation is less than threshold frequency, increasing intensity will not cause electrons to be ejected

Frequency of photons

✎ Increasing frequency of photons above threshold frequency will result in an increase in maximum kinetic energy of photo-electrons
✎Maximum kinetic energy increases linearly with the frequency of the incident photons above the threshold frequency
✎Maximum kinetic energy is independent of the intensity of incident light
N:B if the frequency of incident radiation is greater than or equal to f_0, Increasing frequency of incident light also increases the number of photo-electrons per second

EMISSION AND ABSORPTION SPECTRA

Source of atomic emission spectra

✎This can be demonstrated using discharge tubes in an experiment

Procedure

1. Fill the discharge tubes with the following gases
2. Excite the gases in their respective tubes with a high voltage of about 5000V
3. Observe the colours they glow

Results

Gas	Colour
1. Hydrogen	Blue—violet
2. Helium	Pink—orange
3. Neon	Red
4. Argon	Violet
5. Krypton	Lavender

Observations

✎When high voltage coil is connected to the gas tubes, their gases glow showing their respective colours as shown in the table above

Interpretation

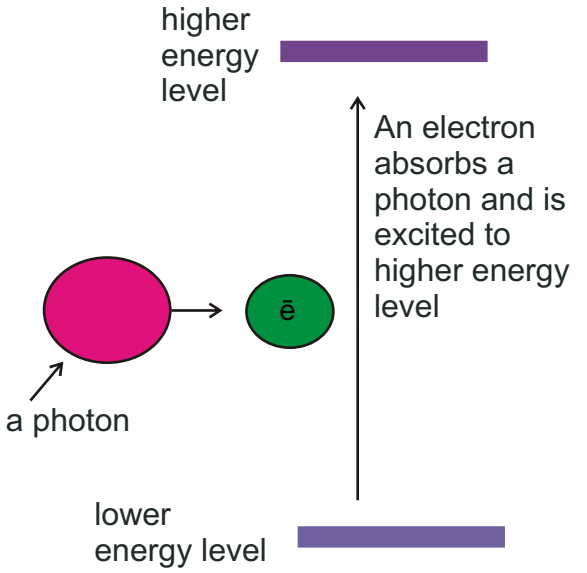
✎Photons from high voltage coils will transfer their energy to electrons in the gaseous atoms
✎Electrons will absorb the photons, get excited and jump to higher energy levels
✎To return to ground state the electrons must emit the photons in the form of light
✎Now the light emitted by different elements differs in colour due to different wavelengths of light that must be released
✎It is these colours that are used to produce atomic emission spectra of various elements
✎Because each element has a unique atomic emission spectrum, it helps scientists to identify unknown elements

Difference between atomic absorption and emission spectra

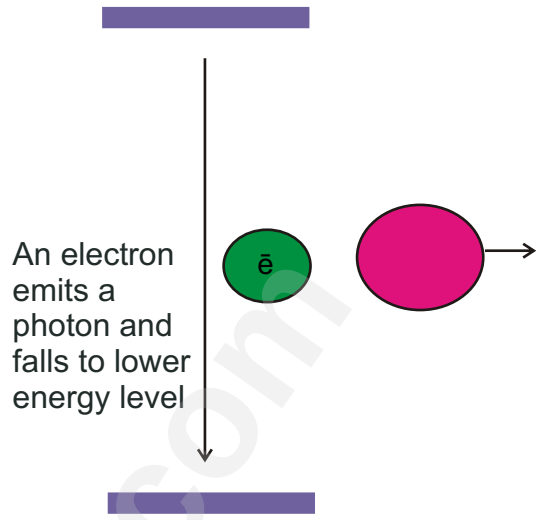
✎Absorption spectra shows wavelengths of light that the material absorbs whilst emission spectra shows wavelengths of light that the material emits when energy is put into it
✎The diagram overleaf illustrates both absorption and emission spectra

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(i) Absorption spectra illustration



(ii) emission spectra illustration

EXAM TYPE WORKED EXAMPLES

QUESTION 1 (FEB 2009/P1/Q15)

The work function of three metals is shown in the table below.

METAL	WORK FUNCTION (W_0) in J
Aluminium	$6{,}54 \times 10^{-19}$
Zinc	$6{,}89 \times 10^{-19}$
Silver	$7{,}58 \times 10^{-19}$

1.1 Give a reason why different metals have different work functions. (1)

1.2 Light of wavelength $2{,}3 \times 10^{-7}$ m is shone onto a metal X. The average speed of the emitted electrons is $4{,}78 \times 10^{5}$ m·s^{-1}.

Identify metal X by performing a relevant calculation. (6)

1.3 What conclusion about the nature of light is drawn from the photo-electric effect? (1)
[8]

SOLUTION 1

1.1 Different metals have different ionisation energies/Different metals attract electrons with different forces.

1.2 $hf = W_0 + \frac{1}{2} mv^2$ and $c = f\lambda$

$$\frac{hc}{\lambda} = W_0 + \frac{1}{2} mv^2$$

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$(6.63 \times 10^{-34})(3\times10^{8}) = W_0 + \frac{1}{2}(9.11\times10^{-31})(4.78\times10^{5})^2$
(2.3×10^{-7})

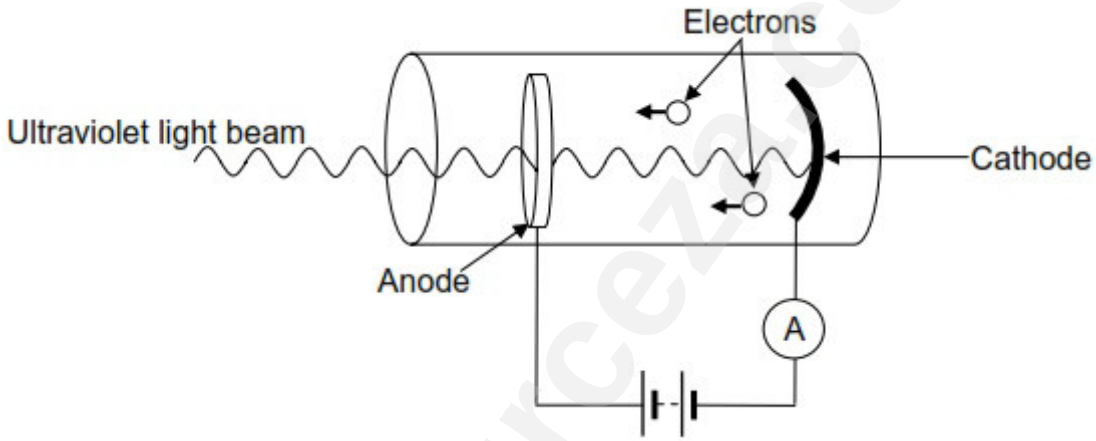
$W_0 = 7.58\times10^{-19}J$

Therefore Metal X is Silver

1.3 Establish particle nature of light

QUESTION 2 (NOV 2009/P1/Q14)

The photo-electric effect has many practical applications. A photocell, such as the one below used in burglar alarm systems, is one such application.



Ultraviolet light of wavelength 100 nm is used to illuminate the photocell. When a person interrupts the ultraviolet beam, the sudden drop in current activates a switch, which sets off the alarm.

2.1 Define the term threshold frequency. (2)

2.2 How will an increase in intensity of the ultraviolet light influence the ammeter reading? Write only INCREASES, DECREASES or REMAINS THE SAME. Explain your answer. (3)

2.3 The work function of the metal used as a cathode in the photocell is $8,7 \times 10^{-19}J$. Calculate the velocity at which the electrons are emitted. (6)
[11]

SOLUTION 2

14.1 The minimum frequency of light needed to emit electrons from a certain metal. 99
14.2 Increases
- Higher intensity, more photons strike metal plate per second
- More photo-electrons emitted per second

14.3 $hf = W_0 + E_K$

$= \frac{(6,63\times10^{-34})(3\times10^{8})}{100\times10^{-9}} = 8,7\times10^{-19} + \frac{1}{2}(9,1\times10^{-31})v^2$

Therefore $v = 1.57 \times 10^{6} ms^{-1}$

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QUESTION 3 (MAR 2010/P1/Q14)

During an experiment to determine the work function of a certain metal light of different frequencies was shone on the metal surface and the corresponding kinetic energies of the photoelectrons were recorded as shown in the table below.

Frequency of incident light ($\times 10^{14}$ Hz)	Kinetic energy of photoelectrons ($\times 10^{-19}$ J)
6,6	0,7
8,2	1,6
9,2	2,2
10,6	3,0
12,0	3,8

3.1 Define the term work function. (2)

3.2 Use the data in the table above to draw a graph of kinetic energy versus frequency on the graph paper provided. (6)

3.3 Extrapolate your graph to cut the X-axis.

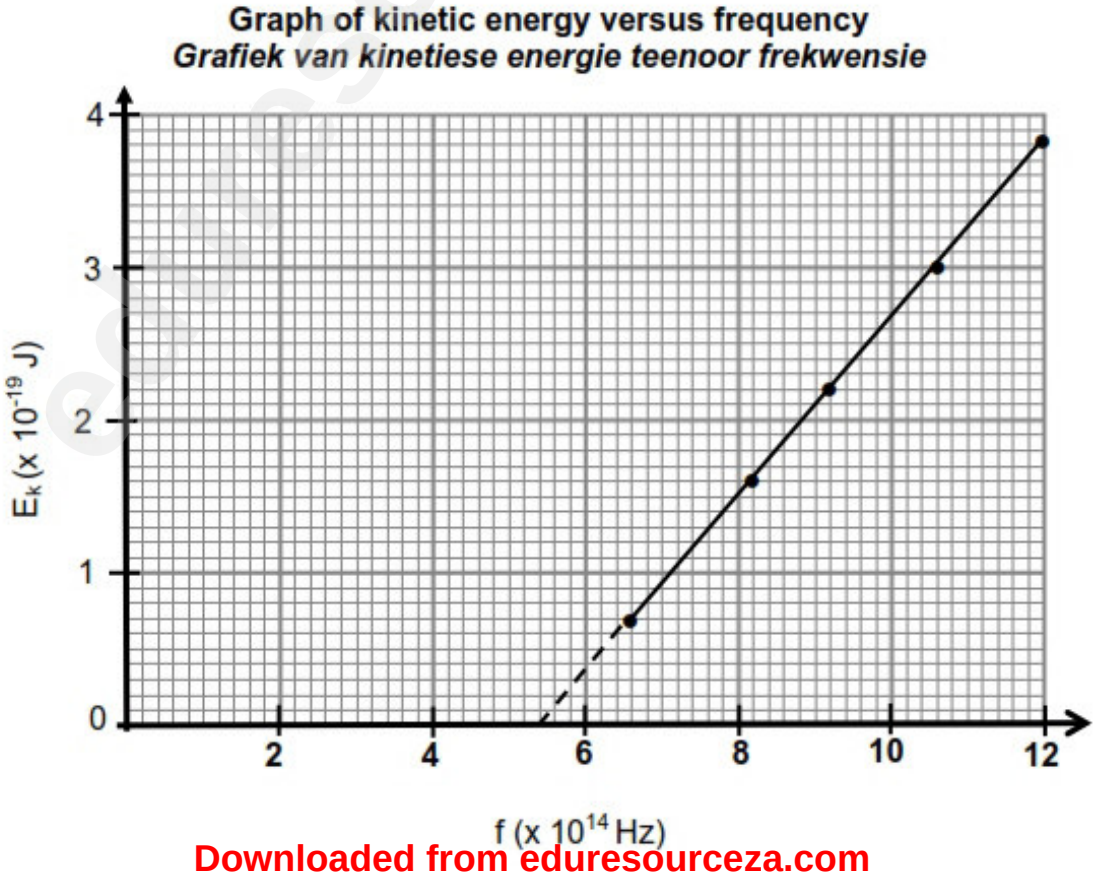
3.3.1 What is the frequency at the point of intercept? (2)
3.3.2 What term is used to describe this frequency? (1)

3.4 Use your graph to determine the work function of the metal. (3)
[14]

SOLUTION 3

3.1 Minimum amount of energy needed to remove an electron from the surface of a metal/conducting material.

3.2



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3.3

3.3.1 fo = 5,4 x 10^{14} Hz

3.3.2 Threshold frequency

3.3 $W_0 = hf_0$

$= (6,63 \times 10^{-31})(5,4 \times 10^{14})$

$= 3,58 \times 10^{-19}$ J

QUESTION 4 (NOV 2010/P1/Q12)

Sunlight is a major source of ultraviolet light.

12.1 Overexposure to ultraviolet light could have harmful effects on humans. State ONE of these harmful effects on humans. (1)

12.2 Medical practitioners expose surgery equipment to ultraviolet light. Give a reason for doing this. (1)

A certain metal has a work function of 3,84 x 10^{-19} J. The surface of the metal is irradiated with ultraviolet light of wavelength 200 nm causing photoelectrons to be emitted.

12.3 Calculate the energy of a photon of ultraviolet light. (4)

12.4 Calculate the maximum velocity of the emitted photoelectrons. (4)

12.5 Will photoelectrons be emitted from the surface of this metal if it is irradiated with X-rays? Give a reason for the answer. (2)

[12]

SOLUTION 4

4.1 Any ONE:
Damage to skin./Causes (skin) cancer.
Damage to eyes./Increased occurrence of cataracts.
Damage to crops resulting in food shortages.

4.2 Kills bacteria / germs / Sterilises/ sanitises / disinfects

4.3 $E = \frac{hc}{\lambda}$

$= \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{200 \times 10^{-9}}$

$= 9.95 \times 10^{-19}$J

4.4 $E = W_0 + E_K$

$hf = hf_0 + \frac{1}{2} mv^2$

$9.95 \times 10^{-19} = 3.84 \times 10^{-19} + \frac{1}{2} (9.11 \times 10^{-31})v^2$

Therefore $v = 1.16 \times 10^{6}$ ms^{-1}

4.5 Yes
(Photons of) X rays have a higher frequency than ultraviolet radiation

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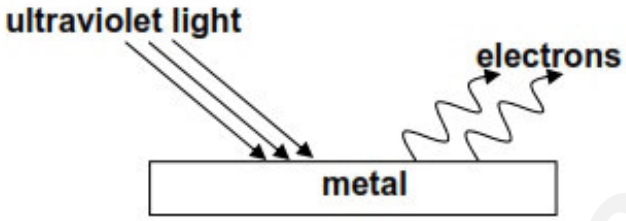
TASK 14

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QUESTION 1 (NOV 2011/P1/Q12)

A metal surface is illuminated with ultraviolet light of wavelength 330 nm. Electrons are emitted from the metal surface.

The minimum amount of energy required to emit an electron from the surface of this metal is 3,5 x 10-19 J



1.1 Name the phenomenon illustrated above. (1)

1.2 Give ONE word or term for the underlined sentence in the above paragraph. (1)

1.3 Calculate the frequency of the ultraviolet light. (4)

1.4 Calculate the kinetic energy of a photoelectron emitted from the surface of the metal when the ultraviolet light shines on it. (4)

1.5 The intensity of the ultraviolet light illuminating the metal is now increased. What effect will this change have on the following:

1.5.1 Kinetic energy of the emitted photoelectrons (Write down only INCREASES, DECREASES or REMAINS THE SAME.) (1)

1.5.2 Number of photoelectrons emitted per second (Write down only INCREASES, DECREASES or REMAINS THE SAME.) (1)

1.6 Overexposure to sunlight causes damage to skin cells.

1.6.1 Which type of radiation in sunlight is said to be primarily responsible for this damage? (1)

1.6.2 Name the property of this radiation responsible for the damage. (1)

[14]

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TOPIC 12 ELECTROCHEMICAL REACTIONS

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Definition: Galvanic cells

- These are cells which converts chemical energy to electrical energy
- They are self sufficient and hence do not need an external power supply

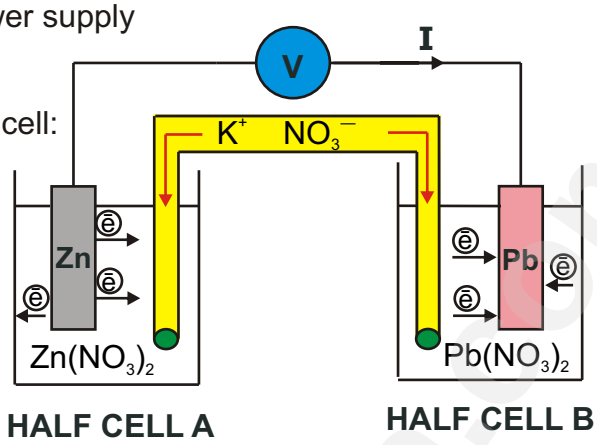
Definition: Electrolytic cells

- These are cells which converts electrical energy into chemical energy
- They need an external power supply

GALVANIC CELLS

- The following is a galvanic cell:

N.B An electrode should always be dipped in an electrolyte of its ions e.g Zn electrode is dipped in an electrolyte with zinc ions and Pb electrode is dipped in an electrolyte with lead ions.



N.B Mass of the anode gradually decreases, whilst mass of the cathode increases gradually

Identifying the cathode and anode by inspection

- An **anode** is an electrode where oxidation takes place (oxidation is **L**oss **O**f **E**lectrons)
- A **cathode** is an electrode where reduction takes place (reduction is **G**ain **O**f **E**lectrons)
- Nevertheless by mere looking at the electrode potentials of two electrodes we can easily determine whether an electrode is an anode or cathode
- An electrode potential with a number that is far on the negative side is an anode, whilst an electrode potential with a number that is on the far positive side is a cathode
- The electrode potential for Zn is -0.76 V and that for Pb is -0.13 V
- Therefore in this cell Zn is the anode while Pb is the cathode

Oxidation and reduction half reactions

- A half reaction goes in one direction only, and hence it should always have one arrow
- Since Zn is an anode it will always be oxidized by losing electrons to form Zn^{2+}
- The half reaction in half cell A (at the anode) will be:

$$Zn(s) \rightarrow Zn^{2+}(aq) + 2e$$

Pb is however a cathode which is being reduced by gaining electrons to form Pb^{2+}

- The half reaction in half cell B (at the cathode) will be:

$$Pb^{2+}(aq) + 2e \rightarrow Pb(s)$$

N.B Electrons are said to be lost (oxidation) when they are on the right side of an arrow in all half reactions, however they are being gained (reduction) if they are on the left side of the arrow

Cell operation

- Before the cell start operating, two half cells are having a balance of charge: positive and negative charges in each half cell are equal

(i) Half cell A (the anode)

- When Zn (anode) loses electrons, more Zn^{2+} are deposited in the electrolyte in half cell A
- Hence concentration of positive Zn^{2+} ions in half cell A becomes more than that of negative NO_3^- ions
- This way balance of charge in half cell A will be disturbed
- Since half cell A have more positive ions than negative ions it makes the cell to have a net positive charge (take note that the anode is negatively charged but the electrolyte in which the anode is dipped is positively charged)

(ii) Half cell B (the cathode)

- Electrons lost by Zn will flow from the anode to the cathode (Pb) through connecting wires
- Pb^{2+} in half cell B will gain the electrons to form P(s)
- This means that concentration of positive Pb^{2+} ions will decrease from half cell B as compared to the concentration of negative NO_3^-
- This way balance of charge in half cell B is disturbed
- Since half cell A have more negative ions than positive ions it makes the cell to have a net

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negative charge Downloaded from eduresourceza.com

Salt bridge

- When charges are no longer balanced in half cells current will stop flowing
- The following are some of the uses of a salt bridge

(i) To balance the charge / to maintain electrical neutrality in the half cells
(ii) To connect two half cells of a galvanic cell
(iii) To separate the two half cells of a galvanic cell

Flow of current and ions

- Current will always flow from anode to cathode
- Positive ions in the salt bridge will always flow to the cathode side to restore balance of charge
- Negative ions in the salt bridge will always flow to the anode side to restore balance of charge

Standard Hydrogen Electrode (SHE)

- Electrode potential for a hydrogen half cell is given a standard value of $E^{\theta} = 0.00V$
- A hydrogen half cell has an inert platinum electrode
- When a half cell of copper ($Cu^{2+}||Cu$) is coupled with SHE ($Pt \mid H_2$ (g, 1 atm) $\mid H^+$(aq), 1M), then E^{θ}_{cell} = + 0.33 V. In this cell copper half cell is the cathode (positive terminal) and hydrogen half cell is the anode (negative terminal) in a galvanic cell
- If however a half cell of zinc ($Zn^{2+} \mid\mid Zn$) is coupled with SHE, then E^{θ}_{cell}= —0.76 V. In this cell zinc half cell is the anode and hydrogen half cell is the cathode.

Standard conditions

- Standard conditions for any half cell electrode system are (i) Temperature of 25^0**C** or 298K (**ii**) Pressure of 1 atmosphere or 101.3 kPa (iii) Concentration of 1mold**m**$^{-3}$

Standard electrode potential of a half cell (E^{θ})

- To determine the standard electrode potential of an unknown electrode, the unknown electrode should be paired with a Standard Hydrogen Electrode (SHE) or by another electrode with a known potential
- Once paired, they form a galvanic cell - and standard electrode potential of the unknown electrode will be easily determined.
- The standard potential of any electrode paired with a SHE is its reduction potential value e.g when Zn half cell is paired with SHE its standard electrode potential is -0.76 V.

Standard electrode potential of a cell (E^{θ}_{cell})

- To determine electrode potential of a cell, the following formula is used: $E^{\theta}_{cell} = E^{\theta}_{cathode} - E^{\theta}_{anode}$
- When E^{θ}_{cell} is positive the reaction is said to be spontaneous
- When E^{θ}_{cell} is negative the reaction is non spontaneous

SIMILAR EQUATIONS

$E^{\theta}_{cell} = E^{\theta}_{reduction} - E^{\theta}_{oxidation}$

$E^{\theta}_{cell} = E^{\theta}_{oxidizing\ agent} - E^{\theta}_{reducing\ agent}$

Standard cell notation

- A general cell notation is written in this order:

— Anode (s) | Anode ions (aq) 1moldm^{-3} || Cathode ions (aq) 1moldm^{-3} | Cathode (s) +

- Now, our cell notation for the galvanic cell of Zn and Pb is:

— $Zn(s) \mid Zn^{2+}(aq)$ 1moldm^{-3} $\mid\mid Pb^{2+}(aq)$ 1moldm^{-3} | Pb(s) +

Application of chemical equilibrium in galvanic cells

- Let us consider the galvanic cell we had from the beginning for Zn and Pb
- The overall reaction of the cell is:

$$Zn(s) + Pb^{2+}(aq) \rightarrow Zn^{2+}(aq) + Pb(s)$$

- If we decrease concentration of Zn^{2+} from its standard concentration of 1M to a very low value then, according to Le Chartelier's principle, the system will shift to the right until a new equilibrium is reached. Therefore a decrease in concentration of Zn^{2+}will cause more Zn^{2+} (aq) and Pb(s) be produced. So more current will be produced until a new equilibrium is reached
- At equilibrium, the cell is dead and as a result no work is done

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When work is not done the potential difference of a cell is zero

ELECTROLYTIC CELLS

Electrolysis

It is the separation of pure elements from impure compounds using electrical energy

In other words it is the use of electrical energy to bring about a chemical change

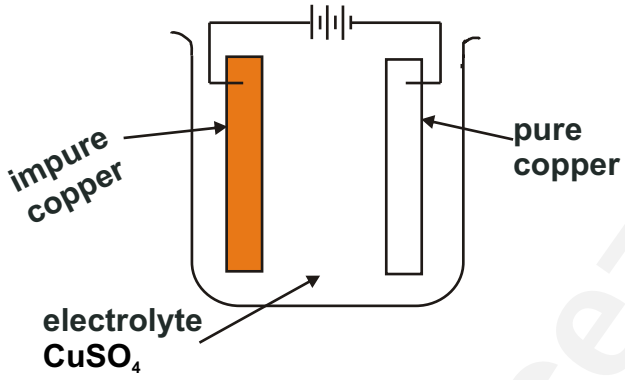
Identifying the cathode and anode

An **anode** is where oxidation take place whereas a **cathode** is where reduction takes place

By mere looking at the terminals of the power supply connected to an electrode in an electrolytic cell, we can easily determine whether an electrode is an anode or cathode

An electrode connected to a positive terminal is the anode, however a cathode is the one connected to a negative terminal

(I) Extraction/ electrolysis of copper



In order to purify copper from its impurities it should undergo electrolysis in an electrolytic cell

Impure copper should always be at the anode while pure copper at the cathode

Cell operation

(i) **At the anode**

Cu(s) is being oxidized to form Cu^{2+} ions

Half reaction at the anode is :

$$Cu(s) \rightarrow Cu^{2+}(aq) + 2\bar{e}$$

The Cu^{2+} ions formed at the anode will enter into the electrolyte and migrate from anode to cathode

(ii) At the cathode

At the cathode Cu^{2+} ions will be reduced to Cu (s) by gaining electrons

Half reaction at the cathode is:

$$Cu^{2+}(aq) + 2\bar{e} \rightarrow Cu(s)$$

Cu(s) deposited at the cathode becomes purified copper

NB:

During electrolysis of copper, the same metal (copper) that is being oxidized at the anode is the same which is being reduced at the cathode

For this reason the same number of moles that are being oxidized at the anode is the same number of moles that are being reduced at the cathode

Hence concentration of the electrolyte remains constant throughout the process

Change in mass of electrodes

Mass of the anode gradually decreases, but mass of the cathode gradually increases

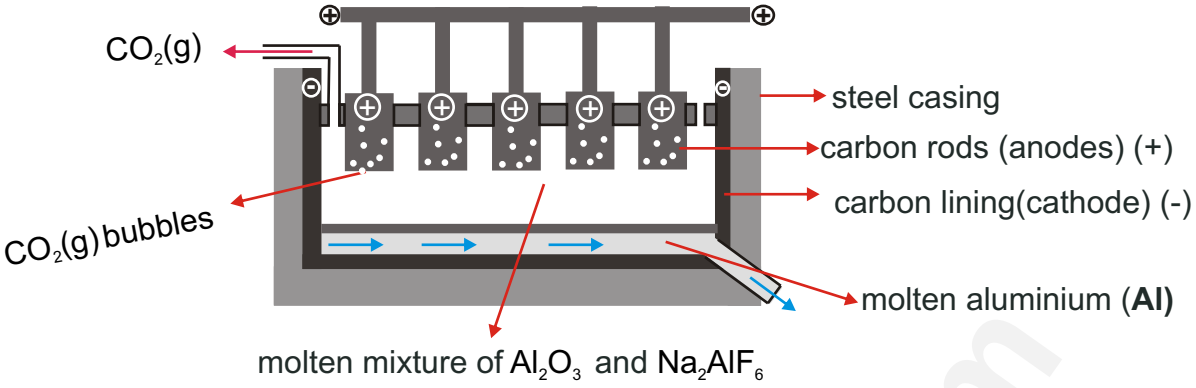
Eventually impurities will get deposited at the bottom of the anode

These impurities are known as sludge, which can be used for various economical purposes such as construction, jewelery, etc.

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(ii) **Extraction/ electrolysis of aluminum**



Aluminum oxide (Al_2O_3) in a container decomposes to its separate ions namely Al^{3+} and O^{2-} as shown in the equation below:

$$Al_2O_3\ (s) \rightarrow 2Al^{3+}\ (aq) + 3O^{2-}\ (aq)$$

During electrolysis negative ions will always be deposited at the positive terminal and positive ions on the negative terminals

So Al^{3+} will be deposited at the negative terminal (cathode), and O^{2-} will be deposited at the positive terminal (anode)

Cathode and anode

Carbon rods are the anodes

Carbon lining of a steel tank casing is the cathode

(i) Half reactions at the anode

When O^{2-} is deposited at the anode, it will first be oxidized to $O_2(g)$ as shown in the equation below:

$$2O^{2-}(aq) \rightarrow O_2(g) + 4e$$

The $O_2(g)$ formed will then react with the anode (carbon rod) to form carbon dioxide as shown in the equation below:

$$C\ (s) + O_2(g) \rightarrow CO_2(g)$$

Carbon rods get used up as time goes on because they react with oxygen to form carbon dioxide, hence they must be replaced

(ii) Half reactions at the cathode

When is deposited at the cathode, it will be reduced to Al (s) according to the reaction below:

$$Al^{3+}\ (aq) + 3e \rightarrow Al(s)$$

Disadvantages of aluminum extraction process

It is uneconomical due to its large amounts of electricity consumption

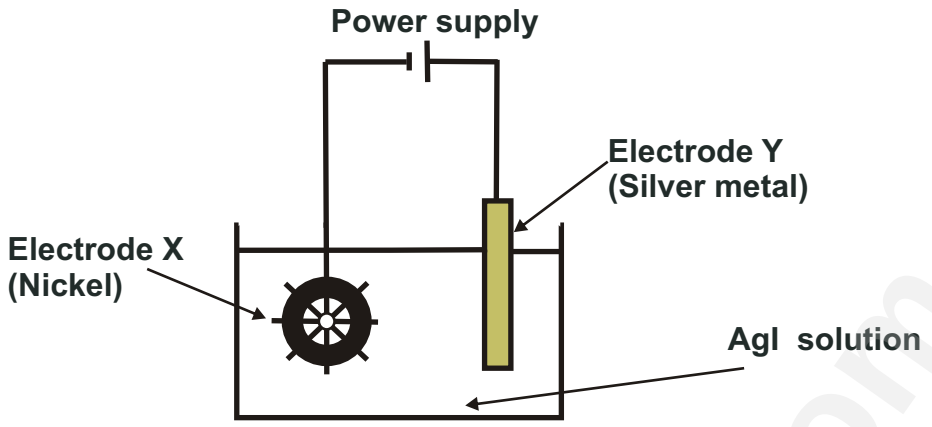
It pollutes the environment

It is expensive to maintain since carbon rods have to be replaced regularly

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(iii) Electroplating



Electroplating is a process whereby electricity is used to reduce metal cations on the surface of another metal to form a coating

Identifying the anode and cathode

Oxidation takes place at the **anode**

Reduction takes place at the **cathode**

When there are two different electrodes in an electrolytic cell, we can easily determine whether an electrode is anode or cathode by merely looking at their electrode potential values

An electrode with electrode potential value on the far positive side is the anode, and the other with a value on the far negative side is the cathode.

In our given example above E^{θ} for Ni is -0.27V and that for Ag is +0.80V

From their electrode potentials we can see that Ag is a stronger oxidizing agent compared to Ni, hence it must be at the anode terminal.

On the other end Ni is a stronger reducing agent than Ag, hence it must be at the cathode

Cell structure

The item to be coated should be at the cathode, in this case Ni

The metal which is used to coat another should be at the anode, in this case Ag

The electrolyte should have ions of the metal at the anode which is going to coat the other, in this case Ag^+ (to allow cations to migrate)

Cell operation

(i) Half reaction at the anode

Ag is oxidized at the anode by losing electrons

The half reaction at the anode is as shown by the chemical equation below:

$$Ag(s) \rightarrow Ag^+(aq) + e$$

(ii) Half reaction at the cathode

Because the electrolyte is a solution of Ag^+ ions it helps Ag^+ ions to migrate from the anode to the cathode where they will be reduced to Ag(s)

Due to its strong reducing ability, Ag will be reduced in preference to Ni at the cathode

The half reaction at the cathode will be as follows:

$$Ag^+(aq) + e \rightarrow Ag(s)$$

Changes in mass of electrodes and concentration of electrolytes

Mass of the anode gradually decreases with time

Mass of the cathode gradually increases with time

Concentration of electrolyte remains constant because since the same number of moles of a metal that is oxidized at the anode is the same number of moles that is reduced at the cathode

Why electroplating?

Preventing rust

To improve appearance and value of objects

Increase thickness of objects

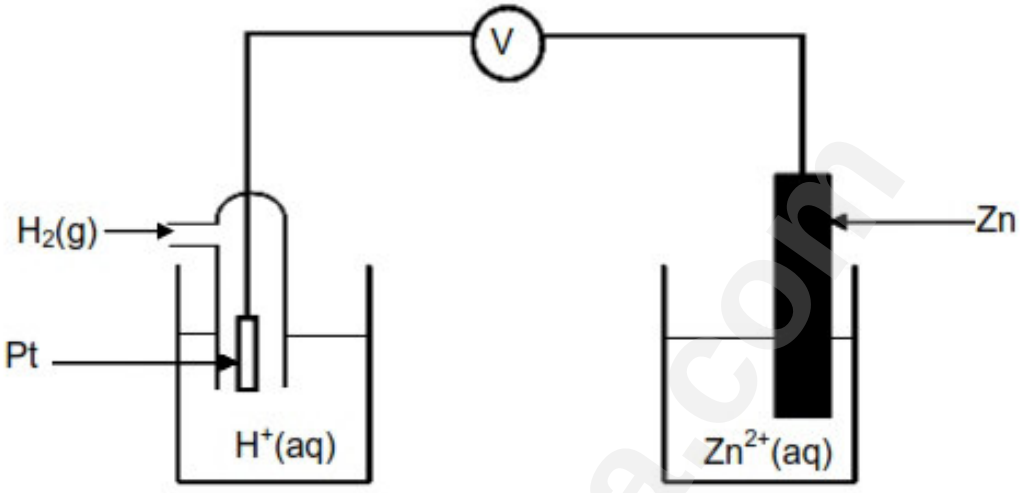
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EXAM TYPE WORKED EXAMPLES

QUESTION 1 (FEB 2009/P2/Q10)

The discovery of electrochemical cells has revolutionised our way of life. The diagram below represents an electrochemical cell.



1.1 Name the type of electrochemical cell that converts chemical energy to electrical energy. (1)

1.2 If the electrochemical cell is set up as illustrated, there will be no reading on the voltmeter. Give a reason for this observation. (1)

1.3 Write down the value of the standard emf of the electrochemical cell when it is functioning. (1)

1.4 Write down the voltmeter reading when the net cell reaction in the above electrochemical cell reaches equilibrium. (1)

1.5 Write down the equation for the reaction that occurs at the anode. (2)

1.6 Another electrochemical cell is set up under standard conditions by replacing the standard hydrogen half-cell with a standard magnesium half-cell.

1.6.1 Which electrode will undergo a decrease in mass? Give a reason for your answer. (2)

1.6.2 Calculate the initial emf of this electrochemical cell at standard conditions. (4)

1.6.3 After a while the emf of this electrochemical cell decreases. Explain this observation by referring to the concentration of the electrolytes. (2)

1.7 Electrochemical cells such as motor car batteries with plastic casings can harm the environment if not disposed of safely. Suggest TWO ways how motor car batteries can be safely disposed of. (2)

[16]

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SOLUTION 1

1.1 galvanic/voltaic cell
1.2 Incomplete circuit/No salt bridge
1.3 0,76 V
1.4 Zero

1.5 $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$

1.6.1 Mg
Mg is oxidised

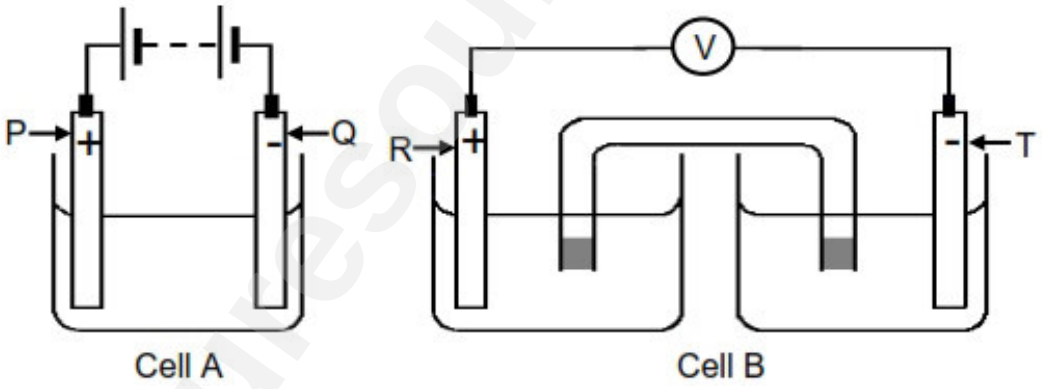
1.6.2 $E^0_{cell} = E^0_{oxidizing\ agent} - E^0_{reducing\ agent}$
$= - 0,76 - (- 2,36)$
$= + 1,6$ V

1.6.3 As the cell functions, the concentration of zinc ions (reactants) decreases relative to standard conditions and the concentration of magnesium ions (products) increases relative to standard conditions. The reverse reaction starts opposing the forward reaction causing the emf to decrease relative to standard conditions.

1.7
- Neutralise acid before disposal
- Recycle plastic casing and lead electrodes

QUESTION 2 (NOV 2009/P2/Q9)

The diagrams below represent two types of electrochemical cells. The electrodes of Cell A are labelled P and Q, and the electrodes of Cell B are labelled R and T.



2.1 Use the labels P, Q, R or T to identify the anode in:
2.1.1 Cell A (1)
2.1.2 Cell B (1)

2.2 Cell A represents the type of cell that can be used to plate an iron coin with nickel.
2.2.1 Write down the formula of the ION that can be used as oxidising agent in this cell. (1)
2.2.2 Which electrode, P or Q, should consist of the iron coin? Write down the relevant half-reaction that will occur at this electrode. (3)
2.2.3 The concentration of the electrolyte does not change during this process. Explain how this is possible. (2)
2.2.4 Apart from it looking attractive, what is the advantage of electroplating iron? (1)

+

2.3 An Al/Al^3 and a Ag^+/Ag half-cell is used to construct Cell B. A reading is noted on the voltmeter.

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2.3.1 State the energy conversion that occurs in this cell. (2)

2.3.2 Write down a balanced equation for the overall (or net) cell reaction taking place in this cell. (3)

2.3.3 Calculate the EMF of this cell at standard conditions. (4)

2.3.4 Distilled water is added to the Ag+ solution. How will the EMF of the cell be affected? Write only INCREASES, DECREASES or REMAINS THE SAME. (1)

2.3.5 In which direction will electrons flow in the external circuit? Write only 'from Al to Ag' or 'from Ag to Al'. (1)

[20]

SOLUTION 2

2.1.1 P

2.1.2 T

2.2.1 $Ni^{2+}(aq)$

2.2.2 Q
$Ni^{2+} + 2e^- \rightarrow Ni$

2.2.3 For each mole of nickel oxidised at the anode a mole of nickel is reduced at the cathode.

2.2.4 Protects iron from rusting

2.3.1 Chemical energy to electrical energy

2.3.2 $A\ell + 3Ag^+ \rightarrow A\ell^{3+} + 3Ag$ Bal

2.3.3 $E^0_{cell} = E^0_{oxidizing\ agent} - E^0_{reducing\ agent}$

$= 0,80 - (- 1,66)$
$= 2,46\ V$

2.3.4 Decreases

2.3.5 Aℓ to Ag

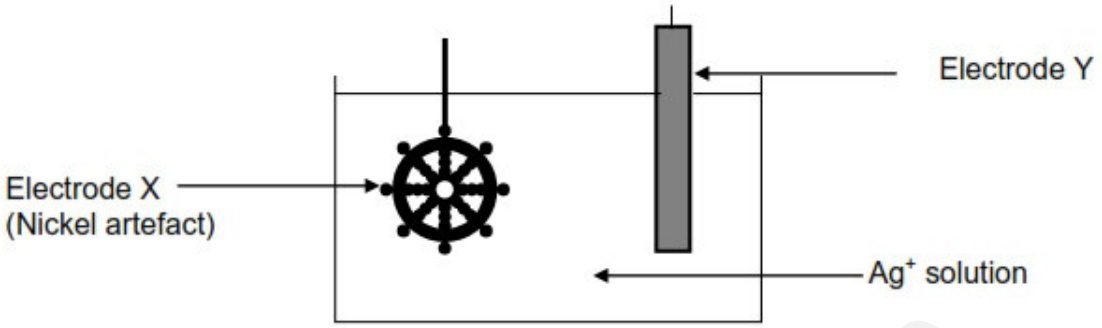
QUESTION 3 (FEB 2009/P2/Q11)

An attractive silver appearance can be created by electroplating artefacts made from cheaper metals, such as nickel, with silver.

The simplified diagram below represents an arrangement that can be used to electroplate a nickel artefact with silver.

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3.1 Which electrode (cathode/anode) will the nickel artefact represent? (1)
3.2 Name the metal represented by electrode Y. (1)

3.3 Write down the half-reaction responsible for the change that occurs at the surface of the artefact. (2)

3.4 Give a reason why the concentration of the electrolyte remains constant during electroplating. (2)

3.5 In industry some plastic articles are sometimes electroplated. Explain why plastic must be coated with graphite before electroplating. (2)

3.6 Give a reason why, from a business point of view, it is not advisable to plate platinum with silver. (1)
[9]

SOLUTION 3

3.1 cathode

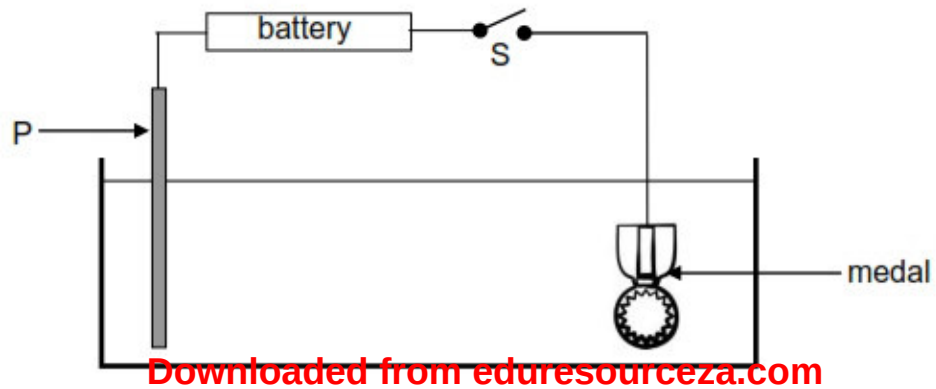
3.2 Silver

3.3 $Ag^+ + e^- \rightarrow Ag$

3.4 The rate of oxidation of silver at the anode is equal to the rate of reduction of silver ions at the cathode.
3.5 Plastic is a non-conductor/Graphite is a conductor
3.6 Platinum is expensive/more durable than other metals

QUESTION 4 (NOV 2010/P2/Q9)

The diagram below represents a cell that can be used to electroplate a tin medal with a thin layer of silver to improve its appearance.



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4.1 Which one of P or the MEDAL is the anode in this cell? (1)

4.2 Write down the following:

4.2.1 NAME or SYMBOL of the element of which electrode P is composed (1)
4.2.2 NAME or FORMULA of the electrolyte that has to be used to achieve the desired results (1)

4.3 Switch S is now closed. Write down the visible changes that will occur at the following:

4.3.1 Electrode P (1)
4.3.2 The medal (1)

4.4 Write down the equation for the half-reaction to support the answer to QUESTION 4.3.2. (2)

4.5 How will the concentration of the electrolyte change during the electroplating process? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1)

4.6 You want to coat the medal with copper instead of silver. State TWO changes that you will make to the above cell to obtain a medal coated with copper. (2)

[10]

SOLUTION 4

4.1 P

4.2 4.2.1 Ag / Silver

4.2.2 Silver nitrate / $AgNO_3$ or silver ethanoate /acetate / CH_3COOAg.

(These are the only two soluble silver salts.)

4.3 4.3.1 Silver /metal bar becomes eroded /pitted/ smaller / thinner / eaten away

4.3.2 A (silver) layer forms on the medal.

4.4 $Ag^+ + e^- \rightarrow Ag$

4.5 Remains the same.

4.6 Replace the silver solution with a copper solution/soluble copper salt.

Replace the silver bar/electrode P/anode with a copper bar.

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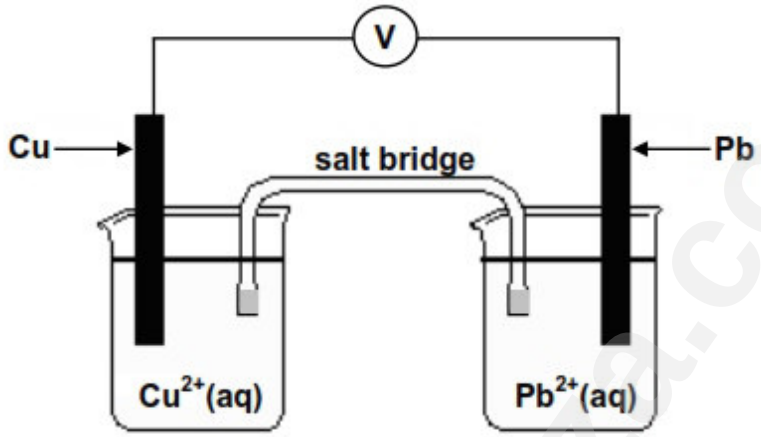
TASK 15

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QUESTION 1 (NOV 2011/P2/Q8)

The potential difference of a galvanic cell, measured experimentally by learners, is COMPARED with its potential difference calculated at standard conditions.

They set up the galvanic cell shown below.



The voltmeter measures an initial reading of 0,3 V.

1.1 Write down the energy conversion that takes place in this cell. (1)

1.2 State ONE function of the salt bridge. (1)

1.3 Write down the half-reaction that takes place at the anode. (2)

1.4 In which direction do electrons flow in the external circuit when this cell delivers a current? Write down only 'from Cu to Pb' or 'from Pb to Cu'. (1)

1.5 Write down the balanced net (overall) cell reaction. (3)

1.6 Is the cell reaction exothermic or endothermic? (1)

1.7 Use the Table of Standard Reduction Potentials to calculate the initial potential difference (emf) of the above cell at STANDARD CONDITIONS. (4)

1.8 From the results obtained the learners conclude that the measured potential difference differs from the calculated potential difference.

Give TWO possible reasons for this difference in values. (4)

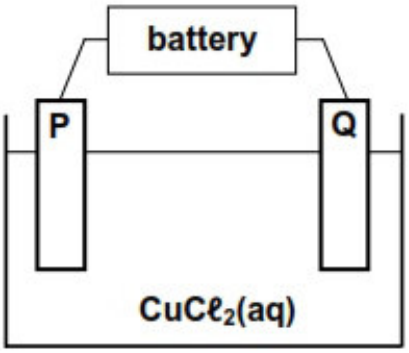
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QUESTION 2 (NOV 2011/P2/Q9)

In the electrolytic cell, represented below, two CARBON RODS are used as electrodes and a concentrated copper(II) chloride solution is used as electrolyte.



When the cell is functioning, a gas is released at electrode P, whilst electrode Q is coated with a reddish brown layer.

9.1 Define the term electrolyte. (2)

9.2 Write down a half-reaction to explain the observation made at:

9.2.1 Electrode P (2)

9.2.2 Electrode Q (2)

9.3 Which electrode, P or Q, is the cathode? Give a reason for the answer. (2)

9.4 The carbon rods in the above cell are now replaced with COPPER RODS.

The following observations are made at electrode P:

- No gas is released.
- Its surface appears rough and eroded.

9.4.1 Refer to the RELATIVE STRENGTHS OF REDUCING AGENTS to explain this observation. (3)

9.4.2 This cell can be used for the refining of copper. Which electrode (P or Q) will be replaced with impure copper during the refining process? (1)

[12]

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TOPIC 13: CHEMICAL INDUSTRY

THE FERTILIZER INDUSTRY (N, P, K)

- Plants produce their own food to survive
- The process by which they produce their food is called **photosynthesis**

Non - mineral nutrients

- To produce their own food (which is mainly in form of starches and sugars), plants absorbs carbon dioxide and water in the presence of light energy
- Carbon dioxide (CO_2) and water (H_2O) contains the three main non-mineral nutrients namely:

C - carbon
H - hydrogen
O - oxygen

- Sources of these non-minerals are water and air
- The supply of these nutrients is constant and hence no need to control them

Mineral nutrients

- Mineral elements are considered **essential elements** (essential for plant nutrition) when:
  - they are involved in plant metabolic functions
  - the plant cannot complete its cycle without the element
  - deficiency of these elements can be seen by symptoms that the plant will
  - show, and can be corrected by applying the relevant nutrient in correct proportion

- Mineral nutrients are divided into **macronutrients** and **micronutrients**
- Macronutrients are also divided int **primary** and **secondary** nutrients
- Primary nutrients are Nitrogen (N), Phosphorus (P), and Potassium (K)
- Mineral nutrients dissolve in water in the soil and are absorbed by the roots of plants
- The supply of these nutrients is not constant and hence they need to be controlled
- Excess or shortage of the nutrients will have a negative effect on the yield of the plant
- So to correct shortage of these nutrients fertilizers are needed, since there are not always enough of these nutrients in the soil for healthy growth of plants

Advantages of inorganic fertilizers

- **Inorganic fertilizers** are artificial fertilizers manufactured chemically in the laboritory or refinery
- The following are the advantages of inorganic fertilizers:
  (i) dissolve quickly and are immediately available for plant use
  (ii) predefined content of nutrients is guaranteed - contains all nutrients that are ready to use
  (iii) they are easy to use
  (iv) cheaper than organic fertilizers
  (v) saves time and effort

Alternatives to inorganic fertilizers (IKS)

(i) Use cover crops
(ii) Use animal byproducts e.g bone meal, blood meal etc
(iii) Use plant byproducts e.g soybean meal, maize meal, animal manure etc
(iv) Crop rotation
(v) Lime application

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EUTROPHICATION

Is a phenomenon whereby Nitrogen - rich (and phosphorus) nutrients or fertilizers get into water causing rapid growth of algae. When algae die, their decomposition by bacteria removes oxygen from water, and hence living organisms die.

CAUSES OF EUTROPHICATION

- over - application of fertilizers
- emissions from vehicles
- factory emissions
- sewage; waste disposal systems
- stock farming

PREVENTION OF EUTROPHICATION

- control (reduce) the use of fertilizers
- control (reduce) waste disposal
- control vehicle and factory emissions

NEGATIVE EFFECTS OF EUTROPHICATION

- leads to dead zones
- excessive alien growth at the expense of indigenous plants
- ground water contamination (when fertilizers seeps into the ground)
- Blue baby syndrome

N, P, K FERTILIZERS

FUNCTIONS OF N, P, K IN PLANTS

(I) NITROGEN (N)

- for rapid growth and green leaves

(ii) PHOSPHORUS (P)

- for strong roots
- better yield and quality of fruits
- flower development

(iii) POTASSIUM (K)

- protects against cold and dry whether

SOURCES OF N, P, K

NITROGEN (N) - **Guano** : is the excrement of birds which has exceptionally high content of nitrogen, phosphorus and potassium. It was the main source of fertilizers before and after world war one

PHOSPHORUS (P) - **Bone meal** : is a mixture of grounded animal bones with exceptionally high content of phosphorus. It was the main source of fertilizers before and after world war one. Phosphorus is also found in super phosphates e.g $Ca(H_2PO_4)_2$

POTASSIUM (K) - **German mines**: potassium cannot be manufactured synthetically. The main source of potassium where German mines which had potassium salt rocks or potassium bearing salt solutions underground. It is mostly found in the form of potash. Potash is a blanket name for compounds such as KNO_3, K_2SO_4, KNO_3

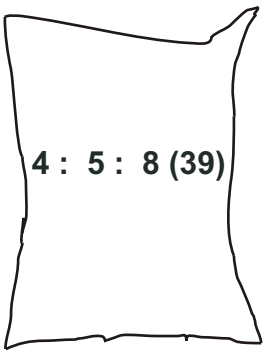
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N: P: K FERTILIZER RATIO

- N: P: K ratio gives the proportion of nitrogen, phosphorus and potassium in a fertilizer
- Suppose we are given a fertilizer bag with ratio as shown below:

4 + 5 + 8 = 17



- what this ratio means is 39% of the fertilizer mass in the bag constitutes of N, P and K
- $\frac{4}{17}$ of 39% is a % containing N
- $\frac{5}{17}$ of 39% is a % containing P
- $\frac{5}{17}$ of 39% is a % containing K

- Now a question comes, what is the 61% (100% - 39%) of the mass in the fertilizer bag made up of?
- The remainder mass constitutes of **fillers**
- A filler: is a non-nutrient material added to a fertilizer mixture to make up the differences between the mass of nutrient materials and the desired mass of fertilizer
- Examples of filler materials are sand, soil, ashes, saw dust etc

Mass of N, P and K

- Given the N:P:K ratio and mass of contents in the fertilizer bag, it is possible to determine the mass of N, P and K

Example 1

A 50kg fertilizer bag is written 3:1:2 (38), determine the mass of N, P and K

Solution 1

Percentage of N:

$\frac{3}{6}$ x 38% = 19%

Mass of N :

$\frac{19}{100}$ x 50kg = 9.5kg

Percentage of P:

$\frac{1}{6}$ x 38% = 6.33%

Mass of P :

$\frac{6.33}{100}$ x 50kg = 3.17kg

Percentage of N:

$\frac{2}{6}$ x 38% = 12.67%

Mass of N :

$\frac{12.67}{100}$ x 50kg = 6.33kg

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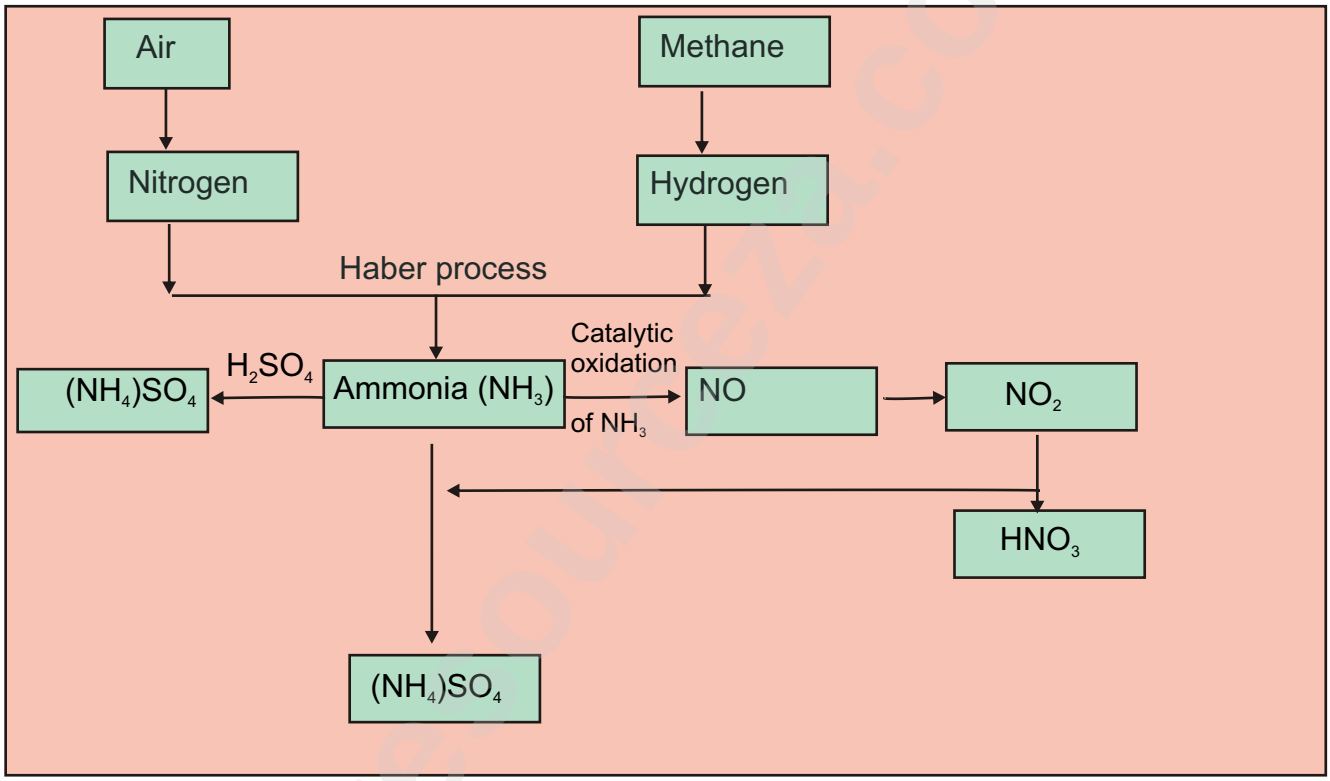
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MANUFACTURE OF FERTILIZERS

- The gap between food production and demand in several parts of the world is influenced by population growth and urbanization, as well as income levels and changes in dietary preferences
- Due to repeated cultivation over years, most soils in the world lacks the necessary nutrients for the crops
- Soil cannot replenish nutrients at a fast enough rate to sustain growth and globally there is bigger demand for food
- Hence fertilizers are greatly needed to replenish the lost nutrients faster and meet the global demand for food

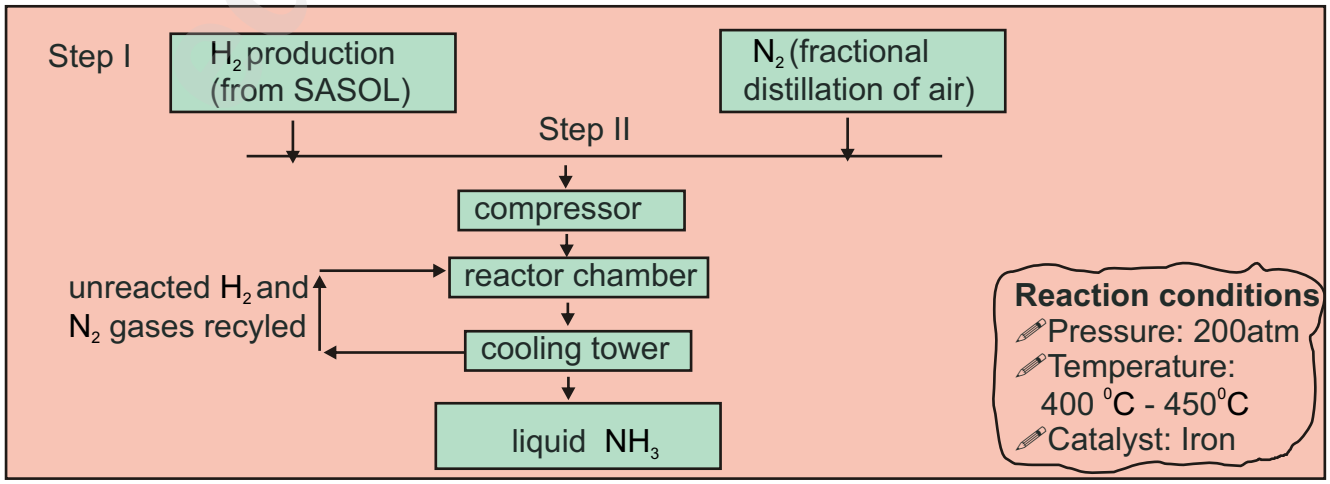
FLOW DIAGRAM TO SHOW THE MAIN STEPS IN THE INDUSTRIAL PREPARATION OF FERTILIZERS

- Fertilizers are made by neutralizing sulphuric acid / nitric acid with ammonia as shown in the flow diagram below:



HABER PROCESS

- This is one of the industrial preparations for ammonia
- The following is the **flow diagram** for the preparation of ammonia using the Haber process:



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✎**Stage I** is the preparation of H_2 and N_2 gas)

H_2 - at SASOL from coal and steam
N_2 - from fractional distillation of air

✎**Stage II** is the preparation of NH_3

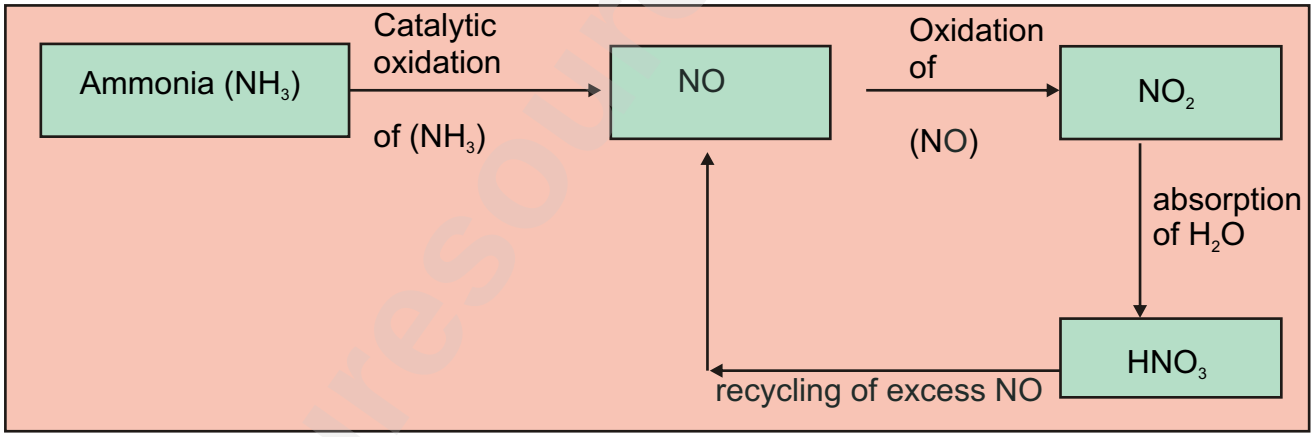
Hydrogen is reacted with nitrogen as shown below:

$$3H_2(g) + N_2(g) \rightleftharpoons NH_3(g) \quad \Delta H < 0$$

✎The reaction is an exothermic one
✎**According to Le Chatelier's principle** high yield of NH_3 favoured by lowering the temperature in the reaction
✎However lowering temperature will result in a **slow rate of reaction**
✎High temperatures on the other hand will produce NH_3 at a **faster rate**, even though the **yield is lower**
✎Therefore it is more economical to have a lower yield produced at a faster rate than vice versa
✎ It is for this reason that high temperatures of approximately 450 ^{0}C are used in the Haber process

OSTWALD PROCESS

✎Is one of the processes used in the production of nitric acid



✎**Stage I** is catalytic oxidation of NH_3
The following is a reaction for the catalytic oxidation of NH_3

$$4NH_3(g) + 5O_2(g) \xrightarrow[\text{(catalyst)}]{\text{Pt, Rd}} 4NO(g) + 6H_2O(g) \quad \Delta H = -905.2kJ \text{ (strongly exothermic)}$$

Reaction conditions
✎Pressure : 4 - 10atm
✎Temperature: ±900^{0}C
✎Catalyst: Pt or Rd

✎**Stage II** is the oxidation of NO
The following is a reaction for the oxidation of NO

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

✎**Stage III** is the absorption stage (the NO_2 gas is readily absorbed by water)
The following is a reaction for the absorption of $NO_2(g)$ by water

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In the presence of **limited oxygen**

$3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(g) + NO(g)$ (NO is recycled)

OR

In the presence of **excess oxygen**

$4NO_2(g) + 2H_2O(l) + O_2(g) \rightarrow 4HNO_3(aq)$

Application of Le Chartelier's principle

- Since the overall reaction is exothermic, theoretically according to Le Chartelier's principle increasing temperature will shift the position of equilibrium to the left, thereby reducing the yield of nitric acid
- However in practice lower temperatures slow the rate of reaction to uneconomical levels
- Therefore high temperatures of 1000^0C is used to provide activation energy and increase the rate of reaction
- According to Le Chartelier's principle, adding more pressure will favor forward reaction (with fewer molecules)

CONTACT PROCESS

- Is one of the industrial processes used in the production of sulphuric acid (H_2SO_4)
- The following are the steps involved in the production of sulphuric acid:

Step I: $S(s) + O_2(g) \rightarrow SO_2(g)$

- combining sulphur with oxygen to produce sulphur dioxide

Step II: $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ $\Delta H = -197$ kJ

- adding excess oxygen to sulphur dioxide in the presence of a catalyst to produce sulphur trioxide
- **Reaction conditions**

  Temperature : $450\ ^0C$
  Catalyst: Vanadium (V) oxide
  Pressure: 1 atm

Step (IV): $SO_3(g) + H_2SO_4(l) \rightarrow H_2S_2O_7(l)$

- adding sulphur trioxide to sulphuric acid to produce oleum

Step (V): $H_2S_2O_7(l) + H_2O(l) \rightarrow H_2SO_4(aq)$

- Adding oleum to water to produce sulphuric acid

Interpretation using Le Chaterlier's principle

- Consider the reaction below:

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ $\Delta H = -197$ kJ

- Theoretically, according to Le Chaterlier's principle, lowering temperature in the above reaction will shift the chemical equilibrium to the right, and hence increase percentage yield

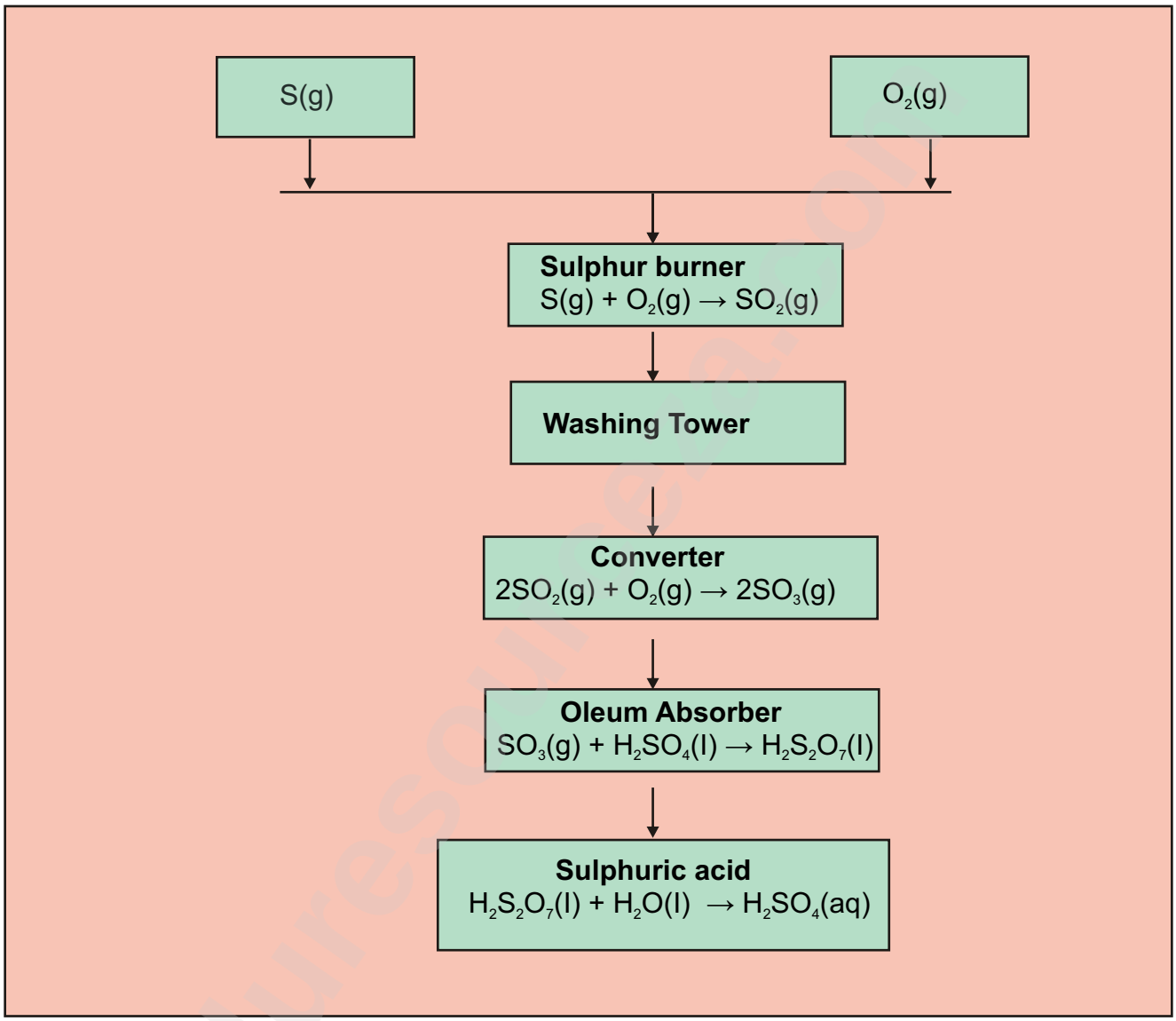
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of SO_3.

- But practically very low temperatures will slow the rate of reaction to an uneconomical level
- In order to make the reaction economical, it is better to increase rate of reaction by using high temperatures (450 ^{0}C), medium pressure (1 - 2 atm), and vanadium (5) oxide catalyst

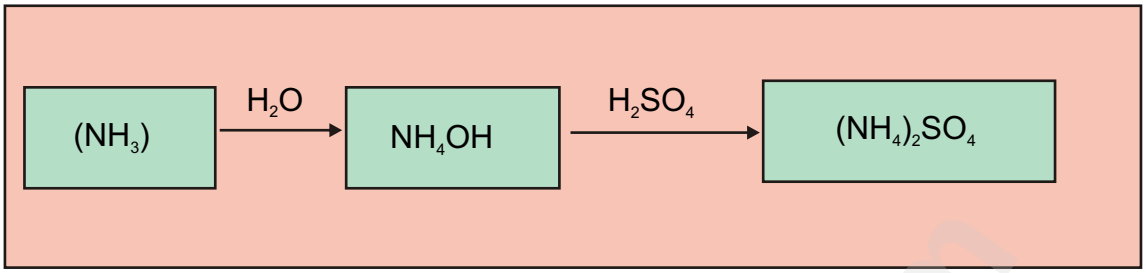
FLOW DIAGRAM FOR THE CONTACT PROCESS



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(i) Ammonium sulphate fertilizer



✎Sulphuric acid is **neutralized** with ammonia according to the following chemical reactions:

- Ammonia is first hydrated to form ammonium hydroxide as follows:
  NH_3 (g) + H_2O (l) → NH_4OH (aq)

- Ammonium hydroxide is then added to sulphuric acid, and will be neutralized to form salt (ammonium sulphate) and water as shown below:

$2NH_4OH$ (aq) + H_2SO_4 (l) → $(NH_4)_2SO_4$ (s) + H_2O (l)

✎Water is then evaporated from the mixture to separate ammonium sulphate, which will be ready for use

(ii) Ammonium nitrate fertilizer

✎Nitric acid is **neutralized** with ammonia according to the following chemical reactions:

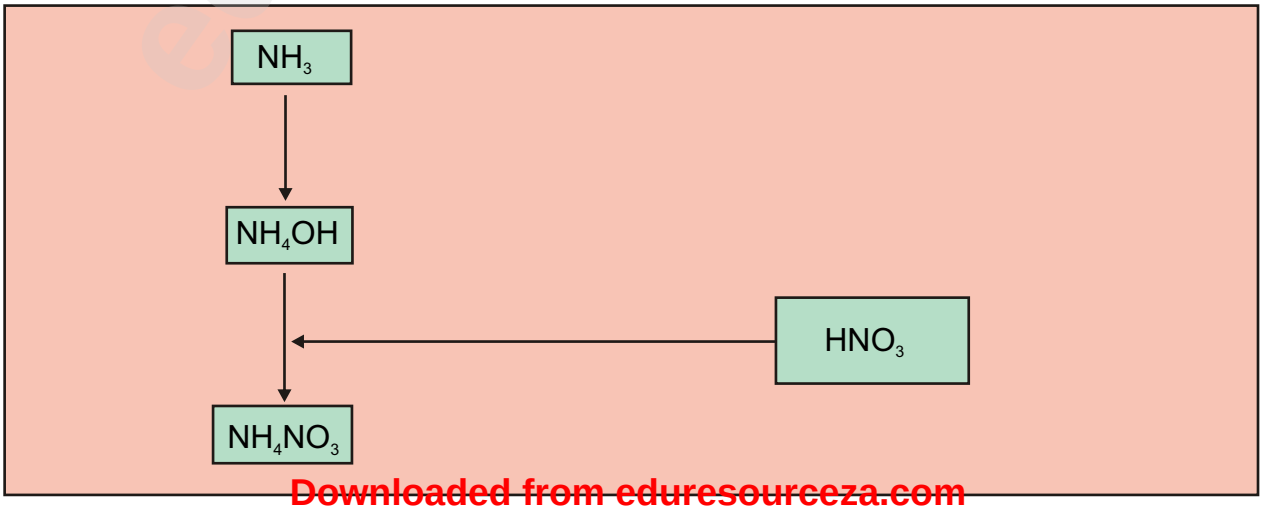
- Ammonia is first hydrated to form ammonium hydroxide as follows:
  NH_3 (g) + H_2O (l) → NH_4OH (aq)

- Ammonium hydroxide is then added to nitric acid, and will be neutralized to form salt (ammonium nitrate) and water as shown below:

NH_4OH (aq) + HNO_3 (l) → NH_4NO_3 (s) + H_2O (l)

✎Water is then evaporated from the mixture to separate ammonium nitrate, which will be ready for use

✎The following flow diagram shows the steps involved in the production of ammonium nitrate



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(iii) Urea fertilizer

Bosch Meiser urea process

- This is one of the industrial processes which is used in the production of urea
- It involves two main steps

Step I: carbamate formation

$2NH_3(l) + CO_2(g) \rightleftharpoons H_2N\text{-}COONH_4$ (ammonium carbamate) $\Delta H < 0$

- The above reaction is a fast exothermic reaction between $NH_3(l)$ and $CO_2(g)$

Step II: urea formation

$H_2N\text{-}COONH_4 \rightleftharpoons (NH_2)_2CO + H_2O$ $\Delta H > 0$

- The above reaction is a slow endothermic decomposition of ammonium carbamate into urea and water

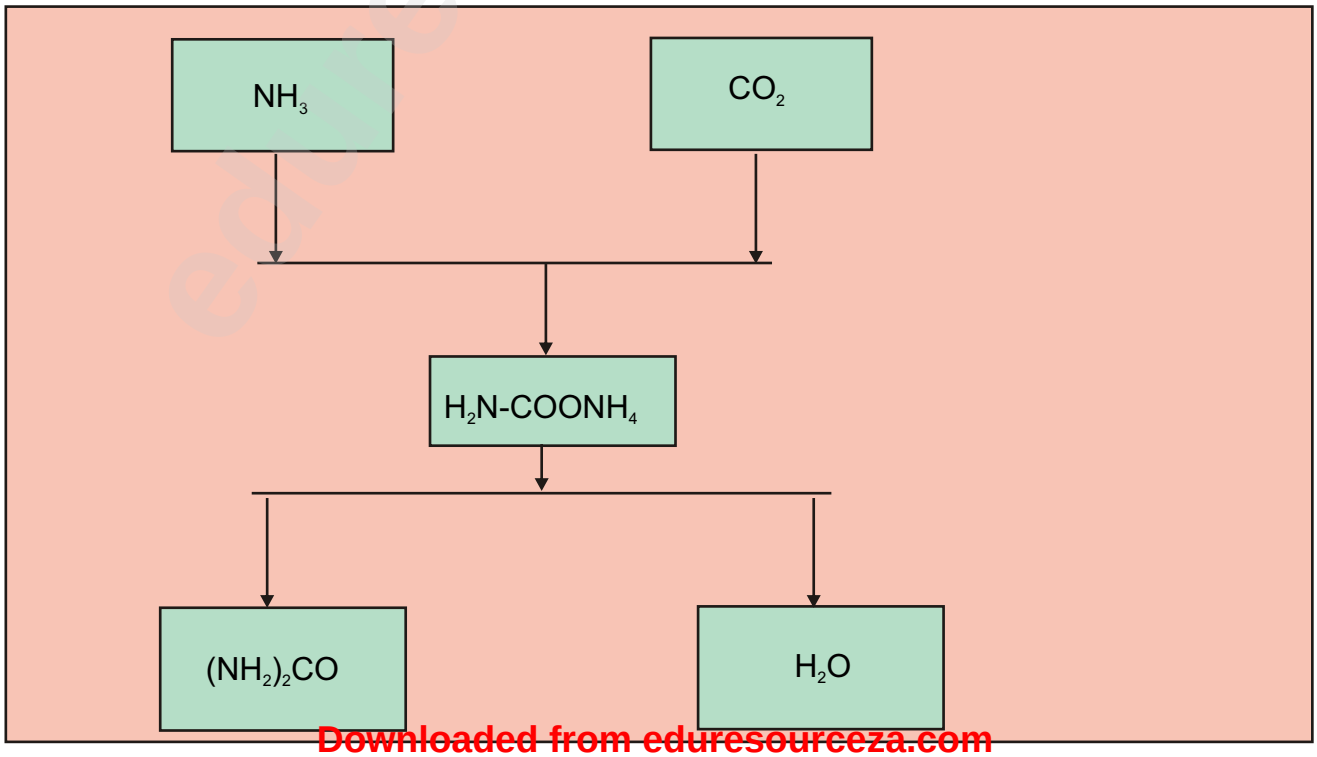
Reaction conditions

- High temperature
- High pressure

According to Le Chartelier's principle a high temperature will slow down the formation of ammonium carbamate and hence less yield of urea. But however this ill-effect is compensated by high pressure (since pressure will favour the forward reaction with less number of molecules)

NOTE: The overral reaction for the formation of urea is exothermic as shown below:

$2NH_3(aq) + CO_2(aq) \rightarrow CH_4N_2O(aq) + H_2O(l)$ $\Delta H < 0$



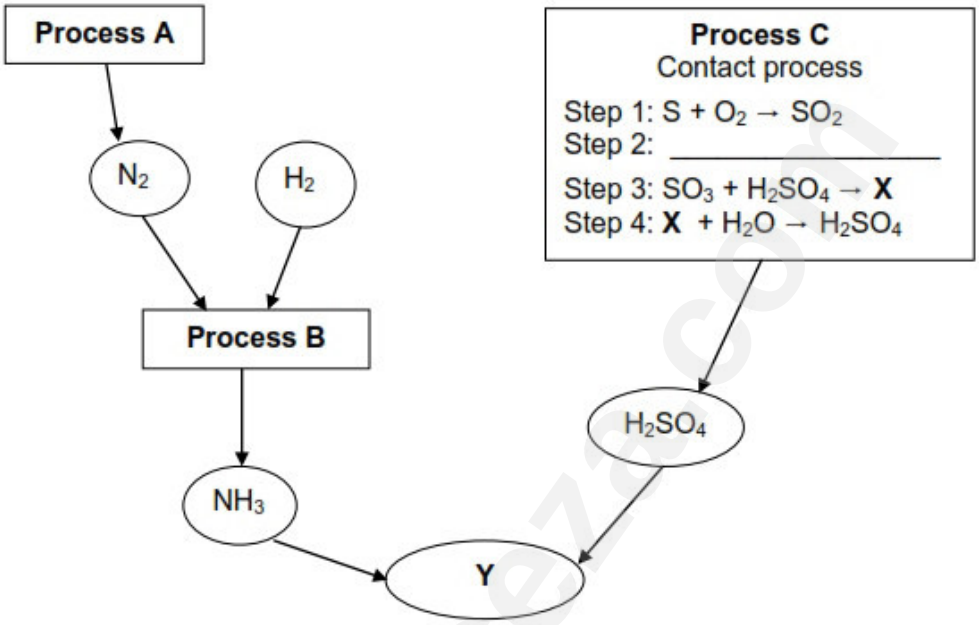
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EXAM TYPE WORKED EXAMPLES

QUESTION 1 (FEB 2009/P2/Q12)

About one third of the protein consumed by humans comes from fertilisers. The flow diagram below shows three industrial processes, A, B and C, that result in the production of fertilisers.



1.1 Write down the name of the Process A. (1)

1.2 Write down the balanced equation for the reaction which takes place in process B. (3)

1.3 Write down the balanced equation for step 2 of Process C. (3)

1.4 Write down the FORMULA and the NAME of product X in step 3 of Process C. (2)

1.5 Write the FORMULA and the NAME of the fertiliser represented by Y. (3)

1.6 Fertiliser prices increased by more than 200 per cent since 2007. This rise is fuelled by new demand.

1.6.1 Give TWO reasons why there is a continuous demand for fertilisers. (2)

1.6.2 Give TWO reasons why there is an increase in the price of fertilisers. (2)
[16]

SOLUTION 1

1.1 Fractional distillation of (liquid) air
1.2 $3H_2 + N_2 \rightleftarrows 2NH_3$ bal
1.3 $2SO_2 + O_2 \rightleftarrows 2SO_3$ bal
1.4 $H_2S_2O_7$
Oleum/pyrosulphuric acid
1.5 $(NH_4)_2SO_4$
Ammonium sulphate
1.6.1 Soil cannot replenish nutrients at a fast enough rate to sustain

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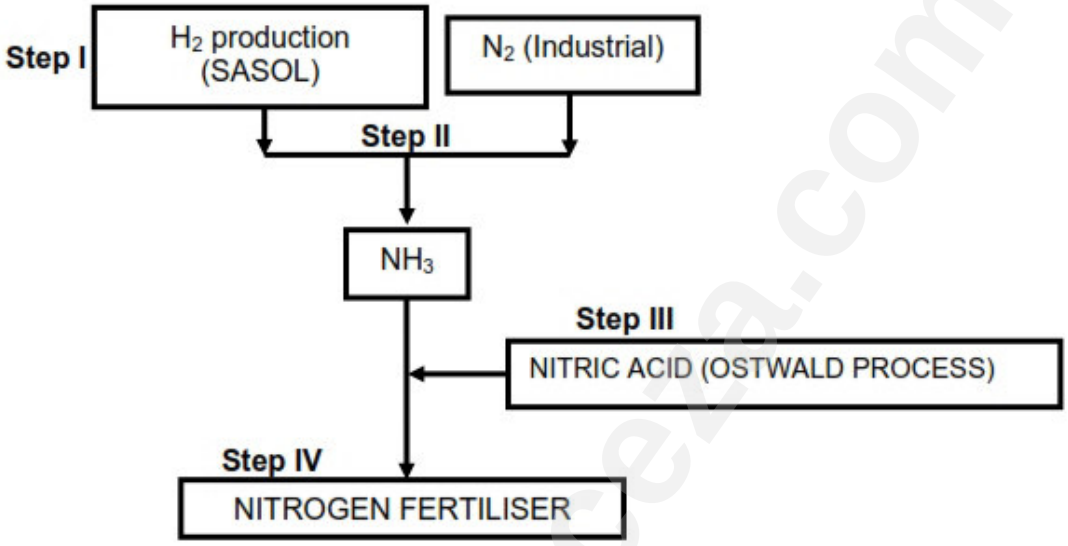
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1.6.1 - Soil cannot replenish nutrients at a fast enough rate to sustain growth.
- Globally a bigger demand for food

1.6.2 - Increase in oil price
- Increase in price of raw materials

QUESTION 2 (FEB 2010/P2/Q12)

A learner who is revising for a test on fertilisers, summarises her notes as follows:



2.1 Write down the NAME of the industrial process in Step I used to extract nitrogen gas from the atmosphere. (1)

2.2 The Haber process, indicated in Step II, is represented by the following equation:

$$3H_2(g) + N_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H < 0$$

In this process, high temperatures of approximately 450 °C are used.

Explain in terms of reaction rate, equilibrium and temperature why such a high temperature, and not a lower temperature, is used. (4)

2.3 Write a balanced chemical equation for the reaction that produces the nitrogen fertiliser in Step IV. (3)

2.4 The learner decides to educate the community about the possible negative effects of the overuse of nitrogen fertilisers on the environment.

Write down the main arguments that she will raise to convince the community to avoid excessive use of nitrogen fertilisers. (4)

2.5 The learner notes that fertiliser with an *NPK* ratio of 7:1:1 is needed for the growth of maize plants.

2.5.1 State what the term NPK ratio means. (2)

2.5.2 Will the fertiliser with this NPK ratio lead to a good crop yield? Explain the answer. (3)

[17]

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SOLUTION 2

2.1 Fractional distillation

2.2 Low temperature increases the amount of NH_3.
Rate is too slow.
At higher temperature NH3 is produced at a faster rate.

2.3 $HNO_3(aq) + NH_3(g) \rightarrow NH_4NO_3(aq)$ bal

2.4 - Rain washes excess of fertilisers into dams, lakes, streams and rivers causing eutrofication that leads to dead zones.
- Excessive fertiliser in the environment promotes excessive alien growth at the expense of indigenous plants.
- Groundwater can be contaminated when excessive fertiliser seeps into it.
- Nitrates in water that can result in blue baby syndrome.

2.5.1 The ratio (proportion) in which nitrogen, phosphorous and potassium occurs in a certain quantity of fertiliser.

2.5.2 No
The higher proportion of N will enhance leaf growth and less crops.

QUESTION 3 (NOV 2011/P2/Q11)

Nitric acid is used in the preparation of fertiliser. The flow diagram below shows the three steps (**A**, **B** and **C**) in the industrial preparation of nitric acid.



3.1 Write down the following:

3.1.1 Name of this industrial process in the preparation of nitric acid (1)

3.1.2 Balanced equation for step **B** (3)

3.2 $NH_3(g)$ reacts with $O_2(g)$ to form two products in step **A**. One of the products is nitrogen(II) oxide. Write down the NAME or FORMULA of the OTHER product. (1)

3.3 In step **C**, water is added to the reaction mixture. This step can be represented by the following incomplete equation:

NO2(g) + ___+ H2O(ℓ) → HNO3(ℓ)

Copy the above incomplete equation into your ANSWER BOOK, fill in the missing reactant and balance the equation. (2)

3.4 A 50 kg bag of fertiliser is labelled as shown in the diagram below.

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Calculate the mass of nitrogen present in this bag of fertiliser. (3)

3.5 Uncontrolled use of fertiliser may cause excess fertiliser to run down into streams and rivers, leading to eutrophication.

State ONE negative impact that eutrophication in water may have on humans. (2)
[12]

SOLUTION 3

11.1
11.1.1 Ostwald process (1)
11.1.2 $2NO + O_2 \rightarrow 2NO_2$ Balancing (3)
11.2 H2O / water (1)
11.3 4NO2+ O2 + 2H2O → 4HNO3 Balancing (2)

11.4. $\frac{3}{9} \times 30 = 10\%$

↔ 10% of 50kg = 5kg (3)

11.5 **ANY ONE:**
- Fish / Aquatic life dies.
  Results in loss of income / jobs / food.
- Leads to poor water quality.
  Not enough drinking water. / Poses health risk.
- Water recreation areas become unattractive / dangerous.
  Lack of income due to decline in tourism. / Less recreation facilities.

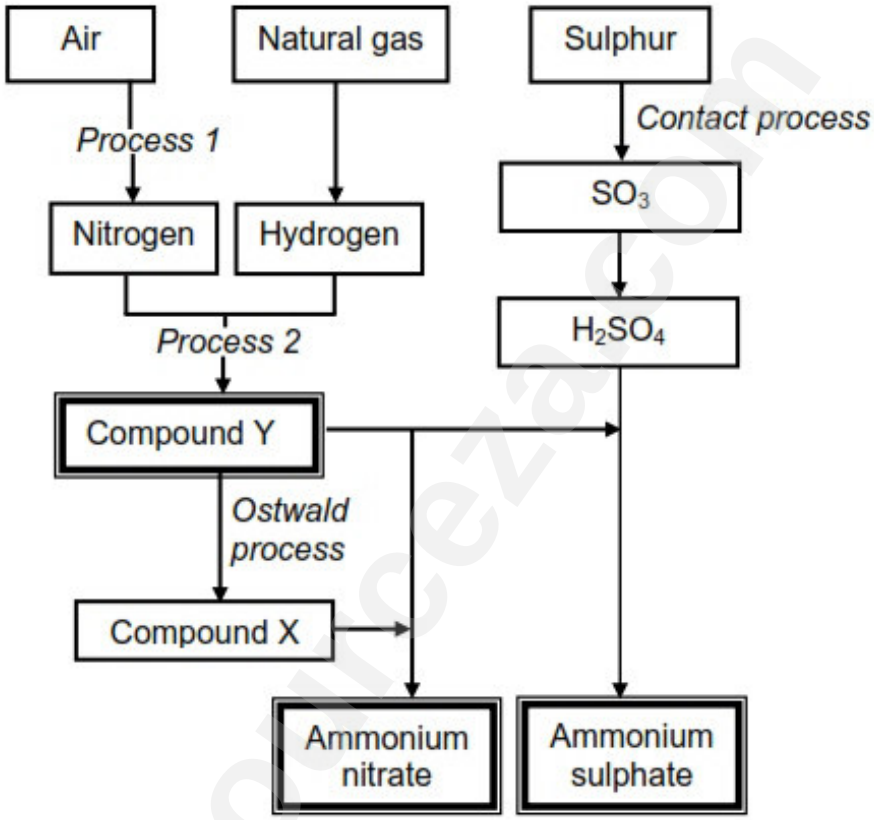
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TASK 16

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QUESTION 1 (NOV 2010/P2/Q7)

Ammonia, ammonium nitrate and ammonium sulphate are three important nitrogen-containing fertilisers. The flow diagram below shows how these fertilisers are produced in industry



1.1 Use the information in the flow diagram above and write down the following:

1.1.1 Name of Process 1 (1)

1.1.2 Balanced equation for Process 2 (3)

1.1.3 NAME or FORMULA of compound X (1)

1.1.4 Balanced equation for the preparation of ammonium sulphate using sulphuric acid and compound Y (3)

1.1.5 NAME or SYMBOL of the primary nutrient in ammonium sulphate (1)

1.2 Write down ONE positive impact of fertilisers on humans. (2)

1.3 Write down TWO negative impacts of the use of ammonium nitrate, as fertiliser, on humans. (4)

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Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE

GRADE 12

PHYSICAL SCIENCES: PHYSICS (P1)

FEBRUARY/MARCH 2012

MARKS: 150

TIME: 3 hours

This question paper consists of 16 pages and 3 data sheets.

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INSTRUCTIONS AND INFORMATION

1. Write your centre number and examination number in the appropriate spaces on the ANSWER BOOK.

2. Answer ALL the questions in the ANSWER BOOK.

3. This question paper consists of TWO sections:

   SECTION A (25)
   SECTION B (125)

4. You may use a non-programmable calculator.

5. You may use appropriate mathematical instruments.

6. Number the answers correctly according to the numbering system used in this question paper.

7. YOU ARE ADVISED TO USE THE ATTACHED DATA SHEETS.

8. Give brief motivations, discussions, et cetera where required.

9. Round off your final numerical answers to a minimum of TWO decimal places.

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SECTION A

QUESTION 1: ONE-WORD ITEMS

Give ONE word/term for each of the following descriptions. Write only the word/term next to the question number (1.1–1.5) in the ANSWER BOOK.

1.1 The type of energy an object has due to its motion (1)

1.2 The phenomenon which occurs when two light waves meet at a given point (1)

1.3 The unit of measurement of electrical resistance (1)

1.4 The basic principle on which electric generators function (1)

1.5 The type of line spectrum observed when electrons in an atom move from the excited state to the ground state (1)
[5]

QUESTION 2: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Write only the letter (A–D) next to the question number (2.1–2.10) in the ANSWER BOOK.

2.1 A car of mass m collides head-on with a truck of mass $2m$. If the car exerts a force of magnitude F on the truck during the collision, the magnitude of the force that the truck exerts on the car is …

A $\frac{1}{2}F$

B F

C $2F$

D $4F$ (2)

2.2 An object moves in a straight line on a ROUGH horizontal surface. If the net work done on the object is zero, then …

A the object has zero kinetic energy.

B the object moves at constant speed.

C the object moves at constant acceleration.

D there is no frictional force acting on the object. (2)

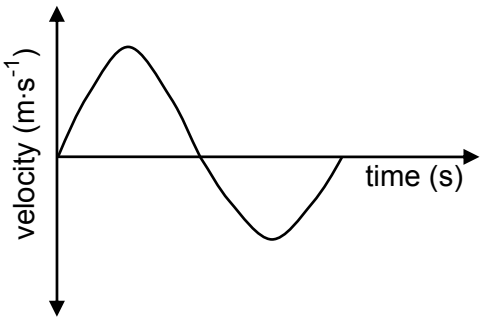
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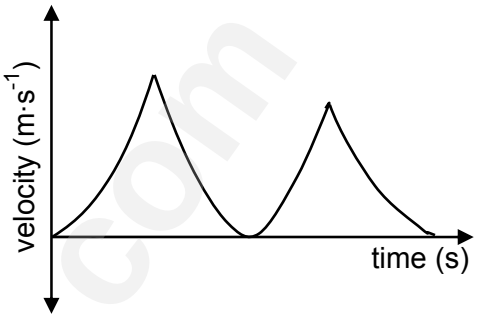
2.3 A ball is released from rest from a certain height above the floor and bounces off the floor a number of times. Ignore the effects of air resistance.

Which ONE of the following velocity-time graphs best represents the motion of the ball?

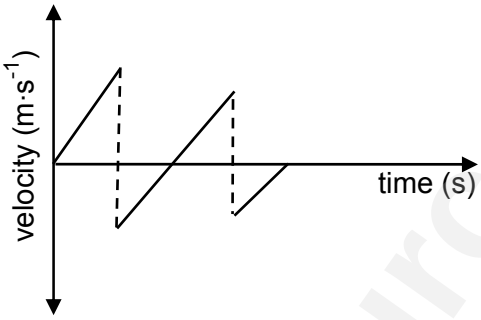
A



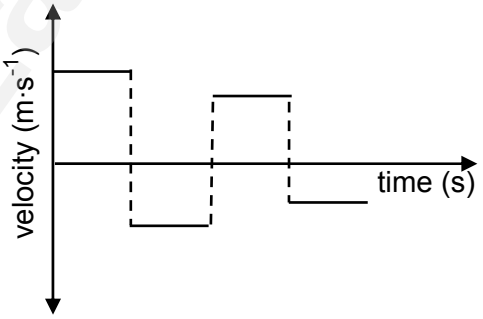
B



C

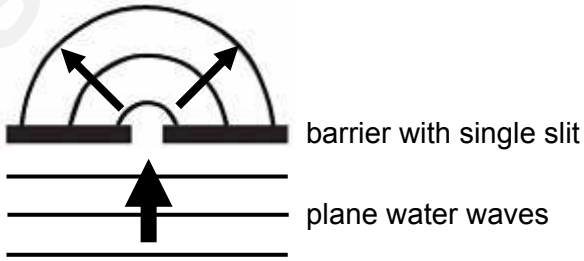


D



(2)

2.4 The diagram below shows plane water waves that spread out after passing through a single slit.



The wave phenomenon observed after the water waves pass through the slit is …

A reflection.

B diffraction.

C refraction.

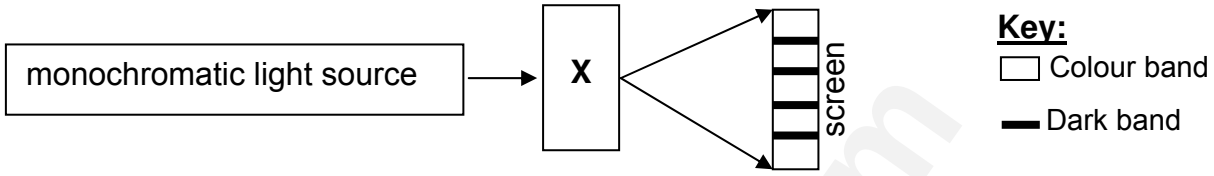
D photoelectric effect. (2)

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2.5 Monochromatic light from a point source passes through a device **X**.

A pattern is observed on a screen, as shown in the diagram below.



From the observation on the screen, it can be concluded that device **X** is a …

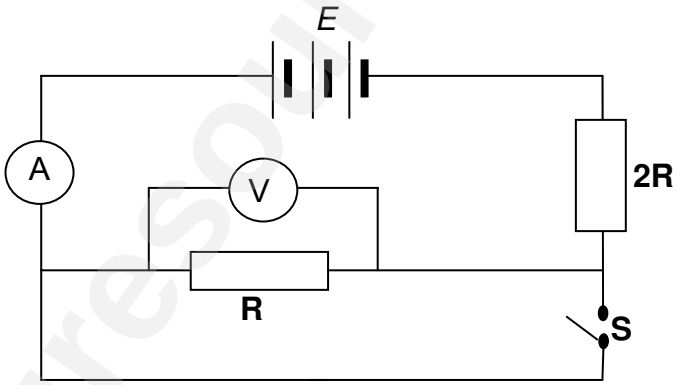
A prism.

B single slit.

C double slit.

D concave lens. (2)

2.6 In the circuit diagram below, the internal resistance of the battery and the resistance of the conducting wires are negligible. The emf of the battery is *E*.



When switch **S** is closed, the reading on voltmeter V, in volts, is ...

A 0

B $\frac{1}{3}E$

C $\frac{2}{3}E$

D E (2)

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2.7 Two identical small metal spheres on insulated stands carry equal charges and are a distance *d* apart. Each sphere experiences an electrostatic force of magnitude *F*.

The spheres are now placed a distance $\frac{1}{2}d$ apart.

The magnitude of the electrostatic force each sphere now experiences is …

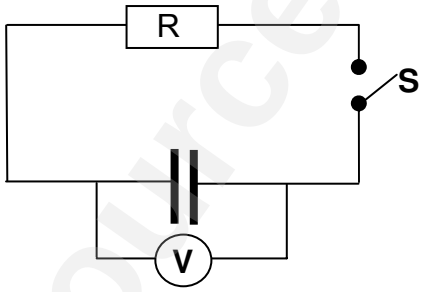
A $\frac{1}{2}F$

B F

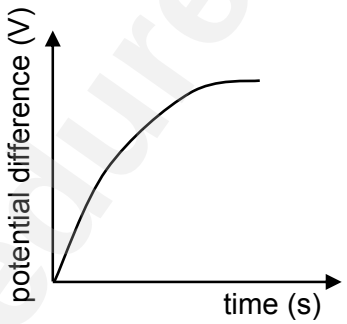
C $2F$

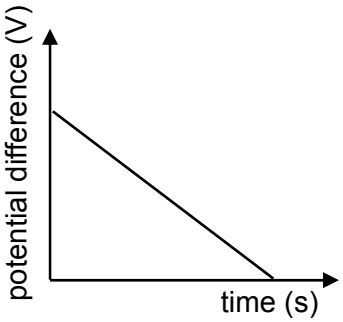
D $4F$ (2)

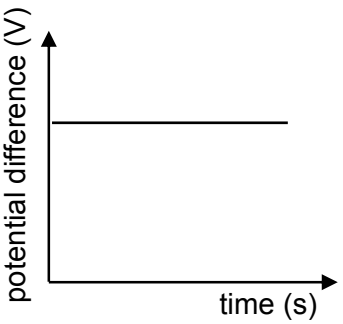
2.8 A fully charged capacitor is connected in a circuit, as shown below. The capacitor discharges when switch **S** is closed.

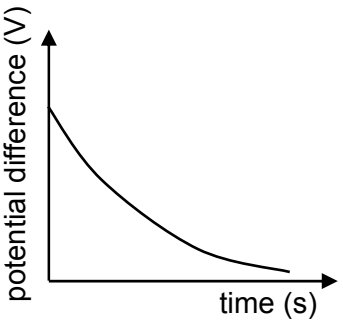


Which ONE of the following graphs correctly shows the change in the voltmeter reading with time when switch **S** is closed?

A


B


C


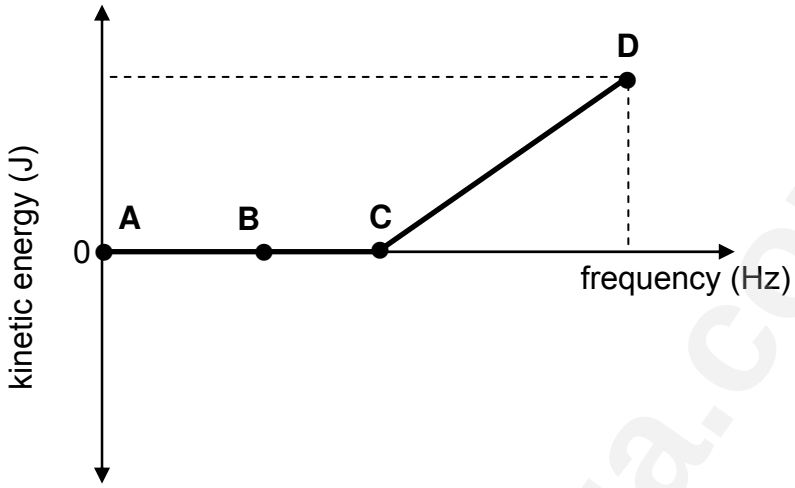
D


(2)

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2.9 When light shines on a metal plate in a photocell, electrons are emitted. The graph below shows the relationship between the kinetic energy of the emitted photoelectrons and the frequency of the incoming light.



Which ONE of the points (**A**, **B**, **C** or **D**) on the graph represents the threshold frequency?

A A

B B

C C

D D (2)

2.10 Overexposure to sunlight causes damage to plants and crops.

Which ONE of the following types of electromagnetic radiation is responsible for this damage?

A Ultraviolet rays

B Radio waves

C Visible light

D X-rays (2)

[20]

TOTAL SECTION A: 25

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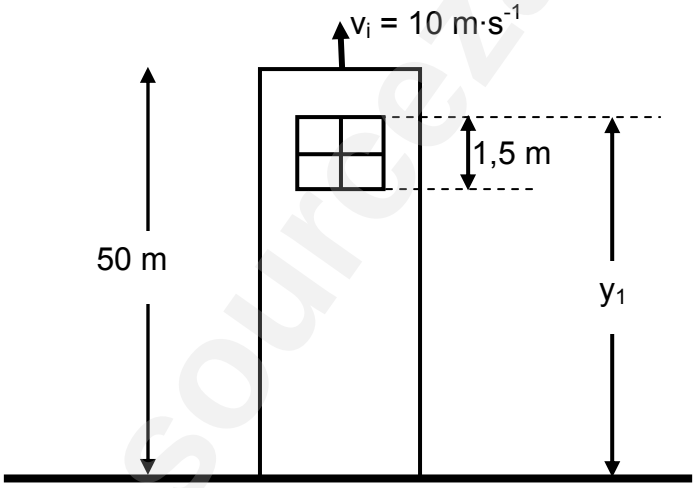
SECTION B

INSTRUCTIONS AND INFORMATION

1. Start EACH question on a NEW page.
2. Leave ONE line between two subquestions, for example between QUESTION 3.1 and QUESTION 3.2.
3. Show the formulae and substitutions in ALL calculations.
4. Round off your final numerical answers to a minimum of TWO decimal places.

QUESTION 3 (Start on a new page.)

A stone is thrown vertically upward at a velocity of 10 $m \cdot s^{-1}$ from the top of a tower of height 50 m. After some time the stone passes the edge of the tower and strikes the ground below the tower. Ignore the effects of friction.



3.1 Draw a labelled free-body diagram showing the force(s) acting on the stone during its motion. (1)

3.2 Calculate the:

3.2.1 Time taken by the stone to reach its maximum height above the ground (4)

3.2.2 Maximum height that the stone reaches above the ground (4)

3.3 USING THE GROUND AS REFERENCE (zero position), sketch a position-time graph for the entire motion of the stone. (3)

3.4 On its way down, the stone takes 0,1 s to pass a window of length 1,5 m, as shown in the diagram above.

Calculate the distance (y_1) from the top of the window to the ground. (7)

[19]

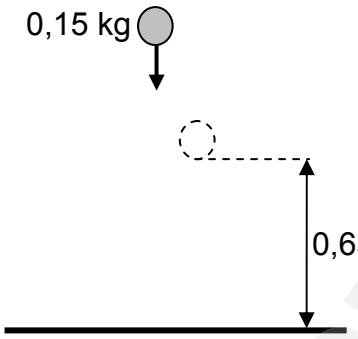
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QUESTION 4 (Start on a new page.)

The bounce of a cricket ball is tested before it is used. The standard test is to drop a ball from a certain height onto a hard surface and then measure how high it bounces.

During such a test, a cricket ball of mass 0,15 kg is dropped from rest from a certain height and it strikes the floor at a speed of 6,2 $m \cdot s^{-1}$. The ball bounces straight upwards at a velocity of 3,62 $m \cdot s^{-1}$ to a height of 0,65 m, as shown in the diagram below. The effects of air friction may be ignored.



4.1 Define the term *impulse* in words. (2)

4.2 Calculate the magnitude of the impulse of the net force applied to the ball during its collision with the floor. (3)

4.3 To meet the requirements, a cricket ball must bounce to one third of the height that it is initially dropped from.

Use ENERGY PRINCIPLES to determine whether this ball meets the minimum requirements. (5)
[10]

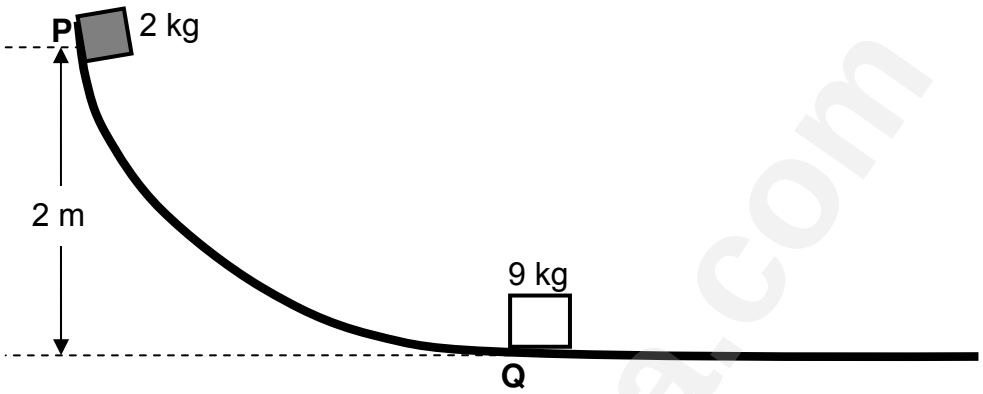
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QUESTION 5 (Start on a new page.)

A wooden block of mass 2 kg is released from rest at point **P** and slides down a curved slope from a vertical height of 2 m, as shown in the diagram below. It reaches its lowest position, point **Q**, at a speed of 5 m·s^{-1}.



5.1 Define the term *gravitational potential energy*. (2)

5.2 Use the work-energy theorem to calculate the work done by the average frictional force on the wooden block when it reaches point **Q**. (6)

5.3 Is mechanical energy conserved while the wooden block slides down the slope? Give a reason for the answer. (2)

5.4 The wooden block collides with a stationary crate of mass 9 kg at point **Q**. After the collision, the crate moves to the right at 1 m·s^{-1}.

5.4.1 Calculate the magnitude of the velocity of the wooden block immediately after the collision. (4)

5.4.2 The total kinetic energy of the system before the collision is 25 J. Use a calculation to show that the collision between the wooden block and the crate is inelastic. (5)

[19]

QUESTION 6 (Start on a new page.)

An ambulance approaches an accident scene at constant velocity. The siren of the ambulance emits sound waves at a frequency of 980 Hz. A detector at the scene measures the frequency of the emitted sound waves as 1 050 Hz.

6.1 Calculate the speed at which the ambulance approaches the accident scene. Use the speed of sound in air as 340 m·s^{-1}. (4)

6.2 Explain why the measured frequency is higher than the frequency of the source. (2)

6.3 The principle of the Doppler effect is applied in the Doppler flow meter. State ONE positive impact of the use of the Doppler flow meter on humans. (2)

[8]

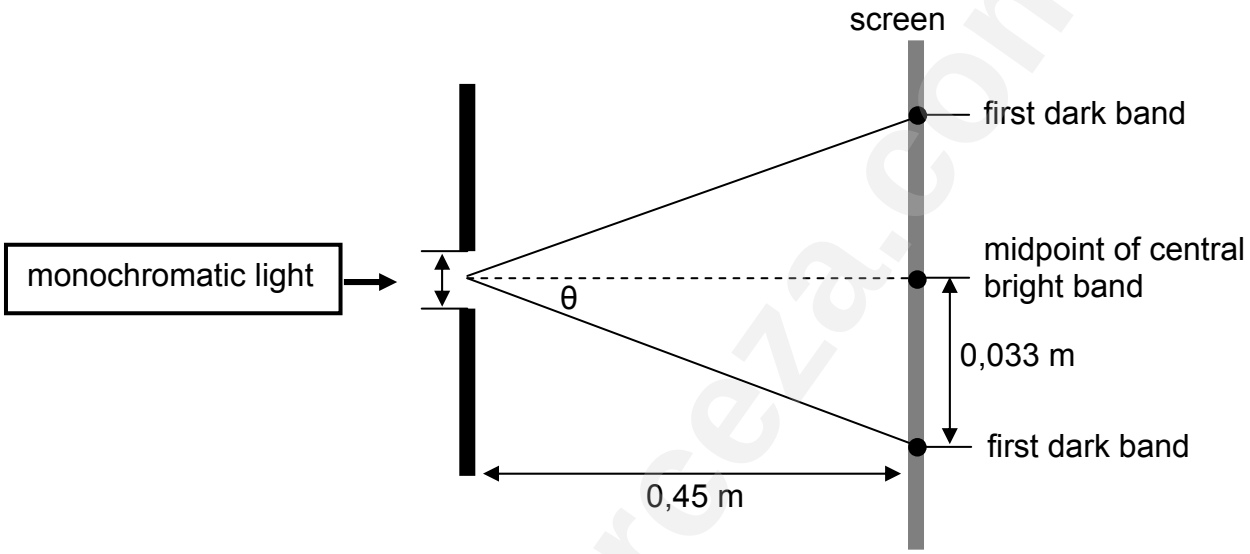
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QUESTION 7 (Start on a new page.)

Learners investigate the change in the broadness of the central bright band formed when monochromatic light of different wavelengths passes through a single slit.

They set up the apparatus, as shown in diagram below, and measure the broadness of the central bright band in the pattern observed on the screen. The width of the slit is $5,6 \times 10^{-7}$ m.



7.1 Write down an investigative question. (2)

7.2 Which TWO variables are kept constant? (2)

7.3 In one of their experiments, the distance from the midpoint of the central bright band to the first dark band is measured to be 0,033 m.

Calculate the wavelength of the light used in this experiment. (5)

7.4 How will the broadness of the central bright band of red light compare with that of blue light? Write down only GREATER THAN, SMALLER THAN or EQUAL TO.

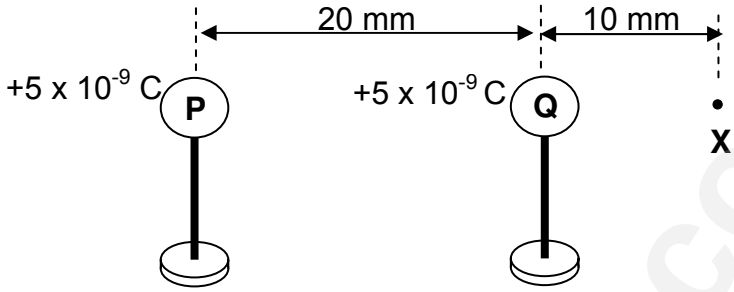
Give a reason for the answer. (2)
[11]

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QUESTION 8 (Start on a new page.)

Two metal spheres, **P** and **Q**, on insulated stands, carrying charges of +5 x 10^{-9} C and +5 x 10^{-9} C respectively, are placed with their centres 20 mm apart. **X** is a point at a distance of 10 mm from sphere **Q**, as shown below.



8.1 Define the term *electric field.* (2)

8.2 Sketch the net electric field pattern for the two charges. (3)

8.3 Calculate the net electric field at point **X** due to the presence of **P** and **Q**. (6)

8.4 Use your answer to QUESTION 8.3 to calculate the magnitude of the electrostatic force that an electron will experience when placed at point **X**. (3)
[14]

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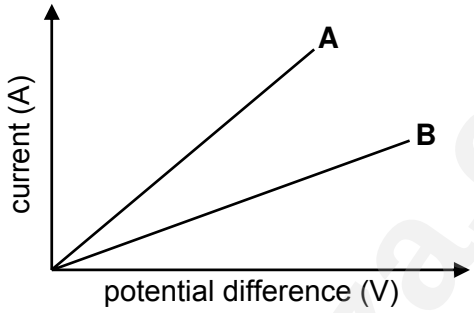
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QUESTION 9 (Start on a new page.)

9.1 Learners use Ohm's law to determine which ONE of two resistors **A** and **B** has the greater resistance.

For each resistor, they measure the current through the resistor for different potential differences across its ends. The graph below shows the results obtained in their investigation.



9.1.1 The learners are supplied with the following apparatus:

6 V battery
Voltmeter
Ammeter
Rheostat
Resistors **A** and **B**
Conducting wires

Draw a circuit diagram to show how the learners must use the above apparatus to obtain each of the graphs shown above. (4)

9.1.2 Write down ONE variable that must be kept constant during this investigation. (1)

9.1.3 Which ONE of **A** or **B** has the higher resistance?

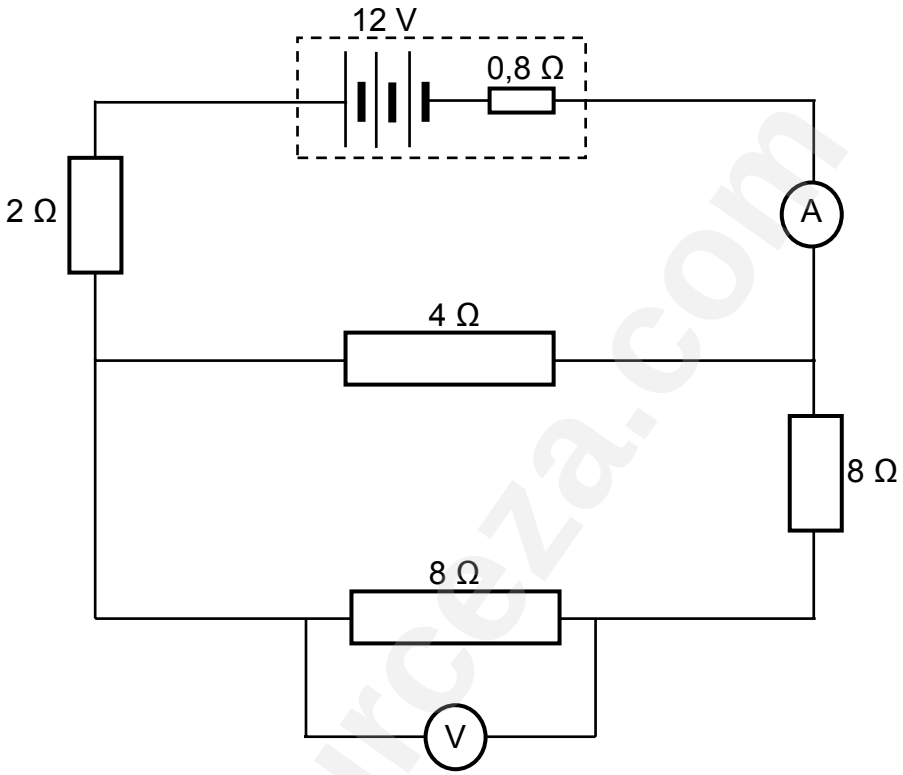
Give an explanation for the answer. (3)

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9.2 In the circuit diagram below, the battery has an emf of 12 V and an internal resistance of 0,8 Ω. The resistance of the ammeter and connecting wires may be ignored.



Calculate the:

9.2.1 Effective resistance of the circuit (4)

9.2.2 Reading on the ammeter (3)

9.2.3 Reading on the voltmeter (4)
[19]

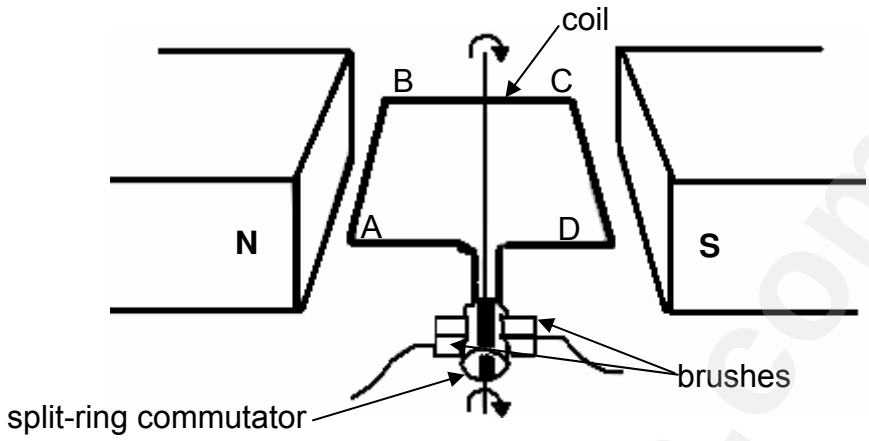
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QUESTION 10 (Start on a new page.)

10.1 The essential components of a simplified DC motor are shown in the diagram below.



When the motor is functioning, the coil rotates in a clockwise direction, as shown.

10.1.1 Write down the function of each of the following components:

(a) Split-ring commutator (1)

(b) Brushes (1)

10.1.2 What is the direction of the conventional current in the part of the coil labelled **AB**? Write down only FROM A TO B or FROM B TO A. (1)

10.1.3 Will the coil experience a maximum or minimum turning effect (torque) if the coil is in the position as shown in the diagram above? (1)

10.1.4 State ONE way in which this turning effect (torque) can be increased. (1)

10.2 Alternating current (AC) is used for the long-distance transmission of electricity.

10.2.1 Give a reason why AC is preferred over DC for long-distance transmission of electricity. (1)

10.2.2 An electric appliance with a power rating of 2 000 W is connected to a 230 V rms household mains supply.

Calculate the:

(a) Peak (maximum) voltage (3)

(b) rms current passing through the appliance (3)

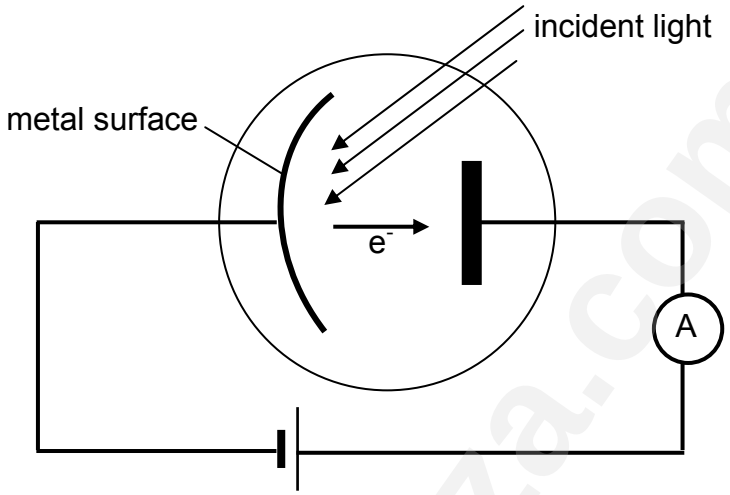
[12]

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QUESTION 11 (Start on a new page.)

In the diagram shown below, electrons are released from a metal plate when light of a certain frequency is shone on its surface.



11.1 Name the phenomenon described above. (1)

11.2 The frequency of the incident light on the metal plate is $6,16 \times 10^{14}$ Hz and electrons are released with a kinetic energy of $5,6 \times 10^{-20}$ J.

Calculate the:

11.2.1 Energy of the incident photons (3)

11.2.2 Threshold frequency of the metal plate (5)

11.3 The brightness of the incident light is now increased. What effect will this change have on the following: (Write down only INCREASES, DECREASES or REMAINS THE SAME.)

11.3.1 The reading on the ammeter
Explain the answer. (2)

11.3.2 The kinetic energy of the released photoelectrons
Explain the answer. (2)
[13]

TOTAL SECTION B: 125
GRAND TOTAL: 150

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GRADE/*GRAAD* 12

PHYSICAL SCIENCES: PHYSICS (P1)
FISIESE WETENSKAPPE: FISIKA (V1)

FEBRUARY/MARCH/*FEBRUARIE/MAART* 2012

MEMORANDUM

MARKS/*PUNTE:* **150**

This memorandum consists of 15 pages.
Hierdie memorandum bestaan uit 15 bladsye.

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Learning Outcomes and Assessment Standards ***Leeruitkomste en Assesseringstandaarde***		
LO/*LU* 1	**LO/*LU* 2**	**LO/*LU* 3**
AS 12.1.1: Design, plan and conduct a scientific inquiry to collect data systematically with regard to accuracy, reliability and the need to control variables. *Ontwerp, beplan en voer 'n wetenskaplike ondersoek uit om data te versamel ten opsigte van akkuraatheid, betroubaarheid en die kontroleer van veranderlikes.*	**AS 12.2.1:** Define, discuss and explain prescribed scientific knowledge. *Definieer, bespreek en verduidelik voorgeskrewe wetenskaplike kennis.*	**AS 12.3.1:** Research, discuss, compare and evaluate scientific and indigenous knowledge systems and knowledge claims by indicating the correlation among them, and explain the acceptance of different claims. *Doen navorsing, bespreek, vergelyk en evalueer wetenskaplike en inheemse kennissisteme en kennisaansprake deur die ooreenkoms aan te dui en verduidelik die aanvaarding van verskillende aansprake.*
AS 12.1.2: Seek patterns and trends, represent them in different forms, explain the trends, use scientific reasoning to draw and evaluate conclusions, and formulate generalisations. *Soek patrone en tendense, stel dit in verskillende vorms voor, verduidelik tendense, gebruik wetenskaplike beredenering om gevolgtrekkings te maak en te evalueer, en formuleer veralgemenings.*	**AS 12.2.2:** Express and explain prescribed scientific principles, theories, models and laws by indicating the relationship between different facts and concepts in own words. *Verduidelik en druk voorgeskrewe wetenskaplike beginsels, teorieë, modelle en wette uit deur die verwantskap tussen verskillende feite en konsepte in eie woorde aan te dui.*	**AS 12.3.2:** Research case studies and present ethical and moral arguments from different perspectives to indicate the impact (pros and cons) of different scientific and technological applications. *Vors gevallestudies na en lewer etiese en morele argumente uit verskillende perspektiewe om die impak (voordele en nadele) van verskillende wetenskaplike en tegnologiese toepassings aan te dui.*
AS 12.1.3: Select and use appropriate problem-solving strategies to solve (unseen) problems. *Kies en gebruik geskikte probleemoplossingstrategieë om (ongesiene) probleme op te los.*	**AS 12.2.3:** Apply scientific knowledge in everyday life contexts. *Pas wetenskaplike kennis in kontekste van die alledaagse lewe toe.*	**AS 12.3.3:** Evaluate the impact of scientific and technological research and indicate the contribution to the management, utilisation and development of resources to ensure sustainability continentally and globally. *Evalueer die impak van wetenskaplike en tegnologiese navorsing en dui die bydrae tot bestuur, benutting en ontwikkeling van bronne om volhoubaarheid kontinentaal en globaal te verseker.*
AS 12.1.4: Communicate and defend scientific arguments with clarity and precision. *Kommunikeer en verdedig wetenskaplike argumente duidelik en presies.*		

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SECTION A/*AFDELING A*

QUESTION 1/*VRAAG 1*

1.1 Kinetic energy/*Kinetiese energie* ✓ (1)

1.2 Interference/*Interferensie* ✓ (1)

1.3 Ohm ✓ (1)

1.4 Electromagnetic induction/*Elektromagnetiese induksie* ✓
OR/***OF***
Faraday's law/*Faraday se wet* (1)

1.5 (Line) emission (spectrum) ✓ (1)
(Lyn)emissie(spektrum) **[5]**

QUESTION 2/*VRAAG 2*

2.1 B ✓✓ (2)

2.2 B ✓✓ (2)

2.3 C ✓✓ (2)

2.4 B ✓✓ (2)

2.5 C ✓✓ (2)

2.6 A ✓✓ (2)

2.7 D ✓✓ (2)

2.8 D ✓✓ (2)

2.9 C ✓✓ (2)

2.10 A ✓✓ (2)
[20]

TOTAL SECTION A /*TOTAAL AFDELING A*: 25

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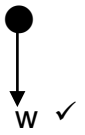
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SECTION B/*AFDELING B*

QUESTION 3/*VRAAG 3*

3.1

Accepted Labels/*Aanvaarde benoemings*	
w	F_g / F_w / force of Earth on stone/weight/mg/gravitational force *F_g / F_w / krag van Aarde op klip/gewig/mg/gravitasiekrag*



(1)

3.2.1

Option 1/*Opsie 1*:

Upward positive/*Opwaarts positief*:

$v_f = v_i + a\Delta t$ ✓

$0 = 10$ ✓$+(-9,8)\Delta t$ ✓

$\therefore \Delta t = 1,02$ s ✓

Upward negative/*Opwaarts negatief*:

$v_f = v_i + a\Delta t$ ✓

$0 = -10$ ✓$+ 9,8\Delta t$ ✓

$\therefore \Delta t = 1,02$ s ✓

Option 2/*Opsie 2*:

Upward positive/*Opwaarts positief*:

$v_f^2 = v_i^2 + 2a\Delta y$

$0^2 = 10^2 + 2(-9,8)\Delta y$ ✓

$\therefore y = 5,1$ m

$\Delta y = \left(\frac{v_i + v_f}{2}\right)\Delta t$

$5,1 = (\frac{10+0}{2})\Delta t$ ✓

$\therefore \Delta t = 1,02$ s ✓

✓Both formulae/ *Beide formules*

Upward negative/*Opwaarts negatief*:

$v_f^2 = v_i^2 + 2a\Delta y$

$0^2 = (-10)^2 + 2(9,8)\Delta y$ ✓

$\therefore y = -5,1$ m

$\Delta y = \left(\frac{v_i + v_f}{2}\right)\Delta t$

$-5,1 = (\frac{-10+0}{2})\Delta t$ ✓

$\therefore \Delta t = 1,02$ s ✓

✓ Both formulae/ *Beide formules*

(4)

3.2.2 **POSITIVE MARKING FROM QUESTION 3.2.1 TO QUESTION 3.2.2**
POSITIEWE NASIEN VAN VRAAG 3.2.1 NA VRAAG 3.2.2

Option 1/*Opsie 1:*

Upward positive/*Opwaarts positief*:

$v_f^2 = v_i^2 + 2a\Delta y$ ✓

$0^2 = 10^2 + 2(-9,8)\Delta y$ ✓

$\therefore \Delta y = 5,1$ m

Height/*Hoogte* = 50 + ✓ 5,1
= 55,1 m ✓

Upward negative/*Opwaarts negatief*:

$v_f^2 = v_i^2 + 2a\Delta y$ ✓

$0^2 = (-10)^2 + 2(9,8)\Delta y$ ✓

$\therefore \Delta y = -5,1$ m

Height/*Hoogte* = 50 + ✓ 5,1
= 55,1 m ✓

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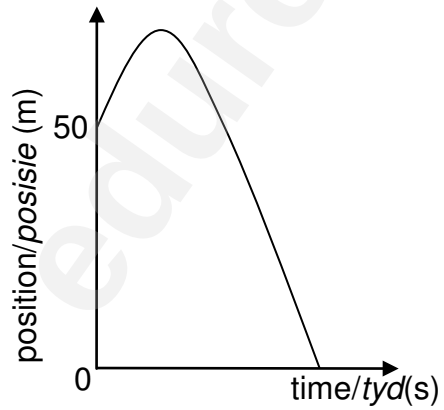
Option 2/*Opsie 2:*	**Option 3/*Opsie 3*:**
Upward positive/*Opwaarts positief*: $\Delta y = \left(\frac{v_i + v_f}{2}\right)\Delta t$ ✓ $\Delta y = (\frac{10+0}{2})1{,}02$ ✓ $\therefore$ = 5,1 m Height = 50 + ✓ 5,1 = 55,1 m ✓	**Consider downward motion/ *Beskou afwaartse beweging*:** $\Delta y = \left(\frac{v_i + v_f}{2}\right)\Delta t$ ✓ $\Delta y = (\frac{-10+0}{2})1{,}02$ ✓ $\therefore$ = -5,1 m Height = 50 + ✓ 5,1 = 55,1 m ✓
Upward negative/*Opwaarts negatief*: $\Delta y = \left(\frac{v_i + v_f}{2}\right)\Delta t$ ✓ $\Delta y = (\frac{-10+0}{2})1{,}02$ ✓ $\therefore$ $\therefore \Delta y$ = - 5,1 m Height/*Hoogte* = 50 + ✓ 5,1 = 55,1 m ✓	**Upward negative/*Opwaarts negatief*:** $\Delta y = \left(\frac{v_i + v_f}{2}\right)\Delta t$ ✓ $\Delta y = (\frac{-10+0}{2})1{,}02$ ✓ $\therefore$ = - 5,1 m Height/*Hoogte* = 50 +✓ 5,1 = 55,1 m✓

(4)

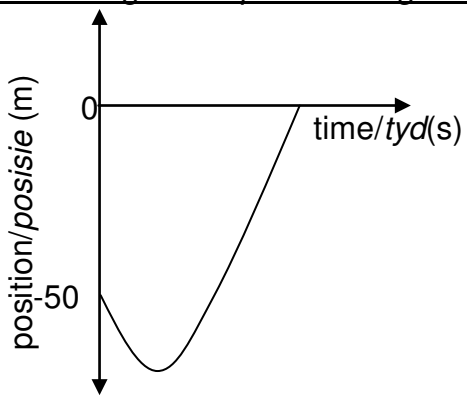
3.3

Criteria for graph/Kriteria vir grafiek	Marks/ *Punte*
Correct shape/*Korrekte vorm*	✓
Final position lower than initial position.	✓
Graph ends on x axis./*Grafiek eindig op x-as.*	✓

Upward positive/*Opwaarts positief*



Upward negative/*Opwaarts negatief*



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3.4

Option 1/*Opsie 1*

$\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$ ✓

$1,5$ ✓ $= v_i(0,1) + \frac{1}{2}(9,8)(0,1)^2$ ✓

$\therefore v_i = 14,51\ m\cdot s^{-1}$

From maximum height/*Van maksimum hoogte:*

$v_f^2 = v_i^2 + 2a\Delta y$ ✓

$14,51^2$ ✓ $= (0)^2 + 2(9,8)\Delta y$ ✓

$\therefore \Delta y = 10,74\ m$

Height/*Hoogte* = 55,1 –10,74
= 44,36 m ✓

Option 2/*Opsie 2*

$\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$ ✓

$1,5$ ✓ $= v_i(0,1) + \frac{1}{2}(9,8)(0,1)^2$ ✓

$\therefore v_i = 14,51\ m\cdot s^{-1}$

Downwards from top of tower to top of window:/*Afwaarts van bopunt van toring tot bopunt van venster*

$v_f^2 = v_i^2 + 2a\Delta y$ ✓

$14,51^2$ ✓ $= (10)^2 + 2(9,8)\Delta y$ ✓

$\therefore \Delta y = 5,64\ m$

Height/*Hoogte* = 50 – 5,64
= 44,36 m ✓

Option 3/*Opsie 3*

$\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$ ✓

$1,5$ ✓ $= v_i(0,1) + \frac{1}{2}(9,8)(0,1)^2$ ✓

$\therefore v_i = 14,51\ m\cdot s^{-1}$

From original point of projection:/*Van oorspronklike punt van projeksie*

$v_f^2 = v_i^2 + 2a\Delta y$ ✓

$14,51^2$ ✓ $= (-10)^2 + 2(9,8)\Delta y$ ✓

$\therefore \Delta y = 5,64\ m$

Height/*Hoogte* = 50 – 5,64
= 44,36 m ✓

Option 4/*Opsie 4*

$\bar{v} = \frac{\Delta y}{\Delta t} = \frac{1,5}{0,1} = 15\ m\cdot s^{-1}$

$\bar{v} = \frac{v_i + v_f}{2} = \underline{15}$

$\therefore v_i + v_f = 30\ m\cdot s^{-1}$

$\therefore v_f = 30 - v_i$

$v_f = v_i + a\Delta t$ ✓

$\underline{30 - v_i}$ ✓ $= \underline{v_i + 9,8(0,1)}$ ✓

$\therefore v_i = 14,51\ m\cdot s^{-1}$

$v_f^2 = v_i^2 + 2a\Delta y$ ✓

$14,51^2$ ✓ $= (0)^2 + 2(9,8)\Delta y$ ✓

$\therefore \Delta y = 10,74\ m$

Height/*Hoogte* = 55,1 – 10,74
= 44,36 m ✓

(7)
[19]

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QUESTION 4/*VRAAG 4*

4.1 Impulse is the product of the (net/average) force and the time during which the force acts. ✓✓
Impuls is die produk van die (netto/gemiddelde) krag en die tyd waartydens die krag inwerk. ✓✓

OR/*OF*
Impulse is the change in momentum. ✓✓
Impuls is gelyk aan verandering in momentum. ✓✓ (2)

4.2

Option 1/*Opsie 1:*	**Option 2/*Opsie 2:***
Upward positive:/*Opwaarts positief* $F_{net}\Delta t = \Delta p$ ✓ $= m(v_f - v_i)$ $= 0,15(3,62 - (-6,2))$ ✓ $= 1,473$ N·s / kg·m·s^{-1} ✓ upward/*opwaarts*	Upward negative:/*Opwaarts negatief* $F_{net}\Delta t = \Delta p$ ✓ $= m(v_f - v_i)$ $= 0,15[(-3,62 - (6.2))$ ✓ $= -1,473$ N·s /kg·m·s^{-1} $F_{net}\Delta t = 1,473$ N·s /kg·m·s^{-1} ✓ upward/*opwaarts*
Option 3/*Opsie 3:*	**Option 4/*Opsie 4:***
Upward positive: /*Opwaarts positief* $F_{net}\Delta t = \Delta p$ ✓ $= mv_f - mv_i$ $= (0,15)(3,62) - (0,15)(-6,2)$ ✓ $= 1,473$ N·s / kg·m·s^{-1} ✓ upward/*opwaarts*	Upward negative: /*Opwaarts negatief* $F_{net}\Delta t = \Delta p$ ✓ $= mv_f - mv_i)$ $= (0,15)(-3,62) - (0,15)(6,2)$ ✓ $= -1,473$ N·s /kg·m·s^{-1} $F_{net}\Delta t = 1,473$ N·s /kg·m·s^{-1} ✓ upward/*opwaarts*

(3)

4.3 $(U + K)_{top/bo} = (U + K)_{bottom/onder}$ ✓
$mgh_f + \frac{1}{2} m v_f^2 = mgh_i + \frac{1}{2} m v_i^2$
$(0,15)(9,8)h + 0$ ✓ $= 0 + \frac{1}{2}(0,15)(6,2)^2$ ✓
$\therefore$ h = 1,96 m ✓

$\frac{1,96}{3} = 0,65$ m
Yes/Meets requirements ✓

Ja/Voldoen aan vereistes. ✓

K(bottom/*onder*) = U(top/*bo*)
Max.: $\frac{0}{4}$
Other formulae/*Ander formules*:
$E_{mech(A)} = E_{mech(B)}$ / $E_{mech(i)} = E_{mech(f)}$
$E_{mech(top)} = E_{mech(bottom)}$
$(E_p + E_k)_A = (E_p + E_k)_B$
$(E_p + E_k)_{bottom} = (E_p + E_k)_{top}$
$E_p + E_k)_i = (E_p + E_k)_f$
$(U + K)_i = (U + K)_f$
$(U + K)_A = (U + K)_B$
$mgh_B + \frac{1}{2}mv_i^2 = mgh_B + \frac{1}{2}mv_f^2$

(5)
[10]

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QUESTION 5/*VRAAG 5*

5.1 The energy of an object due to its position ✓
above the surface of the earth. ✓

Die energie van 'n voorwerp as gevolg sy posisie ✓
bokant die oppervlak van die aarde. ✓ (2)

5.2

Option 1/*Opsie 1:*
$W_{net} = \Delta K$ ✓
$mg\Delta y\cos\theta + W_f = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$
$(2)(9,8)(2)\cos 0° \checkmark + W_f \checkmark = \frac{1}{2}(2)(5)^2 \checkmark - 0$ ✓
$\therefore W_f = -14,2$ J ✓

Option 2/*Opsie 2:*
$W_{net} = \Delta K$ ✓
$-\Delta U + W_f = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$
$mgh + W_f = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$
$(2)(9,8)(2) \checkmark + W_f \checkmark = \frac{1}{2}(2)(5)^2 \checkmark - 0$ ✓
$\therefore W_f = -14,2$ J ✓ (6)

5.3 No/Nee ✓
Friction is present/*Wrywing is aanwesig*. ✓ (2)

5.4.1 $\Sigma p_{before} = \Sigma p_{after}$ ✓
$(2)(5) + (9)(0) \checkmark = 2v_{f2} + (9)(1)$ ✓

$\therefore v_{f2} = 0,5$ m·s^{-1} ✓ (4)

Notes/*Aantekeninge:*
Other formulae/*Ander formules*:
$m_1v_{i1} + m_2v_{i2} = m_1v_{f1} + m_2v_{f2}$
$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

5.4.2 K(total after/*total na*) $= \frac{1}{2}m_1v_f^2 + \frac{1}{2}m_2v_f^2$ ✓
$= \frac{1}{2}(2)(0,5)^2 \checkmark + \frac{1}{2}(9)(1)^2 \checkmark$
$= 4,75$ J ✓
K(total before) ≠ K(total after) ✓
∴ inelastic

K(totaal na) ≠ *K(totaal voor)* ✓
∴ *onelasties* (5)
[19]

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QUESTION 6/*VRAAG 6*

6.1
$$f_L = \frac{v \pm v_L}{v \pm v_s} f_s \text{ OR } f_L = \frac{v}{v - v_s} f_s \checkmark$$
$$\therefore 1\,050 \checkmark = \frac{340 + 0}{340 - v_s}(980) \checkmark$$
$$\therefore v_s = 22{,}67\ m \cdot s^{-1} \checkmark \quad (4)$$

6.2 Waves in front of the moving source are compressed.
The observed wavelength decreases. ✓
For the same speed of sound, ✓a higher frequency will be observed.

Golwe voor die bewegende bron word saamgepers.
Die waargenome golflengte verminder. ✓
Vir dieselfde spoed van klank ✓*sal 'n hoër frekwensie waargeneem word.* (2)

6.3 Any ONE/*Enige EEN*:

- Determine whether arteries are clogged/narrowed ✓
  so that precautions can be taken in advance/to prevent heart attack /stroke. ✓
  Bepaal of are verstop/vernou is, ✓✓
  sodat voorsorg getref kan word/om hartaanvalle/beroerte te voorkom. ✓

- Determine heartbeat of foetus
  to assure that child is alive/does not have a heart defect.
  Bepaal die hartklop van 'n fetus
  om seker te maak of baba leef/geen hartdefekte het nie. (2)

[8]

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QUESTION 7/*VRAAG 7*

7.1

Criteria for investigative question/*Kriteria vir ondersoekende vraag:*	**Mark/*Punt***
The dependent and independent variables are stated. *Die afhanklike en onafhanklike veranderlikes is genoem.*	✓
Asks a question about the relationship between dependent and independent variables. *Vra 'n vraag oor die verwantskap tussen die afhanklike en onafhanklike veranderlikes.*	✓

Dependent variable:
***Afhanklike veranderlike*:**
Broadness of central (bright) band/degree of diffraction
Breedte van sentrale (helder) band/mate van diffraksie
Independent variable:
Onafhanklike veranderlike:
Wavelength (of light)/Golflengte (van lig)

Example/*Voorbeeld:*
How will the width of the central band change/differ when the wavelength (of the light) changes/is increased/is decreased?
Hoe sal die breedte van die sentrale helder band verander wanneer die golflengte (van die lig) toeneem/afneem? (2)

7.2 Slit width/*Spleetwydte* ✓
Distance between slit and screen/*Afstand tussen spleet en skerm.* ✓ (2)

7.3 $\tan\theta = \frac{0,033}{0,45}$ ✓ $\therefore \theta = 4,19(4)°$

$\sin\theta = \frac{m\lambda}{a}$ ✓

$\sin 4,19°$ ✓ $= \frac{(1)\lambda}{5,6\times10^{-7}}$ ✓

$\therefore \lambda = 4,1 \times 10^{-8}$ m ✓ (5)

7.4 Greater than/*Groter as* ✓
Red light has a longer wavelength (and is diffracted more.) ✓
Rooilig het 'n langer golflengte (en word meer diffrakteer.)

OR/*OF* (2)
Diffraction/*Diffraksie* α λ ✓ **[11]**

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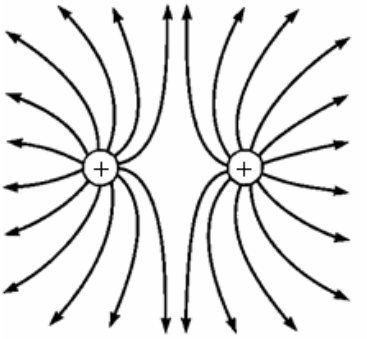
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QUESTION 8/*VRAAG 8*

8.1 The (electrostatic) force experienced at a point ✓
per unit charge at that point. ✓
Die elektrostatiese krag ondervind by 'n punt ✓
per eenheidslading by daardie punt. ✓

OR/*OF*
The (electrostatic) force experienced ✓
by a charge placed at that point divided by the charge itself. ✓
Die (elektrostatiese) krag ondervind ✓
deur 'n lading geplaas by daardie punt gedeel deur die lading self. ✓ (2)

8.2



Criteria for sketch/*Kriteria vir skets*	Marks/ *Punte*
Correct shape as shown. *Korrekte vorm soos getoon*	✓
Direction from positive to negative. *Rigting van positief na negatief.*	✓
Field lines start on spheres and do not cross. *Veldlyne begin op elke sfeer en kruis nie.*	✓

(3)

8.3 $E_P = \frac{kQ}{r^2}$ ✓

$= \frac{(9\times10^{9})(5\times10^{-9})}{(30\times10^{-3})^2}$ ✓

$= 5 \times 10^4$ N·C^{-1} to the right/*na regs*

$E_Q = \frac{kQ}{r^2}$

$= \frac{(9\times10^{9})(5\times10^{-9})}{(10\times10^{-3})^2}$ ✓

$= 4{,}5 \times 10^5$ N·C^{-1} to the right/*na regs*

$E_{net} = 5 \times 10^4 + 4{,}5 \times 10^5$

$= 5 \times 10^5$ N·C^{-1} to the right/*na regs* ✓ (6)

8.4 **POSITIVE MARKING FROM QUESTION 8.3 TO QUESTION 8.4/**
POSITIEWE NASIEN VAN VRAAG 8.3 NA VRAAG 8.4

$E = \frac{F}{q}$ ✓

$5 \times 10^5 = \frac{F}{1{,}6\times10^{-19}}$ ✓

$F = 8 \times 10^{-14}$ N ✓ (3)

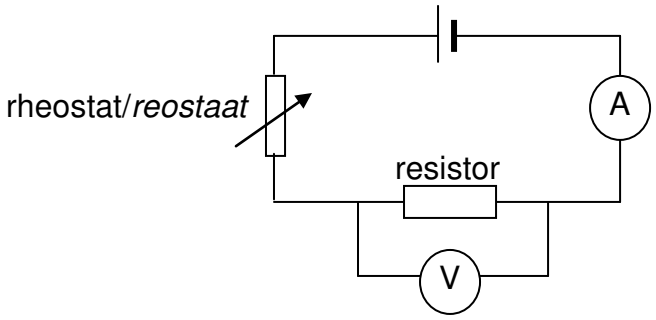
[14]

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QUESTION 9/*VRAAG 9*

9.1
9.1.1



Criteria for circuit diagram/*Kriteria vir stroombaandiagram*	**Mark/*Punt***
Battery connected to the resistor as shown – correct symbols used. *Battery aan resistor geskakel soos getoon – korrekte simbole is gebruik.*	✓
Rheostat connected in series with resistor – correct symbols used. *Reostaat in serie geskakel met resistor – korrekte simbole is gebruik.*	✓
Ammeter connected in series so that it measures the current through resistor – correct symbols used. *Ammeter in serie geskakel sodat dit die stroom deur die resistor meet – korrekte simbole is gebruik.*	✓
Voltmeter connected in parallel across resistor – correct symbols used. *Voltmeter in parallel geskakel oor resistor – korrekte simbole is gebruik.*	✓

(4)

9.1.2 Temperature/*Temperatuur* ✓ (1)

9.1.3 B ✓

The ratio $\frac{V}{I}$ is greater than that of A. ✓✓

B ✓

Die verhouding $\frac{V}{I}$ *is groter as die van A.* ✓✓

OR/*OF*

B ✓

The ratio $\frac{I}{V}$ is smaller than that of A. ✓✓

B ✓

Die verhouding $\frac{I}{V}$ *is kleiner as die van A.* ✓✓

(3)

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9.2

9.2.1 $\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2}$ ✓ $= \frac{1}{4} + \frac{1}{16}$ ✓

$\therefore$ R = 3,2 Ω ↘

$R_{effective/effektief}$ = 3,2 Ω + 2 Ω + 0,8 Ω✓
= 6 Ω ✓ (4)

9.2.2

Option 1/*Opsie 1:*	**Option 2/*Opsie 2*:**
V = IR ✓ 12 = I(6) ✓ I = 2 A ✓	emf = I(R + r) ✓ 12 = I(5,2 + 0,8) ✓ I = 2 A ✓

(3)

9.2.3

Option 1/*Opsie 1*:	**Option 2/*Opsie 2*:**
$V_{parallel}$ = IR ✓ =(2)(3,2) ✓ = 6,4 V ↓ $V_{8\Omega} = \frac{6,4}{2}$ ✓= 3,2 V ✓	$Vp = \frac{R_p}{R}$ x V ✓ $= \frac{3,2}{6}$ ✓ x 12 ✓ = 6,4 V $\therefore V_{8\Omega}$ = 3,2 V ✓
Option 3/*Opsie 3*:	**Option 4/*Opsie 4*:**
$I_{8\Omega} = \frac{4}{20}(2)$ ✓ = 0,4 A ↓ $V_{8\Omega}$ = IR ✓ = (0,4)(8) ✓ = 3,2 V ✓	emf = I(R + r) ✓ 12 = $IR_{2\,\Omega}$ + V_p + Ir 12 = (2)(2) + V_p + (2)(0,8) ✓ Vp = 6,4 V ↓ $V_{8\Omega} = \frac{6,4}{2}$ ✓= 3,2 V ✓

(4)
[19]

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QUESTION 10/*VRAAG 10*

10.1
10.1.1
(a) Reverses the direction of the current in the coil each half cycle. ✓
Keer die stroomrigting in die spoel elke halwe siklus. ✓

OR/*OF*
Maintains constant direction of rotation of the coil.
Onderhou die konstante rigting van rotasie van die spoel. (1)

10.1.1 Makes electrical contact (with the commutator). ✓
(b) *Maak elektriese kontak (met kommutator).* ✓

OR/*OF*
Allows split-ring commutator to rotate freely.
Laat splitringkommutator toe om vry te roteer.

OR/*OF*
Allows charges to flow/current in and out of the coil.
Laat vloei van lading/stroom in en uit spoel toe. (1)

10.1.2 B to/*na* A ✓ (1)

10.1.3 Maximum/*Maksimum* ✓ (1)

10.1.4 Any ONE/*Enige EEN*:
- Increase the current in the coil. ✓
  Verhoog die stroom in die spoel. ✓
- Increase the magnitude of the magnetic field./Use a stronger magnet.
  Vergroot die grootte van die magneetveld./Gebruik 'n sterker magneet.
- Increase the number of turns in the coil.
  Verhoog die aantal windinge in die spoel.
- Use a soft iron core as the core of the *coil.*
  Gebruik 'n sagte ysterkern in die spoel.

(1)

10.2
10.2.1 Any ONE/*Enige EEN:*
- Can be transmitted over long distances without major energy loss. ✓
  Kan oor groot afstande oorgedra word sonder groot energieverlies. ✓
- The potential difference can be increased or decreased.
  Die potensiaalverskil kan verhoog of verlaag word. (1)

10.2.2
(a) $V_{rms/wgk} = \frac{V_{max/\,maks}}{\sqrt{2}}$ ✓

$230 = \frac{V_{max/\,maks}}{\sqrt{2}}$ ✓

$V_{max/maks} = 325,27$ V ✓

(3)

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10.2.2

(b) $P_{ave} = V_{rms/wgk}I_{rms/wgk}$ ✓

$2\ 000 = (230)I_{rms/wgk}$ ✓

$I_{rms/wgk} = 8,70$ A ✓ (8,696 A) (3)

[12]

QUESTION 11/*VRAAG 11*

11.1 Photoelectric effect/*Foto-elektriese effek* ✓ (1)

11.2

11.2.1 $E = hf$ ✓

$= (6,63 \times 10^{-34})(6,16 \times 10^{14})$ ✓

$= 4,08 \times 10^{-19}$ J ✓ (3)

11.2.2 $E = W_0 + K$ ✓

$4,08 \times 10^{-19}$ ✓ $= (6,63 \times 10^{-34})f_0$ ✓ $+ 5,6 \times 10^{-20}$ ✓

$f_0 = 5,31 \times 10^{14}$ Hz ✓ (5)

11.3

11.3.1 Increases ✓

More photoelectrons emitted per second ✓

Vermeerder ✓

Meer foto-elektrone vrygestel per sekonde ✓ (2)

11.3.2 Remains the same ✓

Intensity does not affect energy. ✓

Bly dieselfde ✓

Intensiteit het geen effek op energie nie. ✓

OR/*OF*

Remains the same ✓

The frequency of light remains the same. ✓

Bly dieselfde ✓

Die frekwensie van die lig bly dieselfde. ✓ (2)

[13]

TOTAL SECTION B/*TOTAAL AFDELING B*: 125

GRAND TOTAL/*GROOTTOTAAL*: 150

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NATIONAL SENIOR CERTIFICATE

GRADE 12

PHYSICAL SCIENCES: CHEMISTRY (P2)

FEBRUARY/MARCH 2012

MARKS: 150

TIME: 3 hours

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INSTRUCTIONS AND INFORMATION

1. Write your centre number and examination number in the appropriate spaces on the ANSWER BOOK.
2. Answer ALL the questions in the ANSWER BOOK.
3. This question paper consists of TWO sections:

   SECTION A (25)
   SECTION B (125)
4. You may use a non-programmable calculator.
5. You may use appropriate mathematical instruments.
6. Number the answers correctly according to the numbering system used in this question paper.
7. Data sheets and a periodic table are attached for your use.
8. Give brief motivations, discussions, et cetera where required.
9. Round off your final numerical answers to a minimum of TWO decimal places.

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SECTION A

QUESTION 1: ONE-WORD ITEMS

Give ONE word/term for each of the following descriptions. Write only the word/term next to the question number (1.1–1.5) in the ANSWER BOOK.

1.1 An atom or a group of atoms that gives an organic compound its chemical properties (1)

1.2 The type of addition reaction in which a hydrogen halide is added to an alkene (1)

1.3 The minimum energy needed to start a reaction (1)

1.4 The component of a galvanic cell that allows for the movement of ions between the half-cells (1)

1.5 The type of cell that cannot be recharged (1)
[5]

QUESTION 2: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Write only the letter (A–D) next to the question number (2.1–2.10) in the ANSWER BOOK.

2.1 Which ONE of the following compounds CANNOT be an alkene?

A C_2H_4

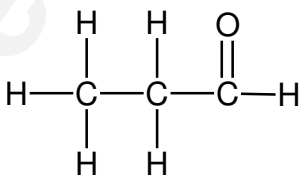
B C_3H_6

C C_3H_8

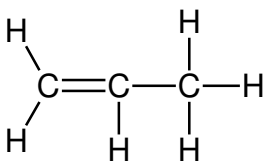
D C_4H_8 (2)

2.2 Which ONE of the compounds represented below is an UNSATURATED hydrocarbon?

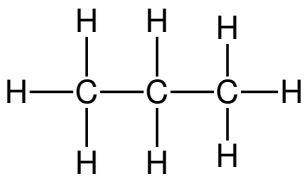
A



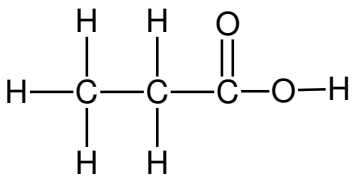
B



C



D

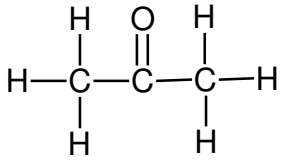
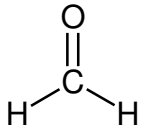


(2)

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2.3 Consider the two organic compounds represented by **I** and **II**, as shown below.

I	**II**
	

Which ONE of the following correctly represents the homologous series to which each belongs?

	I	**II**
A	aldehyde	alcohol
B	ketone	alcohol
C	ketone	aldehyde
D	aldehyde	ketone

(2)

2.4 Consider the chemical reaction represented by the equation below.

$$CaCO_3(s) + 2HC\ell(aq) \rightarrow CaC\ell_2(aq) + CO_2(g) + H_2O(\ell)$$

Which ONE of the following changes will increase the rate of production of $CO_2(g)$?

A Increase in pressure

B Increase in mass of $CaCO_3$

C Increase in volume of $HC\ell(aq)$

D Increase in concentration of $HC\ell(aq)$ (2)

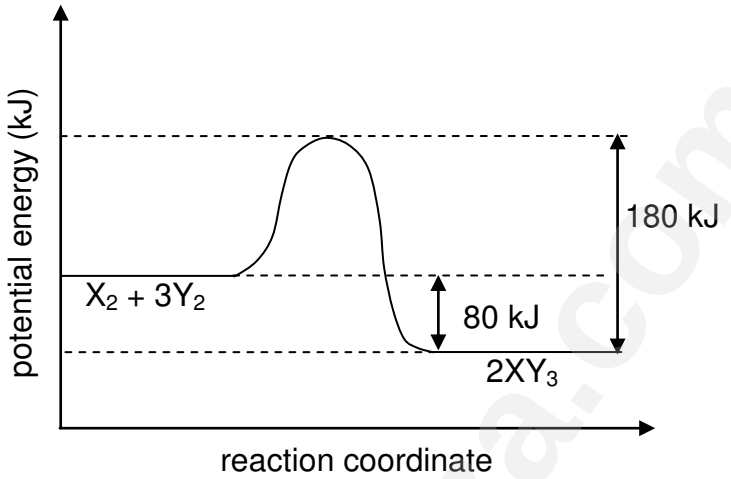
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2.5 The diagram below shows the change in potential energy for a hypothetical reaction, represented by the following equation:

$$X_2(g) + 3Y_2(g) \rightarrow 2XY_3(g)$$



The activation energy for the forward reaction is …

A -80 kJ

B 80 kJ

C 100 kJ

D 180 kJ (2)

2.6 The following hypothetical reaction reaches equilibrium in a closed container at a certain temperature:

$$X_2(g) + Y_2(g) \rightleftharpoons 2XY(g) \qquad \Delta H < 0$$

Which ONE of the following changes will increase the AMOUNT of XY(g)?

A Decrease in temperature

B Increase in temperature

C Increase in pressure

D Decrease in pressure (2)

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2.7 The gain of electrons by a substance in a chemical reaction is known as …

A oxidation.

B reduction.

C electrolysis.

D oxidation and reduction. (2)

2.8 Which ONE of the following statements regarding a copper-silver galvanic cell is TRUE?

A Silver is formed at the anode.

B Copper is formed at the anode.

C Silver is formed at the cathode.

D Copper is formed at the cathode. (2)

2.9 Which ONE of the following substances can be used as an electrolyte?

A Mercury

B Molten copper

C Sugar dissolved in distilled water

D Table salt dissolved in distilled water (2)

2.10 Which ONE of the following is NOT associated with eutrophication in water?

A Dead zones

B Algal bloom

C Depletion of oxygen

D Increased aquatic life (2)
[20]

TOTAL SECTION A: 25

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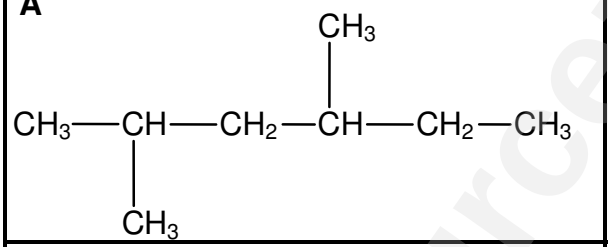
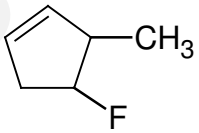
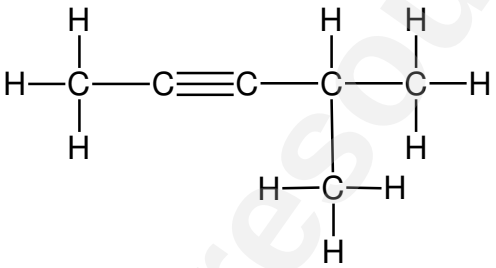
SECTION B

INSTRUCTIONS

1. Start EACH question on a NEW page.
2. Leave ONE line between two subquestions, for example between QUESTION 3.1 and QUESTION 3.2.
3. Show the formulae and substitutions in ALL calculations.
4. Round off your final numerical answers to a minimum of TWO decimal places.

QUESTION 3 (Start on a new page.)

Four compounds, labelled **A**, **B**, **C** and **D**, are shown below.

A 	**B** 
C 	**D** hexanoic acid

Write down the:

3.1 Homologous series to which compound **A** belongs (1)

3.2 IUPAC name of compound **A** (2)

3.3 IUPAC name of compound **B** (2)

3.4 IUPAC name of compound **C** (2)

3.5 Structural formula of compound **D** (2)
[9]

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QUESTION 4 (Start on a new page.)

4.1 In the petroleum industry smaller, more useful hydrocarbons are obtained from larger ones by a process called cracking.

4.1.1 Define the term *hydrocarbon*. (2)

The compound $C_{10}H_{22}$ is cracked to obtain alkane **X** and another hydrocarbon. The cracking reaction is represented by the following incomplete equation:

$$C_{10}H_{22} \rightarrow C_5H_{10} + \mathbf{X}$$

4.1.2 Write down the molecular formula of compound **X**. (1)

The cracking process requires very high temperatures. Therefore engineers use a catalyst in the reaction.

4.1.3 Give TWO reasons why they use a catalyst. (2)

2-methylbut-1-ene (C_5H_{10}) is one of the compounds formed in this reaction.

4.1.4 Write down the structural formula of 2-methylbut-1-ene. (2)

4.1.5 Name the type of reaction that occurs when 2-methylbut-1-ene reacts with hydrogen. (1)

4.2 Consider the structural isomers represented by **A**, **B** and **C** shown below.

	COMPOUND	BOILING POINT (°C)
A	$CH_3—CH_2—CH_2—CH_2—CH_3$	36
B	$CH_3—CH_2—CH(CH_3)—CH_3$	28
C	$CH_3—C(CH_3)_2—CH_3$	9

4.2.1 Give a reason why the above compounds are considered to be structural isomers. (2)

4.2.2 Describe the trend in the boiling points from **A** to **C**, as shown in the table. Explain this trend by referring to molecular structure, intermolecular forces and energy involved. (4)

4.2.3 Give a reason why branched hydrocarbons are preferred to straight chain hydrocarbons as fuel. (2)

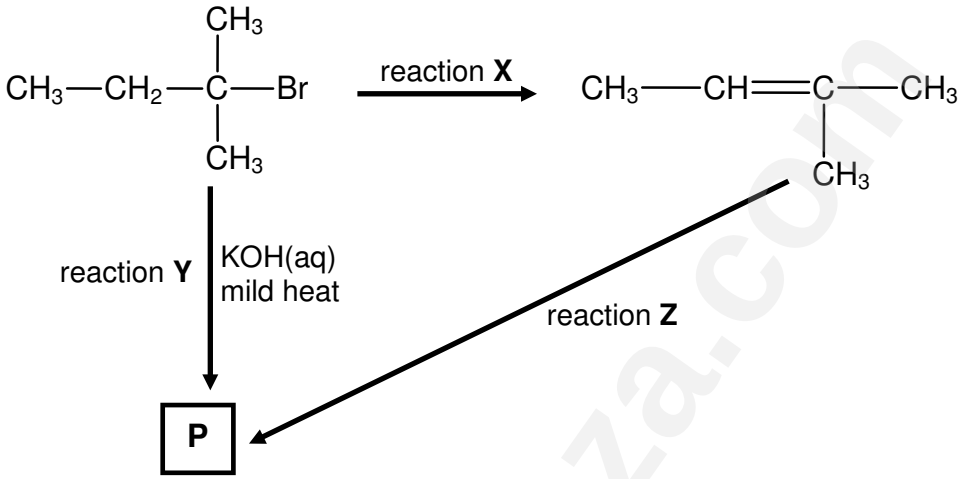
[16]

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QUESTION 5 (Start on a new page.)

5.1 In the flow diagram below, **X**, **Y** and **Z** represent three different types of organic reactions. **P** represents an organic compound.



5.1.1 Name the type of reaction represented by **X**. (1)

5.1.2 State TWO reaction conditions needed for reaction **X**. (2)

5.1.3 Reaction **Y** represents a substitution reaction. Write down the structural formula of compound **P** formed in this reaction. (2)

5.1.4 Apart from the organic reactant, write down the NAME or FORMULA of the other reactant needed in reaction **Z**. (1)

5.1.5 Name the type of reaction represented by **Z**. (1)

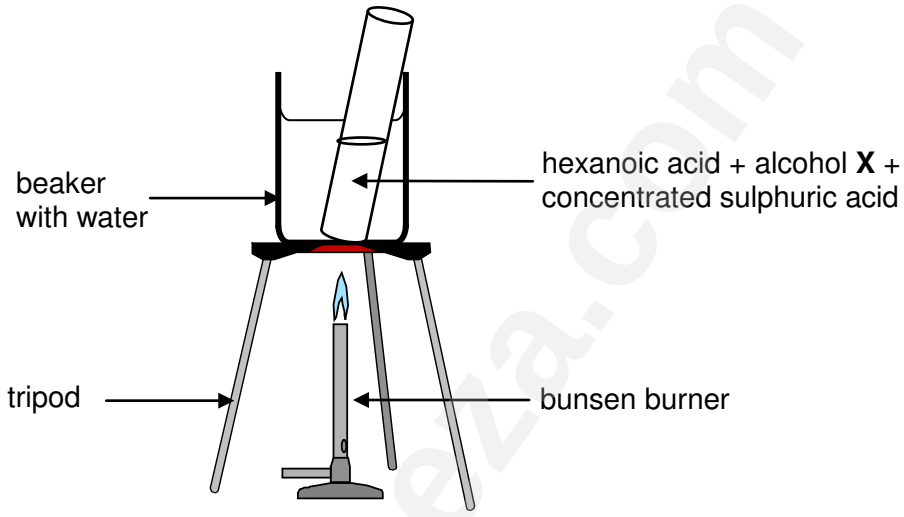
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5.2 Hexanoic acid is responsible for the unique odour associated with goats. When it reacts with alcohol **X**, ethyl hexanoate, which is used commercially as a fruit flavour, is formed.

Learners set up the apparatus shown below to prepare ethyl hexanoate in a laboratory.



5.2.1 Write down the IUPAC name of alcohol **X.** (2)

5.2.2 What is the role of the sulphuric acid in the above reaction? (1)

5.2.3 Use structural formulae to write down a balanced equation for the preparation of ethyl hexanoate. (6)

5.2.4 Give a reason why the test tube and its contents are heated in a water bath and not directly over the flame. (1)

5.2.5 Write down ONE use of esters in the food manufacturing industry. (1)
[18]

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QUESTION 6 (Start on a new page.)

A group of learners use the reaction between zinc and sulphuric acid to investigate one of the factors that affects reaction rate. The equation below represents the reaction that takes place.

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$

They add 6,5 g of zinc granules to excess DILUTE sulphuric acid and measure the mass of zinc used per unit time.

The learners then repeat the experiment using excess CONCENTRATED sulphuric acid.

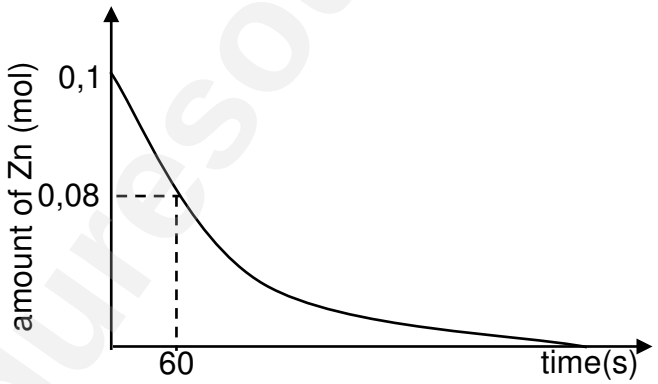
6.1 Define the term *reaction rate.* (2)

6.2 Give a reason why the acid must be in excess. (1)

6.3 Write down a hypothesis for this investigation. (2)

6.4 Give a reason why the learners must use the same amount of ZINC GRANULES in both experiments. (1)

The results obtained for the reaction using DILUTE sulphuric acid are represented in the graph below.



6.5 Using the graph, calculate the mass of zinc used from t = 0 s to t = 60 s. (4)

6.6 Calculate the average rate of the reaction (in gram per second) during the first 60 s. (2)

6.7 Copy the above graph into your ANSWER BOOK. ON THE SAME SET OF AXES, use a dotted line to show the curve that will be obtained when concentrated sulphuric acid is used. Label that curve **P** (no numerical values are required). (2)

[14]

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QUESTION 7 (Start on a new page.)

The rapidly increasing human population is resulting in an ever-increasing demand for food. To meet this demand, farmers apply fertiliser to the same cultivated land EACH YEAR.

7.1 Explain why farmers have to apply fertilisers to their land EACH YEAR. (2)

7.2 Write down ONE negative impact that OVERFERTILISATION can have on humans. (2)

7.3 Sulphuric acid is an important substance used in the manufacture of fertilisers.

The equation below represents one of the steps in the industrial preparation of sulphuric acid.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H < 0$$

7.3.1 Write down the name of the process used to prepare sulphuric acid in industry. (1)

7.3.2 Write down the NAME or FORMULA of the catalyst used in the process in QUESTION 7.3.1. (1)

7.3.3 Is the forward reaction exothermic or endothermic? Give a reason for the answer. (2)

7.3.4 Write down the NAME or FORMULA of the fertiliser formed when sulphuric acid reacts with ammonia. (2)

The reaction, represented by the equation in QUESTION 7.3, reaches equilibrium at a certain temperature in a 2 dm^3 closed container.

On analysis of the equilibrium mixture, it is found that 0,6 mole of $SO_2(g)$, 0,5 mole of $O_2(g)$ and 0,4 mole of $SO_3(g)$ are present in the container.

7.3.5 List THREE changes that can be made to this equilibrium to increase the yield of $SO_3(g)$. (3)

7.3.6 The temperature is NOW increased and the reaction is allowed to reach equilibrium for the second time at the new temperature. On analysis of this new equilibrium mixture, it is found that 0,2 mole of $SO_3(g)$ is present in the container.

Calculate the equilibrium constant for this reaction at the new temperature. (8)

[21]

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QUESTION 8 (Start on a new page.)

Learners conduct an investigation to determine which combination of two half-cells will provide the largest emf at standard conditions.

Three half-cells, represented as **A**, **B** and **C** in the table below, are available.

HALF-CELL A	HALF-CELL B	HALF-CELL C
$Mg\|Mg^{2+}$	$Pb\|Pb^{2+}$	$A\ell\|A\ell^{3+}$

The learners set up galvanic cells using different combinations of the above half-cells.

8.1 Write down the standard conditions under which these cells operate. (2)

8.2 Write down the dependent variable in this investigation. (1)

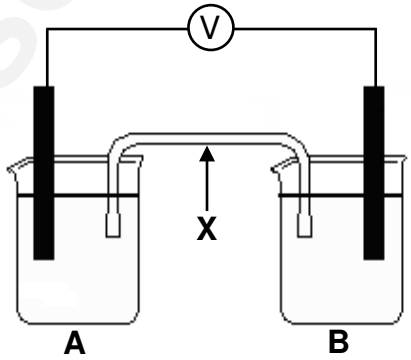
8.3 Use the Table of Standard Reduction Potentials to determine which ONE of the three half-cells (**A**, **B** or **C**) contains the:

8.3.1 Strongest reducing agent (1)

8.3.2 Strongest oxidising agent (1)

8.4 Without any calculation, write down the combination of two half-cells which will produce the highest emf. Write down only **AB**, **BC** or **AC**. (1)

8.5 One group of learners set up a galvanic cell using half-cells **A** and **B**, as shown below. **X** represents one of the components of the galvanic cell.



8.5.1 Write down the NAME or SYMBOL of the substance that will act as the anode in this cell. Give a reason for the answer. (2)

8.5.2 Calculate the initial emf of this cell. (4)

8.5.3 How will an increase in the concentration of the electrolyte in half-cell **B** affect the intial emf of the cell? Write down only INCREASES, DECREASES or REMAINS THE SAME. (2)

8.5.4 Briefly explain how component **X** ensures electrical neutrality while the cell is functioning. (2)

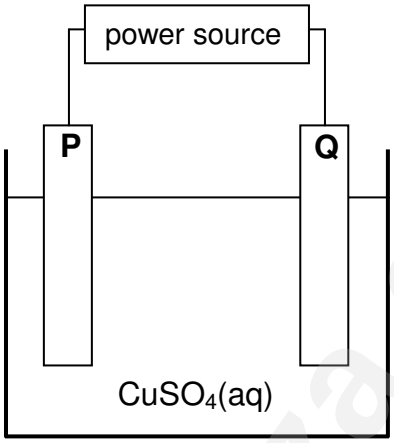
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QUESTION 9 (Start on a new page.)

The simplified diagram below represents an electrochemical cell used in the refining of copper. One of the electrodes consists of impure copper and the other one of pure copper.



9.1 What type of power source is used to drive the reaction in this cell? Write down only AC or DC. (1)

9.2 Give a reason why the copper(II) sulphate is dissolved in water before it is used in this cell. (1)

When an electric current passes through the solution, electrode **P** becomes coated with copper.

9.3 Is electrode **P** the cathode or the anode? Support your answer by writing the half-reaction that takes place at electrode **P**. (3)

9.4 Write down the half-reaction that takes place at electrode **Q**. (2)

It is found that the impure copper plate contains platinum. The platinum forms a residue at the bottom of the container during electrolysis.

9.5 Refer to the relative strengths of reducing agents to explain why platinum forms a residue at the bottom of the container. (2)

9.6 How will the concentration of the copper(II) sulphate solution change during electrolysis? Write down only INCREASES, DECREASES or REMAINS THE SAME.

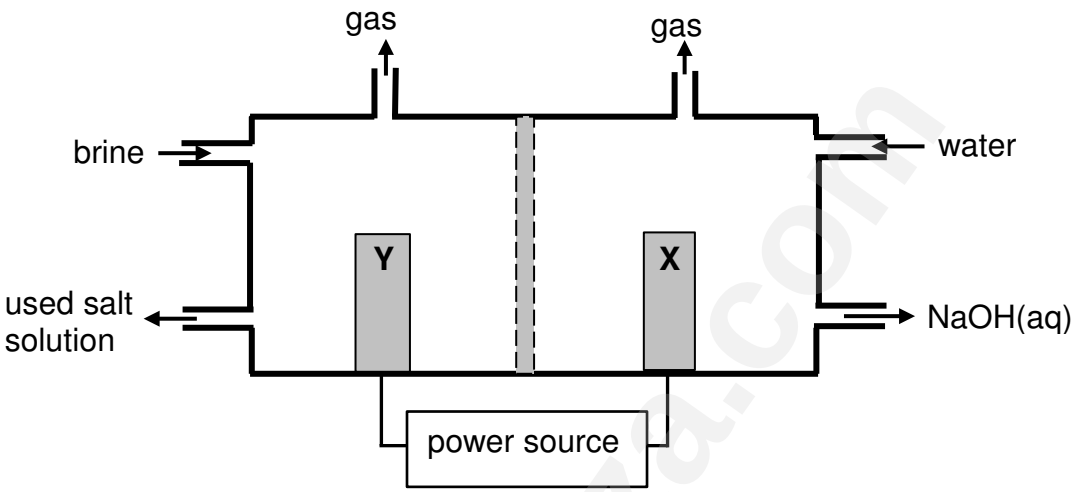
Give a reason for the answer. (3)
[12]

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QUESTION 10 (Start on a new page.)

The simplified diagram of a cell used in the chlor-alkali industry is shown below.



10.1 Write down the CHEMICAL FORMULA of brine. (1)

10.2 At which electrode, **X** or **Y**, is chlorine gas formed? (1)

10.3 Write down a half-reaction that explains the formation of hydrogen gas at one of the electrodes. (2)

10.4 The purity of the sodium hydroxide produced in the chlor-alkali industry depends on the extent to which it is separated from the chlorine gas produced by this cell. Briefly describe how chlorine gas and sodium hydroxide are prevented from mixing in this cell. (2)

10.5 Apart from advantages and disadvantages of products produced, write down for this process:

10.5.1 ONE positive impact on humans (2)

10.5.2 ONE negative impact on humans (2)
[10]

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QUESTION 11 (Start on a new page.)

Mercury(II) oxide batteries are sometimes used in watches and cameras.

The two half-reactions involved in this battery and their respective reduction potentials are given below.

A: $HgO(s) + H_2O(\ell) + 2e^- \rightleftharpoons Hg(\ell) + 2OH^-(aq)$ $E^\circ_{reduction} = 0,098$ V

B: $ZnO(s) + H_2O(\ell) + 2e^- \rightleftharpoons Zn(s) + 2OH^-(aq)$ $E^\circ_{reduction} = -1,252$ V

11.1 Which half-reaction (**A** or **B**) takes place at the cathode of this battery? Refer to the given reduction potentials and give a reason for the answer. (2)

11.2 Write down the net (overall) reaction that takes place in this battery. (3)

11.3 Write down the SYMBOL or FORMULA or NAME of the substance that acts as reducing agent in this battery.

Use oxidation numbers to explain the answer. (2)

11.4 State ONE safety concern regarding the disposal of these batteries. (2)
[9]

TOTAL SECTION B: 125
GRAND TOTAL: 150

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GRADE/*GRAAD 12*

PHYSICAL SCIENCES: CHEMISTRY (P2)
FISIESE WETENSKAPPE: CHEMIE (V2)

FEBRUARY/MARCH/*FEBRUARIE/MAART* 2012

MEMORANDUM

MARKS/*PUNTE:* **150**

This memorandum consists of 15 pages.
Hierdie memorandum bestaan uit 15 bladsye.

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Learning Outcomes and Assessment Standards *Leeruitkomste en Assesseringstandaarde*		
LO/*LU* 1	**LO/*LU* 2**	**LO/*LU* 3**
AS 12.1.1: Design, plan and conduct a scientific inquiry to collect data systematically with regard to accuracy, reliability and the need to control variables. *Ontwerp, beplan en voer 'n wetenskaplike ondersoek uit om data te versamel ten opsigte van akkuraatheid, betroubaarheid en die kontroleer van veranderlikes.*	**AS 12.2.1:** Define, discuss and explain prescribed scientific knowledge. *Definieer, bespreek en verduidelik voorgeskrewe wetenskaplike kennis.*	**AS 12.3.1:** Research, discuss, compare and evaluate scientific and indigenous knowledge systems and knowledge claims by indicating the correlation among them, and explain the acceptance of different claims. *Doen navorsing, bespreek, vergelyk en evalueer wetenskaplike en inheemse kennissisteme en kennisaansprake deur die ooreenkoms aan te dui en verduidelik die aanvaarding van verskillende aansprake.*
AS 12.1.2: Seek patterns and trends, represent them in different forms, explain the trends, use scientific reasoning to draw and evaluate conclusions, and formulate generalisations. *Soek patrone en tendense, stel dit in verskillende vorms voor, verduidelik tendense, gebruik wetenskaplike beredenering om gevolgtrekkings te maak en te evalueer, en formuleer veralgemenings.*	**AS 12.2.2:** Express and explain prescribed scientific principles, theories, models and laws by indicating the relationship between different facts and concepts in own words. *Verduidelik en druk voorgeskrewe wetenskaplike beginsels, teorieë, modelle en wette uit deur die verwantskap tussen verskillende feite en konsepte in eie woorde aan te dui.*	**AS 12.3.2:** Research case studies and present ethical and moral arguments from different perspectives to indicate the impact (pros and cons) of different scientific and technological applications. *Vors gevallestudies na en lewer etiese en morele argumente uit verskillende perspektiewe om die impak (voordele en nadele) van verskillende wetenskaplike en tegnologiese toepassings aan te dui.*
AS 12.1.3: Select and use appropriate problem-solving strategies to solve (unseen) problems. *Kies en gebruik geskikte probleemoplossingstrategieë om (ongesiene) probleme op te los.*	**AS 12.2.3:** Apply scientific knowledge in everyday life contexts. *Pas wetenskaplike kennis in kontekste van die alledaagse lewe toe.*	**AS 12.3.3:** Evaluate the impact of scientific and technological research and indicate the contribution to the management, utilisation and development of resources to ensure sustainability continentally and globally. *Evalueer die impak van wetenskaplike en tegnologiese navorsing en dui die bydrae tot bestuur, benutting en ontwikkeling van bronne om volhoubaarheid kontinentaal en globaal te verseker.*
AS 12.1.4: Communicate and defend scientific arguments with clarity and precision. *Kommunikeer en verdedig wetenskaplike argumente duidelik en presies.*		

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SECTION A/*AFDELING A*

QUESTION 1/*VRAAG 1*

1.1 Functional group/*Funksionele groep* ✓ (1)

1.2 Hydrohalogenation/*Hidrohalogenering of hidrohalogenasie* ✓ (1)

1.3 Activation energy/*Aktiveringsenergie* ✓ (1)

1.4 Salt bridge/*Soutbrug* ✓ (1)

1.5 Primary (cells)/*Primêre (selle)* ✓ (1)
[5]

QUESTION 2/*VRAAG 2*

2.1 C ✓✓ (2)

2.2 B ✓✓ (2)

2.3 C ✓✓ (2)

2.4 D ✓✓ (2)

2.5 C ✓✓ (2)

2.6 A ✓✓ (2)

2.7 B ✓✓ (2)

2.8 C ✓✓ (2)

2.9 D ✓✓ (2)

2.10 D ✓✓ (2)
[20]

TOTAL SECTION A: 25

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SECTION B/*AFDELING B*

QUESTION 3/*VRAAG 3*

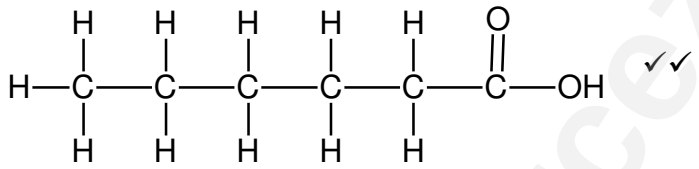
3.1 Alkanes/*Alkane* ✓ (1)

3.2 2,4-dimethyl✓hexane ✓
2,4-dimetiel✓heksaan ✓ (2)

3.3 4-fluoro-3-methyl✓cyclopentene ✓
4-fluoro-3-metiel✓siklopenteen ✓
4-fluoor-3-metiel✓siklopenteen ✓
(2)

3.4 4-methyl✓pent-2-yne ✓ OR 4-methyl✓-2-pentyne ✓
4-metiel✓pent-2-yn ✓ OF *4-metiel✓-2-pentyn* ✓ (2)

3.5



✓✓

(2)
[9]

QUESTION 4/*VRAAG 4*

4.1
4.1.1 (An organic) compound/substance/ molecule which contains/consists of carbon and hydrogen (atoms only). ✓✓

('n Organiese) verbinding/stof/ molekuul wat slegs uit koolstof- en waterstof(atome) bestaan. ✓✓ (2)

4.1.2 C_5H_{12} ✓ (1)

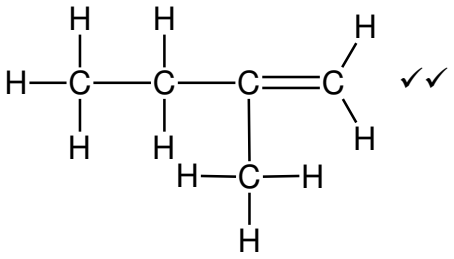
4.1.3 Any TWO:
Speeds up the reaction/Increase reaction rate. ✓
Reaction runs at a lower temperature/energy. ✓
Cost is reduced/better safety.

Enige TWEE:
Versnel die reaksie./Verhoog reaksietempo. ✓
Reaksie verloop by laer temperatuu/energie. ✓
Koste word verminder/groter veiligheid. (2)

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4.1.4



✓✓

(2)

4.1.5 Addition/hydrogenation ✓
Addisie/hidrogenering (1)

4.2

4.2.1 Compounds have the same molecular formula, but different structural formulae. ✓✓

Verbindings het dieselfde molekulêre formule, maar verskillende struktuurformules. ✓✓ (2)

4.2.2 **From A to C:/*Van A na C:***
Boiling points decrease from **A** to **C**. ✓
*Kookpunte verminder van **A** na **C**.*

Branching increases./Molecules become more compact./Molecules become more spherical./Decrease in surface area (over which the intermolecular forces act.) ✓
Decrease in (strength) of intermolecular forces. ✓
Less energy needed to overcome intermolecular forces. ✓

Vertakking vermeerder./Molekule word meer kompak./Molekule word meer sferies./Afname in oppervlak (waaroor intermolekulêre kragte werk.) ✓
Afname in (sterkte) van intermolekulêre kragte. ✓
Minder energie benodig om intermolekulêre kragte te oorkom. ✓

OR/*OF*
From C to A:/*Van C na A*:
Boiling points increase from **C** to **A**. ✓
*Kookpunte verhoog van **C** na **A**.*

Less branching./Molecules become less compact./Molecules become less spherical./Increase in surface area (over which intermolecular forces act.) ✓
Increase in (strength) of intermolecular forces. ✓
More energy needed to overcome intermolecular forces. ✓

Vertakking verminder./Molekule word minder kompak./Molekule word minder sferies./Toename in oppervlak (waaroor intermolekulêre kragte werk.) ✓
Toename in (sterkte) van intermolekulêre kragte. ✓
Meer energie benodig om intermolekulêre kragte te oorkom. ✓ (4)

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4.2.3 (Branched chains have weaker intermolecular forces)
therefore they (burn) <u>react faster.</u> ✓✓

Vertakte kettings het swakker intermolekulêre kragte)
Dus (brand) <u>reageer hulle vinniger.</u> ✓✓

OR/*OF*
Branched chains have <u>higher vapour pressures</u>. ✓✓
Vertakte kettings het <u>hoër dampdrukke</u>. ✓✓ (2)
[16]

QUESTION 5/*VRAAG 5*

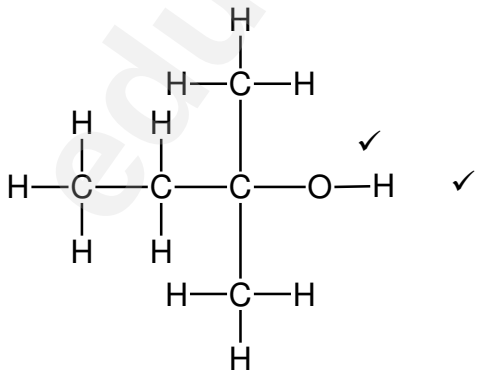
5.1
5.1.1 Ellimination/dehydrohalogenation/dehydrobromination ✓
Eliminasie/dehidrohalogenering/dehidrobrominering ✓ (1)

5.1.2 Heat ✓
<u>Concentrated sodium hydroxide</u> (NaOH)/<u>Concentrated</u> potassium hydroxide (KOH)/Concentrated strong base ✓
OR sodium hydroxide (NaOH)/potassium hydroxide (KOH)/strong base dissolved in ethanol/alcohol

Hitte ✓
<u>Gekonsentreerde natriumhidroksied</u> (NaOH)/<u>Gekonsentreerde</u> kalium-hidroksied (KOH)/Gekonsentreerde sterk basis ✓
***OF** natriumhidroksied kaliumhidroksied/NaOH/KOH/sterk basis opgelos in etanol/ alkohol)*

OR/*OF*
Hot ✓ <u>ethanolic sodium hydroxide</u>/potassium hydroxide/KOH/NaOH ✓
Warm ✓ *<u>etanoliese natriumhidroksied</u>/kaliumhidroksied/KOH/NaOH* ✓ (2)

5.1.3



✓ ✓

(2)

5.1.4 H_2O/water ✓ (1)

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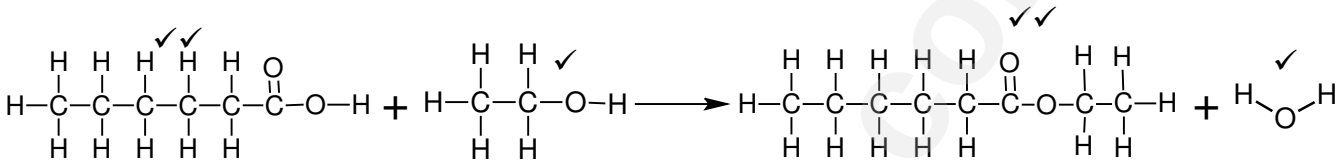
5.1.5 Addition/Hydration ✓ (1)
Addisie/Hidrasie ✓

5.2

5.2.1 Ethanol/*etanol* ✓✓ (2)

5.2.2 Catalyst/*katalisator* ✓
Accept/*Aanvaar*: Dehydrating agent/*Dehidreermiddel* (1)

5.2.3



(6)

5.2.4 Alcohols are flammable/volatile/catch fire easily. ✓
Alkohole is (ont)vlambaar/vlugtig/brand maklik. ✓ (1)

5.2.5 (Food) flavourant/*(Voedsel)geurmiddel* ✓ (1)
[18]

QUESTION 6/*VRAAG 6*

6.1 Amount of reactants used ✓per unit time. ✓
Hoeveelheid reaktanse gebruik per eenheid tyd

OR/*OF*
Amount of products formed per unit time.
Hoeveelheid produkte gevorm per eenheid tyd.

OR/*OF*
Change in concentration of reactants or products per unit time.
Verandering in konsentrasie van reaktanse of produkte per eenheid tyd. (2)

6.2 To ensure that (nearly) all zinc is used up./Zinc is a limiting reagent. ✓
Om seker te maak (feitlik) alle sink word opgebruik./Sink is 'n beperkende reagens. ✓ (1)

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6.3

Criteria for hypothesis: ***Kriteria vir hipotese*:**	**Mark** ***Punt***
The **dependent and independent variables** correctly identified. *Die **afhanklike en onafhanklike veranderlikes** is korrek geïdentifiseer.*	✓
Made a **prediction/statement** about the **relationship between the dependent and independent variables.** *Maak 'n **voorspelling/stelling oor die verwantskap tussen die afhanklike en onafhanklike veranderlikes.***	✓

Examples/*Voorbeelde*:

- Reaction rate increases with increase in concentration.
  Reaksietempo neem toe met toename in konsentrasie.
- Reaction rate decreases with decrease in concentration.
  Reaksietempo neem af met afname in konsentrasie.
- Reaction rate is directly proportional to concentration.
  Reaksietempo is direk eweredig aan konsentrasie.
- The higher the concentration the faster the rate of the reaction.
  Hoe hoër die konsentrasie, hoe vinniger is die reaksietempo.
- Reaction rate increases with decrease in concentration.
  Reaksietempo verhoog met afname in konsentrasie.
- Reaction rate decreases with deceases in concentration.
  Reaksietempo verlaag met toename in konsentrasie.
- Reaction rate is inversely proportional to concentration.
- *Reaksietempo is omgekeerd eweredig aan konsentrasie.*
- The higher the concentration the lower the rate of the reaction.
  Hoe hoër die konsentrasie, hoe laer is die reaksietempo.

(2)

6.4 To make it a fair test./*Om dit 'n regverdige toets te maak.* ✓

OR/*OF*
Ensure validity/reliability of results. ✓
Verseker betroubaarheid van resultate. ✓

OR/*OF*
So that the contact/surface area may not influence the reaction rate./The surface area must not change.
Sodat die (kontak)oppervlak nie die reaksietempo beïnvloed nie./Die oppervlak moenie verander nie.

OR/*OF*
It is the controlled variable./*Dit is die gekontroleerde veranderlike.*

OR/*OF*
To ensure there is only one independent variable.
Om te verseker daar is slegs een onafhanklike veranderlike.

(1)

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6.5 Number of moles used/*Aantal mol gebruik* = 0,1 – 0,08 = 0,02 mol ✓

$n = \frac{m}{M}$ ✓

$0,02 = \frac{m}{65}$ ✓

m = 1,3 g ✓

(4)

6.6 **POSITIVE MARKING FROM QUESTION 6.5 TO 6.6**
POSITIEWE NASIEN VAN VRAAG 6.5 TOT 6.6

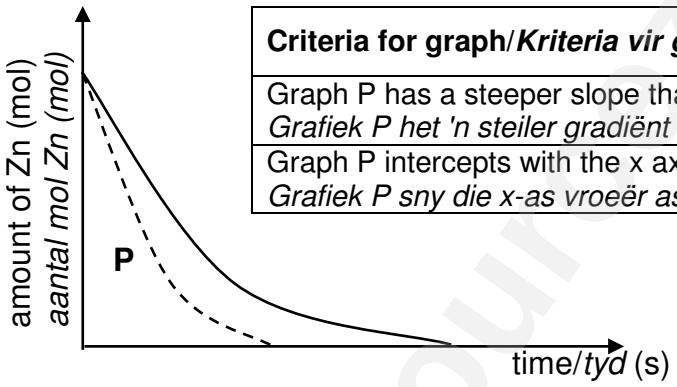
$\text{Average rate} = \frac{\text{mass Zn used}}{\text{time taken}}$

$= \frac{1,3}{60}$ ✓

= 0,02 g·s^{-1} ✓ (0,022 g or 0,0217 g)

(2)

6.7



Criteria for graph/*Kriteria vir grafiek*	Marks/ *Punte*
Graph P has a steeper slope than the original graph. *Grafiek P het 'n steiler gradiënt as oorspronklike grafiek.*	✓
Graph P intercepts with the x axis earlier than original graph. *Grafiek P sny die x-as vroeër as die oorspronklike grafiek.*	✓

(2)
[14]

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QUESTION 7/*VRAAG 7*

7.1 Fertilisers replenish nutrients ✓
depleted by growing of crops. ✓

Kunsmis vul voedingstowwe aan ✓
wat deur groeiende gewasse uitgeput is. ✓ (2)

7.2 Any ONE/*Enige een*:

- Damage to crops/soil ✓
  resulting in small or no harvest./less income. ✓
  Skade aan gewasse/grond ✓
  wat tot klein of geen oeste lei./kleiner inkomste lei. ✓
- Excessive fertiliser seeps into groundwater ✓
  and contaminates drinking water. ✓
  Oormaat kunsmis syfer in grondwater in ✓
  en kontamineer drinkwater. ✓
- Excessive fertiliser run-off into rivers and dams and cause eutrophication ✓
  that may result in less income./starvation./poor quality of drinking water./ fewer recreation areas. ✓
  Oormaat kunsmis loop in riviere en damme in en veroorsaak eutrofikasie ✓
  wat kan lei tot kleiner inkomste./hongersnood./swak kwaliteit drinkwater./ minder ontspanningsgebiede. ✓ (2)

7.3

7.3.1 Contact process/*Kontakproses* ✓ (1)

7.3.2 V_2O_5/vanadium pentoxide/*vanadiumpentoksied* ✓ (1)

7.3.3 Exothermic/*Eksotermies* ✓
$\Delta H < 0$ ✓ (2)

7.3.4 $(NH_4)_2$✓SO_4✓ /ammonium✓ sulphate✓/*ammonium*✓*sulfaat* ✓ (2)

7.3.5 ANY THREE:
Decrease temperature ✓
Increase pressure ✓
Increase concentration of both/any one of reactants. ✓
Remove SO_3 continuously

ENIGE DRIE:
Afname in temperatuur ✓
Toename in druk ✓
Toename in konsentrasie van beide/enige een van reaktanse ✓
Verwyder SO_3 aanhoudend (3)

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7.3.6 **CALCULATIONS USING NUMBER OF MOLES**
BEREKENINGE WAT AANTAL MOL GEBRUIK

Mark allocation:

- Change in $n(SO_3)$ = 0,2 (mol) ✓
- Ratio $n(SO_2) : n(O_2) : n(SO_3) = 2 : 1 : 2$ ✓
- $n(SO_2)$ at equilibrium = initial + change ✓
- $n(O_2)$ at equilibrium = initial + change ✓
- Divide three equilibrium amounts by 2 (calculation of concentration) ✓
- K_c expression ✓
- Substitution into K_c expression ✓
- Final answer = 0,21 ✓

Puntetoekenning:

- *Verandering in $n(SO_3)$ = 0,2 (mol)* ✓
- *Verhouding $n(SO_2) : n(O_2) : n(SO_3) = 2 : 1 : 2$* ✓
- *$n(SO_2)$ by ewewig = aanvanklik + verandering* ✓
- *$n(O_2)$ by ewewig = aanvanklik + verandering* ✓
- *Deel drie ewewigshoeveelhede deur 2 (berekening van konsentrasie)* ✓
- *K_c-uitdrukking* ✓
- *Vervanging in K_c-uitdrukking* ✓
- *Finale antwoord = 0,21* ✓

Option 1/*Opsie 1:*

Amount of SO_3 reacted/*Hoeveelheid SO_3 wat reageer* = 0,2 mol ✓
$n(SO_2$ formed/*gevorm*$)$ = 0,2 mol
$n(O_2$ formed$)$ = ½ $n(SO_3$ formed$)$ = 0,1 mol } Ratio/*verhouding* ✓

At equilibrium/*By ewewig*: $n(SO_2) = 0,6 + 0,2 = 0,8$ mol ✓
$n(O_2) = 0,5 + 0,1 = 0,6$ mol ✓

$$c(SO_3) = \frac{n}{V} = \frac{0,2}{2} = 0,1 \text{ mol·dm}^{-3}$$
$$c(SO_2) = \frac{n}{V} = \frac{0,8}{2} = 0,4 \text{ mol·dm}^{-3}$$
$$c(O_2) = \frac{n}{V} = \frac{0,6}{2} = 0,3 \text{ mol·dm}^{-3}$$
} ✓ divide by/*gedeel deur* 2

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]} \checkmark = \frac{(0,1)^2}{(0,4)^2(0,3)} \checkmark = 0,21 \checkmark \ (0,208)$$

No K_C expression, correct substitution:
Geen K_c-uitdrukking, korrekte vervanging: Max./Maks. $\frac{7}{8}$

Wrong K_C expression/*Verkeerde K_c-uitdrukking:* Max./Maks. $\frac{5}{8}$

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Option 2/*Opsie 2*:

	SO_2	O_2	SO_3	
Molar ratio/*Molverhouding*	2	1	2	
Initial quantity (mol) *Aanvanklike hoeveelheid (mol)*	0,6	0,5	0,4	Ratio/*verhouding* ✓
Change (mol)/*Verandering (mol)*	0,2	0,1	0,2 ✓	
Quantity at equilibrium (mol) *Hoeveelheid by ewewig (mol)*	0,8 ✓	0,6 ✓	0,2	
Concentration ($mol{\cdot}dm^{-3}$) *Konsentrasie ($mol{\cdot}dm^{-3}$)*	0,4	0,3	0,1	Divide by 2 *Gedeel deur 2* ✓

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]} \checkmark = \frac{(0,1)^2}{(0,4)^2(0,3)} \checkmark = 0,21 \checkmark \ (0,208)$$

No K_C expression, correct substitution: *Geen K_c-uitdrukking, korrekte vervanging:*	Max./Maks. $\frac{7}{8}$
Wrong K_C expression/*Verkeerde K_c-uitdrukking:*	Max./Maks. $\frac{5}{8}$

CALCULATIONS USING CONCENTRATION
BEREKENINGE WAT KONSENTRASIE GEBRUIK

Mark allocation:

- Divide three intial amounts by 2 (calculation of concentration) ✓
- Change in $[SO_3]$ = 0,2 ($mol{\cdot}dm^{-3}$) ✓
- Ratio $[SO_2] : [O_2] : [SO_3]$ = 2 : 1: 2 ✓
- $[SO_2]$ at equilibrium = initial + change ✓
- $[O_2]$ at equilibrium = initial + change ✓
- K_c expression ✓
- Substitution into K_c expression ✓
- Final answer = 0,21 ✓

Puntetoekenning:

- *Deel drie aanvangshoeveelhede deur 2 (berekening van konsentrasie)* ✓
- *Verandering in $[SO_3]$ = 0,2 ($mol{\cdot}dm^{-3}$)* ✓
- *Verhouding $[SO_2] : [O_2] : [SO_3]$ = 2 : 1: 2* ✓
- *$[SO_2]$ by ewewig = aanvanklik + verandering* ✓
- *$[O_2]$ by ewewig = aanvanklik + verandering* ✓
- *K_c-uitdrukking* ✓
- *Vervanging in K_c-uitdrukking* ✓
- *Finale antwoord = 0,21* ✓

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Option 3/*Opsie 3:*

	SO_2	O_2	SO_3
Molar ratio/*molverhouding*	2	1	2
Initial concentration ($mol \cdot dm^{-3}$) *Aanvanklike konsentrasie ($mol \cdot dm^{-3}$)*	0,3	0,25	0,2
Change in concentration ($mol \cdot dm^{-3}$) *Verandering in konsentrasie* ($mol \cdot dm^{-3}$)	0,1	0,05	0,1 ✓
Equilibrium concentration ($mol \cdot dm^{-3}$) *Ewewigskonsentrasie ($mol \cdot dm^{-3}$)*	0,4✓	0,3✓	0,1

Divide by 2 ✓ *Gedeel deur 2*
Ratio/ *Verhouding* ✓

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]} \checkmark = \frac{(0,1)^2}{(0,4)^2(0,3)} \checkmark = 0,21 \checkmark (0,208)$$

No K_C expression, correct substitution: *Geen K_c-uitdrukking, korrekte vervanging:*	Max./Maks. $\frac{7}{8}$
Wrong K_C expression/*Verkeerde K_c-uitdrukking:*	Max./Maks. $\frac{5}{8}$

(8)
[21]

QUESTION 8/*VRAAG 8*

8.1 Temperature/*Temperatuur* – 25 °C/298 K ✓
Concentration (of electrolytes)/*Konsentrasie (van elektroliete)* = 1 $mol \cdot dm^{-3}$ ✓ (2)

8.2 Emf/potential difference ✓
Emk/potensiaalverskil ✓ (1)

8.3
8.3.1 (Half-cell/*Halfsel*) A ✓ (1)

8.3.2 (Half-cell/*Halfsel*) B ✓ (1)

8.4 (Combination/*Kombinasie*) AB ✓ (1)

8.5
8.5.1 Magnesium/Mg ✓

Is oxidised/loses electrons/increase in oxidation number/stronger reducing agent. ✓
Word geoksideer/verloor elektrone/toename in oksidasiegetal/sterker reduseermiddel. ✓ (2)

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8.5.2

Option 1/*Opsie 1:*	**Option 2/*Opsie 2:***
$E^o_{cell} = E^o_{cathode} - E^o_{anode}$ ✓ $= -0,13$ ✓$- (-2,36)$ ✓ $E^o_{anode} = 2,23$ V ✓	✓ $Mg \rightarrow Mg^{2+} + 2e^-$ $E° = +2,36$ ✓ $Pb^{2+} + 2e^- \rightarrow Pb$ $E° = -0,13$ ✓ $E° = 2,23$ V ✓

(4)

8.5.3 Increases/*Vermeerder* ✓✓ (2)

8.5.4 Allows for the migration of positive ions to the cathode half-cell. ✓
Laat migrasie van positiewe ione na die katodehalfsel toe.

Allows for the migration of negative ions to the anode half-cell. ✓
Laat migrasie van negatiewe ione na die anodehalfsel toe.

(2)
[16]

QUESTION 9/*VRAAG 9*

9.1 DC/*GS*✓ (1)

9.2 Free ions needed to conduct electricity. ✓
Vrye ione benodig om elektrisiteit te gelei. ✓ (1)

9.3 Cathode/*Katode* ✓

$Cu^{2+} + 2e^- \rightarrow Cu$ ✓✓ (3)

9.4 $Cu \rightarrow Cu^{2+} + 2e^-$ ✓✓ (2)

9.5 Pt is a weaker reducing agent ✓ (than Cu)
and will not be oxidised. ✓
Pt is 'n swakker reduseermiddel (as Cu) ✓
en sal nie geoksideer word nie. ✓

OR/*OF*
Cu is a stronger reducing agent (than Pt)
and will be oxidised.
Cu is 'n sterker reduseermiddel (as Pt)
en sal geöksideer word. (2)

9.6 Remains the same/Bly dieselfde ✓

The rate at which Cu is oxidised ✓at the anode equals the rate at which $Cu^{2+}(aq)$ is reduced at the cathode. ✓
Die tempo waarteen Cu geoksideer word ✓*by die anode is gelyk aan die tempo waarteen* $Cu^{2+}(aq)$ *gereduseer word by die katode.* ✓ (3)
[12]

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QUESTION 10/*VRAAG 10*

10.1 $NaC\ell$ /Na^+(aq) & $C\ell^-$(aq)✓ (1)

10.2 Y ✓ (1)

10.3 $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ ✓✓ (2)

10.4 The membrane ✓
prevents chloride ions from moving to the cathode/only allows positive ions. ✓

Die membraan ✓
verhoed dat chloriedione (Cℓ⁻-ione) na die katode beweeg/laat slegs positiewe ione deur. ✓ (2)

10.5

10.5.1 Job creation ✓
resulting in more people having a better life. ✓

Werkskepping ✓
wat tot 'n beter lewe vir meer mense lei. ✓ (2)

10.5.2 Use huge amounts of electricity ✓
resulting in load shedding ✓
Gebruik groot hoeveelhede elektrisiteit ✓
wat tot beurtkrag lei. ✓

OR/*OF*
Chemical plant uses a lot of space ✓
that could have been used for housing/gardens, etc. ✓
Chemiese plant gebruik baie spasie ✓
wat andersins vir bou van huise/tuine, ens. gebruik kon word. ✓ (2)
[10]

QUESTION 11

11.1 A ✓
More positive reduction potential./Larger reduction potential. ✓
Meer positiewe reduksiepotensiaal./Groter reduksiepotensiaal. ✓ (2)

11.2 $HgO(s) + Zn(s)$ ✓→ $Hg(\ell) + ZnO(s)$ ✓ Bal. ✓ (3)

11.3 Zn ✓
Oxidation number increases from 0 to +2 ✓ and is thus oxidised.
Oksidasiegetal neem toe van 0 tot +2 en word dus geöksideer. (2)

11.4 Mercury is poisonous/corrosive when in contact with skin ✓
May contaminate ground water/water resources/soil/crops. ✓

Kwik is giftig/vretend wanneer dit in kontak kom met die vel. ✓
Kan die grondwater/waterbronne/grond/gewasse kontamineer. ✓ (2)
[9]

TOTAL SECTION B/*TOTAAL AFDELING B:* 125
GRAND TOTAL/*GROOTTOTAAL*: 150

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basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE

GRADE 12

PHYSICAL SCIENCES: PHYSICS (P1)

NOVEMBER 2012

MARKS: 150

TIME: 3 hours

This question paper consists of 17 pages and 3 data sheets.

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INSTRUCTIONS AND INFORMATION

1. Write your centre number and examination number in the appropriate spaces on the ANSWER BOOK.

2. This question paper consists of TWO sections:

   SECTION A (25)
   SECTION B (125)

3. Answer ALL the questions in the ANSWER BOOK.

4. You may use a non-programmable calculator.

5. You may use appropriate mathematical instruments.

6. Number the answers correctly according to the numbering system used in this question paper.

7. YOU ARE ADVISED TO USE THE ATTACHED DATA SHEETS.

8. Give brief motivations, discussions, et cetera where required.

9. Round off your final numerical answers to a minimum of TWO decimal places.

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SECTION A

QUESTION 1: ONE-WORD ITEMS

Give ONE word/term for each of the following descriptions. Write only the word/term next to the question number (1.1–1.5) in the ANSWER BOOK.

1.1 The number of complete waves that pass a point in one second (1)

1.2 A circuit component which stores electric charge and releases it instantly (1)

1.3 The component in a generator needed to change it from an AC to a DC generator (1)

1.4 The tiny 'packets' (quanta) of energy that light consists of (1)

1.5 The vector difference of two velocities measured from the same frame of reference (1)

[5]

QUESTION 2: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Write only the letter (A–D) next to the question number (2.1–2.10) in the ANSWER BOOK.

2.1 The net force acting on an object is equal to the ...

A mass of the object.

B acceleration of the object.

C change in momentum of the object.

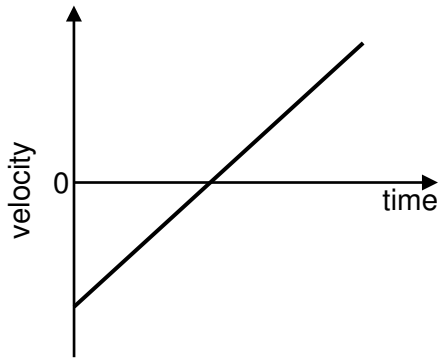
D rate of change in momentum of the object. (2)

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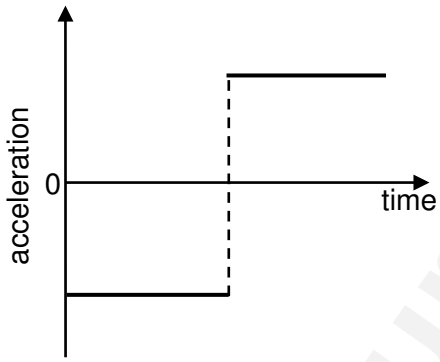
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2.2 The velocity-time graph below represents the motion of an object.

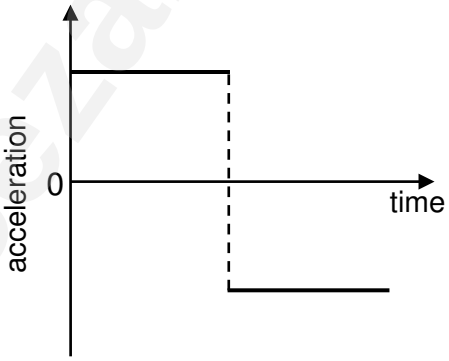


Which ONE of the following graphs represents the corresponding acceleration-time graph for the motion of this object?

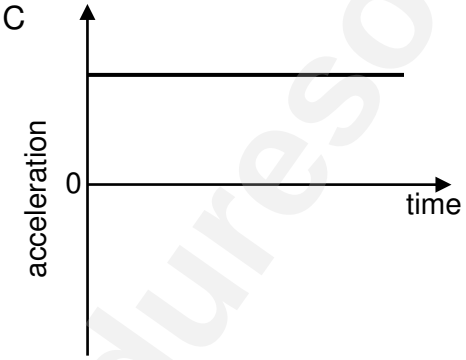
A



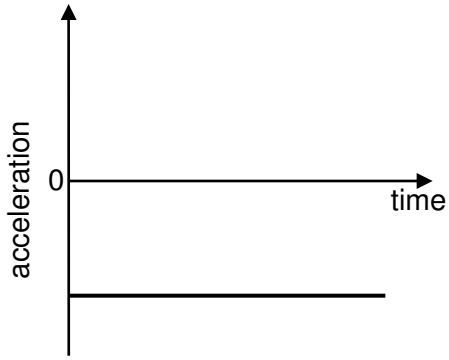
B



C



D



(2)

2.3 A car moves up a hill at CONSTANT speed. Which ONE of the following represents the work done by the weight of the car as it moves up the hill?

A ΔE_k

B ΔE_p

C $-\Delta E_k$

D $-\Delta E_p$ (2)

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2.4 A central bright band is observed when light of wavelength λ passes through a single slit of width *a*.

Light of wavelength 2λ is now used. Which ONE of the following slit widths would produce a central bright band of the SAME broadness?

A $\frac{1}{4}a$

B $\frac{1}{2}a$

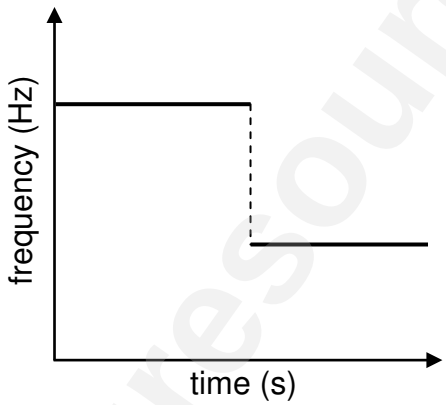
C a

D $2a$ (2)

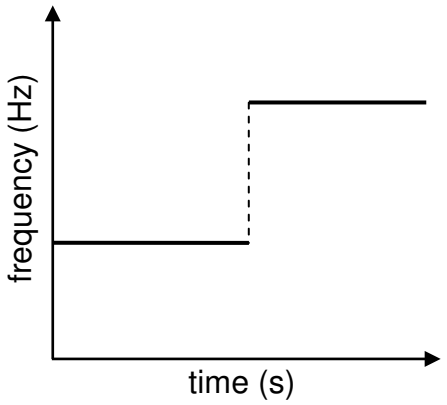
2.5 A source of sound approaches a stationary listener in a straight line at constant velocity. It passes the listener and moves away from him in the same straight line at the same constant velocity.

Which ONE of the following graphs best represents the change in observed frequency against time?

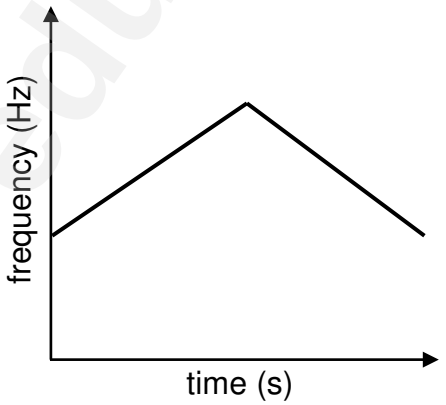
A



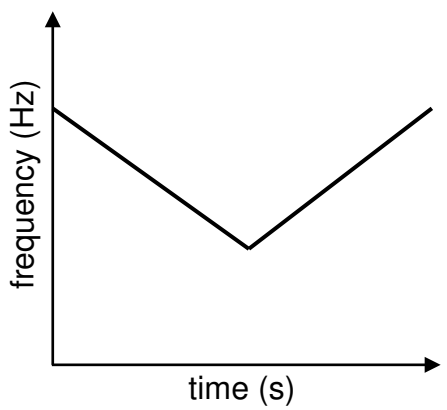
B



C



D



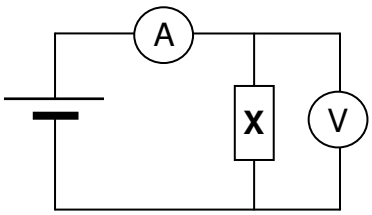
(2)

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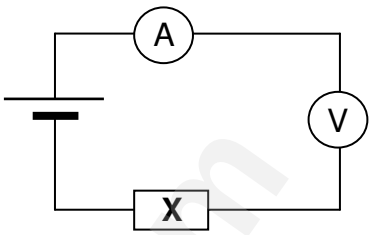
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2.6 Which ONE of the circuits below can be used to measure the current in a conductor **X** and the potential difference across its ends?

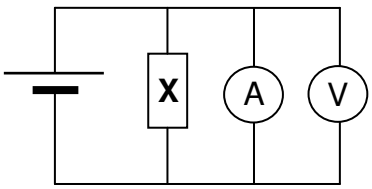
A



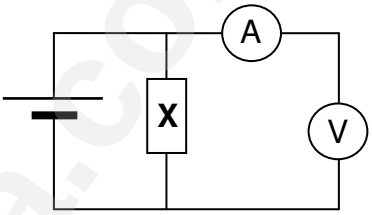
B



C

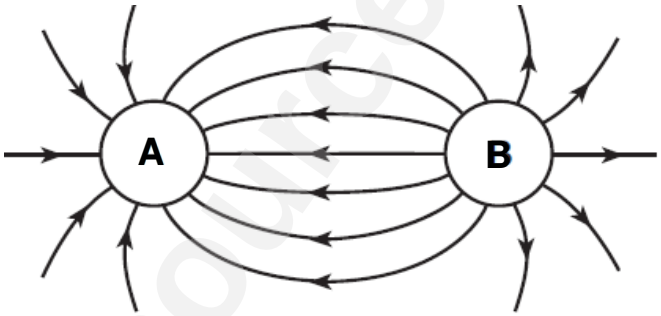


D



(2)

2.7 The electric field pattern between two charged spheres, **A** and **B**, is shown below.



Which ONE of the following statements regarding the charge on spheres **A** and **B** is CORRECT?

A Spheres **A** and **B** are both positively charged.

B Spheres **A** and **B** are both negatively charged.

C Sphere **A** is positively charged and sphere **B** is negatively charged.

D Sphere **A** is negatively charged and sphere **B** is positively charged. (2)

2.8 Which ONE of the following shows the different types of electromagnetic radiation in order of increasing frequency?

A X-rays; ultraviolet rays; infrared rays; visible light

B Infrared rays; X-rays; visible light; ultraviolet rays

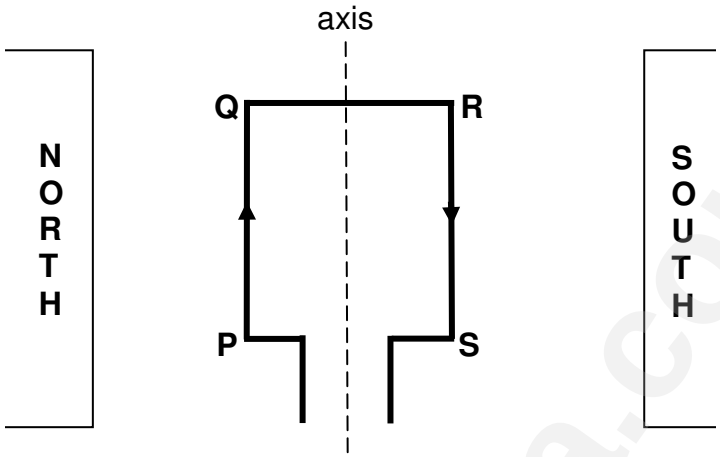
C Infrared rays; visible light; ultraviolet rays; X-rays

D X-rays; ultraviolet rays; visible light; infrared rays (2)

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2.9 A rectangular current-carrying coil, **PQRS**, is placed in a uniform magnetic field with its plane parallel to the field as shown below. The arrows indicate the direction of the conventional current.



The coil will ...

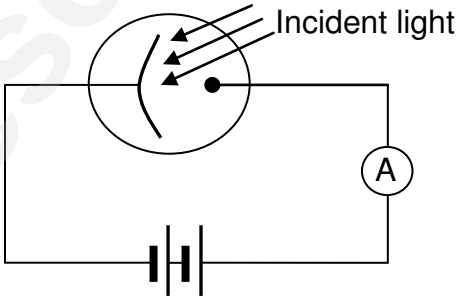
A rotate clockwise.

B remain stationary.

C rotate anticlockwise.

D rotate clockwise and then anticlockwise. (2)

2.10 The diagram below shows light incident on the cathode of a photocell. The ammeter registers a reading.



Which ONE of the following correctly describes the relationship between the intensity of the incident light and the ammeter reading?

	INTENSITY	AMMETER READING
A	Increases	Increases
B	Increases	Remains the same
C	Increases	Decreases
D	Decreases	Increases

(2)
[20]

TOTAL SECTION A: 25

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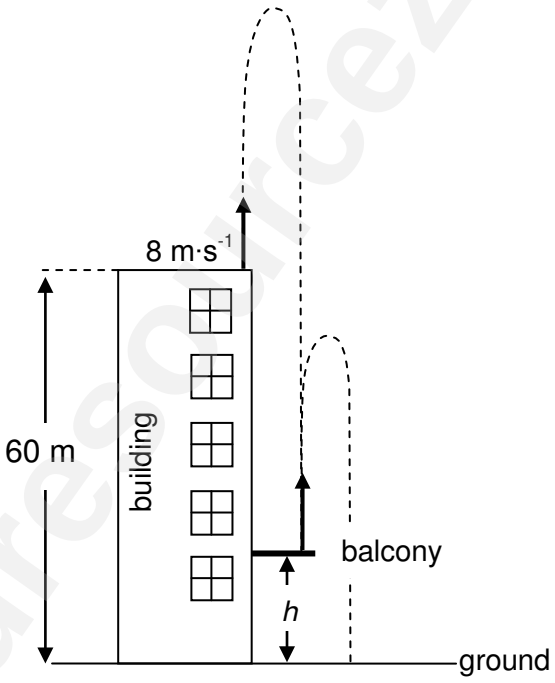
SECTION B

INSTRUCTIONS AND INFORMATION

1. Start EACH question on a NEW page.
2. Leave ONE line between two subquestions, for example between QUESTION 3.1 and QUESTION 3.2.
3. Show the formulae and substitutions in ALL calculations.
4. Round off your final numerical answers to a minimum of TWO decimal places.

QUESTION 3 (Start on a new page.)

An object is projected vertically upwards at 8 $m \cdot s^{-1}$ from the roof of a building which is 60 m high. It strikes the balcony below after 4 s. The object then bounces off the balcony and strikes the ground as illustrated below. Ignore the effects of friction.



3.1 Is the object's acceleration at its maximum height UPWARD, DOWNWARD or ZERO? (1)

3.2 Calculate the:

3.2.1 Magnitude of the velocity at which the object strikes the balcony (4)

3.2.2 Height, *h*, of the balcony above the ground (5)

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The object bounces off the balcony at a velocity of 27,13 m·s^{-1} and strikes the ground 6 s after leaving the balcony.

3.3 Sketch a velocity-time graph to represent the motion of the object from the moment it is projected from the ROOF of the building until it strikes the GROUND. Indicate the following velocity and time values on the graph:

- The initial velocity at which the object was projected from the roof of the building
- The velocity at which the object strikes the balcony
- The time when the object strikes the balcony
- The velocity at which the object bounces off the balcony
- The time when the object strikes the ground (6)

[16]

QUESTION 4 (Start on a new page.)

The diagram below shows a car of mass *m* travelling at a velocity of 20 m·s^{-1} east on a straight level road and a truck of mass 2*m* travelling at 20 m·s^{-1} west on the same road. Ignore the effects of friction.



4.1 Calculate the velocity of the car relative to the truck. (2)

The vehicles collide head-on and stick together during the collision.

4.2 State the *principle of conservation of linear momentum* in words. (2)

4.3 Calculate the velocity of the truck-car system immediately after the collision. (6)

4.4 On impact the car exerts a force of magnitude *F* on the truck and experiences an acceleration of magnitude *a*.

4.4.1 Determine, in terms of *F*, the magnitude of the force that the truck exerts on the car on impact. Give a reason for the answer. (2)

4.4.2 Determine, in terms of *a*, the acceleration that the truck experiences on impact. Give a reason for the answer. (2)

4.4.3 Both drivers are wearing identical seat belts. Which driver is likely to be more severely injured on impact? Explain the answer by referring to acceleration and velocity. (3)

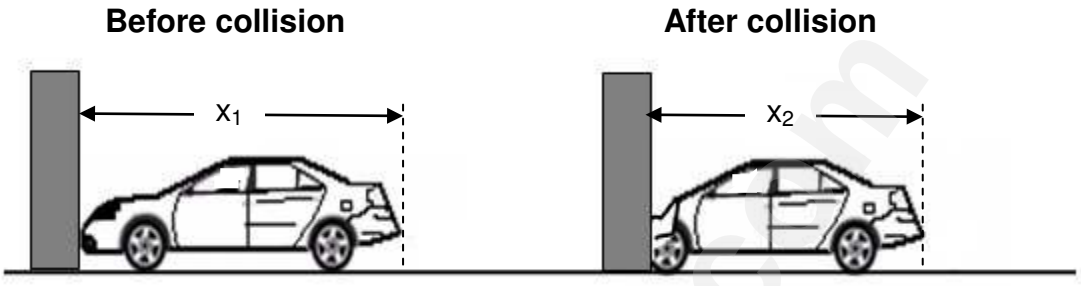
[17]

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QUESTION 5 (Start on a new page.)

In order to measure the net force involved during a collision, a car is allowed to collide head-on with a flat, rigid barrier. The resulting crumple distance is measured. The crumple distance is the length by which the car becomes shorter in coming to rest.



In one of the tests, a car of mass 1 200 kg strikes the barrier at a speed of 20 $m \cdot s^{-1}$. The crumple distance, $(x_1 - x_2)$, is measured as 1,02 m. (Ignore the effects of frictional forces during crumpling.)

5.1 Draw a labelled free-body diagram showing ALL the forces acting on the car during the collision. (3)

5.2 State the *work-energy theorem* in words. (2)

5.3 Assume that the net force is constant during crumpling.

5.3.1 USE THE WORK-ENERGY THEOREM to calculate the magnitude of the net force exerted on the car as it is brought to rest during crumpling. (4)

5.3.2 Calculate the time it takes the car to come to rest during crumpling. (4)
[13]

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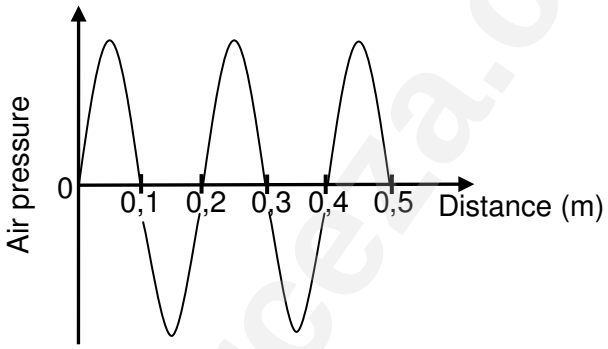
QUESTION 6 (Start on a new page.)

A bird flies directly towards a stationary birdwatcher at constant velocity. The bird constantly emits sound waves at a frequency of 1 650 Hz. The birdwatcher hears a change in pitch as the bird comes closer to him.

6.1 Write down the property of sound that is related to pitch. (1)

6.2 Give a reason why the birdwatcher observes a change in pitch as the bird approaches him. (1)

The air pressure versus distance graph below represents the waves detected by the birdwatcher as the bird comes closer to him. The speed of sound in air is 340 $m \cdot s^{-1}$.



6.3 From the graph, write down the wavelength of the detected waves. (1)

6.4 Calculate the:

6.4.1 Frequency of the waves detected by the birdwatcher (3)

6.4.2 Magnitude of the velocity at which the bird flies (5)
[11]

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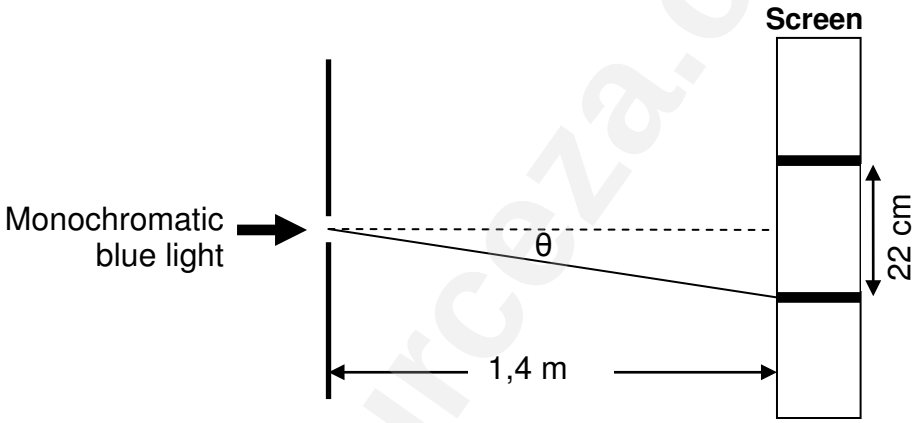
QUESTION 7 (Start on a new page.)

Learners use monochromatic blue light to investigate the difference between an interference pattern and a diffraction pattern.

7.1 Apart from the blue light and a screen, write down the name of ONE item that the learners will need to obtain an interference pattern. (1)

7.2 Briefly describe the interference pattern that will be observed on the screen. (2)

7.3 In one of their experiments they place the screen at a distance of 1,4 m from a single slit and observe a pattern on the screen. The width of the central bright band is measured as 22 cm.



Calculate the:

7.3.1 Angle θ at which the first minimum will be observed on the screen (3)

7.3.2 The width of the slit used if the wavelength of the blue light is 470 nm (5)

7.4 The width of the central band INCREASES when the blue light is replaced with monochromatic red light. Explain this observation. (2)
[13]

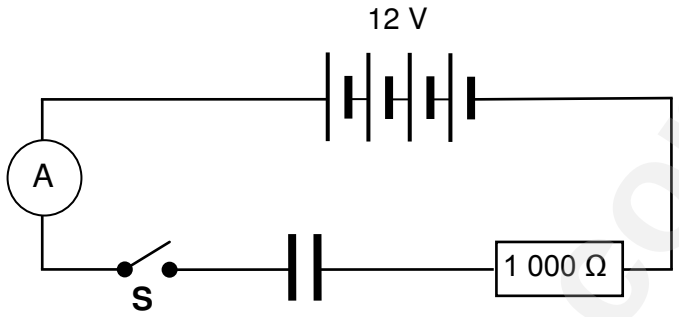
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QUESTION 8 (Start on a new page.)

In the circuit represented below, an uncharged capacitor is connected in series with a 1 000 Ω resistor. The emf of the battery is 12 V. Ignore the internal resistance of the battery and the ammeter.



8.1 Calculate the initial current in the circuit when switch **S** is closed. (3)

8.2 Write down the potential difference across the plates of the capacitor when it is fully charged. (1)

The capacitor has a capacitance of 120 μF and the space between its plates is filled with air.

8.3 Calculate the charge stored on the plates of the capacitor when it is fully charged. (3)

After discharging the capacitor, it is connected in the same circuit to a resistor of HIGHER resistance and switch **S** is closed again.

8.4 How would this change affect each of the following:
(Write down INCREASES, DECREASES or REMAINS THE SAME.)

8.4.1 The initial charging current (1)

8.4.2 The time it takes for the capacitor to become fully charged (1)

8.5 The two parallel plates of the fully charged capacitor are 12 mm apart.

8.5.1 Sketch the electric field pattern between the parallel plates. (3)

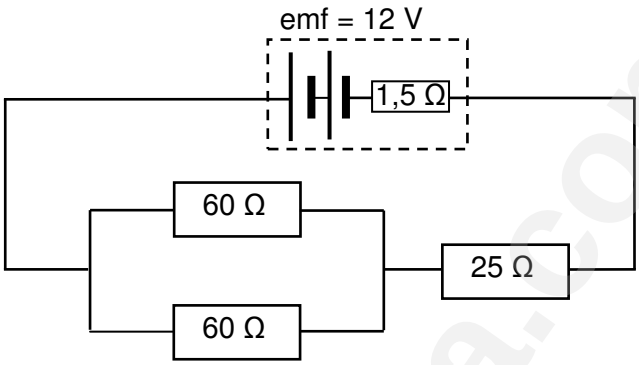
8.5.2 Calculate the magnitude of the electric field at a point midway between the plates. (3)
[15]

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QUESTION 9 (Start on a new page.)

9.1 In the circuit represented below, two 60 Ω resistors connected in parallel are connected in series with a 25 Ω resistor. The battery has an emf of 12 V and an internal resistance of 1,5 Ω.



Calculate the:

9.1.1 Equivalent resistance of the parallel combination (3)

9.1.2 Total current in the circuit (5)

9.1.3 Potential difference across the parallel resistors (3)

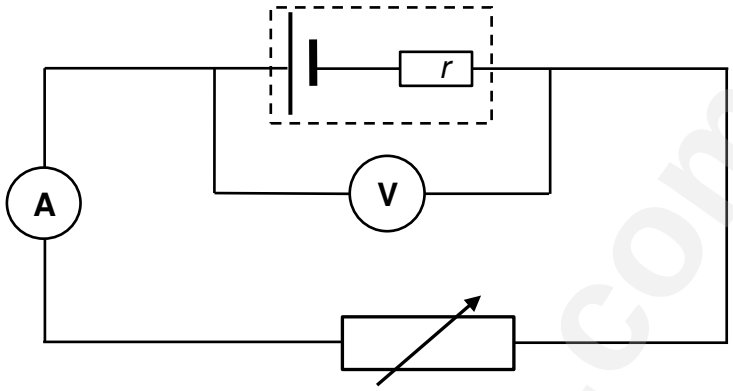
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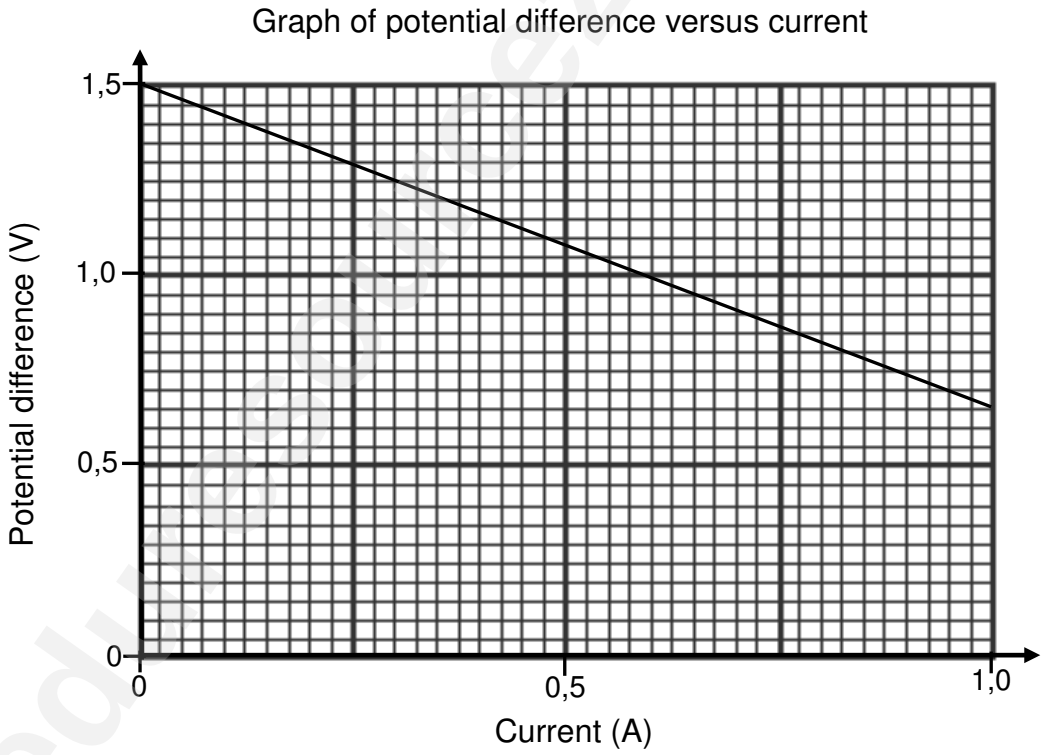
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9.2 Learners conduct an investigation to determine the emf and internal resistance (*r*) of a battery.

They set up a circuit as shown in the diagram below and measure the potential difference using the voltmeter for different currents in the circuit.



The results obtained are shown in the graph below.



9.2.1 Use the graph to determine the emf of the battery. (1)

9.2.2 Calculate the gradient of the graph. (3)

9.2.3 Which physical quantity is represented by the magnitude of the gradient of the graph? (2)

9.2.4 How does the voltmeter reading change as the ammeter reading increases? Write down INCREASES, DECREASES or REMAINS THE SAME. Use the formula emf = IR + Ir to explain the answer. (3)

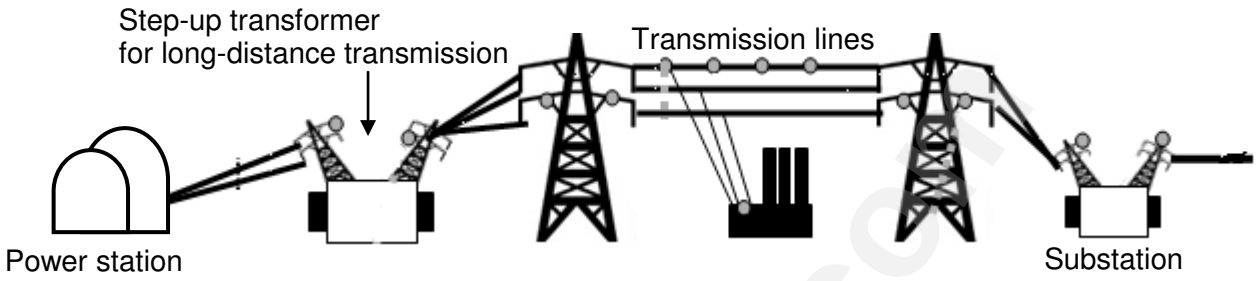
[20]

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QUESTION 10 (Start on a new page.)

The diagram below illustrates how electricity generated at a power station is transmitted to a substation.



10.1 Does the power station use an AC or a DC generator? (1)

10.2 Sketch a graph of the potential difference generated at the power station versus time. (2)

10.3 The average power produced at the power station is $4,45 \times 10^9$ W.

Calculate the rms current in the transmission lines if the power is transmitted at a maximum voltage of 30 000 V. (5)

10.4 Give a reason why electricity should be transmitted at high voltage and low current. (1)
[9]

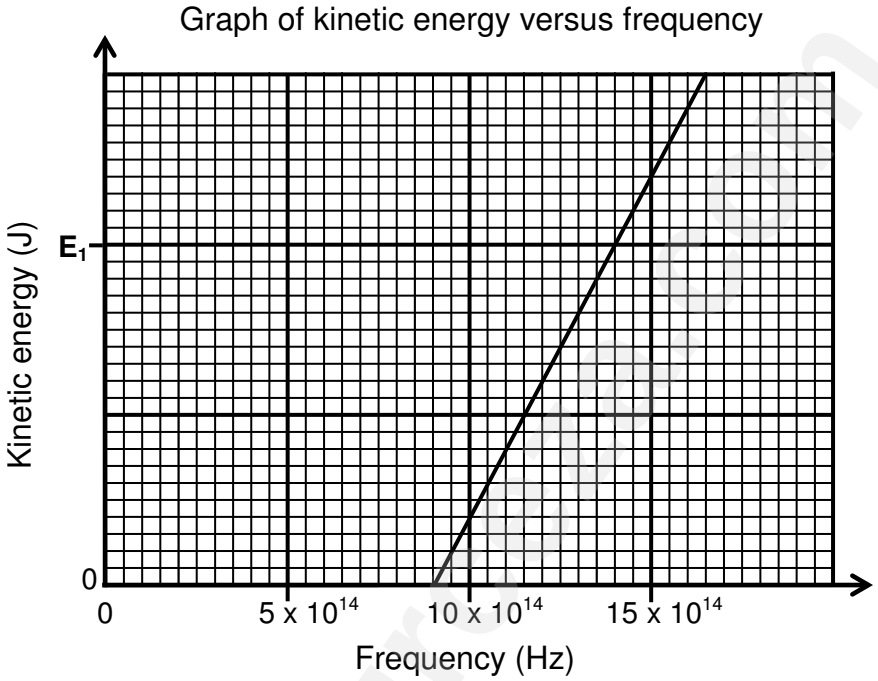
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QUESTION 11 (Start on a new page.)

During an investigation, light of different frequencies is shone onto the metal cathode of a photocell. The kinetic energy of the emitted photoelectrons is measured. The graph below shows the results obtained.



11.1 For this investigation, write down the following:

11.1.1 Dependent variable (1)

11.1.2 Independent variable (1)

11.1.3 Controlled variable (1)

11.2 Define the term *threshold frequency*. (2)

11.3 Use the graph to obtain the threshold frequency of the metal used as cathode in the photocell. (1)

11.4 Calculate the kinetic energy at E_1 shown on the graph. (4)

11.5 How would the kinetic energy calculated in QUESTION 11.4 be affected if light of higher intensity is used? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1)
[11]

TOTAL SECTION B: 125
GRAND TOTAL: 150

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GRADE/*GRAAD* 12

PHYSICAL SCIENCES: PHYSICS (P1)
FISIESE WETENSKAPPE: FISIKA (V1)

NOVEMBER 2012

MEMORANDUM

MARKS/*PUNTE*: 150

This memorandum consists of 12 pages.
Hierdie memorandum bestaan uit 12 bladsye.

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SECTION A

QUESTION 1/*VRAAG 1*

1.1 Frequency/*Frekwensie* ✓ (1)

1.2 Capacitor/*Kapasitor* ✓ (1)

1.3 Split ring commutator ✓
Splitringkommutator (1)

1.4 Photons/*Fotone* ✓ (1)

1.5 Relative velocity/*Relatiewe snelheid* ✓ (1)
[5]

QUESTION 2/*VRAAG 2*

2.1 D ✓✓ (2)

2.2 C ✓✓ (2)

2.3 D ✓✓ (2)

2.4 D ✓✓ (2)

2.5 A ✓✓ (2)

2.6 A ✓✓ (2)

2.7 D ✓✓ (2)

2.8 C ✓✓ (2)

2.9 C ✓✓ (2)

2.10 A ✓✓ (2)
[20]

TOTAL SECTION A/*TOTAAL AFDELING A*: 25

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SECTION B/*AFDELING B*

QUESTION 3/*VRAAG 3*

3.1 Downward/*afwaarts* ✓ (1)

3.2

3.2.1 **Upwards positive/*Opwaarts positief:***

$v_f = v_i + a\Delta t$ ✓
$= 8$ ✓$+ (-9,8)(4)$ ✓
$= -31,2\ m{\cdot}s^{-1}$
$\therefore v_f = 31,2\ m{\cdot}s^{-1}$ ✓

Downwards positive/*Afwaarts positief:*

$v_f = v_i + a\Delta t$✓
$= -8$ ✓$+ (9,8)(4)$ ✓
$\therefore v_f = 31,2\ m{\cdot}s^{-1}$ ✓ (4)

3.2.2

OPTION 1/*OPSIE 1*

Upwards positive/*Opwaarts positief*:

$\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$✓
$= (8)(4)$ ✓ $+ \frac{1}{2}(-9,8)(4)^2$ ✓
$= -46,4$ m

Height of balcony/*Hoogte van balkon:*
60 – 46,4 ✓= 13,6 m ✓

Downwards positive/*Afwaarts positief:*

$\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$✓
$= (-8)(4)$ ✓ $+ \frac{1}{2}(9,8)(4)^2$ ✓
$= 46,4$ m

Height of balcony/*Hoogte van balkon:*
60 – 46,4 ✓= 13,6 m ✓

OPTION 2/*OPSIE 2*

Upwards positive/*Opwaarts positief:*

$\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$✓
$= (27,13)$ ✓ (6) ✓$+ \frac{1}{2}(-9,8)(6)^2$✓
$= -13,62$ m

Height of balcony/*Hoogte van balkon:*
= 13,62 m ✓

Downwards positive/*Afwaarts positief:*

$\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$✓
$= (-27,13)$ ✓ (6) ✓$+ \frac{1}{2}(9,8)(6)^2$✓
$= 13,62$ m

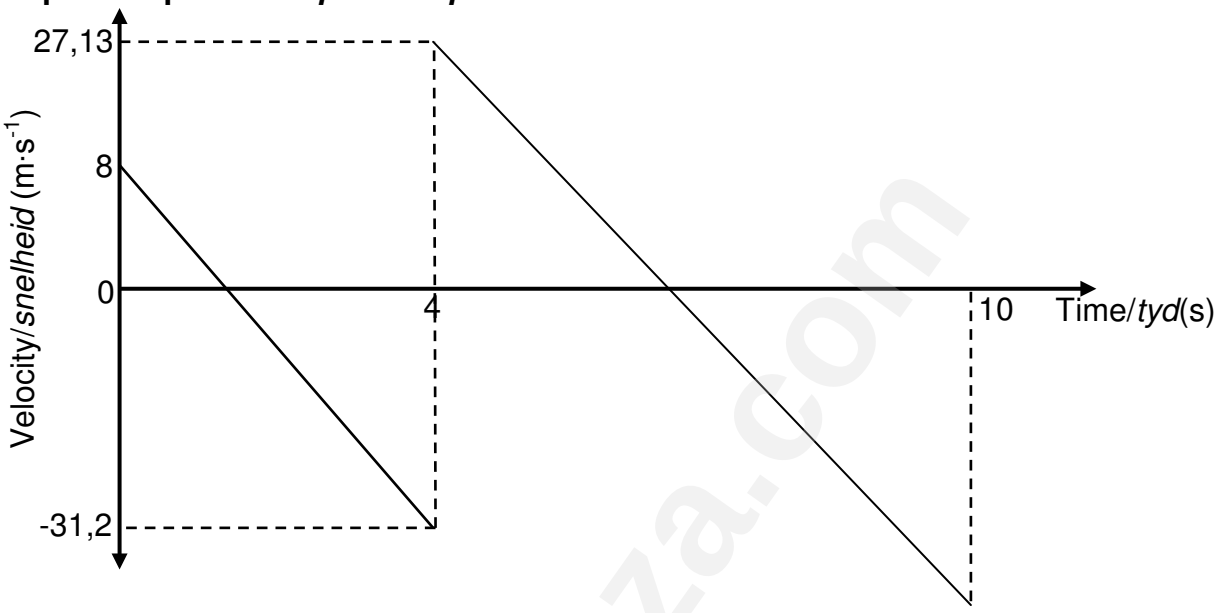
Height of balcony/*Hoogte van balkon:*
= 13,62 m ✓ (5)

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3.3 **OPTION 1/*OPSIE 1***

Upwards positive/*Opwaarts positief:*



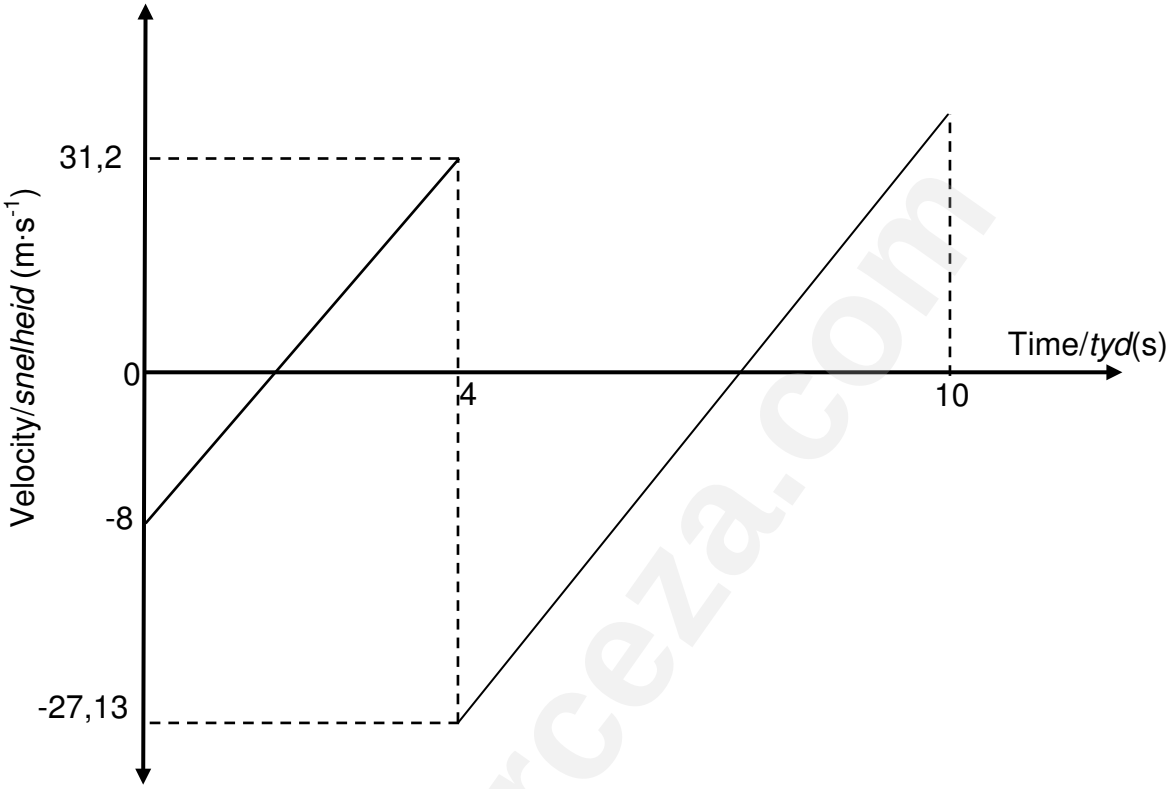
Criteria for graph/*Kriteria vir grafiek:*	**Marks/ *Punte***
Shape has two parallel lines with a gradient. *Vorm het twee ewewydige lyne met gradient.*	✓
First part of graph starts at v = 8 m·s^{-1} at t = 0 s *Eerste deel van grafiek begin by v = 8 m·s^{-1} by t = 0 s.*	✓
Positive marking from QUESTION 3.2.1: ***Positiewe nasien vanaf VRAAG 3.2.1:*** First part of the graph extends below the x axis until v = -31,2 m·s^{-1} at t = 4 s. *Eerste deel van die grafiek verleng onder x-as tot* v = -31,2 m·s^{-1} by *t = 4 s.*	✓
Graph is discontinuous and object changes direction at 4 s. *Grafiek is nie kontinu nie en voorwerp verander van rigting by 4 s.*	✓
Second part of graph starts at v = 27,13 m·s^{-1} at t = 4 s. *Tweede deel van grafiek begin by v = 27,13 m·s^{-1} by t = 4 s.*	✓
Second part of graph extends below the x axis until t = 10 s. *Tweede deel van grafiek verleng onder x-as tot t =10 s.*	✓

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OPTION 2/*OPSIE 2*

Upwards negative/*Opwaarts negatief:*



Criteria for graph/*Kriteria vir grafiek:*	**Marks** ***Punte***
Correct shape as shown (two parallel lines). *Korrekte vorm soos aangetoon (twee ewewydige lyne).*	✓
First part of graph starts at v = -8 m·s^{-1} at t = 0 s *Eerste deel van grafiek begin by v = -8 m·s^{-1} by t = 0 s*	✓
Positive marking from QUESTION 3.2.1. ***Positiewe nasien vanaf VRAAG 3.2.1.*** First part of the graph extends above the x axis until v = 31,2 m·s^{-1} at t = 4 s. *Eerste deel van die grafiek verleng bokant x-as tot* v = 31,2 m·s^{-1} by *t = 4 s.*	✓
Graph is discontinuous and object changes direction at 4 s. *Grafiek is nie kontinu en voorwerp verander van rigting by 4 s.*	✓
Second part of graph starts at v = -27,13 m·s^{-1} at t = 4 s. *Tweede deel van grafiek begin by v = -27,13 m·s^{-1} by t = 4 s.*	✓
Second part of graph extends above the x axis until t = 10 s. *Tweede deel van grafiek verleng bokant x-as tot t = 10 s.*	✓

.

(6)
[16]

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QUESTION 4/*VRAAG 4*

4.1 40 m·s^{-1} ✓east/*oos* ✓ (2)

4.2 The <u>total (linear) momentum remains constant</u>/is conserved ✓
in <u>an isolated</u>/a closed system/the absence of external forces/ if the impulse of external forces is zero. ✓

Die <u>totale (linière) momentum bly konstant</u>/behoue ✓
in 'n <u>geïsoleerde sisteem</u>/geslote sisteem/ die afwesigheid van eksterne kragte./ indien die impuls van eksterne kragte nul is.✓ (2)

4.3 **<u>East positive/*Oos positief:*</u>**
$\Sigma p_i = \Sigma p_f$ ✓
m(20) ✓+ 2m(-20) ✓ = (m + 2m)v_f ✓
$\therefore v_f$ = -6,67 m·s^{-1}
$\therefore v_f$ = 6,67 m·s^{-1} ✓ west /wes ✓
<u>East negative/*Oos negatief:*</u>
$\Sigma p_i = \Sigma p_f$ ✓
m(-20) ✓+ 2m(+20) ✓ = (m + 2m)v_f ✓
$\therefore v_f$ = 6,67 m·s^{-1} ✓ west /*wes* ✓ (6)

4.4
4.4.1 F✓
Newton's Third Law of motion/*Newton se Derde Bewegingswet* ✓ (2)

4.4.2 -½ a / ½ a✓

(Same/*Dieselfe* F_{net}), $a \propto \frac{1}{m}$ ✓ (2)

4.4.3 Car driver ✓
(Car - driver system) have <u>greater acceleration</u>. ✓
(Car - driver system) have <u>greater change in velocity /greater Δv</u>.✓

Motorbestuurder ✓
(Motor -bestuurder sisteem) het groter versnelling. ✓
(Motor -bestuurder sisteem) het groter verandering in snelheid / groter <u>Δv</u>.✓ (3)
[17]

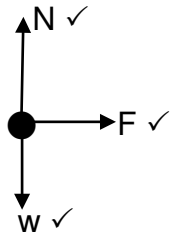
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QUESTION 5/*VRAAG 5*

5.1



(3)

5.2 The net (total) work (done on an object) is equal to ✓
the change in kinetic energy (of the object.) ✓
Die netto (totale) arbeid verrig (op 'n voorwerp) is gelyk aan ✓
die verandering in kinetiese energie (van die voorwerp). ✓ (2)

5.3

5.3.1 $W_{net} = \Delta E_k/\Delta K$ ✓ **OR/*OF*** $F_{net}\Delta x\cos\theta = ½ m(v_f^2 - v_i^2)$
$F_{net}(1{,}02)\cos180° ✓ = ½ (1\ 200)(0 - 20^2)$ ✓
$F_{net} = 235\ 294{,}12$ N ✓ $(2{,}35 \times 10^5$ N)

(4)

5.3.2

OPTION 1 /*OPSIE 1*	**OPTION 2/*OPSIE 1***
$F_{net}\Delta t = m\Delta v$ ✓ $\therefore (-235\ 294{,}12)\Delta t$ ✓ $= (1\ 200)(0 - 20)$ ✓ $\therefore \Delta t = 0{,}1$ s ✓(0,102 s)	$\Delta x = \left(\frac{v_i + v_f}{2}\right)\Delta t$ ✓ $1{,}02$ ✓ $= \left(\frac{20 + 0}{2}\right)\Delta t$ ✓ $\Delta t = 0{,}1$ s✓

(4)
[13]

QUESTION 6/*VRAAG 6*

6.1 Frequency/*Frekwensie* ✓ (1)

6.2 There is relative motion between the bird and the bird watcher. ✓
Daar is relatiewe beweging tussen die voël en die voëlkyker nie. ✓ (1)

6.3 0,2 m ✓ (1)

6.4

6.4.1 $v = f\lambda$ ✓
$340 = f(0{,}2)$ ✓
$\therefore f = 1\ 700$ Hz ✓

(3)

6.4.2 $f_L = \frac{v \pm v_L}{v \pm v_s} f_s$ **OR/*OF*** $f_L = \frac{v}{v - v_s} f_s$ ✓
$\therefore 1\ 700$ ✓ $= \frac{340}{340 - v_s}$ ✓ $(1\ 650)$ ✓
$\therefore v_s = 10\ m\cdot s^{-1}$ ✓

(5)
[11]

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QUESTION 7/*VRAAG 7*

7.1 Double slit/*Dubbelspleet* ✓ (1)

7.2 (Alternate) dark and bright/blue bands. ✓
Bright / blue bands of equal broadness (width). ✓
(Afwisselende) donker en helder/blou bande. ✓
Helder / blou bande van gelyke breedte. ✓ (2)

7.3

7.3.1

$$\tan\theta = \frac{\frac{1}{2}\text{central band}}{\text{screen distance}} \;/\; \frac{\frac{1}{2}\textit{sentraleband}}{\textit{skermafstand}}$$

$$\therefore \tan\theta = \frac{\frac{1}{2}(0{,}22)}{1{,}4} \;\checkmark\checkmark$$

$$\therefore \theta = 4{,}49° \;\checkmark$$ (3)

7.3.2

OPTION 1/*OPSIE 1:*	**OPTION 2/*OPSIE 2:***
$\sin\theta = \frac{m\lambda}{a}$ ✓	$\sin\theta = \frac{m\lambda}{a}$ ✓
$\sin 4{,}49 = \frac{(1)(470\times10^{-9})}{a}$ ✓✓	$\sin(-4{,}49°) = \frac{(-1)(470\times10^{-9})}{a}$ ✓✓
$\therefore a = 6\times10^{-6}$ m ✓(6 003,67 nm)	$\therefore a = 6\times10^{-6}$ m ✓ (6 003,67 nm)

(5)

7.4 $\lambda_{\text{red light}} > \lambda_{\text{blue light}}$ ✓
(Degree of) diffraction/$\sin\theta$/ $\theta \alpha$ wavelength (λ) ✓
$\lambda_{\textit{rooilig}} > \lambda_{\textit{bloulig}}$ ✓
Diffraksie α *golflengte* (λ) ✓ (2)
[13]

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QUESTION 8/*VRAAG 8*

8.1 $R = \frac{V}{I}$ ✓

$1\,000 = \frac{12}{I}$ ✓

$\therefore I = 0{,}01$ A ✓ (3)

8.2 12 V ✓ (1)

8.3 $C = \frac{Q}{V}$ ✓

$120 \times 10^{-6} = \frac{Q}{12}$ ✓

$\therefore Q = 1{,}44 \times 10^{-3}$ C ✓ (3)

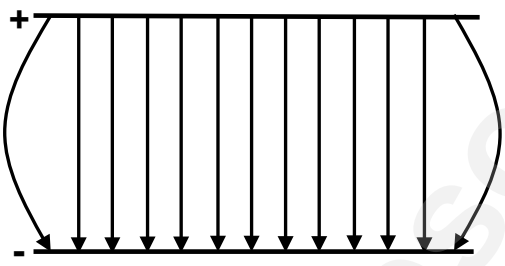
8.4

8.4.1 Decreases/*Verminder* ✓ (1)

8.4.2 Increases/*Vermeerder* ✓ (1)

8.5

8.5.1



Criteria for sketch:/*Kriteria vir skets:*	Marks/ *Punte*
Parallel lines equally spaced. *Parallelle lyne eweredig gespasieer.*	✓
Direction from positive plate towards negative plate.(Polarity of plates must be indicated) *Rigting vanaf positiewe plaat na negatiewe plaat.(Polariteit van plate moet aangedui word)*	✓
Field curved at the ends of the plates. *Veld gekrom aan einde van die plate.*	✓

(3)

8.5.2

$E = \frac{V}{d}$ ✓

$= \frac{12}{12 \times 10^{-3}}$ ✓

$\therefore E = 1\,000$ V·m^{-1} ✓ (3)

[15]

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QUESTION 9/*VRAAG 9*

9.1

9.1.1 $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$ ✓

$= \frac{1}{60} + \frac{1}{60}$ ✓

$\therefore R_p = 30\ \Omega$ ✓ (3)

9.1.2

OPTION 1 / *OPSIE 1*	**OPTION 2 / *OPSIE 2:***
$R_{ext} = 30 + 25 = 55\ \Omega$ ✓	$R_{tot} = (30 + 25)$ ✓$+1,5 = 56,5\ \Omega$
Emf/*emk* = I(R + r) ✓	V = IR✓
$\therefore 12$ ✓$= I(55 + 1,5)$ ✓	12✓ = I(56,5) ✓
$\therefore I = 0,21$ A ✓	$\therefore I = 0,21$ A ✓

(5)

9.1.3

OPTION 1/*OPSIE 1*	**OPTION 2/*OPSIE 2***
V = IR ✓	V = IR ✓
= (0,21)(30) ✓	= (0,105)(60) ✓
= 6,3 V ✓	= 6,3 V ✓

(3)

9.2

9.2.1 1,5 V ✓ (1)

9.2.2 gradient/m $= \frac{\Delta V}{\Delta I}$

$= \frac{0,65 - 1,5}{1,0 - 0}$ ✓✓

$= -0,85\ \Omega$ ✓ (3)

9.2.3 Internal resistance ✓✓
Interne weerstand (2)

9.2.4 Decreases/*Verminder* ✓

When I increases/*Wanneer I toeneem:*
"Lost volts"/ Ir increases./*"Verlore volts"/Ir neem toe.* ✓
V_{ext} = emf – Ir decreases. ✓/V_{ext} = *emk – Ir neem af.* (3)
[20]

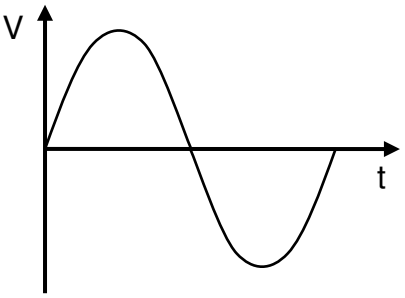
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QUESTION 10/*VRAAG 10*

10.1 AC /*WS* ✓ (1)

10.2



Criteria for graph/*Kriteria vir grafiek:*	**Marks *Punte***
Correct shape as shown; accept more than one cycle. *Korrekte vorm soos aangetoon; aanvaar meer as een siklus.*	✓✓
If no/wrong labels: minus 1 mark *Indien geen/verkeerde byskifte: minus 1 punt*	

(2)

10.3

OPTION 1/*OPSIE 1*

$V_{rms/wgk} = \frac{V_{max/\ maks}}{\sqrt{2}}$ ✓

$= \frac{30 \times 10^3}{\sqrt{2}}$ ✓

$= 2{,}12 \times 10^4$ V

$P_{ave} = V_{rms}I_{rms}/P_{gem.} = V_{wgk}I_{wgk}$ ✓

$4{,}45 \times 10^9$ ✓ $= (2{,}12 \times 10^4)I_{rms/wgk}$

$\therefore I_{rms/wgk} = 2{,}10 \times 10^5$ A ✓

OPTION 2 / *OPSIE 2*

$P_{ave} = V_{rms}I_{rms}/P_{gem.} = V_{wgk}I_{wgk}$

$P_{ave/gem.} = \frac{V_{max}I_{rms}}{\sqrt{2}} / \frac{V_{maks}I_{wgk}}{\sqrt{2}}$ ✓✓

$4{,}45 \times 10^9$ ✓ $= \frac{(30 \times 10^3)I_{rms/wgk}}{\sqrt{2}}$ ✓

$\therefore I_{rms/wgk} = 2{,}10 \times 10^5$ A ✓

(5)

10.4 Less loss in (electrical) energy (as heat). ✓
Minder verlies aan (elektriese) energie (as hitte). ✓ (1)

[9]

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QUESTION 11/*VRAAG 11*

11.1

11.1.1 Kinetic energy /*Kinetiese energie* (E_k)✓ (1)

11.1.2 Frequency /*Frekwensie*✓(f) (1)

11.1.3 (Type of) metal✓
(Soort) metaal ✓ (1)

11.2 The minimum frequency needed to emit electrons ✓
from (the surface of) a metal. ✓
Die minimum frekwensie benodig om elektrone vry te stel vanaf (die oppervlak van) 'n metaal. (2)

11.3 9×10^{14} Hz ✓ (1)

11.4

$E = W_0 + E_k$
$hf = hf_0 + E_k$ } ✓ Any one /*Enige een*

$(6{,}63 \times 10^{-34})(14 \times 10^{14})$ ✓ $= (6{,}63 \times 10^{-34})(9 \times 10^{14})$ ✓ $+ E_k$

$\therefore E_k = 3{,}32 \times 10^{-19}$ J ✓ $(3{,}31 \times 10^{-19}$ J) (4)

11.5 Remains the same/*Bly dieselfde* ✓ (1)
[11]

TOTAL SECTION B/*TOTAAL AFDELING B*: 125
GRAND TOTAL/*GROOTTOTAAL*: 150

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basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE

GRADE 12

PHYSICAL SCIENCES: CHEMISTRY (P2)

NOVEMBER 2012

MARKS: 150

TIME: 3 hours

This question paper consists of 14 pages and 4 data sheets.

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INSTRUCTIONS AND INFORMATION

1. Write your centre number and examination number in the appropriate spaces on the ANSWER BOOK.

2. Answer ALL the questions in the ANSWER BOOK.

3. This question paper consists of TWO sections:

   SECTION A (25)
   SECTION B (125)

4. You may use a non-programmable calculator.

5. You may use appropriate mathematical instruments.

6. Number the answers correctly according to the numbering system used in this question paper.

7. Data sheets and a periodic table are attached for your use.

8. Give brief motivations, discussions, et cetera where required.

9. Round off your final numerical answers to a minimum of TWO decimal places.

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SECTION A

QUESTION 1: ONE-WORD ITEMS

Give ONE word/term for each of the following descriptions. Write only the word/term next to the question number (1.1–1.5) in the ANSWER BOOK.

1.1 The homologous series to which propan-2-one belongs (1)

1.2 The IUPAC name of the alkene with two carbon atoms (1)

1.3 The minimum energy needed for a chemical reaction to occur (1)

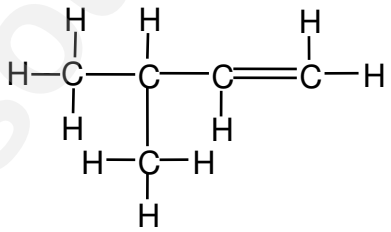
1.4 The general name used for a substance that increases the rate of a reaction without being consumed in the reaction (1)

1.5 The chemical name of brine (1)
[5]

QUESTION 2: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Write only the letter (A–D) next to the question number (2.1–2.10) in the ANSWER BOOK.

2.1 Consider the organic compound represented below.



The compound is ...

A saturated and branched.
B unsaturated and branched.
C saturated and straight-chained.
D unsaturated and straight-chained. (2)

2.2 A structural isomer of butane is ...

A propane.
B 2-methylbutane.
C 2-methylpropane.
D 2,2-dimethylpropane. (2)

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2.3 The alcohols form a homologous series. This means that alcohols have ...

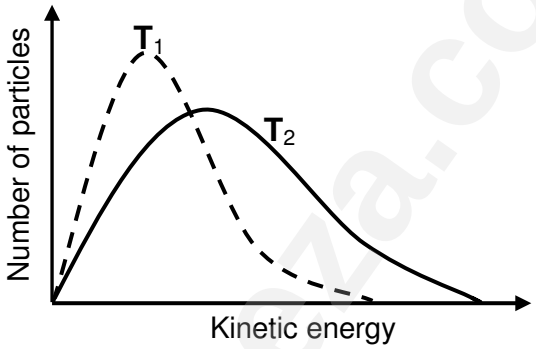
A similar chemical properties.

B similar physical properties.

C the same molecular formula.

D the same structural formula. (2)

2.4 The energy distribution diagrams for particles in a fixed mass of gas at two different temperatures, T_1 and T_2, are shown below.



Which ONE of the following is the correct interpretation of the diagrams as the temperature of the gas changes from **T_1** to **T_2**?

	Activation energy (E_A)	**Number of effective collisions**
A	Remains the same	Increases
B	Decreases	Decreases
C	Decreases	Increases
D	Remains the same	Decreases

(2)

2.5 The expression for the equilibrium constant (K_C) of a hypothetical reaction is given as follows:

$$K_C = \frac{[D]^2[C]}{[A]^3}$$

Which ONE of the following equations for a reaction at equilibrium matches the above expression?

A $3A(s) \rightleftharpoons C(g) + 2D(g)$

B $3A(\ell) \rightleftharpoons C(aq) + 2D(aq)$

C $3A(aq) + B(s) \rightleftharpoons C(g) + D_2(g)$

D $3A(aq) + B(s) \rightleftharpoons C(aq) + 2D(aq)$ (2)

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2.6 The reaction represented by the balanced equation below reaches equilibrium in a closed container.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H < 0$$

Which ONE of the following changes will INCREASE the yield of $N_2O_4(g)$?

A Add a catalyst.
B Remove NO_2 gas from the container.
C Increase the temperature of the system.
D Decrease the temperature of the system. (2)

2.7 In a redox reaction, an oxidising agent is ...

A reduced because it loses electrons.
B reduced because it gains electrons.
C oxidised because it loses electrons.
D oxidised because it gains electrons. (2)

2.8 In a galvanic (voltaic) cell, electrons move from the ...

A anode to the cathode through the salt bridge.
B cathode to the anode through the salt bridge.
C anode to the cathode in the external circuit.
D cathode to the anode in the external circuit. (2)

2.9 During the extraction of aluminium from aluminium oxide, cryolite is added to ...

A increase the yield of aluminium.
B decrease the yield of aluminium.
C increase the melting point of aluminium oxide.
D decrease the melting point of aluminium oxide. (2)

2.10 Which ONE of the following is a primary nutrient needed by plants?

A N
B C
C Mg
D Na (2)

[20]

TOTAL SECTION A: 25

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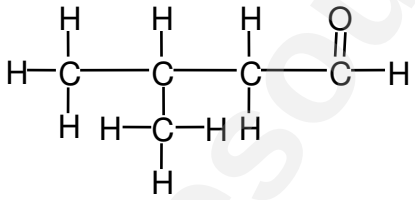
SECTION B

INSTRUCTIONS

1. Start EACH question on a NEW page.
2. Leave ONE line between two subquestions, for example between QUESTION 3.1 and QUESTION 3.2.
3. Show the formulae and substitutions in ALL calculations.
4. Round off your final numerical answers to a minimum of TWO decimal places.

QUESTION 3 (Start on a new page.)

The letters **A** to **F** in the table below represent six organic compounds.

A	$CH \equiv C-CH_2-CH_2-CH_3$	**B**	$CH_3CH_2CH_2CH(OH)CH_3$
C	$CH_2=C(CH_3)-CH_2-CH_3$	**D**	Pentanoic acid
E		**F**	$CH_3-CH_2-O-C(=O)-CH_2-CH_3$

3.1 Write down the letter(s) that represent(s) each of the following:
(A compound may be used more than once.)

3.1.1 An alkyne (1)

3.1.2 Two compounds that are structural isomers (2)

3.1.3 A compound containing a carboxyl group (1)

3.1.4 An aldehyde (1)

3.1.5 An alcohol (1)

3.2 Write down the:

3.2.1 IUPAC name of compound **C** (2)

3.2.2 Structural formula of compound **D** (2)

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3.3 Compound **F** is prepared in the laboratory.

3.3.1 How can one quickly establish whether compound **F** is indeed being formed? (1)

3.3.2 Write down the IUPAC name of the alcohol needed to prepare compound **F**. (2)

3.3.3 Write down the IUPAC name of compound **F**. (2)
[15]

QUESTION 4 (Start on a new page.)

During a practical investigation the boiling points of the first six straight-chain ALKANES were determined and the results were recorded in the table below.

ALKANE	MOLECULAR FORMULA	BOILING POINT (°C)
Methane	CH_4	−164
Ethane	C_2H_6	−89
Propane	C_3H_8	−42
Butane	C_4H_{10}	−0,5
Pentane	C_5H_{12}	36
Hexane	C_6H_{14}	69

4.1 Write down the:

4.1.1 Most important use of the alkanes in the above table (1)

4.1.2 General formula of the alkanes (1)

Refer to the table to answer QUESTION 4.2 and QUESTION 4.3 below.

4.2 For this investigation, write down the following:

4.2.1 Dependent variable (1)

4.2.2 Independent variable (1)

4.2.3 Conclusion that can be drawn from the above results (2)

4.3 Write down the NAME of an alkane that is a liquid at 25 °C. (1)

4.4 Alkanes burn readily in oxygen. Write down a balanced equation, using molecular formulae, for the combustion of propane in excess oxygen. (3)

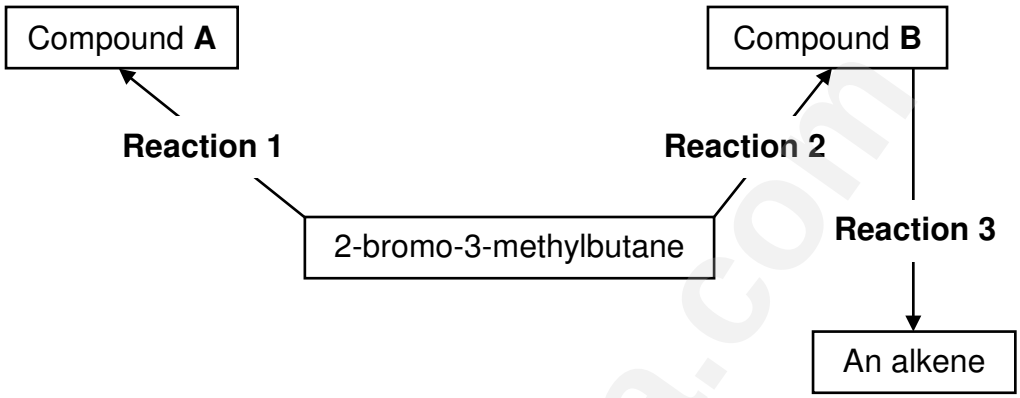
4.5 Will the boiling points of the structural isomers of hexane be HIGHER THAN, LOWER THAN or EQUAL TO that of hexane? Refer to MOLECULAR STRUCTURE, INTERMOLECULAR FORCES and ENERGY NEEDED to explain the answer. (4)
[14]

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QUESTION 5 (Start on a new page.)

The flow diagram below shows how three organic compounds can be prepared from 2-bromo-3-methylbutane.



5.1 Write down the:

5.1.1 Homologous series to which 2-bromo-3-methylbutane belongs (1)

5.1.2 Structural formula of 2-bromo-3-methylbutane (2)

5.2 **Reaction 2** takes place in the presence of a dilute sodium hydroxide solution.

Write down the:

5.2.1 Name of the type of reaction which takes place (1)

5.2.2 Structural formula of compound **B** (2)

5.3 **Reaction 1** takes place in the presence of concentrated sodium hydroxide.

Write down:

5.3.1 Another reaction condition needed for this reaction (1)

5.3.2 The name of the type of reaction which takes place (1)

5.3.3 The structural formula of compound **A**, the major product formed (2)

5.4 **Reaction 3** takes place when compound **B** is heated in the presence of concentrated sulphuric acid. Write down the IUPAC name of the major product formed. (2)

[12]

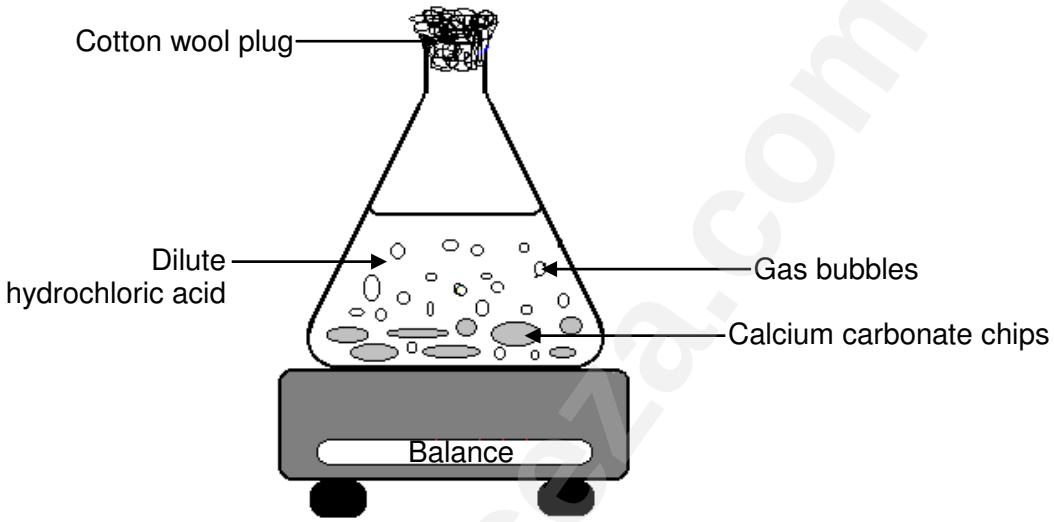
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QUESTION 6 (Start on a new page.)

Calcium carbonate chips are added to an excess dilute hydrochloric acid solution in a flask placed on a balance as illustrated below. The cotton wool plug in the mouth of the flask prevents spillage of reactants and products, but simultaneously allows the formed gas to escape. The balanced equation for the reaction that takes place is:

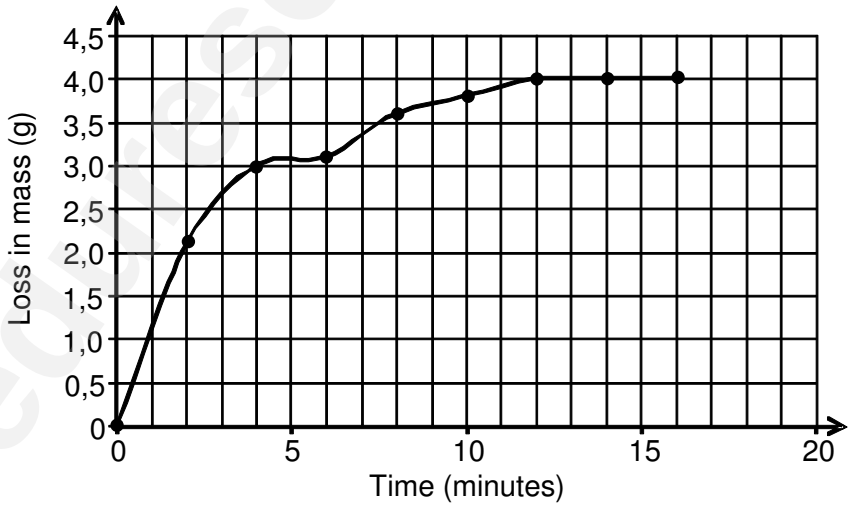
$$CaCO_3(s) + 2HC\ell(aq) \rightarrow CaC\ell_2(aq) + CO_2(g) + H_2O(\ell)$$



6.1 Write down the NAME of the gas that escapes through the cotton wool plug while the reaction takes place. (1)

The loss in mass of the flask and its contents is recorded in intervals of 2 minutes. The results obtained are shown in the graph below.

Graph of loss in mass versus time



6.2 From the graph, write down the following:

6.2.1 The coordinates of the point that represents results that were measured incorrectly (1)

6.2.2 How long (in minutes) the reaction lasts (1)

6.2.3 How long (in minutes) it takes 75% (three quarters) of the reaction to occur (1)

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6.3 The experiment is now repeated using hydrochloric acid of a higher concentration. It is found that the rate of the reaction INCREASES. Use the collision theory to explain this observation. (2)

6.4 How would a higher concentration of hydrochloric acid affect the following: (Write down only INCREASES, DECREASES or REMAINS THE SAME.)

6.4.1 Loss in mass per unit time (1)

6.4.2 Total loss in mass (1)

6.4.3 Time for the reaction to reach completion (1)

6.5 Apart from concentration and temperature changes, write down TWO other changes that can be made to increase the rate of this reaction. (2)

6.6 Calculate the mass of calcium carbonate used when the reaction is completed. Assume that all the gas that was formed, escaped from the flask. (5)
[16]

QUESTION 7 (Start on a new page.)

A hypothetical reaction is represented by the balanced equation below.

$$A(g) + 2B(g) \rightleftharpoons 2C(g)$$

Initially 3 moles of A(g) and 6 moles of B(g) are mixed in a 5 dm^3 sealed container. When the reaction reaches equilibrium at 25 °C, it is found that 4 moles of B(g) is present.

7.1 Define the term *chemical equilibrium.* (2)

7.2 Show by calculation that the equilibrium concentration of C(g) is 0,4 $mol \cdot dm^{-3}$. (3)

7.3 How will an increase in pressure, by decreasing the volume of the container, influence the amount of C(g) in the container at 25 °C?
Write down INCREASES, DECREASES or REMAINS THE SAME. Explain the answer. (3)

7.4 The initial number of moles of B(g) is now increased while the initial number of moles of A(g) remains constant at 25 °C.

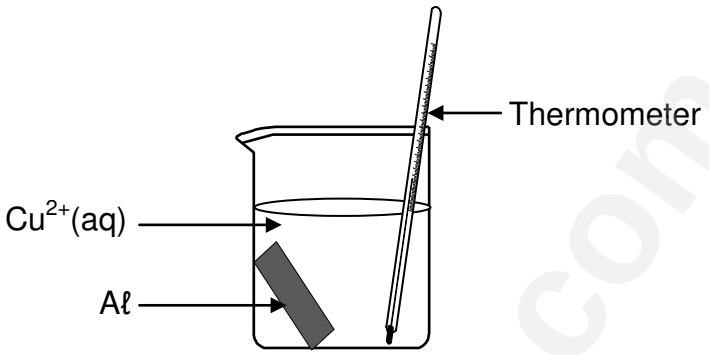
Calculate the number of moles of B(g) that must be ADDED to the original amount (6 mol) so that the concentration of C(g) is 0,8 $mol \cdot dm^{-3}$ at equilibrium. The equilibrium constant (K_C) for this reaction at 25 °C is 0,625. (9)
[17]

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QUESTION 8 (Start on a new page.)

8.1 A strip of aluminium is placed in a beaker containing a blue solution of a copper(II) salt. After a while the solution becomes colourless.

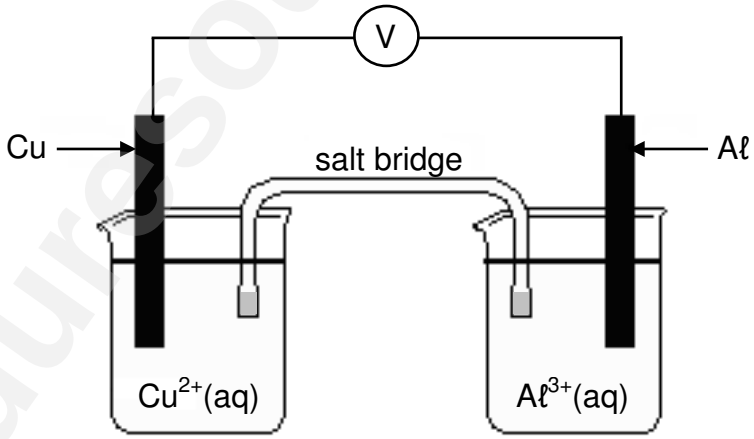


8.1.1 How would the reading on the thermometer change as the reaction proceeds? Write down INCREASES, DECREASES or REMAINS THE SAME. Give a reason for the answer. (2)

8.1.2 Refer to the reducing ability of aluminium to explain why the solution becomes colourless. (2)

8.1.3 Write down the balanced net IONIC equation for the reaction that takes place. (3)

8.2 The electrochemical cell shown below functions at standard conditions.



8.2.1 Which electrode (Cu or Aℓ) is the anode? (1)

8.2.2 Write down the cell notation for this cell. (3)

8.2.3 Calculate the emf of this cell. (4)

The salt bridge is now removed.

8.2.4 What will the reading on the voltmeter be? Give a reason for your answer. (2)

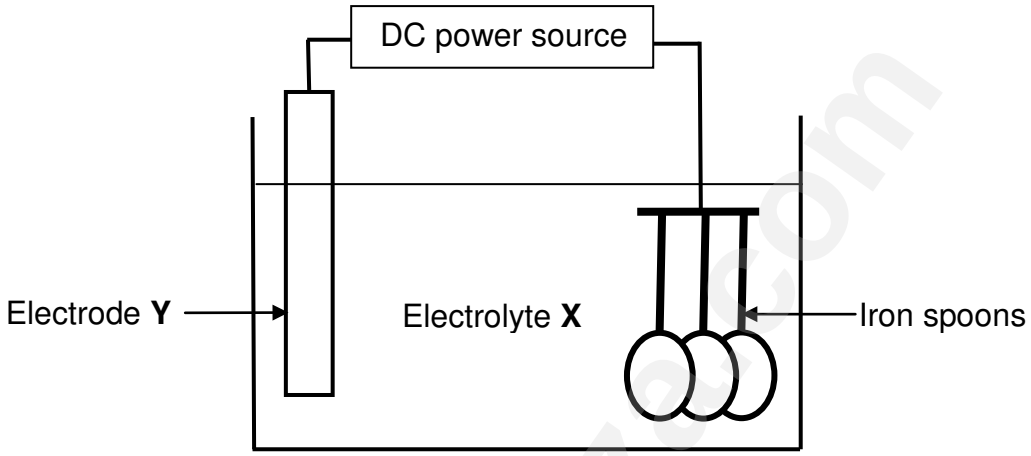
[17]

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QUESTION 9 (Start on a new page.)

The simplified diagram below shows an electrolytic cell used at an electroplating company to coat iron spoons with silver.



9.1 Write down the energy conversion that takes place in this cell. (1)

9.2 Direct current (DC) is used in this process. Give a reason why alternating current (AC) is NOT used. (1)

9.3 Which type of reaction (OXIDATION or REDUCTION) takes place at the spoons? (1)

9.4 Write down the:

9.4.1 Equation for the half-reaction that takes place at electrode **Y** (2)

9.4.2 NAME or FORMULA of electrolyte **X** (1)

9.5 Give a reason why the concentration of electrolyte **X** remains constant during electroplating. (2)

9.6 Apart from the income generated, write down ONE major reason why the company electroplates the spoons. (1)

9.7 Write down the TWO major expenses for the company during the process. (2)
[11]

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QUESTION 10 (Start on a new page.)

The following half-reactions take place when a non-rechargeable alkaline cell is in use:

$$Zn(s) + 2OH^-(aq) \rightarrow ZnO(s) + H_2O(\ell) + 2e^- \quad \text{.....(1)}$$

$$MnO_2(s) + 2H_2O(\ell) + 2e^- \rightarrow Mn(OH)_2(s) + 2OH^-(aq) \quad \text{.....(2)}$$

10.1 Write down the general name used for non-rechargeable cells. (1)

10.2 Which ONE of the above equations (**1** or **2**) represents the half-reaction that takes place at the cathode? Give a reason for your answer. (2)

10.3 Give a reason why the cell 'dies' after delivering current for a while. (1)

10.4 The emf of the alkaline cell is 1,5 V. The maximum electrical work that can be done by this cell is 3×10^4 J.

Calculate the:

10.4.1 Cell capacity of this cell in A·h (4)

10.4.2 Maximum constant current that this cell can deliver for 20 hours (3)

[11]

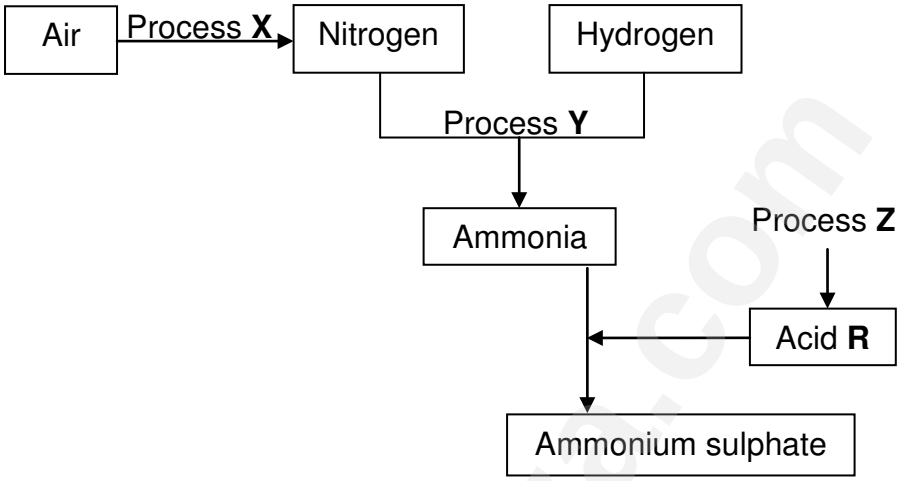
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QUESTION 11 (Start on a new page.)

11.1 The flow diagram below represents processes used in the fertiliser industry.



Write down:

11.1.1 The name of industrial process **X** (1)

11.1.2 A balanced equation for process **Y** (3)

11.1.3 The name of industrial process **Z** (1)

11.1.4 A balanced equation for the preparation of ammonium sulphate using acid **R** (3)

11.1.5 The name of the type of reaction taking place in QUESTION 11.1.4. (1)

11.2 Ammonium nitrate is one of the most common compounds used as fertiliser.

11.2.1 Write down the NAME or FORMULA of the acid needed to prepare ammonium nitrate from ammonia. (1)

11.2.2 Write down TWO properties of ammonium nitrate that make it suitable for use as a fertiliser. (2)
[12]

TOTAL SECTION B: 125
GRAND TOTAL: 150

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GRADE/*GRAAD* 12

PHYSICAL SCIENCES: CHEMISTRY (P2)
FISIESE WETENSKAPPE: CHEMIE (V2)

NOVEMBER 2012

MEMORANDUM

MARKS/*PUNTE*: 150

This memorandum consists of 11 pages.
Hierdie memorandum bestaan uit 11 bladsye.

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SECTION A/*AFDELING A*

QUESTION 1/*VRAAG 1*

1.1 Ketones/*Ketone* ✓ (1)

1.2 Ethene/*Eteen* ✓ (1)

1.3 Activation (energy)/*Aktiverings(energie)* ✓ (1)

1.4 Catalyst/*katalistor* ✓ (1)

1.5 (saturated) sodium chloride solution ✓
(versadigde) natriumchloried oplossing (1)
[5]

QUESTION 2/*VRAAG 2*

2.1 B ✓✓ (2)

2.2 C ✓✓ (2)

2.3 A ✓✓ (2)

2.4 A ✓✓ (2)

2.5 D ✓✓ (2)

2.6 D ✓✓ (2)

2.7 B ✓✓ (2)

2.8 C ✓✓ (2)

2.9 D ✓✓ (2)

2.10 A ✓✓ (2)
[20]

TOTAL SECTION A/*TOTAAL AFDELING A*: 25

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SECTION B/*AFDELING B*

QUESTION 3/*VRAAG 3*

3.1

3.1.1 A ✓ (1)

3.1.2 D & F ✓✓ (2)

3.1.3 D ✓ (1)

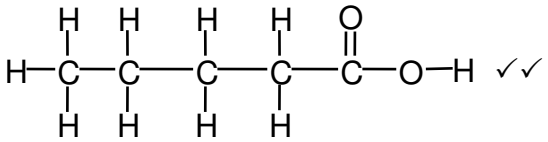
3.1.4 E ✓ (1)

3.1.5 B ✓ (1)

3.2

3.2.1 2-methyl✓but-1-ene ✓
2-metiel✓ but-1-een ✓ (2)

3.2.2



✓✓ (2)

3.3

3.3.1 Pleasant odour ✓
Aangename geur (1)

3.3.2 Ethanol ✓✓
Etanol (2)

3.3.3 Ethyl propanoate ✓✓
Etielpropanoaat (2)

[15]

QUESTION 4/*VRAAG 4*

4.1

4.1.1 Fuels ✓
Brandstowwe ✓ (1)

4.1.2 C_nH_{2n+2} ✓ (1)

4.2

4.2.1 Boiling point/*Kookpunt* ✓ (1)

4.2.2 Chain length/Molecular size/Molecular mass ✓
Kettinglengte/Molekulêre grootte/Molekulêre massa (1)

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4.2.3

Criteria for conclusion/*Kriteria vir gevolgtrekking*:	**Mark/*Punt***
Dependent and independent variables correctly identified. *Afhanklike en onafhanklike veranderlikes korrek geïdentifiseer.*	✓
Relationship between the independent and dependent variables correctly stated. Verwantskap tussen die *afhanklike en onafhanklike veranderlikes korrek genoem.*	✓

Examples/*Voorbeelde*:

- Boiling point increases with increase in chain length/molecular size/molecular mass.
  Kookpunt neem toe met toename in kettinglengte/molekulêre grootte/molekulêre massa.
- Boiling point decreases with decrease in chain length/ molecular size/molecular mass.
  Kookpunt neem af met afname in kettinglengte/molekulêre grootte/molekulêre massa.
- Boiling point is proportional to chain length/molecular size/molecular mass.
  Kookpunt is eweredig aan kettinglengte/molekulêre grootte/molekulêre massa .

(2)

4.3 Pentane/*Pentaan* ✓

OR/*OF*

Hexane/*Heksaan* ✓ (1)

4.4 $C_3H_8 + 5O_2$ ✓→ $3CO_2 + 4H_2O$ ✓ bal ✓ (3)

4.5 Lower than ✓

- **Structure:**
  Isomers have more branching/ more compact or spherical molecules / smaller surface areas over which the intermolecular forces act. ✓
- **Intermolecular forces:**
  Weaker intermolecular forces/less intermolecular forces ✓
- **Energy:**
  Less energy needed to overcome intermolecular forces. ✓

Kleiner as ✓

- ***Struktuur*:**
  Isomere *meer vertak/Molekule meer kompak of sferies./ Kleiner oppervlaktes waaroor intermolekulêre kragte werk.* ✓
- ***Intermolekulêre* kragte**
  Swakker intermolekulêre kragte/ minder intermolekulêre kragte ✓
- ***Energie*:**
  Die minder energie benodig om intermolekulêre kragte te oorkom. ✓

(4)
[14]

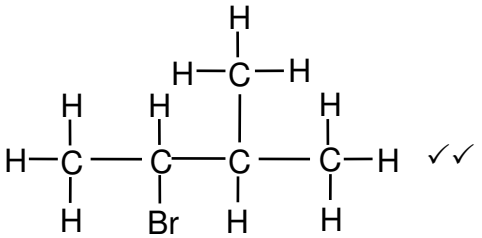
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QUESTION 5/*VRAAG 5*

5.1
5.1.1 Haloalkanes /*Haloalkane* ✓ (1)

5.1.2

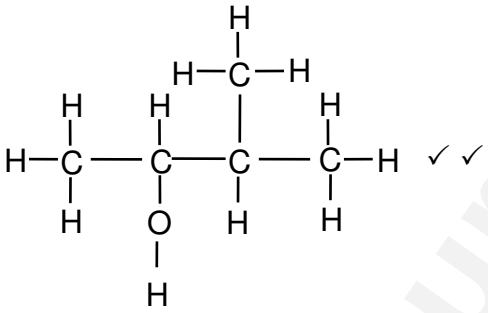


✓✓ (2)

5.2
5.2.1 Substitution/*Substitusie* ✓

OR/*OF*
Hydrolysis/*Hidrolise* ✓ (1)

5.2.2

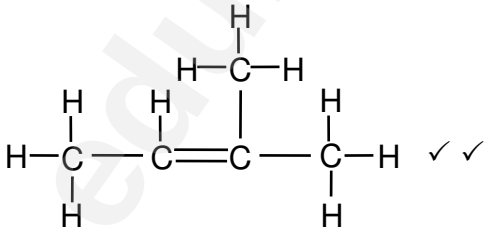


✓ ✓ (2)

5.3
5.3.1 Heat strongly ✓
Verhit sterk (1)

5.3.2 Elimination/dehydrohalogenation/dehydrobromination ✓
Eliminasie/dehidrohalogenering/dehidrobrominering ✓ (1)

5.3.3



✓ ✓ (2)

5.4 2-methylbut-2-ene ✓✓
2-metielbut-2-een (2)
[12]

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QUESTION 6/*VRAAG 6*

6.1 Carbon dioxide ✓
Koolstofdioksied/koolsuurgas (1)

6.2

6.2.1 (6 ; 3,1) ✓ (1)

6.2.2 12 minutes/*minute* ✓ (1)

6.2.3. 4 minutes/*minute* ✓ (1)

6.3 More particles per unit volume ✓
More effective collisions per unit time/second. ✓
Meer deeltjies per eenheids volume deeltjies.
Meer effektiewe botsings per eenheids tyd/sekonde. (2)

6.4

6.4.1 Increases/*Vermeerder* ✓ (1)

6.4.2 Remains the same/*Bly dieselfde* ✓ (1)

6.4.3 Decreases/*Neem af* ✓ (1)

6.5
- Add a catalyst/*Voeg 'n katalisator by* ✓
- Increase surface area of calcium carbonate./Use calcium carbonate powder./Crush calcium carbonate chips. ✓
Verhoog die oppervlakarea van kalsiumkarbonaat./Gebruik kalsiumkarbonaatpoeier./Maak die kalsiumkarbonaatstukkies fyn. (2)

6.6
$n(CO_2) = \frac{m}{M}$ ✓
$= \frac{4}{44}$ ✓
$= 0,09$ mol
$n(CaCO_3) = n(CO_2) = 0,09$ mol
$m(CaCO_3) = nM$
$= (0,09)$✓ (100) ✓ (5)
$= 9$ g ✓ **[16]**

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QUESTION 7/*VRAAG 7*

7.1 The stage in a chemical reaction when the rate of forward reaction equals the rate of reverse reaction. ✓✓
Die stadium in 'n chemiese reaksie wanneer die tempo van die voorwaartse reaksie is gelyk aan die tempo van die terugwaarste reaksie. ✓✓

(2)

7.2 n(B)reacted/*gereageer* = 6 – 4 = 2 mol ✓
n(C)formed/*gevorm* = n(B)reacted/*gereageer*
= 2 mol ✓

$c(C) = \frac{n}{V} = \frac{2}{5}$ ✓ = 0,4 mol·dm^{-3}

(3)

7.3 Increases ✓
- 3 mol/volumes (of gas) produces 2 mol/volumes (of gas)./The reaction which produces the smaller number of moles/volume is favoured. ✓
- Forward reaction is favoured. ✓

Vermeerder ✓
- *3 mol/volumes (gas) produseer 2 mol/volumes (gas)./Die reaksie wat die kleiner getal mol /volume vorm, word bevoordeel.*
- *Voorwaartse reaksie word bevoordeel.*

(3)

7.4 **OPTION 1/*OPSIE 1***
Use *x* as the total initial amount of B(g) that must be used.
Gebruik x as die totale aanvanklike hoeveelheid B(g) wat gebruik moet word.

	A	B	C
Initial quantity (mol) *Aanvangshoeveelheid (mol)*	3	x	0
Change (mol) *Verandering (mol)*	-2	-4	+4
Quantity at equilibrium (mol)/ *Hoeveelheid by ewewig (mol)*	1	x – 4 ✓	4 ✓
Equilibrium concentration (mol·dm^{-3}) *Ewewigskonsentrasie (mol·dm^{-3})*	$\frac{1}{5} = 0,2$	$\frac{x-4}{5}$	0,8

ratio ✓
verhouding

Divide by/*gedeel deur* 5 ✓

$K_C = \frac{[C]^2}{[A][B]^2}$ ✓

$\therefore$ 0,625 ✓ $= \frac{(0,8)^2}{(0,2)(\frac{x-4}{5})^2}$ ✓

$\therefore$ x = 15,3 mol

$\therefore$ n(B) added = 15,3 – 6 ✓
= 9,3 (mol) ✓

No K_C expression, correct substitution/*Geen K_c-uitdrukking*, korrekte substitusie: Max./*Maks.* 8/9

Wrong K_C expression/*Verkeerde K_c-uitdrukking*: Max./*Maks.* 6/9

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OPTION 2/*OPSIE 2*

Use *x* as amount to be added to the amount of B(g) present initially i.e. 6 mol of B(g).
Gebruik x as die hoeveelheid wat by die hoeveelheid van B(g) wat aanvanklik teenwoordig was gevoeg moet word d.i. 6 mol B(g).

	A	B	C
Initial quantity (mol) *Aanvangshoeveelheid (mol)*	3	x + 6 ✓	0
Change (mol) *Verandering (mol)*	-2	-4	+4
Quantity at equilibrium (mol)/ *Hoeveelheid by ewewig (mol)*	1	x + 2 ✓	4 ✓
Equilibrium concentration (mol·dm^{-3}) *Ewewigskonsentrasie (mol·dm^{-3})*	$\frac{1}{5} = 0,2$	$\frac{x+2}{5}$	0,8

ratio ✓
verhouding

Divide by/*gedeel deur* 5

$$K_C = \frac{[C]^2}{[A][B]^2} \checkmark$$

$$\therefore 0,625 \checkmark = \frac{(0,8)^2}{(0,2)(\frac{x+2}{5})^2} \checkmark$$

$$\therefore x = 9,31 \text{ (mol)} \checkmark$$

OPTION 3/*OPSIE 3*

Use *x* as amount to be added to the amount of B(g) present after first equilibrium was established i.e. 4 mol of B(g).
Gebruik x as die hoeveelheid wat by die hoeveelheid van B(g) wat teenwoordig is nadat die eerste ewewig ingestel is, gevoeg moet word d.i. 4 mol B(g).

	A	B	C
Initial quantity (mol) *Aanvangshoeveelheid (mol)*	2	x + 4 ✓	2
Change (mol) *Verandering (mol)*	-1	-2	+2
Quantity at equilibrium (mol)/ *Hoeveelheid by ewewig (mol)*	1	x + 2 ✓	4 ✓
Equilibrium concentration (mol·dm^{-3}) *Ewewigskonsentrasie (mol·dm^{-3})*	$\frac{1}{5} = 0,2$	$\frac{x+2}{5}$	0,8

ratio ✓
verhouding

Divide by /*gedeel deur* 5✓

$$K_C = \frac{[C]^2}{[A][B]^2} \checkmark$$

$$\therefore 0,625 \checkmark = \frac{(0,8)^2}{(0,2)(\frac{x+2}{5})^2} \checkmark$$

$$\therefore x = 9,31 \text{ (mol)} \checkmark$$

(9)
[17]

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QUESTION 8/*VRAAG 8*

8.1

8.1.1 Increases ✓
The reaction is exothermic./Energy (or heat) is released /ΔH < 0.✓

Vermeerder
Die reaksie is eksotermies./Energie (of hitte) word vrygestel/ΔH < 0. (2)

8.1.2 Aluminium is a strong reducing agent/stronger reducing agent ✓ than copper and will reduce the copper(II) ions to copper. ✓

Aluminium is 'n sterk reduseermiddel / sterker reduseermiddel ✓ as koper en sal die koper(II)-ione reduseer na koper. ✓ (2)

8.1.3 $2A\ell(s) + 3Cu^{2+}(aq)\checkmark \rightarrow 2A\ell^{3+}(aq) + 3Cu(s)\checkmark$ bal. ✓ (3)

8.2

8.2.1 Aℓ/Aluminium ✓ (1)

8.2.2 $A\ell(s) \mid A\ell^{3+}(1\ mol{\cdot}dm^{-3}) \checkmark \parallel Cu^{2+}(1\ mol{\cdot}dm^{-3}) \checkmark \mid Cu(s)$ (3)

8.2.3 $E^{o}_{cell} = E^{o}_{cathode} - E^{o}_{anode}$ ✓
$= 0,34$ ✓$- (-1, 66)$ ✓
$E^{o}_{cell} = 2,(00)V$ ✓ (4)

8.2.4 0 (V)/zero/*nul* ✓
The circuit is open. ✓
Die stroombaan is oop (2)
[17]

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QUESTION 9/*VRAAG 9*

9.1 Electrical energy to chemical energy. ✓
Elektriese energie na chemiese energie ✓ (1)

9.2 The polarity of the electrodes must remain constant during plating. ✓
Die polariteit van die elektrodes moet konstant bly tydens elektroplatering. (1)

9.3 Reduction/*Reduksie* ✓ (1)

9.4
9.4.1 $Ag \rightarrow Ag^+ + e^-$ ✓✓ (2)

9.4.2 Silver nitrate/*Silwernitraat*/$AgNO_3$✓

OR/*OF*
Silver ethanoate/silver acetate/*Silweretanoaat/silwerasetaat* ✓
$CH_3COOAg/AgC_2H_3O_2/AgCH_3CO_2$ (1)

9.5 Rate of oxidation is equal to the rate of reduction. ✓✓
Tempo van oksidasie is gelyk aan die tempo van reduksie. (2)

9.6 **Protection/*Beskerming***
Protects it from rusting / corrosion./*Beskerm dit teen roes/korrosie.* ✓

OR/OF
Appearance/*Voorkoms*
Improve appearance of spoons. / *Verbeter voorkoms van die lepels.* (1)

9.7 Cost of electricity/ *Koste van elektrisiteit.* ✓
Cost of silver/ *Koste van silwer* ✓ (2)
[11]

QUESTION 10/*VRAAG 10*

10.1 Primary (cells)/*Primêre (selle)* ✓ (1)

10.2 (Equation/*Vergelyking*) 2 ✓
Reduction takes place (at the cathode)./*Reduksie vind (by die katode) plaas.*✓ (2)

10.3 **ANY ONE/*ENIGE EEN*:**
- The cell reaction reaches equilibrium. ✓
  Die selreaksie bereik ewewig. ✓
- The rates of the forward and reverse reactions become equal. ✓
  Die tempo van die voorwaartse en terugwaartse reaksies is gelyk. ✓
- Substances reach their equilibrium concentrations. ✓
  Stowwe bereik hul ewewigskonsentrasies.

(1)

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10.4

10.4.1 $W = qV$ ✓
$\therefore 3 \times 10^4 = q(1,5)$ ✓
$\therefore q = 2 \times 10^4$ (C)

Cell capacity/*Selkapasiteit* = $\frac{2 \times 10^4}{3600}$ ✓ = 5,56 A·h ✓ (4)

10.4.2

OPTION 1 / *OPSIE 1*	**OPTION 2 / *OPSIE 2***
$q = I\Delta t$ ✓	$q = I\Delta t$ ✓
$\therefore 2 \times 10^4 = I(20)(3600)$ ✓	$\therefore 5,56 = I(20)$ ✓
$\therefore I = 0,28$ A ✓	$\therefore I = 0,28$ A ✓

(3)
[11]

QUESTION 11/*VRAAG 11*

11.1

11.1.1 Fractional distillation (of liquid air) ✓
Fraksionele distillasie (van vloeibare lug) ✓ (1)

11.1.2 $N_2 + 3H_2$ ✓$\rightleftharpoons 2NH_3$ ✓ bal. ✓ (3)

11.1.3 Contact (process)/*Kontak(proses)* ✓ (1)

11.1.4 $H_2SO_4 + 2NH_3$ ✓$\rightarrow (NH_4)_2SO_4$ ✓ bal. ✓ (3)

11.1.5 Neutralisation/Acid-base reaction ✓
Neutralisasie/Suur-basisreaksie ✓ (1)

11.2

11.2.1 Nitric acid/HNO_3/ hydrogen nitrate /*salpetersuur/ waterstofnitraat* ✓ (1)

11.2.2
- Contains (a high percentage of) nitrogen/N/primary nutrient. ✓
  Bevat (*'n hoë persentasie) stikstof/N/primêre voedingstof.* (2)
- High solubility /*Hoë oplosbaarheid* ✓ **[12]**

TOTAL SECTION B/*TOTAAL AFDELING B:* 125
GRAND TOTAL/*GROOTTOTAAL*: 150

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Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE

GRADE 12

PHYSICAL SCIENCES: PHYSICS (P1)

NOVEMBER 2013

MARKS: 150

TIME: 3 hours

This question paper consists of 15 pages and 3 data sheets.

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INSTRUCTIONS AND INFORMATION

1. Write your centre number and examination number in the appropriate spaces on the ANSWER BOOK.

2. Answer ALL the questions in the ANSWER BOOK.

3. This question paper consists of TWO sections:

   SECTION A (25)
   SECTION B (125)

4. You may use a non-programmable calculator.

5. You may use appropriate mathematical instruments.

6. Number the answers correctly according to the numbering system used in this question paper.

7. YOU ARE ADVISED TO USE THE ATTACHED DATA SHEETS.

8. Give brief motivations, discussions, et cetera where required.

9. Round off your final numerical answers to a minimum of TWO decimal places.

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SECTION A

QUESTION 1: ONE-WORD ITEMS

Give ONE word/term for each of the following descriptions. Write only the word/term next to the question number (1.1–1.5) in the ANSWER BOOK.

1.1 The rate of change of velocity (1)

1.2 The distance between two consecutive points in phase on a wave (1)

1.3 A region of space in which an electric charge experiences an electrostatic force (1)

1.4 The type of electromagnetic wave with the shortest wavelength (1)

1.5 The minimum frequency of light needed to remove an electron from the surface of a metal (1)
[5]

QUESTION 2: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Write only the letter (A–D) next to the question number (2.1–2.10) in the ANSWER BOOK.

2.1 Which ONE of the following physical quantities is equal to the product of force and constant velocity?

A Work

B Power

C Energy

D Acceleration (2)

2.2 A 30 kg iron sphere and a 10 kg aluminium sphere with the same diameter fall freely from the roof of a tall building. Ignore the effects of friction.

When the spheres are 5 m above the ground, they have the same ...

A momentum.

B acceleration.

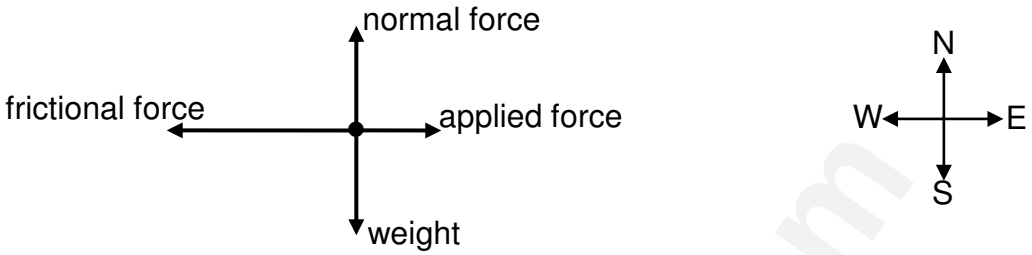
C kinetic energy.

D potential energy. (2)

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2.3 The free-body diagram below shows the relative magnitudes and directions of all the forces acting on an object moving horizontally in an easterly direction.



The kinetic energy of the object ...

A is zero.

B increases.

C decreases.

D remains constant. (2)

2.4 The hooter of a vehicle travelling at constant speed towards a stationary observer, produces sound waves of frequency 400 Hz. Ignore the effects of wind.

Which ONE of the following frequencies, in hertz, is most likely to be heard by the observer?

A 400

B 350

C 380

D 480 (2)

2.5 When two waves meet at a point, the amplitude of the resultant wave is the algebraic sum of the amplitudes of the individual waves.

This principle is known as …

A dispersion.

B the Doppler effect.

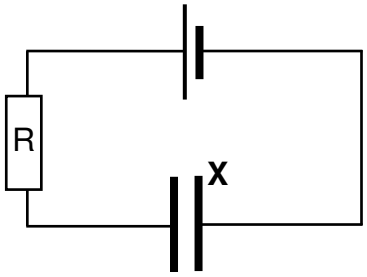
C superposition.

D Huygens' principle. (2)

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2.6 A parallel plate capacitor, **X**, with a vacuum between its plates is connected in a circuit as shown below. When fully charged, the charge stored on its plates is equal to Q.



Capacitor **X** is now replaced with a similar capacitor, **Y**, with the same dimensions but with paper between its plates. When fully charged, the charge stored on the plates of capacitor **Y** is …

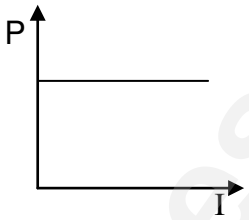
A zero.

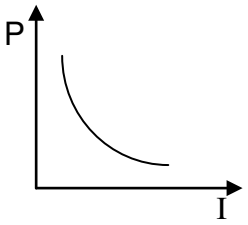
B equal to Q.

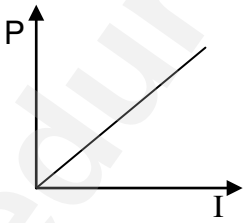
C larger than Q.

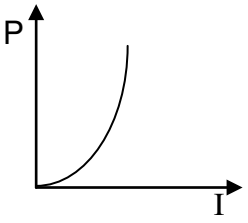
D smaller than Q. (2)

2.7 Which ONE of the following graphs best represents the relationship between the electrical power and the current in a given ohmic conductor?

A


B


C


D


(2)

2.8 In a vacuum, all electromagnetic waves have the same …

A energy.

B speed.

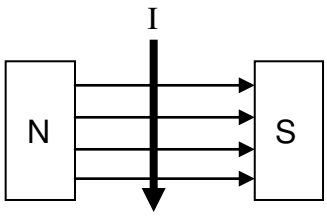
C frequency.

D wavelength. (2)

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2.9 In the sketch below, a conductor carrying conventional current, I, is placed in a magnetic field.



Which ONE of the following best describes the direction of the magnetic force experienced by the conductor?

A Parallel to the direction of the magnetic field

B Opposite to the direction of the magnetic field

C Into the page perpendicular to the direction of the magnetic field

D Out of the page perpendicular to the direction of the magnetic field (2)

2.10 An atom in its ground state absorbs energy *E* and is excited to a higher energy state. When the atom returns to the ground state, a photon with energy ...

A *E* is absorbed.

B *E* is released.

C less than *E* is released.

D less than *E* is absorbed. (2)
[20]

TOTAL SECTION A: 25

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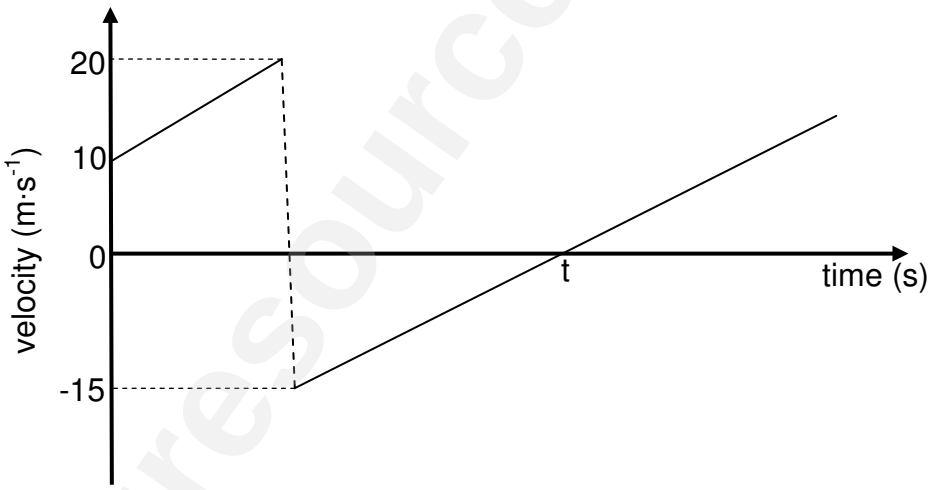
SECTION B

INSTRUCTIONS AND INFORMATION

1. Start EACH question on a NEW page.
2. Leave ONE line between two subquestions, for example between QUESTION 3.1 and QUESTION 3.2.
3. Show the formulae and substitutions in ALL calculations.
4. Round off your final numerical answers to a minimum of TWO decimal places.

QUESTION 3 (Start on a new page.)

A ball of mass 0,15 kg is thrown vertically downwards from the top of a building to a concrete floor below. The ball bounces off the floor. The velocity versus time graph below shows the motion of the ball. Ignore the effects of air friction. TAKE DOWNWARD MOTION AS POSITIVE.



3.1 From the graph, write down the magnitude of the velocity at which the ball bounces off the floor. (1)

3.2 Is the collision of the ball with the floor ELASTIC or INELASTIC? Refer to the data on the graph to explain the answer. (3)

3.3 Calculate the:

3.3.1 Height from which the ball is thrown (4)

3.3.2 Magnitude of the impulse imparted by the floor on the ball (3)

3.3.3 Magnitude of the displacement of the ball from the moment it is thrown until time *t* (4)

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3.4 Sketch a position versus time graph for the motion of the ball from the moment it is thrown until it reaches its maximum height after the bounce. USE THE FLOOR AS THE ZERO POSITION.

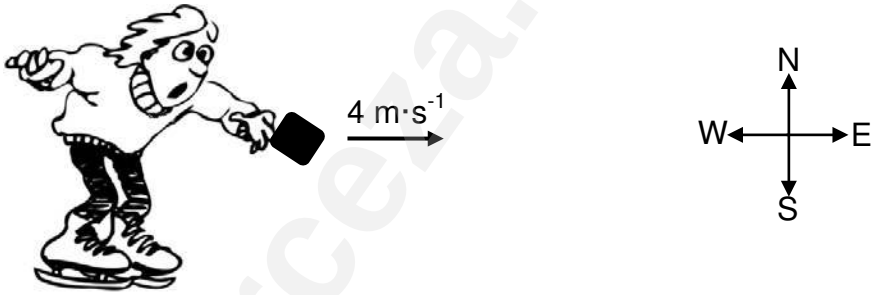
Indicate the following on the graph:

- The height from which the ball is thrown
- Time *t*

(4)
[19]

QUESTION 4 (Start on a new page.)

A boy on ice skates is stationary on a frozen lake (no friction). He throws a package of mass 5 kg at 4 m·s^{-1} horizontally east as shown below. The mass of the boy is 60 kg.



At the instant the package leaves the boy's hand, the boy starts moving.

4.1 In which direction does the boy move? Write down only EAST or WEST. (1)

4.2 Which ONE of Newton's laws of motion explains the direction in which the boy experiences a force when he throws the package? Name and state this law in words. (3)

4.3 Calculate the magnitude of the velocity of the boy immediately after the package leaves his hand. Ignore the effects of friction. (5)

4.4 How will the answer to QUESTION 4.3 be affected if:

(Write down INCREASES, DECREASES or REMAINS THE SAME.)

4.4.1 The boy throws the same package at a higher velocity in the same direction (1)

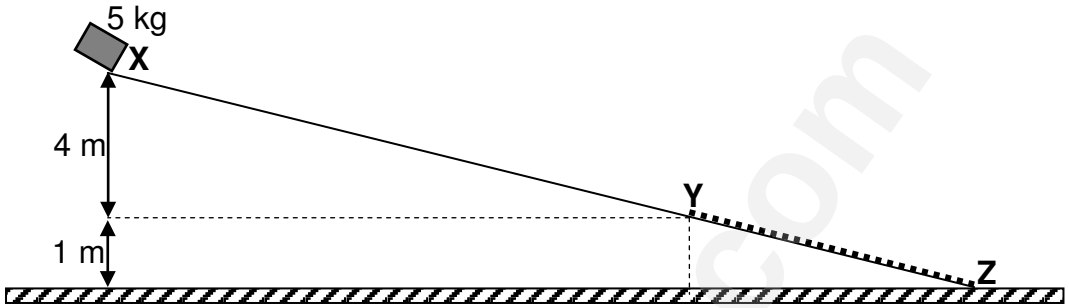
4.4.2 The boy throws a package of double the mass at the same velocity as in QUESTION 4.3. Explain the answer. (3)
[13]

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QUESTION 5 (Start on a new page.)

A 5 kg rigid crate moves from rest down path **XYZ** as shown below (diagram not drawn to scale). Section **XY** of the path is frictionless. Assume that the crate moves in a straight line down the path.



5.1 State, in words, the *principle of the conservation of mechanical energy*. (2)

5.2 Use the principle of the conservation of mechanical energy to calculate the speed of the crate when it reaches point **Y**. (4)

On reaching point **Y**, the crate continues to move down section **YZ** of the path. It experiences an average frictional force of 10 N and reaches point **Z** at a speed of 4 $m \cdot s^{-1}$.

5.3 APART FROM FRICTION, write down the names of TWO other forces that act on the crate while it moves down section **YZ**. (2)

5.4 In which direction does the net force act on the crate as it moves down section **YZ**? Write down only from '**Y** to **Z**' or from '**Z** to **Y**'. (1)

5.5 Use the WORK-ENERGY THEOREM to calculate the length of section **YZ**. (5)

Another crate of mass 10 kg now moves from point **X** down path **XYZ**.

5.6 How will the velocity of this 10 kg crate at point **Y** compare to that of the 5 kg crate at **Y**? Write down only GREATER THAN, SMALLER THAN or EQUAL TO. (1)

[15]

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QUESTION 6 (Start on a new page.)

An ambulance approaches a stationary observer at a constant speed of 10,6 $m \cdot s^{-1}$, while its siren produces sound at a constant frequency of 954,3 Hz. The stationary observer measures the frequency of the sound as 985 Hz.

6.1 Name the medical instrument that makes use of the Doppler effect. (1)

6.2 Calculate the velocity of sound. (5)

6.3 How would the wavelength of the sound wave produced by the siren of the ambulance change if the frequency of the wave were higher than 954,3 Hz? Write down only INCREASES, DECREASES or STAYS THE SAME. (1)

6.4 Give a reason for the answer to QUESTION 6.3. (2)
[9]

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QUESTION 7 (Start on a new page.)

Learners investigate how the broadness of the central bright band in a diffraction pattern changes as the wavelength of light changes. During the investigation, they perform two experiments. The slit width and the distance between the slit and the screen are kept constant.

In the first experiment, they pass light from a monochromatic source through a single slit and obtain pattern **P** on a screen. In the second experiment, they pass light from a different monochromatic source through the single slit and obtain pattern **Q** on the screen.

Pattern P



Pattern Q



7.1 Define the term *diffraction*. (2)

7.2 Which ONE of the two patterns (**P** or **Q**) was obtained using the monochromatic light of a longer wavelength? (1)

7.3 For this investigation, write down the:

7.3.1 Dependent variable (1)

7.3.2 Investigative question (2)

In ONE of their experiments, they use light of wavelength 410 nm and a slit width of 5×10^{-6} m.

7.4 Calculate the angle at which the SECOND MINIMUM will be observed on the screen. (5)

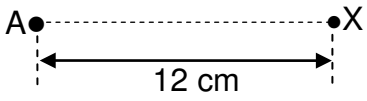
7.5 The single slit is now replaced with a double slit. Describe the pattern that will be observed on the screen. (2)
[13]

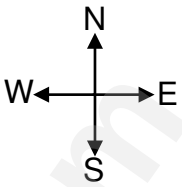
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QUESTION 8 (Start on a new page.)

In the diagram below, point charge **A** has a charge of +16 µC. **X** is a point 12 cm from point charge **A**.





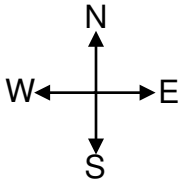
8.1 Draw the electric field pattern produced by point charge **A**. (2)

8.2 Is the electric field in QUESTION 8.1 UNIFORM or NON-UNIFORM? (1)

8.3 Calculate the magnitude and direction of the electric field at point **X** due to point charge **A**. (5)

Another point charge **B** is now placed at a distance of 35 cm from point charge **A** as shown below. The NET electric field at point **X** due to point charges **A** and **B** is 1 x 10^7 $N \cdot C^{-1}$ west.





8.4 Is point charge **B** POSITIVE or NEGATIVE? (1)

8.5 Calculate the magnitude of point charge **B**. (5)
[14]

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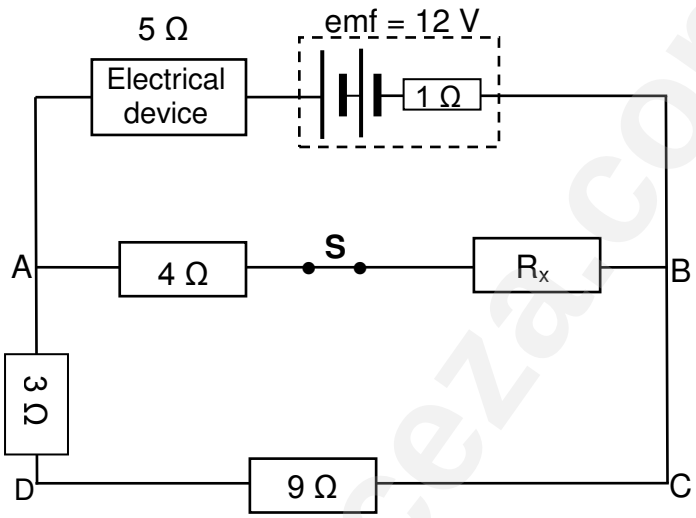
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QUESTION 9 (Start on a new page.)

A learner wants to use a 12 V battery with an internal resistance of 1 Ω to operate an electrical device. He uses the circuit below to obtain the desired potential difference for the device to function. The resistance of the device is 5 Ω.

When switch **S** is **closed** as shown, the device functions at its maximum power of 5 W.



9.1 Explain, in words, the meaning of *an emf of 12 V*. (2)

9.2 Calculate the current that passes through the electrical device. (3)

9.3 Calculate the resistance of resistor $\mathbf{R_x}$. (7)

9.4 Switch **S** is now **opened**. Will the device still function at maximum power? Write down YES or NO. Explain the answer without doing any calculations. (4)
[16]

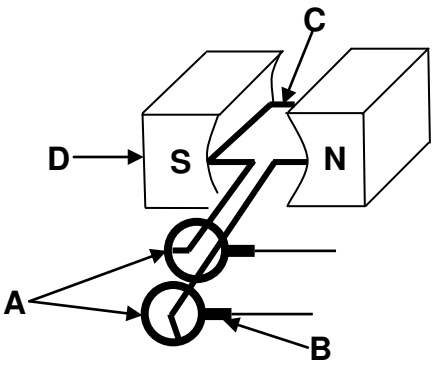
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QUESTION 10 (Start on a new page.)

The simplified sketch represents an AC generator. The main components are labelled **A**, **B**, **C** and **D**.



10.1 Write down the name of component:

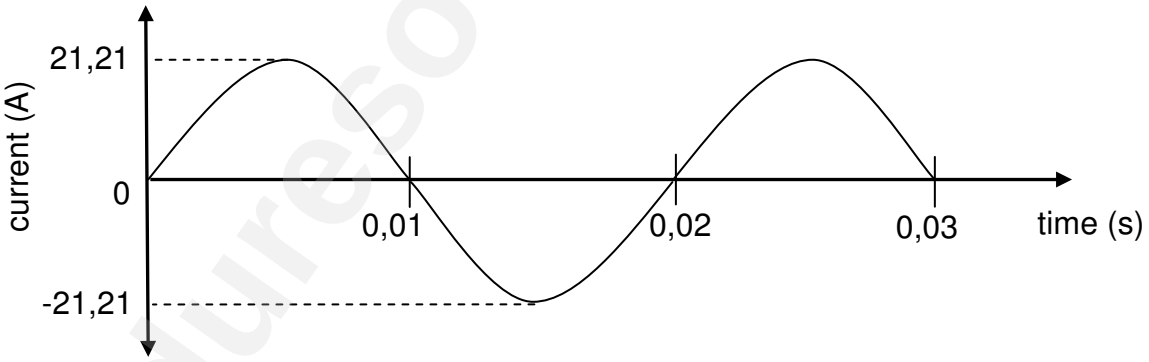
10.1.1 **A** (1)

10.1.2 **B** (1)

10.2 Write down the function of component **B**. (1)

10.3 State the energy conversion which takes place in an AC generator. (1)

A similar coil is rotated in a magnetic field. The graph below shows how the alternating current produced by the AC generator varies with time.



10.4 How many rotations are made by the coil in 0,03 seconds? (1)

10.5 Calculate the frequency of the alternating current. (3)

10.6 Will the plane of the coil be PERPENDICULAR TO or PARALLEL TO the magnetic field at t = 0,015 s? (1)

10.7 If the generator produces a maximum potential difference of 311 V, calculate its average power output. (5)

[14]

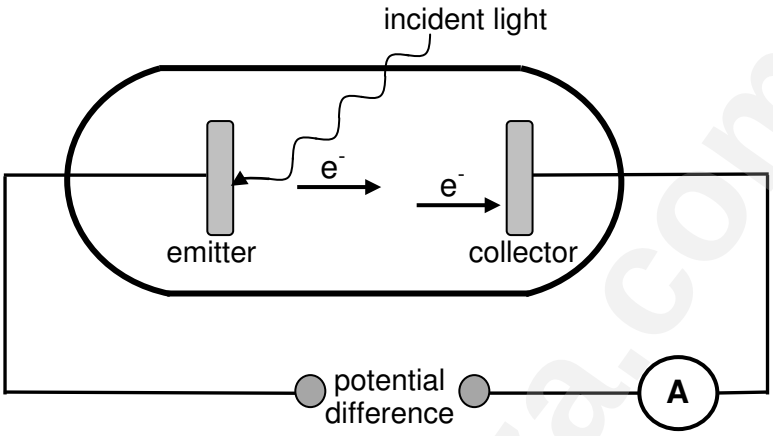
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QUESTION 11 (Start on a new page.)

11.1 In the simplified diagram below, light is incident on the emitter of a photocell. The emitted photoelectrons move towards the collector and the ammeter registers a reading.



11.1.1 Name the phenomenon illustrated above. (1)

11.1.2 The work function of the metal used as emitter is 8,0 x 10^{-19} J. The incident light has a wavelength of 200 nm.

Calculate the maximum speed at which an electron can be emitted. (5)

11.1.3 Incident light of a higher frequency is now used.

How will this change affect the maximum kinetic energy of the electron emitted in QUESTION 11.1.2? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1)

11.1.4 The intensity of the incident light is now increased.

How will this change affect the speed of the electron calculated in QUESTION 11.1.2? Write down INCREASES, DECREASES or REMAINS THE SAME. Give a reason for the answer. (2)

11.2 A metal worker places two iron rods, **A** and **B**, in a furnace. After a while he observes that **A** glows deep red while **B** glows orange.

Which ONE of the rods (**A** or **B**) radiates more energy? Give a reason for the answer. (2)

11.3 Neon signs illuminate many buildings. What type of spectrum is produced by neon signs? (1)

[12]

TOTAL SECTION B: 125
GRAND TOTAL: 150

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GRADE/*GRAAD* 12

PHYSICAL SCIENCES: PHYSICS (P1)
FISIESE WETENSKAPPE: FISIKA (V1)

NOVEMBER 2013

MEMORANDUM

MARKS/*PUNTE*: 150

This memorandum consists of 16 pages.
Hierdie memorandum bestaan uit 16 bladsye.

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SECTION A

QUESTION 1/*VRAAG 1*

1.1 Acceleration / *Versnelling* ✓ (1)

1.2 Wavelength / *Golflengte* ✓ (1)

1.3 Electric field / *Elektriese veld* ✓ (1)

1.4 Gamma / γ (rays) / *Gamma / γ (strale)* ✓ (1)

1.5 Threshold (frequency) / *Drumpel(frekwensie)* ✓ (1)
[5]

QUESTION 2/*VRAAG 2*

2.1 B ✓✓ (2)

2.2 B ✓✓ (2)

2.3 C ✓✓ (2)

2.4 D ✓✓ (2)

2.5 C ✓✓ (2)

2.6 C ✓✓ (2)

2.7 D ✓✓ (2)

2.8 B ✓✓ (2)

2.9 D ✓✓ (2)

2.10 B ✓✓ (2)
[20]

TOTAL SECTION A/*TOTAAL AFDELING A*: 25

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SECTION B/*AFDELING B*

QUESTION 3/*VRAAG 3*

3.1 $15\ m\cdot s^{-1}$ ✓ (1)

3.2

OPTION 1/*OPSIE 1*

Inelastic ✓

The speed/velocity at which the ball leaves the floor is less / different than that at which it strikes the floor. OR The speed/velocity of the ball changes during the collision. ✓

Therefore the kinetic energy changes/is not conserved. ✓

Onelasties

Die spoed/snelheid waarteen die bal die vloer verlaat is kleiner / verskillend as dit waarteen dit die vloer tref. OF Die spoed / snelheid van die bal verander gedurende die botsing.

Die kinetiese energie verander/bly nie behoue nie.

OPTION 2/*OPSIE 2*

Collision is inelastic. ✓

Botsing is onelasties

$\Delta K = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

$= \frac{1}{2}(0,15)(15)^2 - \frac{1}{2}(0,15)(20)^2$ ✓

$= -13,13\ J$

$K_i \neq K_f / \Delta K \neq 0$ ✓

.

OPTION 3/*OPSIE 3*

Collision is inelastic.

Botsing is onelasties. ✓

$K_f = \frac{1}{2}mv_f^2$

$= \frac{1}{2}(0,15)(15)^2$

$= 16,88\ J$

$K_i = \frac{1}{2}mv_i^2$

$= \frac{1}{2}(0,15)(20)^2$ ✓

$= 30\ J$

$K_f \neq K_1 / \Delta K \neq 0$ ✓ (3)

3.3

OPTION 1/*OPSIE 1*

$v_f^2 = v_i^2 + 2a\Delta y$ ✓

$(20)^2$ ✓ $= (10)^2 + 2(9,8)\Delta y$ ✓

$\therefore \Delta y = 15,31\ m$ ✓

OPTION 2/*OPSIE 2*

$W_{net} = \Delta K$ ✓

$F_{net}\Delta y\cos\theta = \frac{1}{2}m(v_f^2 - v_i^2)$

$m(9,8)\Delta y\cos 0°$ ✓ $= \frac{1}{2}m(20^2 - 10^2)$ ✓

$\Delta y = 15,31\ m$ ✓

OPTION 3/*OPSIE 3*

$(E_p + E_k)_{top} = (E_p + E_k)_{bottom}$

$(mgh + \frac{1}{2}mv^2)_{top} = (mgh + \frac{1}{2}mv^2)_{bottom}$ } ✓any one/*enige een*

$m(9,8)h + \frac{1}{2}m(10)^2$ ✓ $= m(9,8)(0) + \frac{1}{2}m(20)^2$ ✓

$h = 15,31\ m$ ✓

OPTION 4/*OPSIE 4*

$v_f = v_i + a\Delta t$

$20 = 10 + (9,8)(\Delta t)$ ✓

$\therefore \Delta t = 1,02\ s$

$\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$

$= (10)(1,02)$ ✓ $+ \frac{1}{2}(9,8)(1,02)^2$ ✓

$\therefore \Delta y = 15,3\ m$ ✓

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OPTION 5/*OPSIE 5*

$v_f = v_i + a\Delta t$

$20 = 10 + (9,8)(\Delta t)$ ✓

$\therefore \Delta t = 1,02$ s

$\Delta y = \left(\frac{v_i + v_f}{2}\right)\Delta t$

$\Delta y = \left(\frac{10+20}{2}\right)$ ✓(1,02) ✓

$\therefore \Delta y = 15,3$ m ✓

OPTION 6/*OPSIE 6*

$v_f = v_i + a\Delta t$

$20 = 10 + (9,8)(\Delta t)$ ✓

$\therefore \Delta t = 1,02$ s

Height = area between graph & *t* axis

Hoogte = opperv. tussen grafiek & t-as

= ½(sum ‖ sides)$h_{\perp}$

= ½(10 + 20) ✓1,02 ✓

= 15,3 m✓

= 15,3 m ✓

OPTION 7/*OPSIE 7*

$v_f = v_i + a\Delta t$

$20 = 10 + (9,8)(\Delta t)$ ✓

$\therefore \Delta t = 1,02$ s

Height = area between graph & *t* axis

Hoogte = opperv. tussen grafiek & t-as

= lb + ½bh = ½(10 + 20)1,02

= (1,02)(10) ✓ + ½(1,02)(10) ✓

= 15,3 m ✓

OPTION 8/*OPSIE 8*

$F_{net} = ma$

$mg = m\left(\frac{v_f^2 - v_i^2}{2\Delta x}\right)$ ✓

(0,15)(9,8) ✓ =(0,15) $\left(\frac{20^2 - 10^2}{2\Delta x}\right)$ ✓

$\Delta x = 15,31$ m✓ (4)

3.3.2 $F_{net}\Delta t = \Delta p$

$F_{net}\Delta t = mv_f - mv_i$ ✓Any one/*Enige een*

$\Delta p = mv_f - mv_i$

$= 0,15(-15 - 20)$ ✓

$= -5,25$ N·s (or $-5,25$ kg·m·s^{-1})

Magnitude/*Grootte* = 5,25 N·s or 5,25 kg·m·s^{-1}✓ (3)

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3.3.3

OPTION 1 / *OPSIE 1*

Displacement from floor to max. height/ *Verplasing van vloer na maks. hoogte*:

$v_f^2 = v_i^2 + 2a\Delta y$ ✓

$(0)^2 = (-15)^2 + 2(9,8)\Delta y$ ✓

$\therefore \Delta y = -11,48$ m

Total displacement / *Totale verplasing*

$= -11,48 + 15,3$ ✓

$= 3,82$ m ✓ / 3,83 m

OPTION 2 / *OPSIE 2*

$v_f = v_i + a\Delta t$

$0 = -15 + (9,8)\Delta t$

$\Delta t = 1,53$ s ✓

$\Delta y = v_i\Delta t + ½ a\Delta t^2$

$= (-15)(1,53) + ½ (9,8)(1,53)^2$ ✓

$= -11,48$ m

Total displacement / *Totale verplasing*

$= -11,48 + 15,3$ ✓

$= 3,82$ m ✓

OPTION 3 / *OPSIE 3*

$v_f = v_i + a\Delta t$

$0 = -15 + (9,8)\Delta t$

$\Delta t = 1,53$ s ✓

$\Delta y = \left(\frac{v_f + v_i}{2}\right)\Delta t$

$= \left(\frac{0 + (-15)}{2}\right)(1,53)$ ✓

$= -11,48$ m

Total displacement / *Totale verplasing*

$= -11,48 + 15,3$ ✓

$= 3,82$ m ✓

OPTION 4 / *OPSIE 4*

$v_f = v_i + a\Delta t$

$0 = -15 + (9,8)\Delta t$

$\Delta t = 1,53$ s ✓

Area = ½ bh

$= ½ (1,53)(-15)$ ✓

$= -11,48$ m

Total displacement / *Totale verplasing*

$= -11,48 + 15,3$ ✓

$= 3,82$ m ✓

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OPTION 5 / *OPSIE 5*

$E_{M(initial)} = E_{M(final)}$
$(E_p + E_k)_{initial} = (E_p + E_k)_{final}$
$(mgh + ½ mv^2)_{initial} = (mgh + ½ mv^2)_{final}$
✓Any one /*Enige een*

$(0,15)(9,8)(0) + ½ (0,15)(15)^2 = (0,15)(9,8)h + ½ (0,15)(0)^2$ ✓
h = 11,48 m

Total displacement / *Totale verplasing*
= 15,31 - 11,48 ✓ = 3,83 m ✓

OPTION 6/*OPSIE 6*

$W_{net} = \Delta K$ ✓
$F_{net}\Delta y\cos\theta = ½ m(v_f^2 - v_i^2)$
$m(9,8)\Delta y\cos 180° = ½ m(0^2 - 15^2)$ ✓
Δy = 11,48 m

Total displacement / *Totale verplasing*
= 15,31 - 11,48 ✓
= 3,83 m ✓

OPTION 7/*OPSIE 7*

$F_{net} = ma$

$mg = m\left(\frac{v_f^2 - v_i^2}{2\Delta x}\right)$ ✓

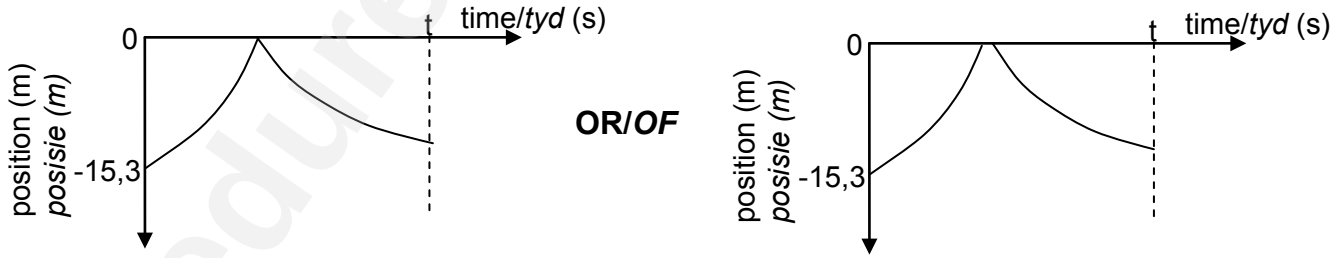
$(0,15)(9,8) = (0,15)\left(\frac{0^2 - (-15)^2}{2\Delta x}\right)$ ✓

Δx = -11,48 m

Total displacement / *Totale verplasing*
= 15,31 - 11,48 ✓
= 3,83 m ✓

(4)

3.4



Marking criteria for graph:/*Nasienriglyne vir grafiek:*	
Correct shape as shown for first part./*Korrekte vorm soos aangetoon vir eerste deel.*	✓
Correct shape as shown for the second part up to t / 2,55 s. *Korrekte vorm soos aangetoon vir tweede deel t / 2,55 s.*	✓
Graph starts at -15,3 m at t = 0 s./*Grafiek begin by -15,3 m by t = 0 s.*	✓
Maximum height after bounce at time *t* / 2,55 s./*Maksimum hoogte na bons by tyd t./ 2,55 s.* Maximum height after bounce less than 15,3 m./*Maksimum hoogte na bons kleiner as 15,3 m.*	✓

(4)
[19]

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QUESTION 4/*VRAAG 4*

4.1 West / *Wes* ✓ (1)

4.2 (Newton's) Third Law (of Motion) ✓
When object A exerts a force on object B,
object B exerts a force equal in magnitude on object A✓, but opposite in direction. ✓

(Newton) se Derde (Bewegings)wet
Wanneer voorwerp A 'n krag op voorwerp B uitoefen,
oefen voorwerp B 'n krag van gelyke grootte op voorwerp A, maar in die teenoorgestelde rigting. (3)

4.3

OPTION 1/ *OPSIE 1*	**OPTION 2/*OPSIE 2***
East as positive/Oos *as positief:*	**East as positive/*Oos as positief:***
$\Sigma p_i = \Sigma p_f$ ✓ 0 ✓ = (60)v_f + (5)(4) ✓ $\therefore v_f$ = - 0,33✓ $\therefore v_f$ = 0,33 m·s^{-1}✓	$\Delta p_A = -\Delta p_B$ ✓ (60)v_f ✓– 0 = -[(5)(4) – 0] ✓ $\therefore v_f$ = - 0,33 ✓ $\therefore v_f$ = 0,33 m·s^{-1}✓
West as positive/*Wes as positief:*	**West as positive/*Wes as positief:***
$\Sigma p_i = \Sigma p_f$ ✓ 0 ✓ = (60)v_f + (5)(-4) ✓ $\therefore v_f$ = 0,33 m·s^{-1}✓✓	$\Delta p_A = -\Delta p_B$ ✓ (60)v_f ✓– 0 = -[(5)(-4) – 0] ✓ $\therefore v_f$ = 0,33 m·s^{-1}✓✓
OPTION 3/ *OPSIE 3*	**OPTION 4/ *OPSIE 4***
East as positive/Oos *as positief*	**West as positive/*Wes as positief***
$F_{BP} = -F_{PB}$✓ $m_Ba_B = -m_Pa_P$ $m_B\left(\frac{v_{Bf}-v_{Bi}}{\Delta t}\right) = -m_P\left(\frac{v_{Pf}-v_{Pi}}{\Delta t}\right)$ (60)$\left(\frac{v_{Bf}-0}{\Delta t}\right)$✓= - (5)$\left(\frac{4-0}{\Delta t}\right)$✓ v_{Bi} = - 0,33 m·s^{-1}✓ = 0,33 m·s^{-1}✓	$F_{BP} = -F_{PB}$✓ $m_Ba_B = -m_Pa_P$ $m_B\left(\frac{v_{Bf}-v_{Bi}}{\Delta t}\right) = -m_P\left(\frac{v_{Pf}-v_{Pi}}{\Delta t}\right)$ (60)$\left(\frac{v_{Bf}-0}{\Delta t}\right)$✓= - (5)$\left(\frac{-4-0}{\Delta t}\right)$✓ v_{Bi} = 0,33 m·s^{-1}✓✓

(5)

4.4
4.4.1 Increases / *Verhoog* ✓ (1)

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4.4.2 Increases / *Verhoog* ✓

- ∆p package increases, thus ∆p boy increases. ✓
  ∆p pakkie vermeerder, dus ∆p seun vermeerder.
- For the same mass of boy, v will be greater. ✓
  Vir dieselfde massa van die seun sal v groter wees.

OR/*OF*

Increases / *Verhoog*✓

From the equation in QUESTION 4.3: $-m_Av_{Af} = m_Bv_{Bf}$

Vanaf die vegelyking in VRAAG 4.3: $-m_Av_{Af} = m_Bv_{Bf}$

- If mass of package/B doubles/increases, the momentum of the boy / A doubles / increases.✓
  Indien die massa van pakkie / B verdubbel / toeneem, verdubbel / vermeerder die momentum van die seun / A
- For same mass of boy / A, the velocity of boy / A doubles/increases.✓
  Vir dieselfde massa van die seun / A, verdubbel/vermeerder die snelheid van die seun /A.

OR/*OF*

Increases / *Verhoog* ✓

$-m_Bv_{Bf} = m_pv_{pf}$

$v_B = \frac{-m_pv_{pf}}{m_B}$ ✓ for same m_B, if m_P doubles, ✓ then v_B doubles

(3)
[13]

QUESTION 5/*VRAAG 5*

5.1 The total mechanical energy remains constant / is conserved ✓
in a closed / isolated system / in absence of external forces /non-conservative forces. ✓
Die totale meganiese energie in bly konstant / bly behoue
in 'n geslote / geïsoleerde sisteem /in afwesigheid van eksterne kragte /nie-konserwatiewe kragte.

OR/*OF*

The sum of the potential and kinetic energy of a system remains constant ✓
in a closed/isolated system. ✓
Die som van die potensiële en kinetiese energie van *'n sisteem bly konstant in 'n geslote / geïsoleerde sisteem.*

OR/*OF*

When the work done on an object by the non-conservative forces is zero✓,
the total mechanical energy is conserved. ✓
Wanneer die arbeid deur die nie-konserwatiewe kragte op 'n voorwerp verrig nul is, bly die totale meganiese energie behoue.

(2)

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5.2

OPTION 1/*OPSIE 1*

$E_{mechanical\ at\ X} = E_{mechanical\ at\ Y}$
$(E_p + E_k)_X = (E_p + E_k)_Y$
$(mgh + ½ mv^2)_X = (mgh + ½ mv^2)_Y$
✓Any one/*Enige een*

$\underline{5(9,8)(5)} + ½(5)(0^2)$✓$= \underline{(5)(9,8)(1)} + ½(5)v_f^2$ ✓
$v = 8,85\ m\cdot s^{-1}$ ✓

OPTION 2/*OPSIE 2*

$E_{mechanical\ at\ X} = E_{mechanical\ at\ Y}$
$(E_p + E_k)_X = (E_p + E_k)_Y$
$(mgh + ½ mv^2)_X = (mgh + ½ mv^2)_Y$
✓ Any one/*Enige een*

$\underline{5(9,8)(4)} + ½(5)(0^2)$✓$= \underline{(5)(9,8)(0)} + ½(5)v_f^2$ ✓
$v = 8,85\ m\cdot s^{-1}$ ✓

(4)

5.3 Weight / gravitational (force) / (force of) gravity ✓
Gewig / Gravitasie(krag)
Normal force / *Normaalkrag* ✓ (2)

5.4 Z to/*na* Y ✓ (1)

5.5

OPTION 1/*OPSIE 1*

$W_{net} = \Delta K$ ✓
$W_w + W_f = ½m(v_f^2 - v_i^2)$
$mg\Delta y\cos 0° + f\Delta x\cos 180° = ½ m(v_f^2 - v_i^2)$
$(5)(9,8)(1)(1)$ ✓ $+ (10)\Delta x(-1)$ ✓ $= ½(5)(4^2 - 8,85^2)$ ✓
$\Delta x = 20,48$ m ✓

OPTION 2/*OPSIE 2*

$W_{net} = \Delta K$ ✓
$W_w + W_f = ½m(v_f^2 - v_i^2)$
$-\Delta E_p + W_f = ½m(v_f^2 - v_i^2)$
$-(0 - mgh) + f\Delta x\cos 180° = ½ m(v_f^2 - v_i^2)$
$(5)(9,8)(1)$ ✓ $+ (10)\Delta x(-1)$ ✓ $= ½(5)(4^2 - 8,85^2)$ ✓
$\Delta x = 20,48$ m ✓

OPTION 3/*OPSIE 3*

$W_{net} = \Delta K$ ✓
$W_w + W_f = ½m(v_f^2 - v_i^2)$
$-\Delta E_p + W_f = ½m(v_f^2 - v_i^2)$
$-(0 - mgh) + f\Delta x\cos 180° = ½ m(v_f^2 - v_i^2)$
$(5)(9,8)(5)$ ✓ $+ (10)\Delta x(-1)$ ✓ $= ½(5)(4^2 - 0^2)$ ✓
$\Delta x = 20,48$ m ✓

OPTION 4/*OPSIE 4*

$W_{net} = \Delta K$ ✓
$W_w + W_f = ½m(v_f^2 - v_i^2)$
$mg\Delta x\cos(90^o - \theta) + f\Delta x\cos 180° = ½ m(v_f^2 - v_i^2)$
$mg\Delta x\sin\theta + f\Delta x\cos 180° = ½ m(v_f^2 - v_i^2)$
$mg\Delta x\left(\frac{1}{\Delta x}\right) + f\Delta x\cos 180° = ½ m(v_f^2 - v_i^2)$
$(5)(9,8)$ ✓ $+ (10)\Delta x(-1)$ ✓ $= ½(5)(4^2 - 8,85^2)$ ✓
$\Delta x = 20,48$ m ✓

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OPTION 5/*OPSIE 5*
$W_{net} = \Delta K$ ✓
$W_{w\|\|} + W_f = ½m(v_f^2 - v_i^2)$
$mgsin\theta\Delta xcos\theta + f\Delta xcos\theta = ½ m(v_f^2 - v_i^2)$
$mg\left(\frac{1}{\Delta x}\right)\Delta xcos0° + f\Delta xcos180° = ½ m(v_f^2 - v_i^2)$
$(5)(9,8)$ ✓ $+ (10)\Delta x(-1)$ ✓ $= ½(5)(4^2 - 8,85^2)$ ✓
$\Delta x = 20,48$ m ✓
OPTION 6/*OPSIE 6*
$W_{net} = \Delta K$ ✓
$F_{net}\Delta xcos\theta = ½m(v_f^2 - v_i^2)$
$(10 - 49sin\theta)\Delta xcos180° = ½ m(v_f^2 - v_i^2)$
$(10 - 49\left(\frac{1}{\Delta x}\right)$)✓$\Delta xcos180° = ½ m(v_f^2 - v_i^2)$
$(10\Delta x - 49)(-1)$✓ $= ½(5)(4^2 - 8,85^2)$ ✓
$\Delta x = 20,48$ m
OPTION 7/*OPSIE 7*
$W_{nc} = \Delta E_p + \Delta E_k$✓
$f\Delta xcos\theta = (mgh_f - mgh_i) + (½ mv_f^2 - ½ mv_i^2)$
$(10)\Delta xcos180°$ ✓$= [0 - (5)(9,8)(1)]$ ✓ $+ [½ (5)(4)^4 - ½ (5)(8,85)^2$✓
$\Delta x = 20,48$ m✓

(5)

5.6 Equal to / *Gelyk aan* ✓ (1)

[15]

QUESTION 6/*VRAAG 6*

6.1 Doppler flow meter / *Dopplervloeimeter* ✓ (1)

6.2 $f_L = \frac{v \pm v_L}{v \pm v_s} f_s$ ✓

985 ✓ $= \frac{v}{(v - 10,6)}$ ✓$(954,3)$ ✓

$v = 340,1$ m·s^{-1} ✓ (5)

6.3 Decreases / *Afneem* ✓ (1)

6.4 For a constant velocity of sound / speed ✓
if the frequency increases, λ decreases. ✓
Vir 'n konstante snelheid van klank /spoed,
as die frekwensie toeneem neem λ af.

OR/*OF*

$\lambda \alpha \frac{1}{f}$ or $f \alpha \frac{1}{\lambda}$ ✓ at constant velocity/speed / *by konstante snelheid/spoed..* ✓ (2)

[9]

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QUESTION 7/*VRAAG 7*

7.1 The bending of waves around obstacles / corners / through an opening / aperture ✓✓
Die buiging van golwe om versperrings / hoeke / deur 'n opening.

OR/*OF*
The spreading of waves around the edge of a barrier/through an opening/aperture.
Die uitspreiding van golwe om die kant van 'n versperring/deur 'n opening. (2)

7.2 P ✓ (1)

7.3

7.3.1 Broadness of the central bright band / diffraction pattern / angle of diffraction / degree of diffraction / sin θ / position of the first minimum ✓
Breedte van die sentrale helderband / diffraksiepatroon/hoek van diffraksie / mate van diffraksie / sin θ / posisie van die eerste minimum (1)

7.3.2

Criteria for investigative question/*Kriteria vir ondersoekende vraag*:	
Dependent and independent variables correctly identified. *Afhanklike en onafhanklike veranderlikes korrek geïdentifiseer.*	✓
Question about the relationship between the independent and dependent variables correctly formulated. Vraag oor die verwantskap tussen die *afhanklike en onafhanklike veranderlikes korrek geformuleer.*	✓

Example/*Voorbeeld*:
What is the relationship between the broadness of the central band and the wavelength (of light used)?
Wat is die verwantskap tussen die breedte van die sentrale band en die golflengte (van die lig)? (2)

7.4

OPTION 1/*OPSIE 1*	**OPTION 2/*OPSIE 2***
$\sin\theta = \frac{m\lambda}{a}$ ✓ $\sin\theta = \frac{(2)(410\times10^{-9})}{5\times10^{-6}}$ ✓ ✓ ✓ $\therefore\theta = 9{,}44°$ ✓ or $9{,}21°$	$\sin\theta = \frac{m\lambda}{a}$ ✓ $\sin\theta = \frac{(-2)(410\times10^{-9})}{5\times10^{-6}}$ ✓ ✓ ✓ $\therefore\theta = -9{,}44°$ ✓ or $-9{,}21°$

(5)

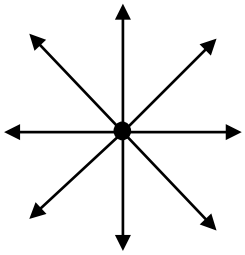
7.5 Light (bright) and dark bands.✓
Light /dark bands of equal width. ✓
Lig (helder) en donker bande eweredig gespasieer.
Helder / donker bande van gelyke breedte /wydte. (2)
[13]

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QUESTION 8/*VRAAG 8*

8.1



Criteria for sketch:/*Kriteria vir skets:*	
Correct shape - field lines radially around charge. *Korrekte vorm – veldlyne radiaal uitwaarts.*	✓
Direction of field lines away from charge. *Rigting van veldlyne weg van lading af.*	✓

(2)

8.2 Non-uniform / *Nie-uniform* ✓ (1)

8.3
$$E = \frac{kQ}{r^2} \checkmark$$
$$= \frac{(9\times10^{9})(16\times10^{-6})}{(0,12)^2} \checkmark$$
$$= 1 \times 10^{7}\ N\cdot C^{-1} \checkmark \text{ east/}oos \checkmark$$ (5)

8.4 Positive / *Positief* ✓ (1)

8.5

West: positive	**West: negative**
$E_A + E_B = E_{net}$	$E_A + E_B = E_{net}$
$-1 \times 10^{7} + E_B$ ✓$= 1 \times 10^{7}$✓	$1 \times 10^{7} + E_B$ ✓$= -1 \times 10^{7}$✓
$\therefore E_B = 2 \times 10^{7}\ N\cdot C^{-1}$	$\therefore E_B = -2 \times 10^{7}\ N\cdot C^{-1}$ $= 2 \times 10^{7}\ N\cdot C^{-1}$
$E_B = \frac{kQ_B}{r^2}$	$E_B = \frac{kQ_B}{r^2}$
$\therefore 2 \times 10^{7}$✓ $= \frac{(9\times10^{9})Q_B}{(0,23)^2}$ ✓	$\therefore 2 \times 10^{7}$ ✓$= \frac{(9\times10^{9})Q_B}{(0,23)^2}$ ✓
$\therefore Q_B = 1,18\times10^{-4}$ C ✓	$\therefore Q_B = 1,18\times10^{-4}$ C ✓
(5)	(5)

(5)
[14]

QUESTION 9/*VRAAG 9*

9.1 12 J of energy are transferred to / work done on ✓
each coulomb (of charge) / per C charge ✓ passing through the battery.

12 J energie word oorgedra aan / arbeid word verrig op
elke coulomb (lading) / per C lading wat deur die battery beweeg. (2)

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9.2

OPTION 1/*OPSIE 1*

$P = I^2R$ ✓
$5 = I^2(5)$ ✓
$\therefore I = 1$ A ✓

OPTION 2/*OPSIE 2*

$P = \frac{V^2}{R}$
$5 = \frac{V^2}{5}$ ✓
$V = 5$ V

$P = VI$
$5 = (5)I$ ✓
$I = 1$ A✓

OPTION 3/*OPSIE 3*

$P = \frac{V^2}{R}$
$5 = \frac{V^2}{5}$ ✓
$V = 5$ V

$V = IR$
$5 = I(5)$ ✓
$I = 1$ A✓

(3)

9.3

OPTION 1 / *OPSIE 1*

Emf = $I(R + r)$ ✓
12 ✓= (1)(R + 1)
R = 11 Ω

R_p = 11 – 5✓ = 6 Ω

OPTION 2 / *OPSIE 2*

Emf = $I(R + r)$ ✓
12 ✓= (1)(R_p + 5 + 1)✓
$\therefore R_p = 6$ Ω

OPTION 3/OPSIE 3

$V = I R_T$ ✓
12✓ = (1)R
R_T = 12 Ω

$R_p = R_T – (5 + 1)$
= 12 – 6 ✓
= 6 Ω

$\frac{1}{R_p} = \frac{1}{R_{12}} + \frac{1}{R}$ ∴ $\frac{1}{6}$✓ = $\frac{1}{12}$✓ + $\frac{1}{4+R_x}$✓ ∴ $\frac{1}{12} = \frac{1}{4+R_x}$ ∴ 12 = 4 + R_x ∴R_x = 8 Ω✓

OR/*OF*

$R_p = \frac{(4+R_x)(12)}{4+R_x+12}$ ✓ ✓ ∴ $R_p = \frac{(4+R_x)(12)}{4+R_x+12}$ ∴ 6 ✓ = $\frac{(4+R_x)(12)}{4+R_x+12}$ ∴ R_x = 8 Ω ✓

OPTION 4/*OPSIE 4*

$V_{5Ω}$ = IR ✓
= (1)(5)
= 5 V

$V_{internal}$ = Ir
= (1)(1)
= 1 V

$V_{parallel}$ = 12✓ – (1 + 5) ✓
= 6 V

$V_{parallel}$ = IR
6 = I(12) ✓
∴I = 0,5 A

I_{Rx} = 1 – 0,5
= 0,5 A

V = IR
6✓ = (0,5)(4 + R_x) ✓
∴R_x = 8 Ω ✓

(7)

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9.4 

No / *Nee* ✓

Total resistance (R) increases. / *Totale weerstand (R) neem toe.*✓
Current (I) decreases / *Stroom (I) neem af.* ✓
(For a constant R) power ($P = I^2R$) decreases.✓
(Vir konstante R) drywing ($P = I^2R$) verminder. (4)
[16]

QUESTION 10/*VRAAG 10*

10.1
10.1.1 slip rings / *sleepringe* ✓ (1)

10.1.2 brush(es) / *borsel(s)* ✓ (1)

10.2 Maintains electrical contact with the slip rings.
Handhaaf elektriese kontak met die sleepringe.

OR/*OF*
To take current out/in of the coil.
Om die stroom uit/in die spoel te neem. (1)

10.3 Mechanical /kinetic energy to electrical energy. ✓
Meganiese / kinetiese energie na elektriese energie. (1)

10.4 1½ ✓ (1)

10.5

OPTION 1/ *OPSIE 1*

$f = \frac{1}{T}$ ✓

$= \frac{1}{0,02}$ ✓

= 50 Hz ✓

(3)

OPTION 2/ *OPSIE 2*

$f = \frac{\text{number of cycles}}{\text{time}}$ ✓

$= \frac{1,5}{0,03}$ or/of $\frac{1}{0,02}$ or/of $\frac{0,5}{0,01}$ ✓

= 50 Hz ✓

(3)

(3)

10.6 Parallel to / *Parallel aan* ✓ (1)

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10.7

OPTION 1/ *OPSIE 1*

$P_{ave} = V_{rms}I_{rms}$ ✓

$= \left(\frac{V_{max}}{\sqrt{2}}\right)\left(\frac{I_{max}}{\sqrt{2}}\right)$ ✓ (1 mark for both formulae / *1 punt vir beide formules*)

$= \left(\frac{311}{\sqrt{2}}\right)$✓$\left(\frac{21{,}21}{\sqrt{2}}\right)$ ✓

= 3 298,16 W ✓ (Accept range / *Aanvaar gebied*: 3298,13 – 3299,18 W)

OPTION 2/ *OPSIE 2*

$P_{ave} = \frac{V_{max}I_{max}}{2}$ ✓✓

$= \frac{(311)(21.21)}{2}$ ✓✓

= 3298,16 W✓

OPTION 3 / *OPSIE 3*

$V_{rms} = \frac{V_{max}}{\sqrt{2}} = \frac{311}{\sqrt{2}}$ ✓✓= 219,91 V

$I_{rms} = \frac{I_{max}}{\sqrt{2}} = \frac{21{,}21}{\sqrt{2}}$ ✓= 14,998 A

$P_{ave} = V_{rms}I_{rms}$ ✓

= (219,91)(14,998)

= 3 298,21 W ✓

OPTION 4/ *OPSIE 4*

$R = \frac{V_{max}}{I_{max}}$

$= \frac{311}{21{,}21}$ ✓

= 14,66 Ω

$V_{rms} = \frac{V_{max}}{\sqrt{2}} = \frac{311}{\sqrt{2}}$ ✓= 219,91 V

$P_{ave} = \frac{V_{rms}^2}{R}$ ✓

$= \frac{(219{,}91)^2}{14{,}66}$ ✓

= 3 298,8 W✓

OPTION 6/*OPSIE 6*

$R = \frac{V_{max}}{I_{max}}$

$= \frac{311}{21{,}21}$ ✓

= 14,66 Ω

$I_{rms} = \frac{I_{max}}{\sqrt{2}} = \frac{21{,}21}{\sqrt{2}}$ ✓= 14,998 A

$P_{ave} = I_{rms}^2R$ ✓

$= (14{,}998)^2(14{,}66)$ ✓

= 3 297,62 W✓

(5)
[14]

QUESTION 11/*VRAAG 11*

11.1

11.1.1 Photo-electric effect / *Foto-elektriese effek* ✓ (1)

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11.1.2

OPTION 1/*OPSIE 1*

$E = W_0 + E_k$

$hf = hf_0 + E_k$

$\frac{hc}{\lambda} = W_0 + \frac{1}{2}mv^2$

✓ Any one/*Enige een*

$\frac{(6{,}63 \times 10^{-34})(3x10^8)}{200 \times 10^{-9}}$ ✓ $= 8 \times 10^{-19}$ ✓ $+ \frac{1}{2}(9{,}11 \times 10^{-31})v^2$ ✓

$v = 6{,}53 \times 10^5$ m·s^{-1} ✓ (653454,89 m·s^{-1})

OPTION 2 / *OPSIE 2*

$c = f\lambda$

$3 \times 10^8 = f(200 \times 10^{-9})$

$f = 1{,}5 \times 10^{15}$ Hz

$hf = hf_0 + E_k$ ✓

$(6{,}63 \times 10^{-34})(1{,}5 \times 10^{15})$ ✓ $= 8 \times 10^{-19}$ ✓ $+ \frac{1}{2}(9{,}11 \times 10^{-31})v^2$ ✓

$v = 6{,}53 \times 10^5$ m·s^{-1} ✓ (5)

11.1.3 Increases / *Vermeerder* ✓ (1)

11.1.4 Remains the same / *Bly dieselfde* ✓
Intensity only affects number of photoelectrons emitted per second. ✓
Intensiteit beïnvloed slegs die getal foto-elektrone vrygestel per sekonde.

OR/*OF*

Remains the same / *Bly dieselfde* ✓
The kinetic energy of the emitted photoelectrons remains the same.
Die kinetiese energie van die vrygestelde foto-elektrone bly dieselfde.

OR/*OF*

Remains the same / *Bly dieselfde* ✓
Only the frequency/wavelength of the incident light affects the maximum kinetic energy.
Slegs the frekwensie/golflengte van die invallende lig beïnvloed die maksimum kinetiese energie. (2)

11.2 B ✓
Orange light has a higher frequency than red light. ✓
Oranje lig het 'n hoër frekwensie as rooi lig.

OR/*OF*

Orange light has smaller wavelength than red light.
Oranje lig het 'n kleiner golflengte as rooi lig. (2)

11.3 Line emission (spectra) / *Lyn emissie(spektrum)* ✓ (1)

[12]

TOTAL SECTION B/*TOTAAL AFDELING B*: 125
GRAND TOTAL/*GROOTTOTAAL*: 150

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Department:
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REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE

GRADE 12

PHYSICAL SCIENCES: CHEMISTRY (P2)

NOVEMBER 2013

MARKS: 150

TIME: 3 hours

This question paper consists of 15 pages and 4 data sheets.

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INSTRUCTIONS AND INFORMATION

1. Write your centre number and examination number in the appropriate spaces on the ANSWER BOOK.

2. Answer ALL the questions in the ANSWER BOOK.

3. This question paper consists of TWO sections:

   SECTION A (25)
   SECTION B (125)

4. You may use a non-programmable calculator.

5. You may use appropriate mathematical instruments.

6. Number the answers correctly according to the numbering system used in this question paper.

7. Data sheets and a periodic table are attached for your use.

8. Give brief motivations, discussions, et cetera where required.

9. Round off your final numerical answers to a minimum of TWO decimal places.

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SECTION A

QUESTION 1: ONE-WORD ITEMS

Give ONE word/term for each of the following descriptions. Write only the word/term next to the question number (1.1–1.5) in the ANSWER BOOK.

1.1 The industrial preparation of nitrogen gas from liquid air (1)

1.2 The removal of water from a compound during a reaction (1)

1.3 A theory used to explain how factors, such as temperature, change the rate of a reaction (1)

1.4 The general term used to describe a substance that donates electrons to another substance (1)

1.5 The general term used to describe a class of organic compounds in which one member differs from the previous one by a CH_2 group (1)
[5]

QUESTION 2: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Write only the letter (A–D) next to the question number (2.1–2.10) in the ANSWER BOOK.

2.1 Which ONE of the following is the functional group of aldehydes?

A ─ COO ─

B ─ COOH

C ─ CHO

D ─ OH (2)

2.2 Which ONE of the following hydrocarbons always gives a product with the same IUPAC name when ANY ONE of its hydrogen atoms is replaced with a chlorine atom?

A Hexane

B Hex-1-ene

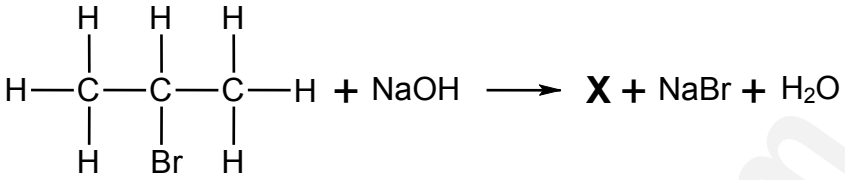
C Cyclohexane

D Cyclohexene (2)

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2.3 The equation below represents the reaction that takes place when an organic compound and concentrated sodium hydroxide are strongly heated. **X** represents the major organic product formed.



Which ONE of the following is the correct IUPAC name for compound **X**?

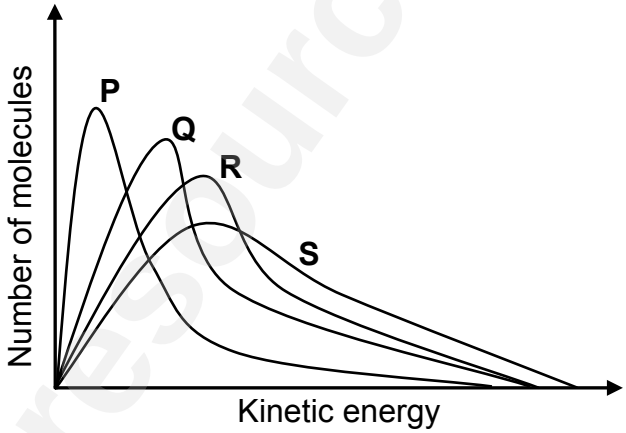
A Prop-1-ene

B Prop-2-ene

C Propan-1-ol

D Propan-2-ol (2)

2.4 The graphs below represent the molecular distribution for a reaction at different temperatures.



Which ONE of the graphs above represents the reaction at the highest temperature?

A P

B Q

C R

D S (2)

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2.5 The reaction represented below reaches equilibrium in a closed container.

$$CuO(s) + H_2(g) \rightleftharpoons Cu(s) + H_2O(g) \quad \Delta H < 0$$

Which ONE of the following changes will increase the yield of products?

A Increase temperature.

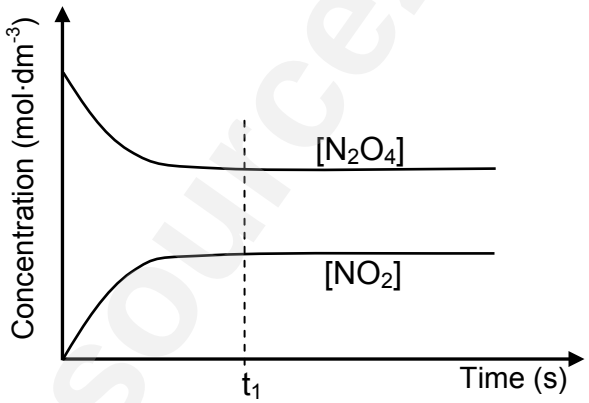
B Decrease temperature.

C Increase pressure by decreasing the volume.

D Decrease pressure by increasing the volume. (2)

2.6 The graph below represents the decomposition of $N_2O_4(g)$ in a closed container according to the following equation:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$



Which ONE of the following correctly describes the situation at t_1?

A The N_2O_4 gas is used up.

B The NO_2 gas is used up.

C The rate of the forward reaction equals the rate of the reverse reaction.

D The concentrations of the reactant and the product are equal. (2)

2.7 Which ONE of the following is the strongest oxidising agent?

A $F_2(g)$

B $F^-(aq)$

C $Li(s)$

D $Li^+(aq)$ (2)

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2.8 Which ONE of the following statements about a galvanic cell in operation is CORRECT?

A ΔH for the cell reaction is positive.

B The overall cell reaction is non-spontaneous.

C The emf is negative.

D ΔH for the cell reaction is negative. (2)

2.9 The function of the salt bridge in a galvanic cell in operation is to ...

A allow anions to travel to the cathode.

B maintain electrical neutrality in the half-cells.

C allow electrons to flow through it.

D provide ions to react at the anode and cathode. (2)

2.10 The major product formed at the ANODE in a membrane cell is ...

A hydrogen.

B oxygen.

C chlorine.

D hydroxide ions. (2)
[20]

TOTAL SECTION A: 25

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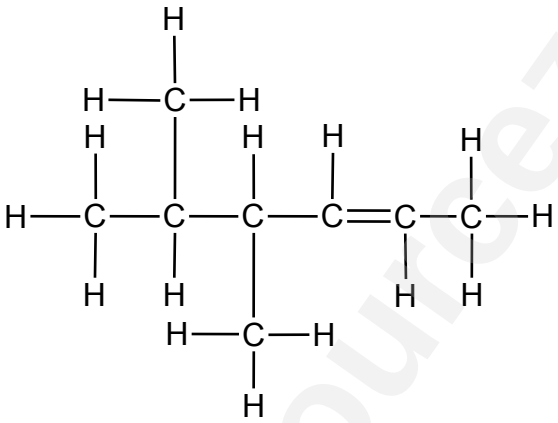
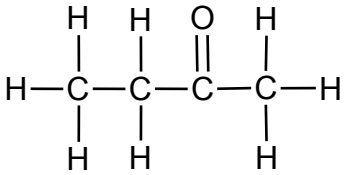
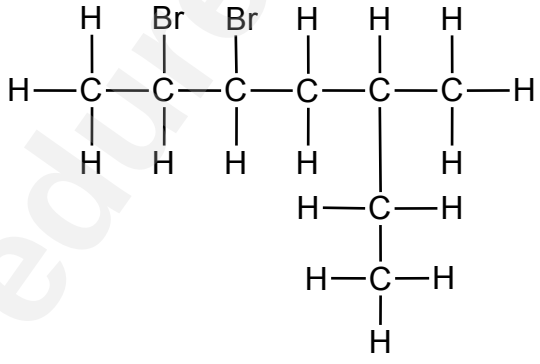
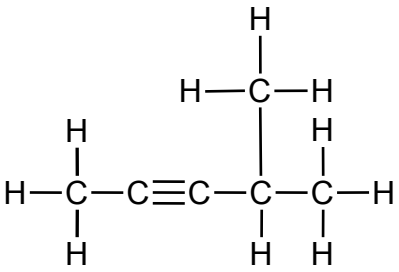
SECTION B

INSTRUCTIONS

1. Start EACH question on a NEW page.
2. Leave ONE line between two subquestions, for example between QUESTION 3.1 and QUESTION 3.2.
3. Show the formulae and substitutions in ALL calculations.
4. Round off your final numerical answers to a minimum of TWO decimal places.

QUESTION 3 (Start on a new page.)

The letters **A** to **F** in the table below represent six organic compounds.

A		**B**	
C	$CH_3CH=CHCH_2CH_2CH_3$	**D**	Pentyl propanoate
E		**F**	

3.1 Write down the letter(s) that represent(s) the following:

3.1.1 Alkenes (2)

3.1.2 A ketone (1)

3.1.3 A compound with the general formula C_nH_{2n-2} (1)

3.1.4 A structural isomer of cyclohexene (2)

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3.2 Write down the IUPAC name of compound:

3.2.1 **A** (2)

3.2.2 **E** (2)

3.2.3 **F** (2)

3.3 Compound **D** is prepared by reacting two organic compounds in the presence of an acid as catalyst.

Write down the:

3.3.1 Homologous series to which compound **D** belongs (1)

3.3.2 Structural formula of compound **D** (2)

3.3.3 IUPAC name of the organic acid used to prepare compound **D** (1)

3.3.4 NAME or FORMULA of the catalyst used (1)
[17]

QUESTION 4 (Start on a new page.)

A laboratory technician is supplied with three unlabelled bottles containing an alcohol, an aldehyde and an alkane respectively of comparable molecular mass. She takes a sample from each bottle and labels them **P**, **Q** and **R**.

In order to identify each sample, she determines the boiling point of each under the same conditions. The results are shown in the table below.

SAMPLE	BOILING POINT (°C)
P	76
Q	36
R	118

4.1 For this investigation, write down the:

4.1.1 Independent variable (1)

4.1.2 Dependent variable (1)

4.2 From the passage above, write down a phrase that shows that this investigation is a fair test. (1)

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4.3 Which sample (**P**, **Q** or **R**) is the:

4.3.1 Alkane (1)

4.3.2 Alcohol (1)

4.3.3 Refer to boiling point and the type of intermolecular forces present between alcohol molecules to give a reason for the answer in QUESTION 4.3.2. (2)

4.4 The alkane is identified as pentane. Will the boiling point of hexane be HIGHER THAN or LOWER THAN that of pentane? Refer to MOLECULAR STRUCTURE, INTERMOLECULAR FORCES and ENERGY needed to explain the answer. (4)

[11]

QUESTION 5 (Start on a new page.)

Two straight chain compounds, **P** and **Q**, each have the following molecular formula:

P: C_4H_{10}

Q: C_4H_8

5.1 Write down the name of the homologous series to which **Q** belongs. (1)

5.2 Compound **P** reacts with chlorine to form 2-chlorobutane.

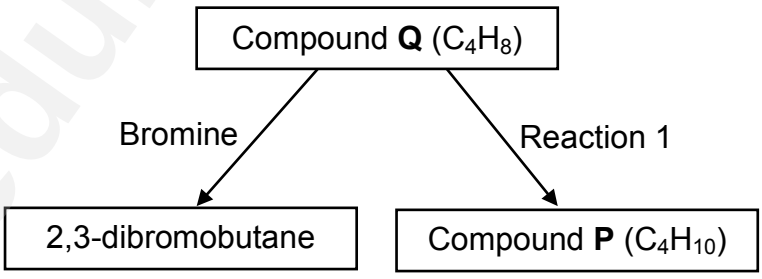
Write down:

5.2.1 A balanced chemical equation, using MOLECULAR FORMULAE, for the reaction that takes place (3)

5.2.2 The type of reaction that takes place (1)

5.2.3 One reaction condition (other than the solvent needed) (1)

5.3 Compound **Q** takes part in reactions as shown in the flow diagram below.



Write down the:

5.3.1 Structural formula for 2,3-dibromobutane (2)

5.3.2 IUPAC name of compound **Q** (2)

5.3.3 Balanced equation, using structural formulae, for **reaction 1** (4)

5.3.4 Type of reaction that occurs in **reaction 1** (1)

[15]

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QUESTION 6 (Start on a new page.)

A hydrogen peroxide solution dissociates slowly at room temperature according to the following equation:

$$2H_2O_2(aq) \rightarrow 2H_2O(\ell) + O_2(g)$$

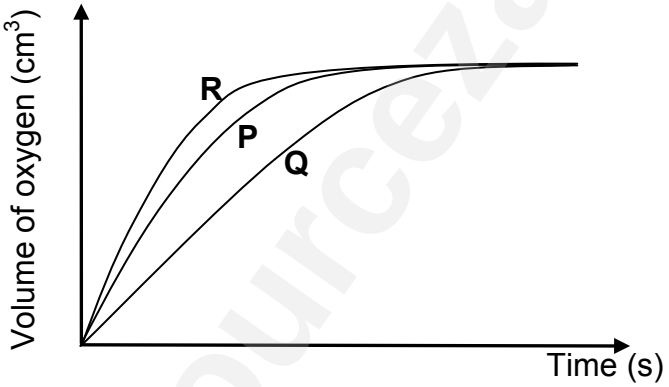
During an investigation, learners compare the effectiveness of three different catalysts on the rate of decomposition of hydrogen peroxide. They place EQUAL AMOUNTS of sufficient hydrogen peroxide into three separate containers. They then add EQUAL AMOUNTS of the three catalysts, **P**, **Q** and **R**, to the hydrogen peroxide in the three containers respectively and measure the rate at which oxygen gas is produced.

6.1 For this investigation, write down the:

6.1.1 Independent variable (1)

6.1.2 Dependent variable (1)

The results obtained are shown in the graph below.



6.2 Which catalyst is the most effective? Give a reason for the answer. (2)

6.3 Fully explain, by referring to the collision theory, how a catalyst increases the rate of a reaction. (3)

In another experiment, the learners obtain the following results for the decomposition of hydrogen peroxide:

TIME (s)	H_2O_2 CONCENTRATION ($mol \cdot dm^{-3}$)
0	0,0200
200	0,0160
400	0,0131
600	0,0106
800	0,0086

6.4 Calculate the AVERAGE rate of decomposition (in $mol \cdot dm^{-3} \cdot s^{-1}$) of $H_2O_2(aq)$ in the first 400 s. (3)

6.5 Will the rate of decomposition at 600 s be GREATER THAN, LESS THAN or EQUAL TO the rate calculated in QUESTION 6.4? Give a reason for the answer. (2)

6.6 Calculate the mass of oxygen produced in the first 600 s if 50 cm^3 of hydrogen peroxide decomposes in this time interval. (5)

[17]

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QUESTION 7 (Start on a new page.)

A chemical engineer studies the reaction of nitrogen and oxygen in a laboratory. The reaction reaches equilibrium in a closed container at a certain temperature, **T**, according to the following balanced equation:

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$$

Initially, 2 mol of nitrogen and 2 mol of oxygen are mixed in a 5 dm^3 sealed container. The equilibrium constant (K_C) for the reaction at this temperature is $1,2 \times 10^{-4}$.

7.1 Is the yield of NO(g) at temperature **T** HIGH or LOW? Give a reason for the answer. (2)

7.2 Calculate the equilibrium concentration of NO(g) at this temperature. (8)

7.3 How will each of the following changes affect the YIELD of NO(g)? Write down only INCREASES, DECREASES or REMAINS THE SAME.

7.3.1 The volume of the reaction vessel is decreased at constant temperature. (1)

7.3.2 An inert gas such as argon is added to the mixture. (1)

7.4 It is found that K_C of the reaction increases with an increase in temperature. Is this reaction exothermic or endothermic? Explain the answer. (3)

[15]

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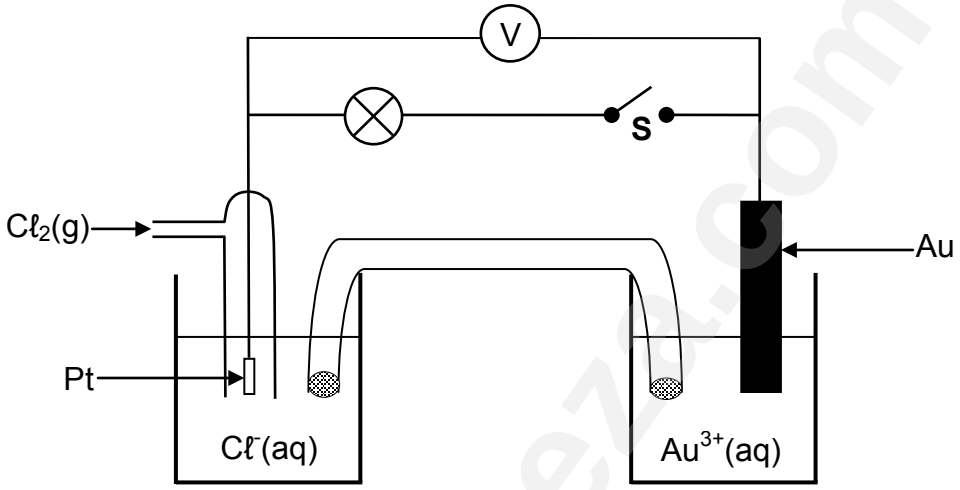
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QUESTION 8 (Start on a new page.)

The diagram below shows a galvanic cell operating under standard conditions. The cell reaction taking place when the cell is functioning is:

$$6C\ell^-(aq) + 2Au^{3+}(aq) \rightarrow 3C\ell_2(g) + 2Au(s)$$



With switch **S** OPEN, the initial reading on the voltmeter is 0,14 V.

8.1 Write down the:

8.1.1 NAME or FORMULA of the oxidising agent (1)

8.1.2 Half-reaction which takes place at the anode (2)

8.1.3 Cell notation for this cell (3)

8.2 Calculate the standard reduction potential of Au. (4)

Switch **S** is now closed and the bulb lights up.

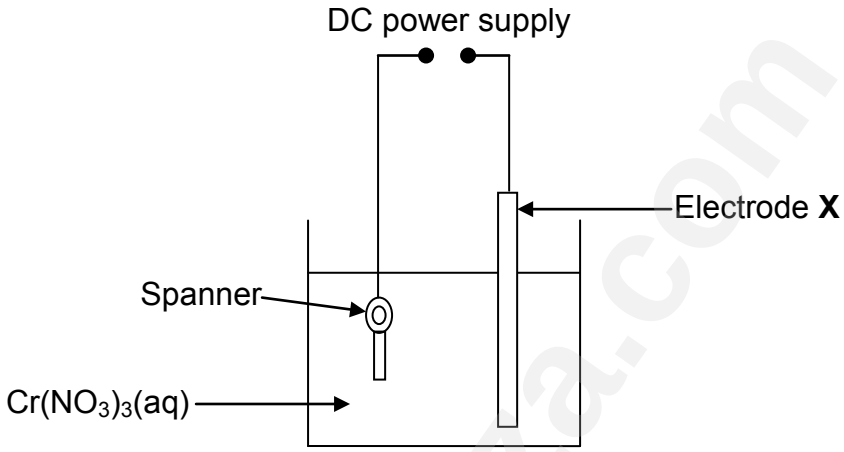
8.3 How will the reading on the voltmeter now compare to the INITIAL reading of 0,14 V? Write down only LARGER THAN, SMALLER THAN or EQUAL TO. Give a reason for the answer. (2)
[12]

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QUESTION 9 (Start on a new page.)

The diagram below represents a simplified electrolytic cell used to electroplate a spanner with chromium. The spanner is continuously rotated during the process of electroplating.



A constant current passes through the solution and the concentration of $Cr(NO_3)_3(aq)$ remains constant during the process. In the process, a total of 0,03 moles of electrons is transferred in the electrolytic cell.

9.1 Define the term *electrolysis*. (2)

9.2 Write down the:

9.2.1 Half-reaction that occurs at the spanner (2)

9.2.2 NAME or FORMULA of the metal of which electrode **X** is made (1)

9.2.3 NAME or FORMULA of the oxidising agent (1)

9.3 Calculate the gain in mass of the spanner. (4)
[10]

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QUESTION 10 (Start on a new page.)

Lead-acid batteries consist of several cells. A sulphuric acid solution is used as electrolyte in these batteries.

10.1 Define the term *electrolyte.* (2)

The standard reduction potentials for the half-reactions that take place in a cell of a lead-acid battery are as follows:

$PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightleftharpoons PbSO_4(s) + 2H_2O(\ell)$ $E^\theta = +1,69$ V

$PbSO_4(s) + 2e^- \rightleftharpoons Pb(s) + SO_4^{2-}(aq)$ $E^\theta = - 0,36$ V

10.2 Write down the half-reaction that takes place at the anode of this cell. (2)

10.3 Write down the overall cell reaction when the cell delivers current. (3)

10.4 A number of the cells above are connected in series to form a 300 V battery which operates at standard conditions.

Calculate the:

10.4.1 Maximum energy stored in the battery if its capacity is 7 500 A·h (5)

10.4.2 Minimum number of cells in this battery (5)

[17]

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QUESTION 11 (Start on a new page.)

11.1 A farmer wants to produce the following fruit and vegetables for the market:

spinach; potatoes; apples

Write down the NAME of the most important primary nutrient required to enhance:

11.1.1 Root growth of potato plants (1)

11.1.2 Leaf growth of spinach (1)

11.1.3 Flower and fruit production of apple trees (1)

11.2 Ammonia must be produced in large quantities to produce nitrogen-based fertilisers.

11.2.1 Write down the name of the process used in the industrial preparation of ammonia. (1)

11.2.2 Write down a balanced chemical equation for the reaction that takes place in the process named in QUESTION 11.2.1. (3)

11.3 Ammonium hydrogen phosphate, $(NH_4)_2HPO_4$, is a type of fertiliser used in agriculture.

Refer to the type of elements of which this fertiliser is composed to give a reason why it will be advantageous for a farmer to use this fertiliser instead of a fertiliser such as ammonium nitrate, NH_4NO_3. (2)

11.4 Describe ONE negative impact on humans when fertiliser runs off into dams and rivers as a result of rain. (2)
[11]

TOTAL SECTION B: 125
GRAND TOTAL: 150

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GRADE/*GRAAD* 12

PHYSICAL SCIENCES: CHEMISTRY (P2)
FISIESE WETENSKAPPE: CHEMIE (V2)

NOVEMBER 2013

MEMORANDUM

MARKS/*PUNTE*: 150

This memorandum consists of 15 pages.
Hierdie memorandum bestaan uit 15 bladsye.

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SECTION A/*AFDELING A*

QUESTION 1/*VRAAG 1*

1.1 Fractional distillation / *Fraksionele distillasie* ✓ (1)

1.2 Dehydration / *Dehidratering / Dehidrasie* ✓ (1)

1.3 Collision (theory) / *Botsings(teorie)* ✓ (1)

1.4 Reducing agent / *Reduseermiddel* ✓ (1)

1.5 Homologous series / *Homoloë reeks* ✓ (1)
[5]

QUESTION 2/*VRAAG 2*

2.1 C ✓✓ (2)

2.2 C ✓✓ (2)

2.3 A ✓✓ (2)

2.4 D ✓✓ (2)

2.5 B ✓✓ (2)

2.6 C ✓✓ (2)

2.7 A ✓✓ (2)

2.8 D ✓✓ (2)

2.9 B ✓✓ (2)

2.10 C ✓✓ (2)
[20]

TOTAL SECTION/TOTAAL AFDELING A: 25

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SECTION B/*AFDELING B*

QUESTION 3/*VRAAG 3*

3.1

3.1.1 A ✓
C ✓ (2)

3.1.2 B ✓ (1)

3.1.3 F ✓ (1)

3.1.4 F ✓✓ (2)

3.2

3.2.1 4,5-dimethyl✓hex-2-ene ✓ / *4,5-dimetiel✓heks-2-een* ✓

OR/*OF*

4,5-dimethyl✓-2-hexene ✓ / *4,5-dimetiel✓-2-hekseen* ✓ (2)

3.2.2 2,3-dibromo-5-methyl✓heptane ✓ / *2,3-dibromo-5-metiel✓heptaan* ✓ (2)

3.2.3 4-methyl✓pent-2-yne ✓ / *4-metielpent-2-yn*

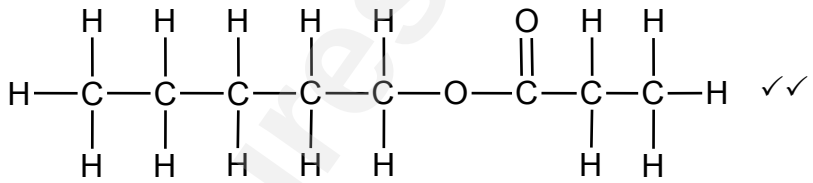
OR/*OF*

4-methyl✓-2-pentyne ✓ / *4-metielpent-2-yn* (2)

3.3

3.3.1 Esters ✓ (1)

3.3.2



✓✓ (2)

3.3.3 Propanoic acid / *Propanoësuur* ✓ (1)

3.3.4 Sulphuric acid / *Swawelsuur* / H_2SO_4 ✓ (1)

[17]

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QUESTION 4/*VRAAG 4*

4.1

4.1.1 Samples / Contents of bottle / (Type of) compound / functional group / homologous series ✓
Monsters / Inhoud van bottel / (Tipe) verbinding / funksionele groep / homoloë reeks (1)

4.1.2 Boiling point / *Kookpunt* ✓ (1)

4.2 ... comparable molecular mass. / ... *vergelykbare molekulêre massa*. ✓

OR/*OF*
... under the same conditions ... / ... *onder dieselfde toestande* ... (1)

4.3

4.3.1 Q ✓ (1)

4.3.2 R ✓ (1)

4.3.3
- R has the highest boiling point. / *R het die hoogste kookpunt*. ✓
- In addition to weak Van der Waals forces, alcohols also have strong hydrogen bonds between molecules. ✓
  Bo en behalwe swak Van der Waalskragte, het alkohole ook sterk waterstofbindings tussen molekule. (2)

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4.4 Higher than ✓

- **Structure:**
  Longer chain length. / More C atoms in chain. / Greater molecular size. / Greater molecular mass. / Larger surface area. ✓
- **Intermolecular forces:**
  Stronger or more intermolecular forces /Van der Waals forces / dispersion forces / London forces. ✓
- **Energy:**
  More energy needed to overcome or break intermolecular forces/ Van der . Waals forces / dispersion forces / London forces.✓

Hoër as

- ***Struktuur:***
  Langer kettinglengte. / Meer C-atome in kettting. / Groter molekule. / Groter molekulêre massa. / Groter reaksieoppervlakte.
- ***Intermolekulêre kragte:***
  Sterker of meer intermolekulêre kragte/ Van der Waalskragte / dispersiekragte / Londonkragte.
- ***Energie:***
  Meer energie benodig om intermolekulêre kragte/ Van der Waalskragte/ dispersiekragte / Londonkragte te oorkom of breek.

OR/*OF*

Higher than ✓

- **Structure:**
  Pentane has a shorter chain length. / Less C atoms in chain. / Smaller molecular size. / Smaller molecular mass. / Smaller surface area. ✓
- **Intermolecular forces:**
  Weaker or less intermolecular forces / Van der Waals forces / dispersion forces / London forces. ✓
- **Energy:**
  Less energy needed to overcome or break intermolecular forces / Van der Waals forces / dispersion forces / London forces. ✓

Hoër as

- ***Struktuur:***
  ***Pentaan** het 'n korter kettinglengte. / Minder C-atome in kettting. / Kleiner molekule. / Kleiner molekulêre massa. / Kleiner reaksieoppervlakte.*
- ***Intermolekulêre kragte:***
  Swakker of minder intermolekulêre kragte/ Van der Waalskragte/ dispersiekragte / Londonkragte .
- ***Energie:***
  Minder energie benodig om intermolekulêre kragte/Van der Waalskragte / dispersiekragte / Londonkragte te oorkom of breek.

(4)
[11]

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QUESTION 5/*VRAAG 5*

5.1 Alkenes / *Alkene* ✓ (1)

5.2

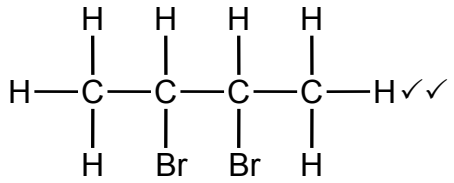
5.2.1 $C_4H_{10} + C\ell_2$ ✓ $\rightarrow C_4H_9C\ell + HC\ell$ ✓ Bal. ✓ (3)

5.2.2 Halogenation / Substitution / Chlorination ✓
Halogenering / Halogenasie / Substitusie / Chlorinering (1)

5.2.3 Heat **OR** (sun)light (UV) / hf ✓
*Hitte **OF** (son)lig (UV) / hf* (1)

5.3

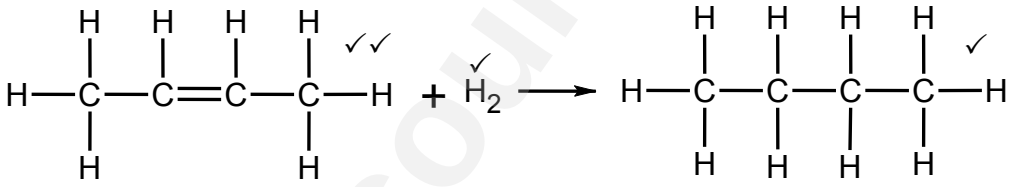
5.3.1



✓✓ (2)

5.3.2 But-2-ene / 2-butene ✓✓
But-2-een / 2-buteen (2)

5.3.3



(4)

5.3.4 Hydrogenation / Addition ✓
Hidrogenering / Hidrogenasie / Addisie (1)
[15]

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QUESTION 6/*VRAAG 6*

6.1

6.1.1 (Type of) catalyst / *(Tipe) katalisator* ✓ (1)

6.1.2 Rate (of reaction) / *(Reaksie)tempo* ✓ (1)

6.2 R ✓
Fastest rate. / Steepest (initial) gradient or slope. /Produces oxygen faster/est / reaches completion faster OR fastest OR in a shorter time ✓
Vinnigste tempo. / Steilste (aanvanklike) gradiënt of helling./ Produseer suurstof vinnigste/er/ bereik voltooiing vinnigste OF vinniger OF in 'n korter tyd.✓ (2)

6.3
- A catalyst provides an alternative pathway of lower activation energy. ✓
  'n Katalisator voorsien 'n alternatiewe pad van laer aktiveringsenergie.
- More molecules have sufficient/enough kinetic energy. / *Meer molekule het voldoende/genoeg kinetiese energie.* ✓
  OR/*OF*
  More molecules have kinetic energy equal to or greater than the activation energy.
  Meer molekule het kinetiese energie gelyk aan of groter as die aktiveringsenergie.
- More effective collisions per unit time./ Rate of effective collisions increases.
  Meer effektiewe botsings per eenheidstyd./ Tempo van effektiewe botsings neem toe. ✓/ (3)

6.4

$$\text{Average rate/}\textit{Gemiddelde tempo} = \frac{\Delta[H_2O_2]}{\Delta t}$$
$$= \frac{0{,}0131 - 0{,}020}{400 - (0)} \checkmark$$
$$= -1{,}73 \times 10^{-5}\ \text{mol·dm}^{-3}\text{·s}^{-1} \checkmark$$
OR/*OF*
$$1{,}73 \times 10^{-5}\ \text{mol·dm}^{-3}\text{·s}^{-1}$$ (3)

6.5 Less than / *Kleiner as* ✓
The concentration of hydrogen peroxide decreases as the reaction proceeds. ✓
Die konsentrasie van die waterstofperoksied verminder soos wat die reaksie verloop. (2)

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6.6

Mark allocation/*Puntetoekenning:*

- $c = \frac{n}{V}$ or/*of* $n = \frac{m}{M}$ or/*of* $c = \frac{m}{MV}$ ✓
- Substitute / *Vervang* (0,0200 - 0,0106) and/*en* 50 x 10^{-3} ✓
- $n(O_2) = ½n(H_2O_2)$ ✓
- Using/*Gebruik* M = 32 in m = nM or/*of* cMV or/*of* a ratio calculation / *'n verhouding berekening* ✓
- Final answer/*Finale antwoord*: 7,52 x 10^{-3} g / 0,008 g / 0,01 g ✓

OPTION 1/*OPSIE 1*

$c = \frac{n}{V}$ ✓

$(0,0200 - 0,0106) = \frac{n}{50 \times 10^{-3}}$ ✓

$\therefore n = 4,7 \times 10^{-4}$ mol

$n(O_2) = ½n(H_2O_2) = ½(4,7 \times 10^{-4})$ ✓

$= 2,35 \times 10^{-4}$ mol

$n(O_2) = \frac{m}{M}$

$2,35 \times 10^{-4} = \frac{m}{32}$ ✓

$\therefore m(O_2) = 7,52 \times 10^{-3}$ g

$= (0,008 \text{ g}) = (0,01 \text{ g})$ ✓

OPTION 2/*OPSIE 2*

$\Delta c(H_2O_2) = 0,0200 - 0,0106$

$= 0,0094$

$\Delta c(O_2) = ½\Delta c(H_2O_2)$

$= ½(0,0094)$ ✓

$= 0,0047$

$c = \frac{m}{MV}$ ✓

$\Delta m(O_2) = cMV$

$= (0,0047)(32)$ ✓ (50×10^{-3}) ✓

$= 7,52 \times 10^{-3}$ g

$= 0,008$ g

$= 0,01$g ✓

(5)
[17]

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QUESTION 7/*VRAAG 7*

7.1 Low / *Laag* ✓
Small K_c value. / *Klein K_c-waarde*. ✓
K_c is smaller than 1/ *K_c is kleiner as 1* (2)

7.2 **CALCULATIONS USING NUMBER OF MOLES:**
BEREKENINGE WAT GETAL MOL GEBRUIK:

Mark allocation/*Puntetoekenning:*

- **USING** ratio/***GEBRUIK*** *verhouding:* $N_2 : O_2 : NO = x : x : 2x$ ✓
- Equilibrium/*Ewewig:* $n(N_2)$ = initial/*aanvanklik* – change/*verandering*
  Equilibrium/*Ewewig*: $n(O_2)$ = initial/*aanvanklik* – change/*verandering* ✓
- Equilibrium/*Ewewig*: n(NO) = initial/*aanvanklik* + change/*verandering* ✓
- Divide $n(N_2)$, $n(O_2)$ & n(NO) by 5 dm^3. ✓
  Deel $n(N_2)$, $n(O_2)$ & n(NO) deur 5 dm^3.
- Correct K_c expression (formulae in square brackets). ✓
  Korrekte K_c-uitdrukking (formules in vierkanthakies).
- Substitution of concentrations into K_c expression. ✓
  Vervanging van konsentrasies in K_c-uitdrukking.
- Substitution of K_c value. ✓
  Vervanging van K_c-waarde .
- Final answer/*Finale antwoord*: $4{,}36 \times 10^{-3}$ mol·dm^{-3} ✓ (0,004 mol·dm^{-3})

OPTION 1/*OPSIE 1*

	N_2	O_2	NO	
Initial quantity (mol) *Aanvangshoeveelheid (mol)*	2	2	0	
Change (mol) *Verandering (mol)*	x	x	2x	ratio ✓
Quantity at equilibrium (mol) *Hoeveelheid by ewewig (mol)*	2-x	2-x ✓	2x ✓	
Equilibrium concentration (mol·dm^{-3}) *Ewewigskonsentrasie (mol·dm^{-3})*	$\frac{2-x}{5}$	$\frac{2-x}{5}$	$\frac{2x}{5}$	Divide by 5 ✓

$$K_C = \frac{[NO]^2}{[N_2][O_2]} \checkmark \quad \therefore 1{,}2 \times 10^{-4} \checkmark = \frac{\left(\frac{2x}{5}\right)^2}{\left(\frac{2-x}{5}\right)\left(\frac{2-x}{5}\right)} \checkmark \quad \frac{0{,}4^2}{0{,}2^2}$$

$$\therefore x = 0{,}0109 \text{ mol}$$

$$\therefore [NO] = \frac{2(0{,}0109)}{5} = 4{,}36 \times 10^{-3} \text{ mol·dm}^{-3} \checkmark (0{,}004 \text{ mol·dm}^{-3})$$

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OPTION 2/*OPSIE 2*

	N_2	O_2	NO	
Initial quantity (mol) *Aanvangshoeveelheid (mol)*	2	2	0	
Change (mol) *Verandering (mol)*	$\frac{x}{2}$	$\frac{x}{2}$	x	ratio ✓
Quantity at equilibrium (mol) *Hoeveelheid by ewewig (mol)*	$2-\frac{x}{2}$	$2-\frac{x}{2}$ ✓	x ✓	
Equilibrium concentration ($mol \cdot dm^{-3}$) *Ewewigskonsentrasie ($mol \cdot dm^{-3}$)*	$\frac{4-x}{10}$	$\frac{4-x}{10}$	$\frac{x}{5}$	Divide by 5 ✓

$$K_C = \frac{[NO]^2}{[N_2][O_2]} \checkmark$$

$$\therefore 1,2 \times 10^{-4} \checkmark = \frac{\left(\frac{x}{5}\right)^2}{\left(\frac{4-x}{10}\right)\left(\frac{4-x}{10}\right)} \checkmark$$

$$\therefore x = 0,022 \text{ mol}$$

$$\therefore [NO] = \frac{0,022}{5} = 4,36 \times 10^{-3} \text{ mol} \cdot \text{dm}^{-3} \checkmark (0,004 \text{ mol} \cdot \text{dm}^{-3})$$

OPTION 3/*OPSIE 3*

	N_2	O_2	NO	
Initial quantity (mol) *Aanvangshoeveelheid (mol)*	2	2	0	
Change (mol) *Verandering (mol)*	$\frac{5x}{2}$	$\frac{5x}{2}$	5x	ratio ✓
Quantity at equilibrium (mol) *Hoeveelheid by ewewig (mol)*	$2-\frac{5x}{2}$	$2-\frac{5x}{2}$ ✓	5x ✓	
Equilibrium concentration / Ewewigskonsentrasie ($mol \cdot dm^{-3}$)	$\frac{4-5x}{10}$	$\frac{4-5x}{10}$	x	Divide by 5 ✓

$$K_C = \frac{[NO]^2}{[N_2][O_2]} \checkmark$$

$$\therefore 1,2 \times 10^{-4} \checkmark = \frac{(x)^2}{\left(\frac{4-5x}{10}\right)\left(\frac{4-5x}{10}\right)} \checkmark$$

$$\therefore x = 4,36 \times 10^{-3} \text{ mol} \cdot \text{dm}^{-3} \checkmark (0,004 \text{ mol} \cdot \text{dm}^{-3})$$

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CALCULATIONS USING CONCENTRATIONS
BEREKENINGE WAT KONSENTRASIES GEBRUIK

Mark allocation/*Puntetoekenning*

- Divide $n(N_2)$ & $n(O_2)$ by 5 dm^3. ✓
  Deel $n(N_2)$ & $n(O_2)$ deur 5 dm^3.
- **USING** ratio/***GEBRUIK*** *verhouding:* $N_2 : O_2 : NO = 1 : 1 : 2$ ✓
- Equilibrium/*Ewewig:* $c(N_2)$ = initial/*aanvanklik* – change/*verandering*
  Equilibrium/*Ewewig*: $c(O_2)$ = initial/*aanvanklik* – change/*verandering*
  Equilibrium/*Ewewig*: c(NO) = initial/*aanvanklik* + change/*verandering* ✓
- Correct K_c expression (formulae in square brackets). ✓
  Korrekte K_c-uitdrukking (formules in vierkanthakies).
- Substitution of concentrations into K_c expression. ✓
  Vervanging van konsentrasies in K_c-uitdrukking.
- Substitution of K_c value ✓
  Vervanging van K_c-waarde
- Calculate c(NO) i.e. 2 x answer of K_c calculation. ✓
  Bereken c(NO) d.i. 2 x antwoord van K_c-berekening.
- Final answer/*Finale antwoord*: $4,36 \times 10^{-3}$ mol·dm^{-3} ✓ (0,004 mol·dm^{-3})

OPTION 3/*OPSIE 3*

	N_2	O_2	NO	
Initial concentration (mol·dm^{-3}) *Aanvangskonsentrasie (mol·dm^{-3})*	0,4	0,4	0	Divide by 5 ✓
Change (mol·dm^{-3}) *Verandering* (mol·dm^{-3})	x	x	2x	ratio ✓
Equilibrium concentration (mol·dm^{-3}) *Ewewigskonsentrasie (mol·dm^{-3})*	0,4-x	0,4-x ✓	2x✓	

$$K_C = \frac{[NO]^2}{[N_2][O_2]^2} \checkmark$$

$$\therefore 1,2 \times 10^{-4} \checkmark = \frac{(2x)^2}{(0,4 - x)(0,4 - x)} \checkmark$$

$$\therefore x = 2,18 \times 10^{-3} \text{ mol·dm}^{-3} \quad (0,00218 \text{ mol·dm}^{-3})$$

$$\therefore [NO] = 2(2,18 \times 10^{-3}) = 4,36 \times 10^{-3} \text{ mol·dm}^{-3} \checkmark (0,004 \text{ mol·dm}^{-3})$$

(8)

7.3

7.3.1 Remains the same / *Bly dieselfde* ✓ (1)

7.3.2 Remains the same / *Bly dieselfde* ✓ (1)

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7.4 Endothermic / *Endotermies* ✓
- (An increase in K_C implies) an increase in concentration of products. ✓
  ('n Toename in K_c impliseer)'n toename in die konsentrasie van produkte.
  OR/*OF*
  (An increase in K_C implies) that the forward reaction is favoured.
  ('n Toename in K_c impliseer) dat die voorwaartse reaksie bevoordeel is.
  OR/*OF*
  (An increase in K_C implies) the equilibrium position shifts to the right.
  ('n Toename in K_c impliseer) dat die ewewigsposisie na regs geskuif het.
- An increase in temperature favours an endothermic reaction. ✓
  'n Toename in temperatuur bevoordeel die endotermiese reaksie.

(3) **[15]**

QUESTION 8/*VRAAG 8*

8.1

8.1.1 Au^{3+} / gold(III) ion ✓
Au^{3+} / goud(III)-ioon (1)

8.1.2 $2C\ell^- \rightarrow C\ell_2 + 2e^-$ ✓✓ (2)

Notes/*Aantekeninge*	
$2C\ell^- \rightleftharpoons C\ell_2 + 2e^-$	$(\frac{1}{2})$
$2C\ell^- \leftarrow C\ell_2 + 2e^-$	$(\frac{0}{2})$
$C\ell_2 + 2e^- \leftarrow 2C\ell^-$	$(\frac{2}{2})$
$C\ell_2 + 2e^- \rightleftharpoons 2C\ell^-$	$(\frac{0}{2})$

8.1.3 $Pt(s) \mid C\ell^-$ (1 mol·dm^{-3}) $\mid C\ell_2(g) \parallel Au^{3+}$(1 mol·dm^{-3}) $\mid Au(s)$ ✓ ✓ ✓

OR/*OF*

$Pt(s) \mid C\ell^-(aq) \mid C\ell_2(g) \parallel Au^{3+}(aq) \mid Au(s)$

OR/*OF*

$Pt \mid C\ell^- \mid C\ell_2 \parallel Au^{3+} \mid Au$ (3)

8.2 **Option 1/*Opsie 1***

$E^o_{cell} = E^o_{cathode} - E^o_{anode}$ ✓
0,14 ✓ = $E^o_{cathode}$ - (1, 36) ✓
$E^o_{cathode}$ = 1,50 V ✓

Option 2/*Opsie 2*

✓ $2C\ell^- \rightarrow C\ell_2 + 2e^-$ E° = - 1,36 ✓
$Au^{3+} + 3e^- \rightarrow Au$ E° = +1,50 ✓
E° = 0,14 V ✓ (4)

8.3 Smaller than / *Kleiner as* ✓
Decrease or drop in potential difference or voltage due to internal resistance or "lost volts". ✓
Val of afname in potensiaalverskil of spanning as gevolg van interne weerstand of "velore volts". (2)
[12]

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QUESTION 9/*VRAAG 9*

9.1 The chemical process in which electrical energy is converted to chemical energy.✓✓
Die chemiese proses waarin elektriese energie omgeskakel word na chemiese energie.

OR/*OF*
The use of electrical energy to produce chemical change. ✓✓
Die gebruik van elektriese energie om chemiese verandering te weeg te bring. (2)

9.2

9.2.1 $Cr^{3+} + 3e^- \rightarrow Cr(s)$ ✓✓ (2)

9.2.2 Cr / chromium / *chroom* ✓ (1)

9.2.3 Chromium(III) ions / *chroom(III)-ione* / Cr^{3+} ✓ (1)

9.3

Mark allocation/*Puntetoekenning:*
- $n = \frac{m}{M}$ or using ratio / *of gebruik van verhouding* ✓
- Ratio: 1 : 3 (1 mole Cr^{3+} gains 3 mole of electrons) ✓
  Verhouding 1: 3 (1 mol Cr^{3+} neem 3 mol elektrone op)
- Using M = 52 in m = nM or in ratio calculation. ✓
  Gebruik M = 52 in m = nM of verhouding berekening .
- Final answer/*Finale antwoord*: 0,52 g ✓

$n = \frac{m}{M}$ ✓

$\left(\frac{0,03}{3}\right)$ ✓$= \frac{m}{52}$ ✓ **OR/*OF*** 0,01 ✓$= \frac{m}{52}$ ✓

$\therefore m = 0,52$ g ✓

OR/*OF*
3 mol e^- ..... 52 g ✓ Cr
0,03 mol e^-..... $\left(\frac{0,03}{3}\right)$ ✓ (52) ✓ = 0,52 g ✓

(4)
[10]

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QUESTION 10/*VRAAG 10*

10.1 A solution which conducts electricty through the movement of ions. ✓✓
'n Oplossing wat elektrisiteit gelei deur die beweging van ione. (2)

10.2 $Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^-$ ✓✓ (2)

10.3 $PbO_2(s) + Pb(s) + 2SO_4^{2-}(aq) + 4H^+(aq)$ ✓→ $2PbSO_4(s) + 2H_2O(\ell)$ ✓ bal. ✓

OR/OF

$PbO_2(s) + Pb(s) + 2H_2SO_4(aq)$ ✓→ $2PbSO_4(s) + 2H_2O(\ell)$ ✓ bal. ✓ (3)

10.4

10.4.1

OPTION 1/*OPSIE 1*	**OPTION 2/*OPSIE 2***
$Q = I\Delta t$ $= (7\ 500)$ ✓ $(3\ 600)$ ✓ $= 2{,}7 \times 10^7$ C $W = VQ$ ✓ $= (300)$ ✓ $(2{,}7 \times 10^7)$ $= 8{,}1 \times 10^9$ J ✓	$W = VI\Delta t$ ✓ $= (300)$✓ (7500) ✓ (3600) ✓ $= 8{,}1 \times 10^9$ J ✓

(5)

10.4.2 $E^\theta_{cell} = E^\theta_{cathode} - E^\theta_{anode}$ ✓

$= +1{,}69$ ✓$- (-0{,}36)$ ✓

$= +2{,}05$ V

$$\text{No. cells} = \frac{300}{2{,}05} \checkmark$$

$= 146{,}34$ cells/*selle*

$\therefore$ 147 cells / *selle* ✓ (5)

[17]

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QUESTION 11/*VRAAG 11*

11.1

11.1.1 Phosphorous / *Fosfor* / P ✓ (1)

11.1.2 Nitrogen / *Stikstof* / N ✓ (1)

11.1.3 Potassium / *Kalium* / K ✓ (1)

11.2

11.2.1 Haber (process)/(*proses)* ✓ (1)

11.2.2 $N_2(g) + 3H_2(g)$ ✓ $\rightleftharpoons 2NH_3(g)$ ✓ bal. ✓ (3)

11.3 The fertiliser contains two primary nutrients N/nitrogen and P/ phosphorous, ✓ whereas the ammonium nitrate contains only N/nitrogen. ✓
Die kunsmis bevat twee primêre nutriente N en P terwyl ammoniumnitraat slegs N bevat. (2)

11.4 **ANY ONE /*ENIGE EEN***

- Fertilisers in water leads to eutrophication which can result in less drinking water / starvation due to dying of fish / less water recreation areas. ✓
  Kunsmis in water lei tot eutrofisering / eutrofikasie wat minder drinkwater // hongersnood weens visvrektes /minder ontspanningsgebiede tot gevolg kan hê.
- Fertilisers in water leads to excess of nitrates in water ✓ resulting in blue baby syndrome / cancer. ✓
  Kunsmis in water lei tot oormaat nitrate in water wat lei tot bloubabasindroom / kanker.

(2)
[11]

TOTAL SECTION B/*TOTAAL AFDELING B:* 125
GRAND TOTAL/*GROOTTOTAAL*: 150

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basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE

GRADE 12

PHYSICAL SCIENCES: PHYSICS (P1)

EXEMPLAR 2014

MARKS: 150

TIME: 3 hours

This question paper consists of 16 pages and 3 data sheets.

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INSTRUCTIONS AND INFORMATION

1. Write your name in the appropriate space on the ANSWER BOOK.
2. This question paper consists of ELEVEN questions. Answer ALL the questions in the ANSWER BOOK.
3. Start EACH question on a NEW page in the ANSWER BOOK.
4. Number the answers correctly according to the numbering system used in this question paper.
5. Leave ONE line between two subquestions, for example between QUESTION 2.1 and QUESTION 2.2.
6. You may use a non-programmable calculator.
7. You may use appropriate mathematical instruments.
8. You are advised to use the attached DATA SHEETS.
9. Show ALL formulae and substitutions in ALL calculations.
10. Round off your final numerical answers to a minimum of TWO decimal places.
11. Give brief motivations, discussions, et cetera where required.
12. Write neatly and legibly.

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QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Write only the letter (A–D) next to the question number (1.1–1.10) in the ANSWER BOOK, for example 1.11 E.

1.1 The net force acting on an object is directly proportional to the ...

A mass of the object.

B acceleration of the object.

C change in momentum of the object.

D rate of change in momentum of the object. (2)

1.2 An astronomer, viewing light from distant galaxies, observes a shift of spectral lines toward the red end of the visible spectrum. This shift provides evidence that …

A the universe is expanding.

B the galaxies are moving closer towards Earth.

C Earth is moving towards the distant galaxies.

D the temperature of Earth's atmosphere is increasing. (2)

1.3 A ball is thrown vertically upwards. Which ONE of the following physical quantities has a non-zero value at the instant the ball changes direction?

A Acceleration

B Kinetic energy

C Momentum

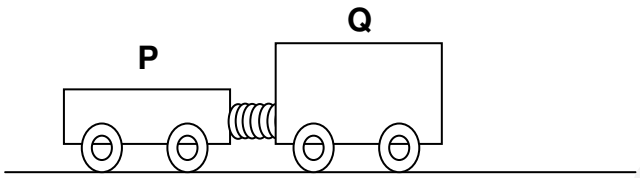
D Velocity (2)

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1.4 Two trolleys, **P** and **Q**, of mass *m* and 2*m* respectively are at rest on a frictionless horizontal surface. The trolleys have a compressed spring between them.



The spring is released and the trolleys move apart. Which ONE of the following statements is TRUE?

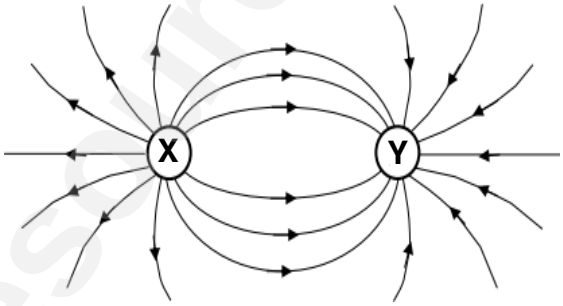
A **P** and **Q** have equal kinetic energies.

B The speed of **P** is less than the speed of **Q**.

C The sum of the final kinetic energies of **P** and **Q** is zero.

D The sum of the final momentum of **P** and **Q** is zero. (2)

1.5 The diagram below shows the electric field pattern due to two point charges **X** and **Y**.



Which ONE of the following represents the charge on **X** and **Y** respectively?

	POINT CHARGE X	POINT CHARGE Y
A	Negative	Negative
B	Positive	Positive
C	Positive	Negative
D	Negative	Positive

(2)

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1.6 Two identical metal spheres, each of mass *m* and separated by a distance *r*, exert a gravitational force of magnitude *F* on each other. The distance between the spheres is now HALVED.

The magnitude of the force the spheres now exerts on each other is:

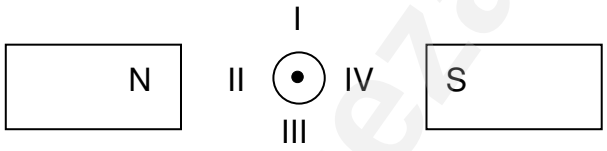
A ½*F*

B *F*

C 2*F*

D 4*F* (2)

1.7 In the diagram below, a conductor placed between two magnets is carrying current out of the page.



The direction of the force exerted on the conductor is towards:

A I

B II

C III

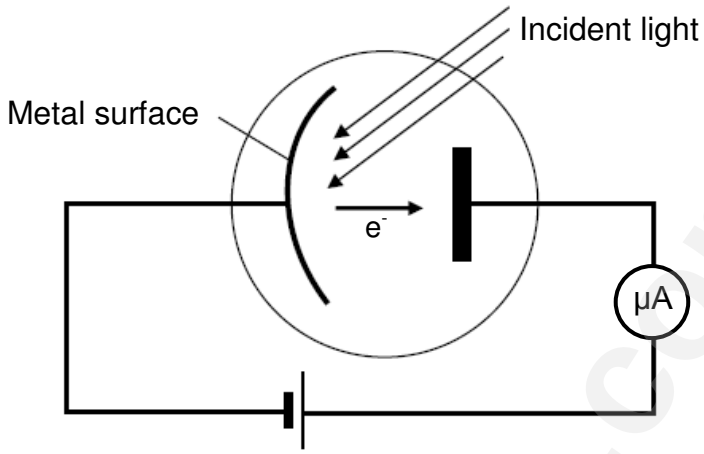
D IV (2)

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1.8 When light of a certain frequency is incident on the cathode of a photocell, the ammeter in the circuit registers a reading.

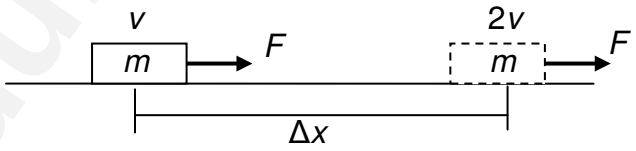


The frequency of the incident light is now increased while keeping the intensity constant. Which ONE of the following correctly describes the reading on the ammeter and the reason for this reading?

	AMMETER READING	REASON
A	Increases	More photoelectrons are emitted per second.
B	Increases	The speed of the photoelectrons increases.
C	Remains the same	The number of photoelectrons remains the same.
D	Remains the same	The speed of the photoelectrons remains the same.

(2)

1.9 An applied force F accelerates an object of mass m on a horizontal frictionless surface from a velocity v to a velocity $2v$.



The net work done on the object is equal to ...

A $\frac{1}{2}mv^2$.

B mv^2.

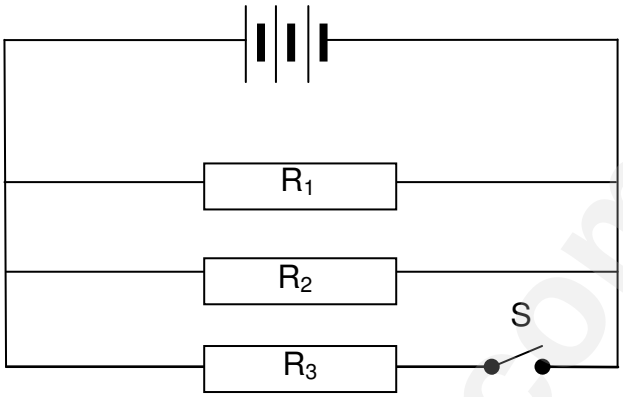
C $\frac{3}{2}mv^2$.

D $2mv^2$. (2)

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1.10 Consider the circuit diagram below.



Which ONE of the following correctly describes the change in total resistance and total current when switch **S** is closed?

	TOTAL RESISTANCE	TOTAL CURRENT
A	Decreases	Decreases
B	Increases	Increases
C	Decreases	Increases
D	Increases	Decreases

(2)
[20]

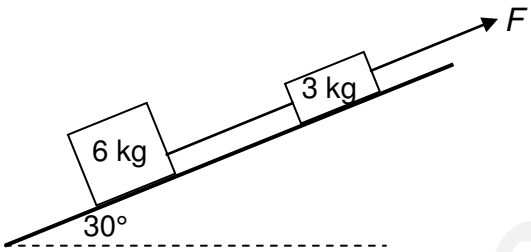
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QUESTION 2 (Start on a new page.)

A light inelastic string connects two objects of mass 6 kg and 3 kg respectively. They are pulled up an inclined plane that makes an angle of 30° with the horizontal, with a force of magnitude *F*. Ignore the mass of the string.



The coefficient of kinetic friction for the 3 kg object and the 6 kg object is 0,1 and 0,2 respectively.

2.1 State Newton's Second Law of Motion in words. (2)

2.2 How will the coefficient of kinetic friction be affected if the angle between the incline and the horizontal increases? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1)

2.3 Draw a labelled free-body diagram indicating all the forces acting on the 6 kg object as it moves up the inclined plane. (4)

2.4 Calculate the:

2.4.1 Tension in the string if the system accelerates up the inclined plane at 4 $m \cdot s^{-2}$ (5)

2.4.2 Magnitude of *F* if the system moves up the inclined plane at CONSTANT VELOCITY (6)

2.5 How would the tension in the string, calculated in QUESTION 2.4.1, be affected if the system accelerates up a FRICTIONLESS inclined plane at 4 $m \cdot s^{-2}$? Write down only INCREASES, DECREASES OR REMAINS THE SAME. (1)

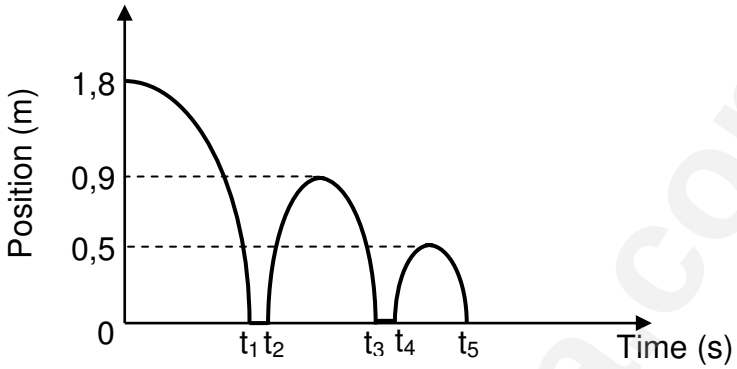
[19]

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QUESTION 3 (Start on a new page.)

A ball of mass 0,5 kg is projected vertically downwards towards the ground from a height of 1,8 m at a velocity of 2 m·s^{-1}. The position-time graph for the motion of the ball is shown below.



3.1 What is the maximum vertical height reached by the ball after the second bounce? (1)

Calculate the:

3.2 Magnitude of the time t_1 indicated on the graph (5)

3.3 Velocity with which the ball rebounds from the ground during the first bounce (4)

The ball is in contact with the ground for 0,2 s during the first bounce.

3.4 Calculate the magnitude of the force exerted by the ground on the ball during the first bounce if the ball strikes the ground at 6,27 m·s^{-1}. (4)

3.5 Draw a velocity-time graph for the motion of the ball from the time that it is projected to the time when it rebounds to a height of 0,9 m.

Clearly show the following on your graph:

- The time when the ball hits the ground
- The velocity of the ball when it hits the ground
- The velocity of the ball when it rebounds from the ground (3)

[17]

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QUESTION 4 (Start on a new page.)

Two boys, each of mass m, are standing at the back of a flatbed trolley of mass 4 m. The trolley is at rest on a frictionless horizontal surface.

The boys jump off simultaneously at one end of the trolley with a horizontal velocity of 2 $m \cdot s^{-1}$. The trolley moves in the opposite direction.

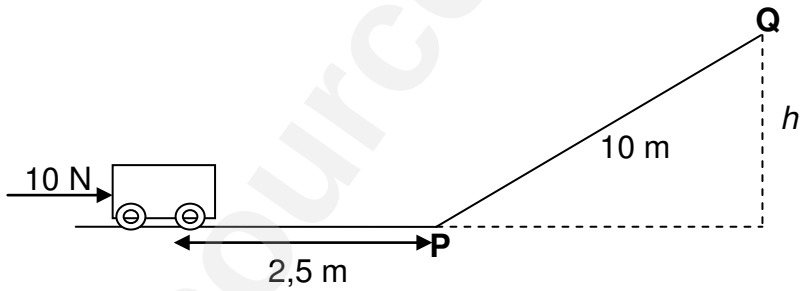
4.1 Write down the *principle of conservation of linear momentum* in words. (2)

4.2 Calculate the final velocity of the trolley. (5)

4.3 The two boys jump off the trolley one at a time. How will the velocity of the trolley compare to that calculated in QUESTION 4.2? Write down only GREATER THAN, SMALLER THAN or EQUAL TO. (1)
[8]

QUESTION 5 (Start on a new page.)

A 3 kg trolley is at rest on a horizontal frictionless surface. A constant horizontal force of 10 N is applied to the trolley over a distance of 2,5 m.



When the force is removed at point **P**, the trolley moves a distance of 10 m up the incline until it reaches the maximum height at point **Q**. While the trolley moves up the incline, there is a constant frictional force of 2 N acting on it.

5.1 Write down the name of a non-conservative force acting on the trolley as it moves up the incline. (1)

5.2 Draw a labelled free-body diagram showing all the forces acting on the trolley as it moves along the horizontal surface. (3)

5.3 State the WORK-ENERGY THEOREM in words. (2)

5.4 Use the work-energy theorem to calculate the speed of the trolley when it reaches point **P**. (4)

5.5 Calculate the height, *h*, that the trolley reaches at point **Q**. (5)
[15]

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QUESTION 6 (Start on a new page.)

The siren of a stationary police car emits sound waves of wavelength 0,55 m.

With its siren on, the police car now approaches a stationary listener at constant velocity on a straight road. Assume that the speed of sound in air is 345 $m \cdot s^{-1}$.

6.1 Will the wavelength of the sound waves observed by the listener be GREATER THAN, SMALLER THAN or EQUAL TO 0,55 m? (1)

6.2 Name the phenomenon observed in QUESTION 6.1. (1)

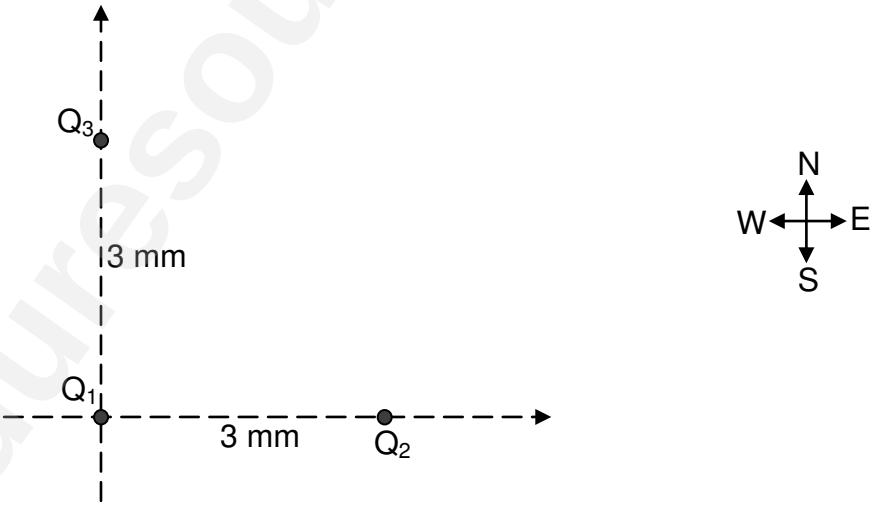
6.3 Calculate the frequency of the sound waves observed by the listener if the car approaches him at a speed of 120 $km \cdot h^{-1}$. (7)

6.4 How will the answer in QUESTION 6.3 change if the police car moves away from the listener at 120 $km \cdot h^{-1}$? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1)

[10]

QUESTION 7 (Start on a new page.)

Three small, identical metal spheres, Q_1, Q_2 and Q_3, are placed in a vacuum. Each sphere carries a charge of – 4 µC. The spheres are arranged such that Q_2 and Q_3 are each 3 mm from Q_1 as shown in the diagram below.



7.1 State Coulomb's law in words. (2)

7.2 Draw a force diagram showing the electrostatic forces exerted on Q_1 by Q_2 and Q_3. (2)

7.3 Calculate the net force exerted on Q_1 by Q_2 and Q_3. (8)

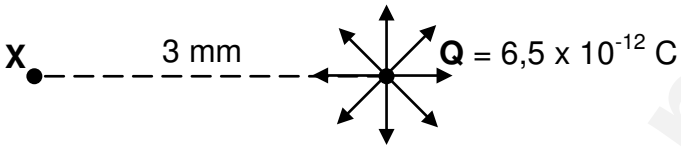
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QUESTION 8 (Start on a new page.)

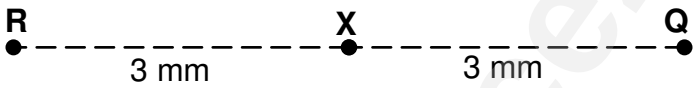
An isolated point charge **Q** is located in space as shown in the diagram below. Point charge **Q** contributes to an electric field as shown. Point **X** is located 3 mm away from point charge **Q**.

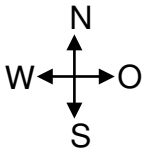


8.1 Define the term *electric field* at a point. (2)

8.2 Calculate the magnitude of the electric field at point **X**. (3)

8.3 Point charge **R** carrying a charge of + 6,5 x 10^{-12} C is placed 3 mm away from point **X** as shown in the diagram below.





Calculate the net electric field at point **X**. (4)
[9]

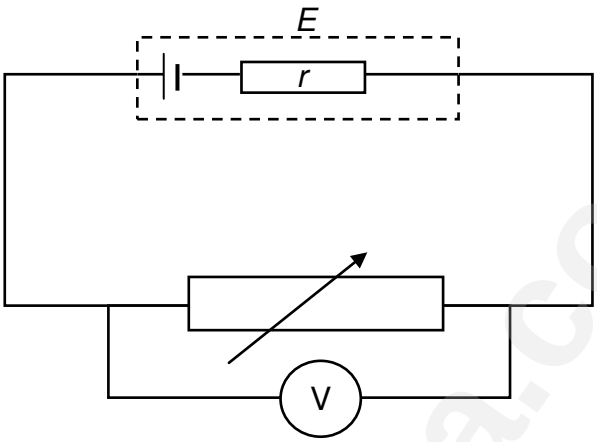
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QUESTION 9 (Start on a new page.)

9.1 In an experiment, learners use the circuit below to determine the internal resistance of a cell.

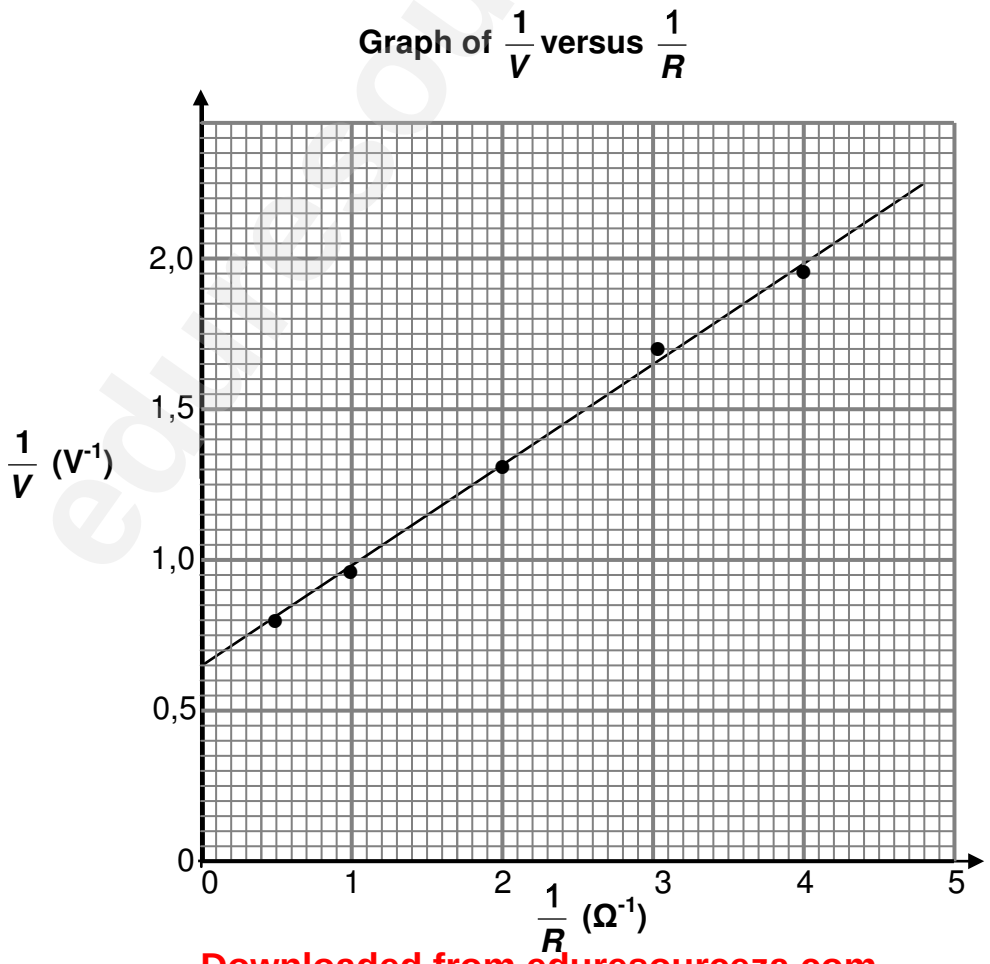


The circuit consists of a cell of emf *E* and internal resistance *r*. A voltmeter is placed across a variable resistor which can be set to *known values* R.

The equation used by the learners is:

$$\frac{1}{V} = \frac{r}{ER} + \frac{1}{E}$$

They obtain the graph below.



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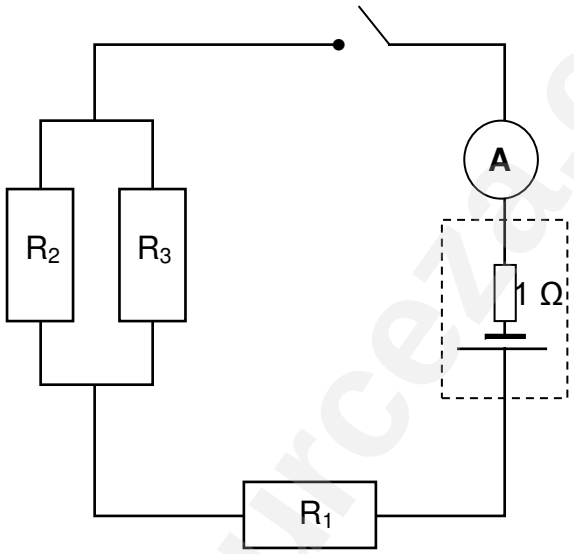
9.1.1 Write down a mathematical relationship for the slope of the graph. (1)

Use the information in the graph and calculate the:

9.1.2 Emf of the cell (2)

9.1.3 Internal resistance of the cell (3)

9.2 In the electrical circuit shown below, the battery has an emf of 6 V and an internal resistance of 1 Ω. The total external resistance of the circuit is 9 Ω.



9.2.1 Calculate the current in R_1 when the switch is closed. (3)

The power dissipated in resistor R_1 is 1,8 W. The resistance of resistor R_3 is 4 times that of resistor R_2. ($R_3 = 4R_2$)

9.2.2 Calculate the resistance of resistor R_2. (5)

9.3 A hair dryer operates at a potential difference of 240 V and a current of 9,5 A.

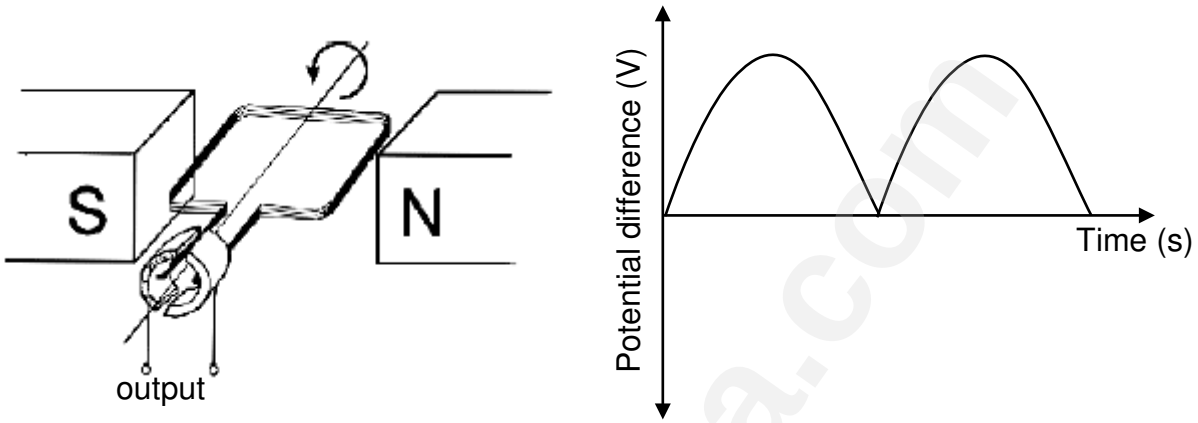
It takes a learner 12 minutes to completely dry her hair. Eskom charges energy usage at R1,47 per unit. Calculate the cost of operating the hairdryer for the 12 minutes. (1 unit = 1 kW·h) (4)
[18]

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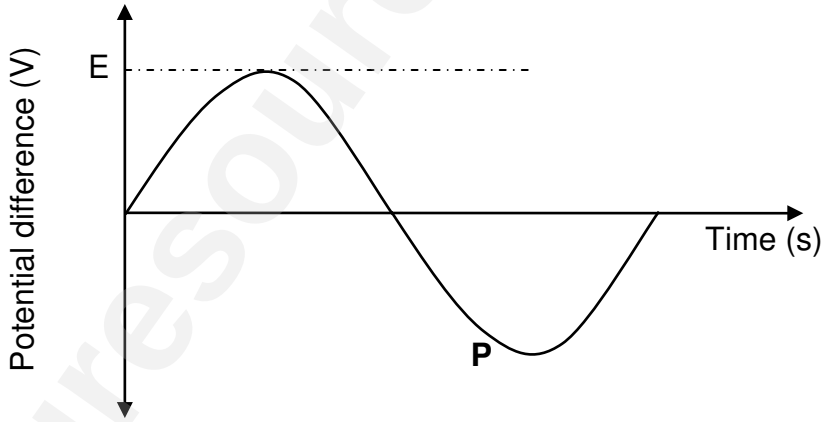
QUESTION 10 (Start on a new page.)

A simplified diagram of a DC generator and a graph of its output potential difference for one cycle is shown below.



10.1 Write down ONE way in which the output of this generator can be increased. (1)

A specific change is made to the structure of the DC generator in QUESTION 10.1. The output potential difference obtained as a result of this change is shown below.



10.2 Write down the change that was made to the DC generator. (1)

10.3 Copy graph **P** into your ANSWER BOOK.

On the same set of axes, sketch the graph of the output potential difference that will be obtained when the new generator is rotated at TWICE its original speed.

Label this graph as **Q**. (2)

10.4 A certain generator operates at a maximum voltage of 340 V. A 120 W appliance is connected to the generator. Calculate the resistance of the appliance. (4)
[8]

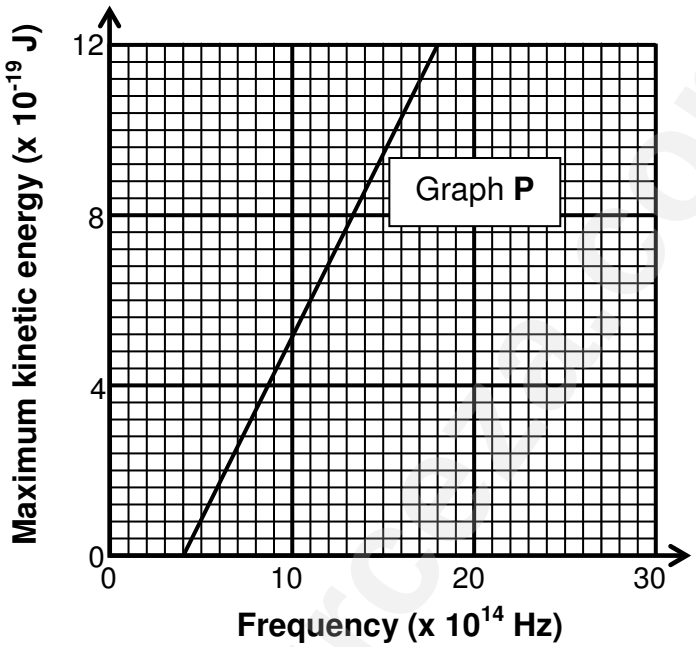
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QUESTION 11 (Start on a new page.)

Graph **P** below shows how the maximum kinetic energy of electrons emitted from the cathode of a photoelectric cell varies with the frequency of the incident radiation.

Graph of maximum kinetic energy versus frequency



11.1 Define the term *work function*. (2)

11.2 Calculate the:

11.2.1 Work function of the metal used as cathode in the photocell (3)

11.2.2 Velocity of photoelectrons emitted when the frequency of the incident light is 8×10^{14} Hz (5)

11.3 The photocell is now replaced with another one in which the work function of the cathode is TWICE that of the metal in the first cell.

The maximum kinetic energy versus frequency graph, **Q**, for this cathode is now drawn on the same set of axes as graph **P**.

11.3.1 How will the gradient of graph **Q** compare to that of graph **P**? Write down GREATER THAN, SMALLER THAN or EQUAL TO. Explain the answer. (2)

11.3.2 What will the value of the x-intercept of graph **Q** be? Explain how you arrived at the answer. (2)

[14]

TOTAL: 150

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GRADE/*GRAAD* 12

PHYSICAL SCIENCES: PHYSICS (P1)
FISIESE WETENSKAPPE: FISIKA (V1)

EXEMPLAR 2014
MODEL 2014

MEMORANDUM

MARKS/*PUNTE*: 150

This memorandum consists of 12 pages.
Hierdie memorandum bestaan uit 12 bladsye.

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QUESTION 1/*VRAAG 1*

1.1	B ✓✓	(2)
1.2	A ✓✓	(2)
1.3	A ✓✓	(2)
1.4	D ✓✓	(2)
1.5	C ✓✓	(2)
1.6	D ✓✓	(2)
1.7	A ✓✓	(2)
1.8	B ✓✓	(2)
1.9	C ✓✓	(2)
1.10	C ✓✓	(2)

[20]

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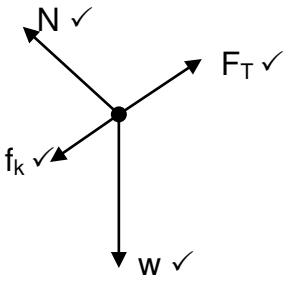
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QUESTION 2/*VRAAG 2*

2.1 When a resultant/net force acts on an object, the object will accelerate in the direction of the force. This acceleration is directly proportional to the force ✓and inversely proportional to the mass of the object. ✓
Wanneer 'n resulterende/netto krag op 'n liggaam inwerk, sal die liggaam in die rigting van die krag versnel. Hierdie versnelling is direk eweredig aan die krag en omgekeerd eweredig aan die massa van die liggaam. (2)

2.2 Remains the same / *Bly dieselfde* ✓ (1)

2.3



Accepted labels/*Aanvaarde benoemings*	
w	F_g / F_w / weight / mg / gravitational force *F_g / F_w / gewig / mg / gravitasiekrag*
f	$F_{friction}$ / F_f / friction *$F_{wrywing}$ / F_w / wrywing*
N	F_N / F_{normal} / normal force F_N / $F_{normaal}$ / *normaalkrag*
F_T	F_t / T / tension F_t / T / *spanning*

(4)

2.4

2.4.1 Up the incline as positive/*Teen die skuinste op as positief:*

$F_{net} = ma$
$F_T + f_k + w_{//} = ma$
$F_T + \mu_k N + w\sin30° = ma$
$F_T + \mu_k mg\cos30° + mg\sin30° = ma$
} ✓ Any one/*Enige een*

$F_T - (0,2)(6)(9,8)\cos30°$✓ $- (6)(9,8)\sin30°$✓ $= (6)(4)$ ✓
$\therefore F_T = 63,58$ N ✓ (5)

2.4.2 Up the incline as positive/*Teen die skuinste op as positief:*

$F_{net} = ma$
$F + f_{k(6\ kg)} + f_{k(3\ kg)} + w_{//} = ma$
$F + \mu_k N_{(6\ kg)} + \mu_k N_{(3\ kg)} + mg\sin30° = ma$
} ✓ Any one/*Enige een*

$F - (0,2)(6)(9,8)\cos30°$✓ $- (0,1)(3)(9,8)\cos30°$✓ $- (9)(9,8)\sin30°$✓ $= 0$ ✓
$\therefore F = 56,83$ N ✓ (6)

2.5 Decreases / *Afneem* ✓ (1)

[19]

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QUESTION 3/*VRAAG 3*

3.1 0,5 m ✓ (1)

3.2 **OPTION 1/*OPSIE 1***

Upwards positive/*Opwaarts positief*:

$v_f^2 = v_i^2 + 2a\Delta y$
$v_f^2 = (-2)^2 + 2(-9,8)(-1,8)$ ✓
$v_f = -6,27\ m{\cdot}s^{-1}$ ✓

$v_f = v_i + a\Delta t$
$-6,27 = -2 + (-9,8)\Delta t$ ✓
$\Delta t = 0,44\ s$ ✓

✓Both equations/*Beide vergelykings*

Downwards positive/*Afwaarts positief:*

$v_f^2 = v_i^2 + 2a\Delta y$ ✓
$v_f^2 = (2)^2 + 2(9,8)(1,89)$ ✓
$v_f = 6,27\ m{\cdot}s^{-1}$ ✓

$v_f = v_i + a\Delta t$
$6,27 = 2 + (9,8)\Delta t$ ✓
$\Delta t = 0,44\ s$ ✓

✓Both equations/*Beide vergelykings*

OPTION 2/*OPSIE 2*

Upwards positive/*Opwaarts positief:*

$\Delta y = v_i\Delta t + \frac{1}{2} a\Delta t^2$ ✓
$-1,8$ ✓ $= (-2)\Delta t$ ✓ $+ \frac{1}{2}(-9,8)\Delta t^2$ ✓

$$\Delta t = \frac{-2 \pm \sqrt{(2)^2 - 4(4,9)(-1,8)}}{2(4,9)}$$
$= 0,44\ s$ ✓

Downwards positive/*Afwaarts positief:*

$\Delta y = v_i\Delta t + \frac{1}{2} a\Delta t^2$ ✓
$1,8$ ✓ $= (2)\Delta t$ ✓ $+ \frac{1}{2}(9,8)\Delta t^2$ ✓

$$\Delta t = \frac{-2 \pm \sqrt{(-2)^2 - 4(4,9)(-1,8)}}{2(4,9)} = 0,44\ s$$ ✓ (5)

3.3 **Upwards positive/*Opwaarts positief:***

$v_f^2 = v_i^2 + 2a\Delta y$ ✓
$0^2 = v_i^2 + 2(-9,8)(0,9)$ ✓
$v_i = 4,2\ m{\cdot}s^{-1}$ ✓ upwards/*opwaarts* ✓

Downwards positive/*Afwaarts positief:*

$v_f^2 = v_i^2 + 2a\Delta y$ ✓
$0^2 = v_i^2 + 2(9,8)(0,9)$ ✓
$v_i = 4,2\ m{\cdot}s^{-1}$ ✓ upwards/*opwaarts* ✓ (4)

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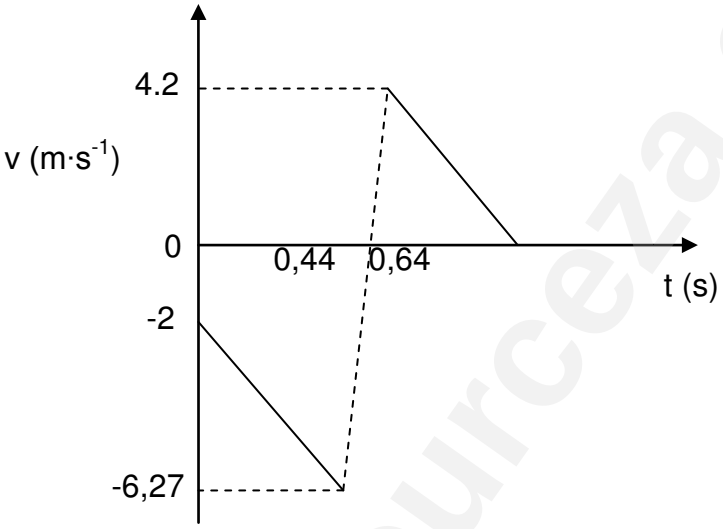
3.4 **Upwards positive/*Opwaarts positief:***

$F_{net}\Delta t = m\Delta v$ ✓
F_{net} (0,2) ✓= (0,5)[(4,2 – (-6,27)] ✓
F_{net} = 26,175 N ✓

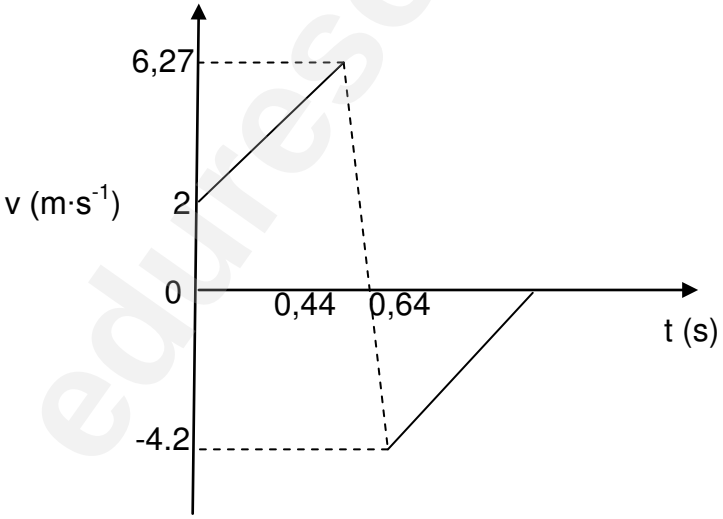
Downwards positive/*Afwaarts positief:*

$F_{net}\Delta t = m\Delta v$ ✓
F_{net} (0,2) ✓ = (0,5)[(-4,2 – (6,27)] ✓
F_{net} = -26,175 N
F_{net} = 26,175 N ✓ (4)

3.5 **Upwards positive/*Opwaarts positief:***



Downwards positive/*Afwaarts positief:*



(3)

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Criteria for graph/*Kriteria vir grafiek:*	**Marks/ *Punte***
First part of the graph starts at v = 2 m·s^{-1} at t = 0 s and extends until v = 6,27 m·s^{-1} at t = 0,44 s. *Eerste deel van die grafiek begin by v = 2 m·s^{-1} by t = 0 s en verleng tot* v = 6,27 m·s^{-1} by *t = 0,44 s.*	✓
Graph is discontinuous and object changes direction at 0,64 s. *Grafiek is nie kontinu nie en voorwerp verander van rigting by 0,64 s.*	✓
Second part of graph starts at v = 4,2 m·s^{-1} at t = 0,64 s until v = 0 m·s^{-1}. *Tweede deel van grafiek begin by v = 4,2 m·s^{-1} by t = 0,64 s tot* v = 0 m·s^{-1}.	✓

[17]

QUESTION 4/*VRAAG 4*

4.1 The total linear momentum in a closed system ✓ remains constant. / is conserved. ✓
Die totale lineêre momentum in 'n geslote sisteem bly konstant / bly behoue.

OR/*OF*
In a closed system ✓ the total linear momentum before collision is equal to the total linear momentum after collision. ✓
In 'n geslote sisteem is die totale lineêre momentum voor botsing gelyk aan die totale lineêre momentum na botsing. (2)

4.2 $\sum p_i = \sum p_f$
$(m_1 + m_2)v_i = m_1v_{1f} + m_2v_{2f}$ } ✓ Any one/*Enige een*
$(2m + 4m)(0)$ ✓ $= 2m(2) + 4m(v_{2f})$ ✓
$-4m = 4mv_f$
$\therefore v_f = -1$ m·s^{-1}
$\therefore v_f = 1$ m·s^{-1} ✓ in the opposite direction to that of the boys ✓
in die teenoorgestelde rigting as dié van die seuns (5)

4.3 Greater than / *Groter as* ✓ (1)
[8]

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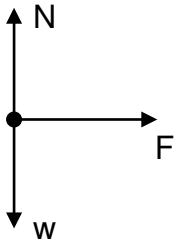
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QUESTION 5/*VRAAG 5*

5.1 Frictional force / *Wrywingkrag* ✓ (1)

5.2 F_N / Normal force / *Normaalkrag* ✓
F_g / Gravitational force / Weight / *Gravitasiekrag* / *Gewig* ✓
F_{app}/ 10 N / Horizontal applied force / *Horisontale toegepaste krag* ✓



Accepted labels/*Aanvaarde benoemings*	
w	F_g / F_w / weight / mg / gravitational force *F_g / F_w / gewig / mg / gravitasiekrag*
N	F_N / F_{normal} / normal force F_N / $F_{normaal}$ / *normaalkrag*
F	F_{app} / applied force / 10 N F_{toeg} / *toegepaste krag/ 10 N*

(3)

5.3 The net work done ✓on an object is equal to the change in kinetic energy ✓of the object.
Die netto arbeid verrig op 'n voorwerp is gelyk aan die verandering in kinetiese energie van die voorwerp. (2)

5.4 $W_{net} = \Delta E_K$ ✓
$W_F + W_w + W_{FN} = ½ m(v_f^2 - v_i^2)$
$(10)(2,5)\cos 0^o + 0 + 0$ ✓$= ½ (3)(v_f^2 - 0^2)$ ✓
$v_f = 4,08 \text{ m·s}^{-1}$ ✓ (4)

5.5 **OPTION 1/*OPSIE 1***
$W_{nc} = \Delta E_p + \Delta E_k$ ✓
$f\Delta x\cos\theta = (mgh_f - mgh^i) + (½ mv_f^2 - ½ mv_i^2)$
$(2)(10)\cos 180^o$ ✓$= (3)(9,8)h_f - 0$ ✓ $+ 0 - ½ (3)(4,08)^2$ ✓
$\therefore h = 0,17$ m ✓

OPTION 2/*OPSIE 2*
$W_{net} = \Delta E_K$ ✓
$W_f + W_w = ½ m(v_f^2 - v_i^2)$
$(2)(10)\cos 180^o$ ✓$+ (3)(9,8)h\cos 180^o$ ✓$= ½ (3)(0^2 - 4,08^2)$ ✓
$\therefore h = 0,17$ m ✓

OPTION 3/*OPSIE 3*
$W_{net} = \Delta E_k$ ✓
$mg\sin\alpha\ \Delta x\cos\theta + f\Delta x\cos\theta = ½ m(v_f^2 - v_i^2)$
$(3)(9,8)(\frac{h}{10})(10)\cos 180^o$ ✓$+ (2)(10)\cos 180^o$ ✓$= ½ (3)(0^2 - 4,08^2)$ ✓
$\therefore h = 0,17$ m ✓ (5)
[15]

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QUESTION 6/*VRAAG 6*

6.1 Smaller than / *Kleiner as* ✓ (1)

6.2 Doppler effect / *Doppler-effek* ✓ (1)

6.3 $v = f\lambda$ ✓
$345 = f(0,55)$ ✓
$\therefore f = 627,27$ Hz

$$f_L = \frac{v \pm v_L}{v \pm v_s} f_s \textbf{ OR/}\textit{OF}\ f_L = \frac{v}{v - v_s} f_s \ \checkmark$$

$$= \frac{345}{345 \overset{\checkmark}{-} 33,33 \checkmark}(627,27) \ \checkmark$$

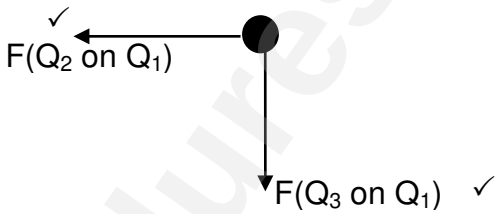
$= 694,35$ Hz ✓ (7)

6.4 Decreases / *Verlaag* ✓ (1)
[10]

QUESTION 7/*VRAAG 7*

7.1 The (magnitude) of the electrostatic force exerted by one charge on another is directly proportional to the (magnitudes of the) charges ✓ and inversely proportional to the square of the distance between their centres. ✓
Die (grootte) van die elektrostatiese krag wat een lading op 'n ander uitoefen, is direk eweredig aan die (groottes van die) ladings en omgekeerd eweredig aan die kwadraat van die afstand tussen hul middelpunte. (2)

7.2



(2)

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7.3 $F = k\frac{Q_1Q_2}{r^2}$ ✓

$F(Q_2 \text{ on } Q_1) = (9 \times 10^9)\frac{(4\times10^{-6})(4\times10^{-6})}{(3\times10^{-3})^2}$ ✓ ✓ $= 1,6 \times 10^4$ N (to left/*na links*)

$F(Q_3 \text{ on } Q_1) = (9 \times 10^9)\frac{(4\times10^{-6})(4\times10^{-6})}{(3\times10^{-3})^2}$ ✓ $= 1,6 \times 10^4$ N

(downwards/*afwaarts*)

$F_{net} = \sqrt{(F_{Q2 \text{ on } Q1})^2 + (F_{Q3 \text{ on } Q1})^2}$

$= \sqrt{(1,6 \times 10^4)^2 + (1,6\times10^4)^2}$ ✓

$= 2,26 \times 10^4$ N

$\tan\theta = \left(\frac{F_{Q3 \text{ on } Q1}}{F_{Q2 \text{ on } Q1}}\right)$

$\tan\theta = \left(\frac{1,6\times10^4}{1,6\times10^4}\right)$ ✓

$\therefore \theta = 45°$

$F_{net} = 2,26 \times 10^3$ N ✓ SW / 225° / 45° south of west / *suid van wes* ✓ (8)

[12]

QUESTION 8/*VRAAG 8*

8.1 The force ✓per unit charge ✓ at that point.
Die krag per eenheidslading by daardie punt. (2)

8.2 $E = \frac{kQ}{r^2}$ ✓

$= \frac{(9\times10^9)(6,5\times10^{-12})}{(0,003)^2}$ ✓

$= 6,5 \times 10^3$ N·C^{-1} ✓ (3)

8.3 **At point X/*By punt X***

$E_Q = 6,5 \times 10^3$ N·C^{-1} west/*wes* ✓

$E_R = \frac{kQ}{r^2}$

$= \frac{(9\times10^9)(6,5\times10^{-12})}{(0,003)^2}$

$= 6,5 \times 10^3$ N·C^{-1} east/*oos* ✓

$E_{net} = E_Q + E_R$ ✓

$= 6,5 \times 10^3 + (-6,5 \times 10^3)$

$= 0$ N·C^{-1} ✓ (4)

[9]

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QUESTION 9/*VRAAG 9*

9.1

9.1.1 From graph/*Van grafiek:* $\frac{R}{V}$ ✓

OR/*OF*

From equation/*Van vergelyking*: $\frac{r}{E}$ (1)

9.1.2 $\frac{1}{E} = 0,65$ ✓

$\therefore E = 1,54$ V✓ (2)

9.1.3 $\frac{r}{E} = \frac{2-1}{4-1}$ ✓✓

$\therefore r = 0,51\ \Omega$ ✓

(Any set of values from the graph can be used to calculate the gradient./*Enige stel waardes van die grafiek kan gebruik word om die gradiënt te bereken.)* (3)

9.2

9.2.1 Emf/*emk* = $I(R + r)$ ✓

$6 = I(9 + 1)$ ✓

$\therefore I = 0,6$ A ✓ (3)

9.2.2 $P = I^2R$ ✓

$1,8 = (0,6)^2R_1$ ✓

$R_1 = 5\ \Omega$

$R_p = 9 - 5 = 4\ \Omega$ ✓

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{4} = \frac{1}{R_2} + \frac{1}{4R_2}$$ ✓

$\therefore R_2 = 5\ \Omega$ ✓ (5)

9.3 $W = VI\Delta t$ ✓

$= (240)(9,5)(12)(60)$ ✓

$= 1,64 \times 10^6$ J

Cost/*Koste* = $\frac{1,64 \times 10^6}{3,6 \times 10^6} \times 1,47$ ✓

= R0,67 or/*of* 67 cents/*sent* ✓ (4)

[18]

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QUESTION 10/*VRAAG10*

10.1 Increase the speed of rotation. / *Verhoog spoed van rotasie.* ✓

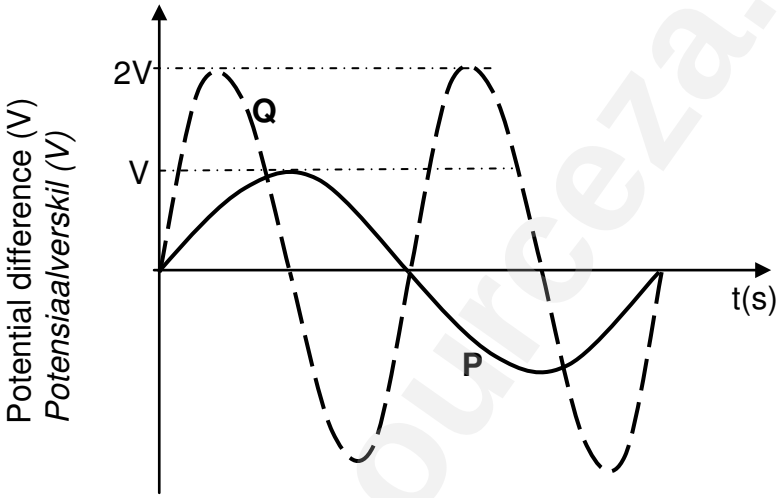
OR/*OF*
Increase the number of coils. / *Verhoog getal windings/spoele.*

OR/*OF*
Increase the strength of the magnetic field. / *Verhoog magetiese veldsterkte.* (1)

10.2 Commutators replaced by slip rings./ *Kommutators vervang met sleepringe.* ✓

OR/*OF*
Slip rings were used. /*Sleepringe is gebruik.* ✓ (1)

10.3



Criteria for graph/*Kriteria vir grafiek:*	**Marks *Punte***
Correct shape with higher amplitude as shown (accept more than one cycle) *Korrekte vorm met hoër amplitude soos aangetoon (aanvaar meer as een siklus)*	✓
Correct shape with higher frequency as shown (accept more than one cycle) *Korrekte vorm met hoër frekwensie soos aangetoon (aanvaar meer as een siklus)*	✓

(2)

10.4

$$P_{ave} = \frac{V_{rms}^2}{R} \checkmark = \frac{\left(\frac{V_{max}}{\sqrt{2}}\right)^2}{R} \checkmark$$

$$120 = \frac{\left(\frac{340}{\sqrt{2}}\right)^2}{R} \checkmark$$

$$R = 481{,}67\ \Omega \checkmark$$

(4)
[8]

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QUESTION 11/*VRAAG 11*

11.1 The minimum energy needed to remove an electron ✓
from the surface of a metal. ✓
Die minimum energie benodig om 'n elektron
vanaf die oppervlak van 'n metaal te verwyder. (2)

11.2
11.2.1 $W_0 = hf_0$ ✓
$= (6{,}63 \times 10^{-34})(4 \times 10^{14})$ ✓
$= 2{,}65 \times 10^{-19}$ J ✓ (3)

11.2.2 $E = W_0 + E_k$
$hf = hf_0 + \frac{1}{2}mv^2$
} ✓ Any one/*Enige een*

$(6{,}63 \times 10^{-34})(8 \times 10^{14})$ ✓ $= 2{,}65 \times 10^{-19}$ ✓ $+ \frac{1}{2}(9{,}11 \times 10^{-31})v^2$ ✓

$\therefore v = 7{,}63 \times 10^{5}$ m·s^{-1} ✓ (5)

11.3
11.3.1 Equal to /*Gelyk aan* ✓
The gradient is Planck's constant./ *Die gradiënt is Planck se konstante.* ✓ (2)

11.3.2 8×10^{14} Hz ✓
f_0 is directly proportional to W_0. / *f_0 is direk eweredig aan W_0.* ✓ (2)
[14]

TOTAL/*TOTAAL*: 150

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basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE

GRADE 12

PHYSICAL SCIENCES: CHEMISTRY (P2)

EXEMPLAR 2014

MARKS: 150

TIME: 3 hours

This question paper consists of 15 pages and 4 data sheets.

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INSTRUCTIONS AND INFORMATION

1. Write your name in the appropriate space on the ANSWER BOOK.
2. This question paper consists of TEN questions. Answer ALL the questions in the ANSWER BOOK.
3. Start EACH question on a NEW page in the ANSWER BOOK.
4. Number the answers correctly according to the numbering system used in this question paper.
5. Leave ONE line between two subquestions, for example between QUESTION 2.1 and QUESTION 2.2.
6. You may use a non-programmable calculator.
7. You may use appropriate mathematical instruments.
8. You are advised to use the attached DATA SHEETS.
9. Show ALL formulae and substitutions in ALL calculations.
10. Round off your final numerical answers to a minimum of TWO decimal places.
11. Give brief motivations, discussions, et cetera where required.
12. Write neatly and legibly.

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QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Write only the letter (A–D) next to the question number (1.1–1.10) in the ANSWER BOOK, for example 1.11 E.

1.1 The primary nutrient needed by plants for the promotion of root growth is …

A nitrogen.

B phosphorus.

C potassium.

D calcium. (2)

1.2 The rate of a chemical reaction can be expressed in …

A grams per mole.

B energy consumed per mole.

C volume of gas formed per unit time.

D moles of product formed per litre of solution. (2)

1.3 Which ONE of the compounds below is an aldehyde?

A CH_3CHO

B CH_3COCH_3

C CH_3COOH

D CH_3OH (2)

1.4 The reaction represented by the equation below takes place in the presence of a catalyst.

$$C_{13}H_{28}(\ell) \rightarrow C_2H_4(g) + C_3H_6(g) + C_8H_{18}(\ell)$$

This reaction is an example of …

A addition.

B cracking.

C substitution.

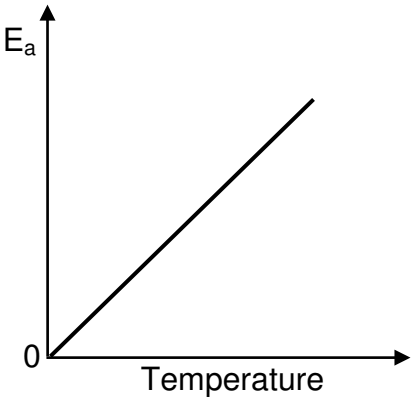
D polymerisation. (2)

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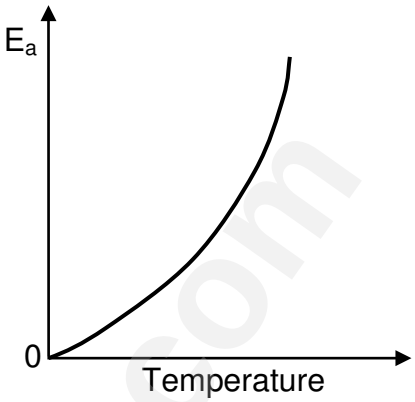
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1.5 Which ONE of the following graphs shows the relationship between activation energy (E_a) of a reaction and temperature?

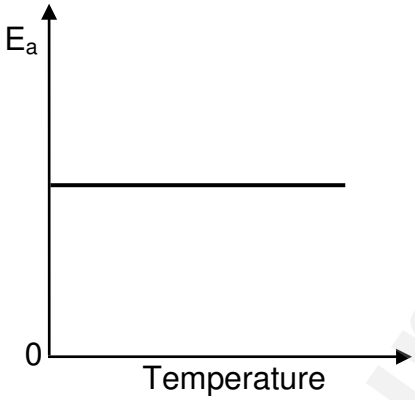
A



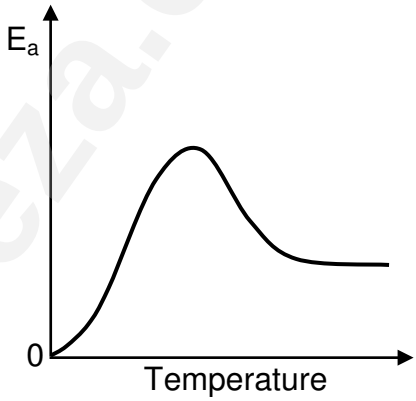
B



C



D



(2)

1.6 Which ONE of the following CANNOT act as a reducing agent?

A Mg

B Br^-

C Fe^{2+}

D MnO_4^-

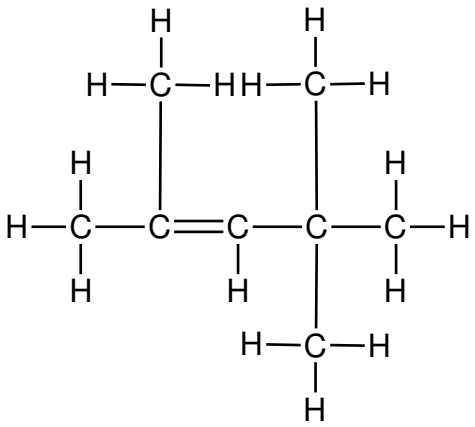
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1.7 Consider the structural formula of an organic compound below.



Which ONE of the following is the correct IUPAC name of this compound?

A 2,2,4-trimethylpent-2-ene

B 2,2,4-trimethylpent-3-ene

C 2,4,4-trimethylpent-2-ene

D 2,4,4-trimethylpent-3-ene (2)

1.8 A sample of silver contains impurities of gold. During purification by electrolysis, the impure silver is used as an electrode.

Which ONE of the following is the best choice of anode and cathode for this process?

	CATHODE	ANODE
A	Pure gold	Impure silver
B	Impure silver	Pure gold
C	Pure silver	Impure silver
D	Impure silver	Pure silver

(2)

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1.9 Initially, a certain amount of $IC\ell(g)$ is sealed in an empty flask at a certain temperature. The reaction that takes place is:

$$2IC\ell(g) \rightleftharpoons I_2(g) + C\ell_2(g)$$

Which of the following statements describe(s) the change(s) occurring as the system proceeds towards equilibrium?

(i) The rate of the reverse reaction increases.
(ii) The concentration of $IC\ell(g)$ increases.
(iii) The concentration of $C\ell_2(g)$ increases.

A (i) only

B (ii) only

C (i) and (iii) only

D (ii) and (iii) only (2)

1.10 Consider the reaction represented by the equation below:

$$H_3PO_4(aq) + HCO_3^-(aq) \rightleftharpoons H_2PO_4^-(aq) + H_2CO_3(aq) \qquad K_a > 1$$

The strongest base in the above reaction is:

A $H_2PO_4^-$

B HCO_3^-

C H_3PO_4

D H_2CO_3 (2)
[20]

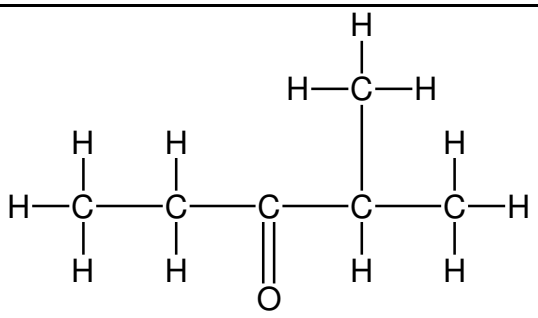
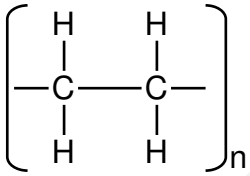
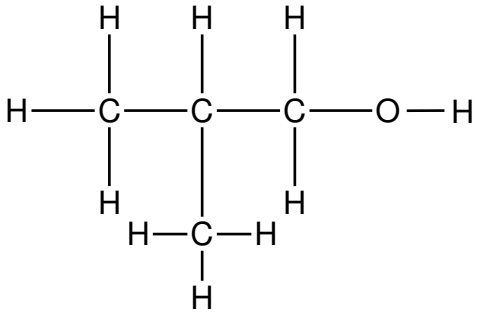
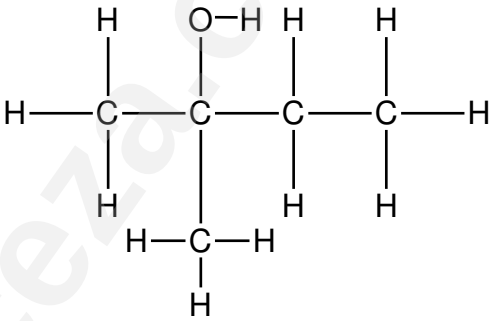
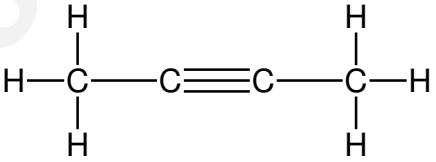
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QUESTION 2 (Start on a new page.)

The letters **A** to **G** in the table below represent seven organic compounds.

A		**B**	
C		**D**	
E	Butane	**F**	
G	Ethyl propanoate		

2.1 Write down the:

2.1.1 Name of the homologous series to which compound **F** belongs (1)

2.1.2 Name of the functional group of compound **D** (1)

2.1.3 Letter that represents a primary alcohol (1)

2.1.4 IUPAC name of compound **A** (2)

2.1.5 Structural formula of the monomer of compound **B** (2)

2.1.6 Balanced equation, using molecular formulae, for the combustion of compound **E** in excess oxygen (3)

2.2 Briefly explain why compounds **C** and **D** are classified as POSITIONAL ISOMERS. (2)

2.3 Compound **G** is prepared using an alcohol as one of the reactants. Write down the balanced equation for the reaction using structural formulae for all the organic reagents. (7)

[19]

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QUESTION 3 (Start on a new page.)

The table below shows the results obtained from experiments to determine the boiling point of some alkanes and alcohols of comparable molecular masses.

Compound	Relative molecular mass	Boiling point (°C)
CH_3CH_3	30	-89
CH_3OH	32	65
$CH_3CH_2CH_3$	44	-42
CH_3CH_2OH	46	78
$CH_3CH_2CH_2CH_3$	58	0
$CH_3CH_2CH_2OH$	60	97
$CH_3CH_2CH_2CH_2CH_3$	72	36
$CH_3CH_2CH_2CH_2CH_2OH$	74	117

3.1 Define the term *boiling point.* (2)

3.2 Consider the boiling points of the four alkanes in the above table.

3.2.1 Describe the trend in their boiling points. (1)

3.2.2 Fully explain the trend in QUESTION 3.2.1. (3)

3.3 The boiling point of each alcohol is much higher than that of the alkane of comparable relative molecular mass. Explain this observation by referring to the type and strength of the intermolecular forces in alkanes and alcohols. (2)
[8]

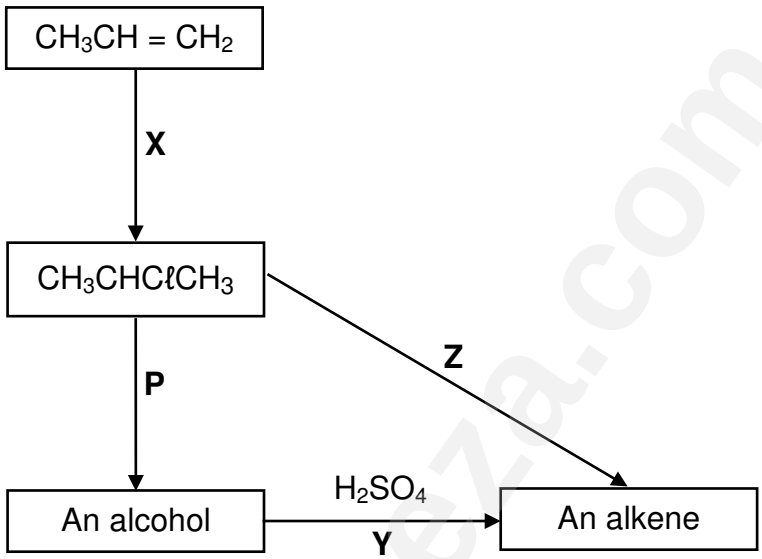
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QUESTION 4 (Start on a new page.)

The flow diagram below shows the preparation of different organic compounds using $CH_3CH = CH_2$ as starting material. **X**, **Y**, **Z** and **P** represent different organic reactions.



4.1 To which homologous series does $CH_3CH = CH_2$ belong? (1)

4.2 Write down the:

4.2.1 Type of reaction of which **X** is an example (1)

4.2.2 Structural formula and IUPAC name of the alcohol produced during reaction **P** (3)

4.2.3 Type of reaction of which **Y** is an example (1)

4.2.4 Function of the acid in reaction **Y** (1)

4.3 For reaction **Z**, write down:

4.3.1 The NAME of the inorganic reagent needed (1)

4.3.2 TWO reaction conditions needed (2)

4.3.3 A balanced equation for the production of the alkene, using structural formulae (5)
[15]

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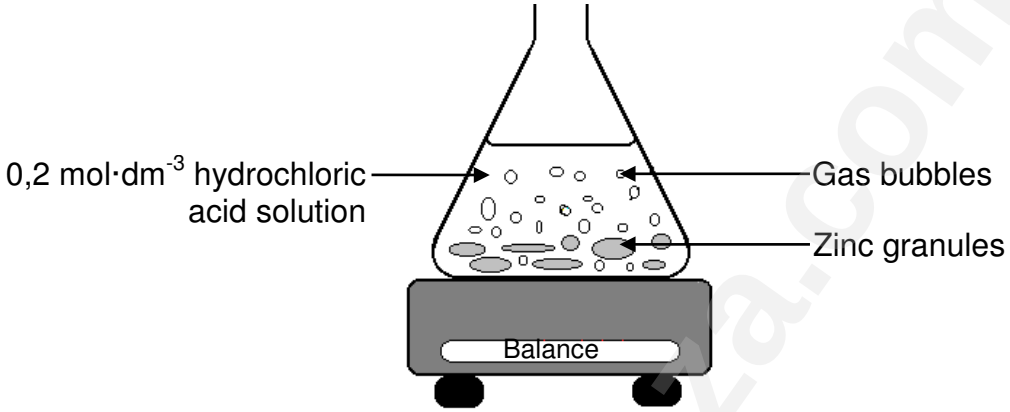
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QUESTION 5 (Start on a new page.)

Zinc granules are added to 100 cm^3 of a 0,2 $mol \cdot dm^{-3}$ hydrochloric acid solution in an Erlenmeyer flask. The equation for the reaction that takes place is:

$$Zn(s) + 2HC\ell(aq) \rightarrow ZnC\ell_2(aq) + H_2(g)$$



The rate of the reaction is followed by measuring the loss in mass of the flask and its contents at regular time intervals. After completion of the reaction, it is found that 0,12 g zinc granules did not react.

5.1 Which reactant is the limiting reagent? (1)

5.2 Give a reason for the loss in mass of the flask and its contents. (1)

5.3 Sketch a graph of the mass of zinc versus time for the above reaction. Label this graph **P**. (2)

5.4 On the same set of axes as in QUESTION 5.3, sketch graph **Q** which represents the same reaction at a HIGHER TEMPERATURE. (1)

5.5 Use the collision theory to explain why graph **Q** differs from graph **P**. (2)

5.6 Calculate the mass of zinc initially present in the flask. (6)
[13]

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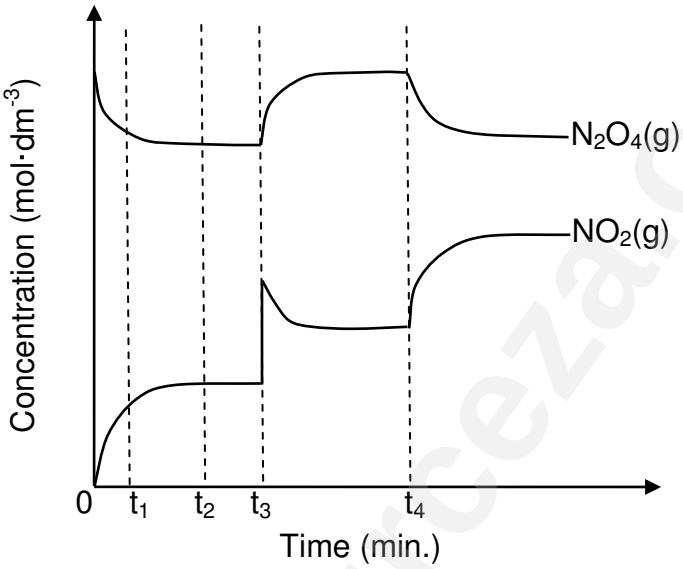
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QUESTION 6 (Start on a new page.)

A sample of N_2O_4 gas is sealed in a container and heated. The N_2O_4 gas decomposes to NO_2 gas and the reaction reaches equilibrium according to the following balanced equation:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H > 0$$

The graph below shows how the concentrations of the two gases change as a result of changes made to the reaction conditions.



6.1 Define the term *chemical equilibrium*. (2)

6.2 How does the rate of the forward reaction compare to that of the reverse reaction at each of the following times? Only write down HIGHER THAN, LOWER THAN or EQUAL TO.

6.2.1 t_1 (1)

6.2.2 t_2 (1)

6.3 What change was made to the reaction conditions at each of the following times? In both instances, the equilibrium constant for the reaction did not change.

6.3.1 t_3 (1)

6.3.2 t_4 (1)

6.4 How will an increase in temperature influence the yield of $NO_2(g)$? Write down INCREASES, DECREASES or REMAINS THE SAME. Use Le Chatelier's principle to explain the answer. (3)

6.5 Initially 0,92 mol N_2O_4 gas is sealed in a 2 dm^3 container and heated to 100 °C. At equilibrium it is found that 20,7% of the N_2O_4 gas has decomposed to NO_2 gas. Calculate the equilibrium constant (K_c) for this reaction at 100 °C. (7)
[16]

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QUESTION 7 (Start on a new page.)

A Grade 12 class wants to determine the percentage of ethanoic acid in a certain bottle of vinegar. They titrate a sample taken from the bottle of vinegar with a standard solution of sodium hydroxide. The equation for the reaction is:

$$CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(\ell)$$

7.1 Define an *acid* in terms of the Arrhenius theory. (2)

7.2 Give a reason why ethanoic acid is classified as a weak acid. (1)

7.3 Explain the meaning of *standard solution*. (1)

7.4 Write down the names of TWO items of apparatus needed to measure accurate volumes of the acid and the base in this titration. (2)

7.5 It is found that 40 mℓ of a 0,5 mol·dm^{-3} sodium hydroxide solution is needed to neutralise 20 mℓ of the vinegar.

Calculate the:

7.5.1 pH of the sodium hydroxide solution (4)

7.5.2 Percentage of ethanoic acid by mass present in the vinegar (Assume that 1 mℓ of vinegar has a mass of 1 g.) (7)

7.6 The sodium ethanoate (CH_3COONa) formed during the above neutralisation reaction undergoes hydrolysis to form an alkaline solution. Write down an equation for this hydrolysis reaction. (3)

[20]

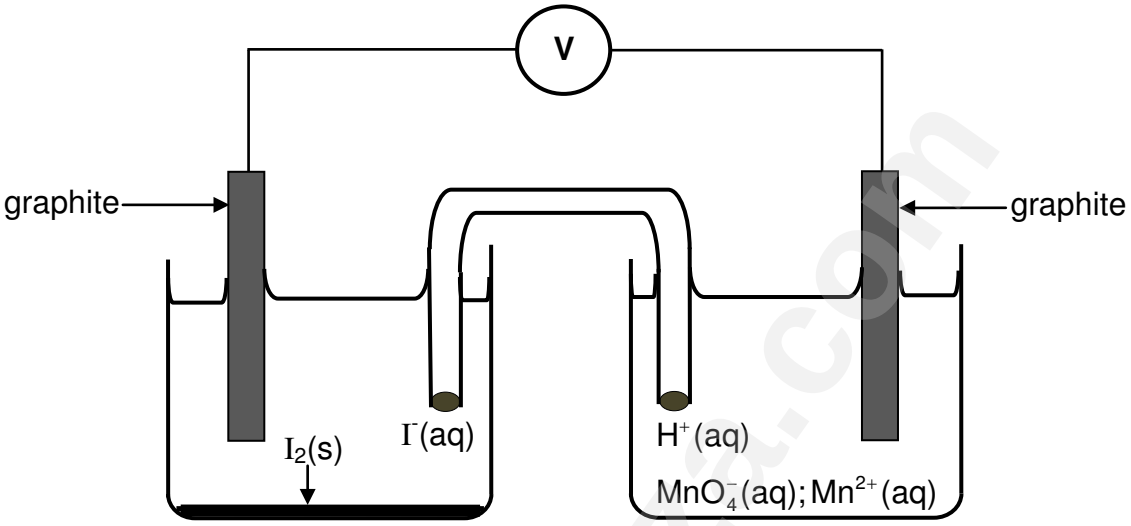
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QUESTION 8 (Start on a new page.)

The voltaic cell represented below functions at standard conditions.



8.1 Write down the concentration of $H^+(aq)$ in the one half-cell. (1)

8.2 Solids present in half-cells are usually used as electrodes. Give a reason why $I_2(s)$ is not suitable to be used as an electrode. (1)

8.3 Write down TWO properties of graphite, other than being a solid, that makes it suitable for use as electrodes in the above voltaic cell. (2)

8.4 For the above voltaic cell, write down the:

8.4.1 NAME of the oxidising agent (1)

8.4.2 Net cell reaction (3)

8.4.3 Cell notation (3)

8.5 Calculate the cell potential of the above cell. (4)

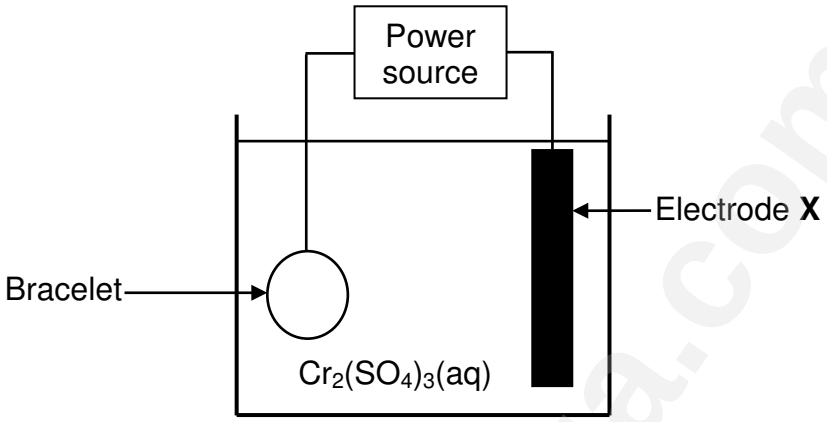
8.6 How will the reading on the voltmeter be affected if the concentration of $MnO_4^-(aq)$ decreases? Only write down INCREASES, DECREASES or NO EFFECT. (1)
[16]

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QUESTION 9 (Start on a new page.)

A technician is plating a bracelet with chromium in an electrolytic cell containing $Cr_2(SO_4)_3(aq)$. A simplified diagram of the electrolytic cell is shown below.



9.1 Define the term *electrolyte*. (2)

9.2 Which electrode, the BRACELET or **X**, is the cathode? (1)

9.3 Write down the:

9.3.1 Metal of which electrode **X** is made (1)

9.3.2 Reduction half-reaction (2)

9.4 During the process, the bracelet is plated with 0,86 g of chromium. Calculate the number of electrons transferred during the process. (6)
[12]

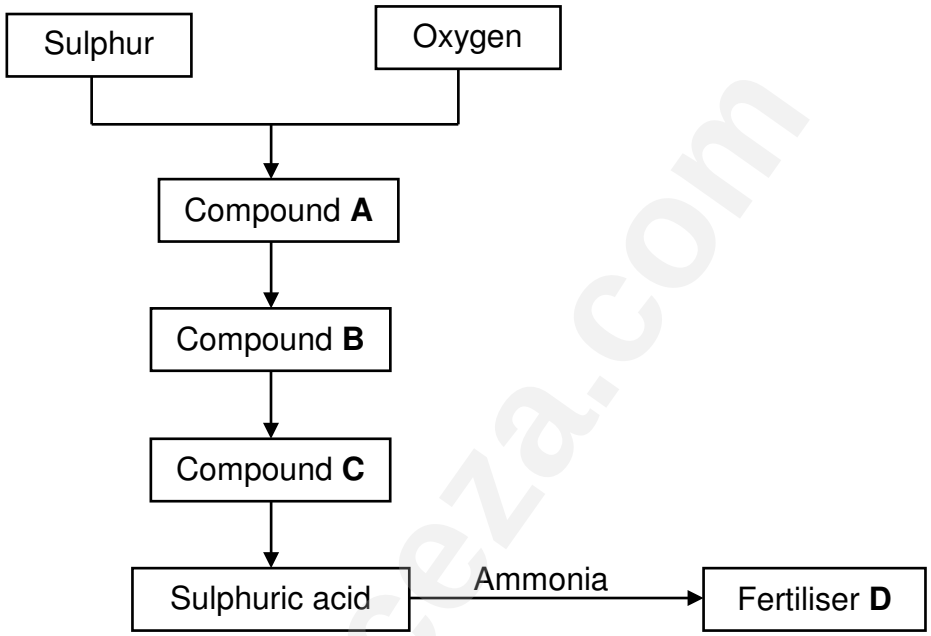
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QUESTION 10 (Start on a new page.)

Sulphuric acid is used, amongst others, in the manufacturing of fertilisers. The flow diagram below shows how fertiliser **D** can be prepared using sulphuric acid as one of the reagents.



10.1 Write down the NAME of the industrial process for the preparation of sulphuric acid. (1)

10.2 Compound **A** is formed when sulphur burns in oxygen. Write down the NAME or FORMULA of compound **A**. (1)

10.3 Compound **B** is formed when compound **A** reacts with oxygen in the presence of a catalyst. Write down the:

10.3.1 NAME or FORMULA of the catalyst (1)

10.3.2 Balanced equation for the reaction which takes place (3)

10.4 Compound **B** is dissolved in concentrated sulphuric acid to form compound **C**.

Write down the:

10.3.1 NAME or FORMULA of compound **C** (1)

10.3.2 Reason why compound **B** is not dissolved in water to form sulphuric acid (1)

10.5 Write down the NAME or FORMULA of fertiliser **D**. (1)

10.6 Inorganic fertilisers are soluble in water. This can result in eutrophication if they are washed off into rivers during heavy rain. Write down ONE negative impact of eutrophication on the economy of a country. (2)

[11]

TOTAL: 150

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NATIONAL SENIOR CERTIFICATE
NASIONALE SENIOR SERTIFIKAAT

GRADE/*GRAAD* 12

PHYSICAL SCIENCES: CHEMISTRY (P2)
FISIESE WETENSKAPPE: CHEMIE (V2)

EXEMPLAR/*MODEL* 2014

MEMORANDUM

MARKS/*PUNTE*: 150

This memorandum consists of 10 pages.
Hierdie memorandum bestaan uit 10 bladsye.

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QUESTION 1/*VRAAG 1*

1.1 B ✓✓ (2)

1.2 C ✓✓ (2)

1.3 A ✓✓ (2)

1.4 B ✓✓ (2)

1.5 C ✓✓ (2)

1.6 D ✓✓ (2)

1.7 C ✓✓ (2)

1.8 C ✓✓ (2)

1.9 C ✓✓ (2)

1.10 B ✓✓ (2)

[20]

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QUESTION 2/*VRAAG 2*

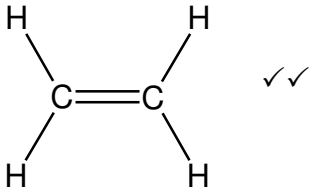
2.1

2.1.1 Alkynes / *Alkyne* ✓ (1)

2.1.2 Hydroxyl group / *Hidroksielgroep* ✓ (1)

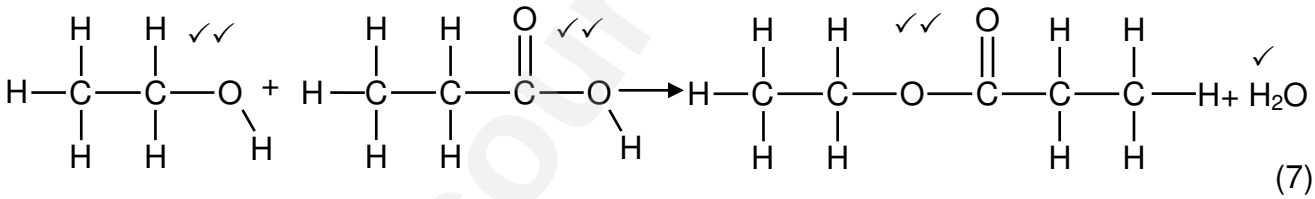
2.1.3 C ✓ (1)

2.1.4 2-methylpentan-3-one / *2-metielpentan-3-oon* ✓✓ (2)

2.1.5  ✓✓ (2)

2.1.6 $2C_4H_{10} + 13O_2$ ✓→ $8CO_2 + 10H_2O$ ✓ Bal. ✓ (3)

2.2 Same molecular formula, ✓
but different positions of the functional group. ✓
Dieselfde molekulêre formule,
maar verskillende posisies van die funksionele groep. (2)

2.3  (7)

[19]

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QUESTION 3/*VRAAG 3*

3.1 Temperature ✓ at which the vapour pressure of the substance equals atmospheric pressure. ✓
Temperatuur waar die dampdruk van die stof gelyk is aan atmosferiese druk. (2)

3.2

3.2.1 Boiling point increases as the chain length / molecular mass increases. ✓
Kookpunt neem toe soos wat die kettinglengte / molekulêre massa toeneem.

OR/*OF*
Boiling point increases from methane to butane.
Kookpunt neem toe van metaan na butaan. (1)

3.2.2
- Chain length increases from methane to butane. ✓
  Kettinglengte neem toe van metaan na butaan.
- Strength of London forces / induced dipole forces increases from methane to butane. ✓
  Sterkte van Londonkragte / geïnduseerde dipoolkragte neem toe van metaan na butaan.
- More energy needed to overcome intermolecular forces in butane than in methane. ✓
  Meer energie benodig om intermolekulêre kragte in butaan as in metaan te oorkom. (3)

3.3 Between molecules of the alkanes are weak London forces or induced dipole forces. / *Tussen molekule van alkane is swak Londonkragte of geïnduseerde dipoolkragte.* ✓
Between alcohol molecules are, in addition to weak London forces or induced dipole forces, also strong hydrogen bonds. / *Tussen alkoholmolekule is sterk waterstofbindings bykomend by tot swak Londonkragte of geïnduseerde dipoolkragte.* ✓ (2)
[8]

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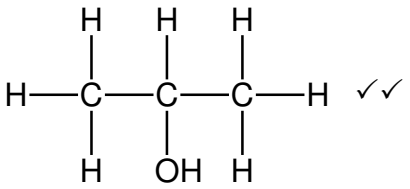
QUESTION 4/*VRAAG 4*

4.1 Alkenes / *Alkene* ✓ (1)

4.2

4.2.1 Addition / Hydrohalogenation / Hydrochlorination ✓
Addisie / Hidrohalogeneging / Hidrochloronering (1)

4.2.2



✓✓

Propan-2-ol ✓ (3)

4.2.3 Elimination / Dehydration ✓
Eliminasie / Dehidrasie (1)

4.2.4 Catalyst / *Katalisator* ✓ (1)

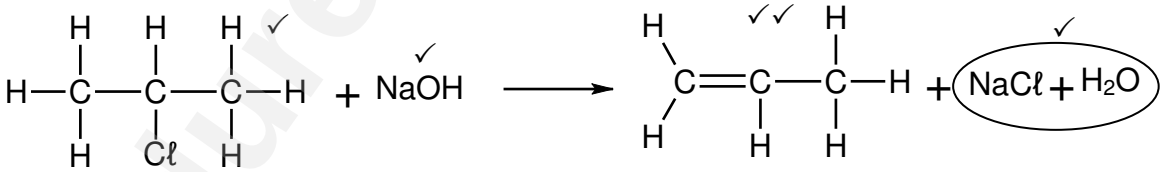
4.3

4.3.1 Sodium hydroxide / Potassium hydroxide ✓
Natriumhidroksied / Kaliumhidroksied (1)

4.3.2 Dissolve base in ethanol. / Concentrated (strong) base) ✓
Heat strongly. ✓

Los basis op in etanol. / Gekonsentreerde (sterk) basis
Verhit sterk. (2)

4.3.3



(5)
[15]

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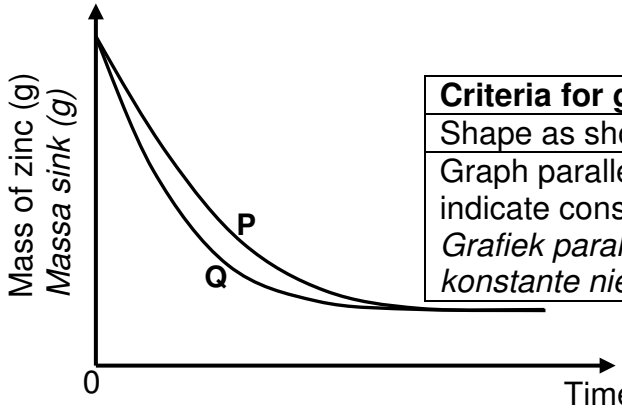
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QUESTION 5/*VRAAG 5*

5.1 Hydrochloric acid / HCℓ / *Soutsuur* ✓ (1)

5.2 Hydrogen gas escapes from the flask. ✓
Waterstofgas ontsnap uit die fles. (1)

5.3



Criteria for graph P: / *Riglyne vir grafiek P:*	
Shape as shown. / *Vorm soos aangetoon.*	✓
Graph parallel to x-axis after a certain time to indicate constant non-zero mass of zinc. *Grafiek parallel aan x-as na 'n sekere tyd om konstante nie-nul massa van sink aan te dui.*	✓

(2)

5.4

Criteria for graph Q / *Riglyne vir grafiek Q*:	
Steeper gradient than Graph **P**. / Steiler gradiënt as Grafiek **P**.	✓
Joins parallel section of Graph **P** after a shorter time. *Verbind met die parallelle deel van Grafiek **P** na 'n korter tyd.*	

(1)

5.5 At a higher temperature:
- More molecules have sufficient kinetic energy / kinetic energy equal to or greater than the activation energy. ✓
- More effective collisions per unit time / second. ✓

By 'n hoër temperatuur:
- *Meer molekule het voldoende kinetiese energie / kinetiese energie gelyk aan of groter as die aktiveringsenergie.*
- *Meer effektiewe botsings per eenheidstyd / sekond.* ✓

(2)

5.6 $c(HC\ell) = \frac{n}{V}$ ✓

$\therefore\ 0,2 = \frac{n}{0,1}$ ✓

$\therefore n(HC\ell) = 0,02$ mol

$n(Zn) = \frac{1}{2}n(HC\ell) = 0,01$ mol ✓

m(Zn reacted / *gereageer*) = nM ✓
= (0,01)(65) ✓
= 0,65 g

Mass of Zn initially in flask / *Massa Zn aanvanklik in fles:*
0,65 + 0,12 = 0,77 g ✓

(6)
[13]

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QUESTION 6/*VRAAG 6*

6.1 The stage in a chemical reaction when the rate of forward reaction equals the rate of reverse reaction. ✓✓
Die stadium in 'n chemiese reaksie wanneer die tempo van die voorwaartse reaksie gelyk is aan die tempo van die terugwaarste reaksie. ✓✓ (2)

6.2
6.2.1 Higher than / *Hoër as* ✓ (1)

6.2.2 Equal to / *Gelyk aan* ✓ (1)

6.3
6.3.1 $NO_2(g)$ added / *bygevoeg* ✓ (1)

6.3.2 Decrease in pressure / *Afname in druk* ✓ (1)

6.4 Increases ✓
An increase in temperature favours the endothermic reaction. ✓
The forward reaction is endothermic. / The forward reaction is favoured. ✓
Verhoog
'n Toename in temperatuur bevoordeel die endotermiese reaksie.
Die voorwaartse reaksie is endotermies. / Die voorwaarste reaksie word bevoordeel. (3)

6.5

	N_2O_4	NO_2
Initial quantity (mol) *Aanvangshoeveelheid (mol)*	0,92	0
Change (mol) *Verandering (mol)*	0,19 ✓	0,38
Quantity at equilibrium (mol)/ *Hoeveelheid by ewewig (mol)*	0,73	0,38 ✓
Equilibrium concentration ($mol \cdot dm^{-3}$) *Ewewigskonsentrasie ($mol \cdot dm^{-3}$)*	$\frac{0,73}{2} = 0,37$	$\frac{0,38}{2} = 0,19$

ratio ✓
verhouding

$$K_C = \frac{[NO_2]^2}{[N_2O_4]} \checkmark$$
$$= \frac{(0,19)^2}{(0,37)} \checkmark$$
$$= 9,76 \times 10^{-2} \checkmark$$

Divide by / *gedeel deur* 2 ✓

No K_C expression, correct substitution /
Geen K_c-uitdrukking, korrekte substitusie:
Max. / *Maks.* $\frac{6}{7}$

Wrong K_C expression / *Verkeerde K_c-uitdrukking*: Max. / *Maks.* $\frac{4}{7}$

(7)
[16]

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QUESTION 7/*VRAAG 7*

7.1 An acid forms hydronium ions / H_3O^+ ions when it dissolves in water. ✓
'n Suur vorm hidroniumione / H_3O^+-ione wanneer dit in water oplos. (2)

7.2 Incompletely / partially ionised ✓
Onvolledig / gedeeltelik geioniseer (1)

7.3 Solution of known concentration. / *Oplossing van bekende konsentrasie.* ✓ (1)

7.4 Burette / *Buret* ✓
Pipette / *Pipet* ✓ (2)

7.5

7.5.1

OPTION 1/*OPSIE 1*	**OPTION 2/*OPSIE 2***
$K_w = [H_3O^+][OH^-]$ $\therefore 1 \times 10^{-14} = [H_3O^+](0,5)$ ✓ $\therefore [H_3O^+] = 2 \times 10^{-14}$ mol·dm^{-3} $pH = -\log[H_3O^+]$ ✓ $= -\log(2 \times 10^{-14})$ ✓ $= 13,7$ ✓	$pOH = -\log[OH^-]$ ✓ $= -\log(0,5)$ ✓ $= 0,3$ $pH = 14 - pOH$ ✓ $= 14 - 0,3$ $= 13,7$ ✓

(4)

7.5.2 $n(NaOH) = cV$ ✓
$= (0,5)(0,04)$ ✓
$= 0,02$ mol

$n(CH_3COOH) = n(NaOH) = 0,02$ mol ✓

$m(CH_3COOH) = nM$ ✓
$= (0,02)(60)$ ✓
$= 1,2$ g

% mass of / *massa van* $CH_3COOH = \frac{1,2}{20} \times 100$ ✓ $= 6\%$ ✓ (7)

7.6 $CH_3COO^-(aq) + H_2O(\ell)$ ✓→ $CH_3COOH(aq) + OH^-(aq)$ ✓ Bal. ✓ (3)
[20]

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QUESTION 8/*VRAAG 8*

8.1 $1\ mol{\cdot}dm^{-3}$ ✓ (1)

8.2 Iodine is not a conductor. / *Jodium is nie 'n geleier nie.* ✓ (1)

8.3 Graphite is a conductor. / *Grafiet is 'n geleier.*✓
Graphite is inert. / *Grafiet is onaktief/traag.* ✓ (2)

8.4

8.4.1 Permanganate ion / *Permanganaat-ioon* ✓ (1)

8.4.2 $2MnO_4^-(aq) + 16H^+(aq) + 10I^-(aq)$ ✓ $\rightarrow 2Mn^{2+}(aq) + 5I_2(s) + 8H_2O(\ell)$ ✓ bal. ✓ (3)

8.4.3 $C(s) \mid I^-(aq) \mid I_2(s) \parallel H^+(aq), MnO_4^-(aq), Mn^{2+}(aq) \mid C(s)$ (3)

8.5 $E^o_{cell} = E^o_{cathode} - E^o_{anode}$ ✓
$= 1,51$ ✓$- 0,54$ ✓
$E^o_{cell} = 0,97\ V$ ✓ (4)

8.6 Decreases / *Verlaag* ✓ (1)
[16]

QUESTION 9/*VRAAG 9*

9.1 A solution that conducts electricity through the movement of ions. ✓✓
'n Oplossing wat elektrisiteit gelei deur die beweging van ione. (2)

9.2 Bracelet / *Armband* ✓ (1)

9.3

9.3.1 Chromium / *Chroom* ✓ (1)

9.3.2 $Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$ ✓✓ (2)

9.4
$$n(Cr) = \frac{m}{M} \checkmark$$
$$= \frac{0,86}{52} \checkmark$$
$$= 0,0165\ mol$$

n(electrons / *elektrone*) = 3n(Cr) ✓ $= 4,96 \times 10^{-2}$ mol

$$n = \frac{N}{N_A} \checkmark$$
$$4,96 \times 10^{-2} = \frac{N}{6,02 \times 10^{23}}$$
$$\therefore N = 2,99 \times 10^{22} \checkmark$$ (6)
[12]

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QUESTION 10/*VRAAG 10*

10.1 Contact process / *Kontakproses* ✓ (1)

10.2 Sulphur dioxide / SO_2 / S*waweldioksied* ✓ (1)

10.3

10.3.1 Vanadium pentoxide / Vanadium(V) oxide / V_2O_5 ✓
Vanadiumpentoksied / Vanadium(V)oksied / V_2O_5 (1)

10.3.2 $2SO_2(g) + O_2$ ✓ ⇌ $2SO_3$ ✓ Bal. ✓ (3)

10.4

10.4.1 Oleum / Pyrosulphuric acid / $H_2S_2O_7$ ✓
Oleum / Piroswawelsuur / $H_2S_2O_7$ (1)

10.4.2 Reaction is highly exothermic and forms a mist. ✓
Die reaksie is hoog eksotermies en vorm 'n mis. (1)

10.5 Ammonium sulphate / $(NH_4)_2SO_4$ ✓
Ammoniumsulfaat / $(NH_4)_2SO_4$ (1)

10.6 Eutrophication leads to the destruction of aquatic life / dead zones. ✓
This results in less income due to selling of food / recreation areas. ✓
Eutrofikasie lei tot die afbreek van waterlewe / dooie sones.
Dit het minder inkomste deur die verkoop van voedsel / ontspanningsareas tot gevolg. (2)

[11]

GRAND TOTAL/*GROOTTOTAAL*: 150

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TASK

ANSWERS

TASK 1 SOLUTION

QUESTION 1

1.1 The total linear momentum in an isolated system is conserved.

1.2 $(U + K)_{bottom} = (U + K)_{top}$

$0 + \frac{1}{2}(m_1 + m_2)v^2 = mgh + 0$

$\frac{1}{2}(0,015 + 5)(v^2) = (0,015 + 5)(9,8)(0,15)$

$v_f = 1,71\ m \cdot s^{-1}$

1.3 $p_t(before) = p_t(after)$

$m_1 v_{i1} + m_2 v_{i2} = (m_1 + m_2)v_f$

$(0,015)v_{i1} + 0 = (0,015 + 5)(1,71)$

1.4 According to Newton's third law, the gun will exert a force on the bullet and the bullet will exert an equal but opposite force on the gun. The force of the gun on the officer pushes him slightly backwards.

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TASK 1 SOLUTION

QUESTION 2

2.1 The total linear momentum remains constant in an isolated/a closed system

2.2 To the right as positive :

$\Sigma \mathbf{p}$ before= $\Sigma \mathbf{p}$ after
$(1\ 000)(40)\ 3+ (5\ 000)(-20)\ 3 = (1\ 000 + 5\ 000)v_f$

Therefore $v_f = -10$ m·s-1

OR $v_f = 10$ m·s-1 to the left

2.3

Force on truck:

Assume motion to the right as positive

$F_{net}\Delta t = \Delta p = mv_f - mv_i$

$F_{net}(0,5) = 5\ 000(-10 - (-20))$

$F_{net} = 1 \times 10^5$ N (100 000 N)
$F_{net} > 85\ 000$ N
Yes, collision is fatal.

TASK 3 SOLUTION

QUESTION 1

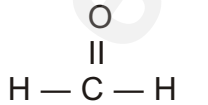
1.1 1.1.1 A

1.1.2 D

1.2 1.2.1 1-bromo-2-methylpropane

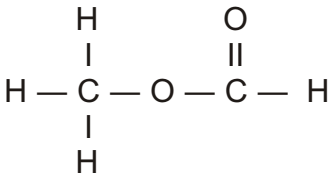
1.2.2 2,4-dimethylhexane

1.3



1.4 Ethanoic acid

1.5



TASK 2 SOLUTION

1.1 **t = 0 s:**

ball starts from rest

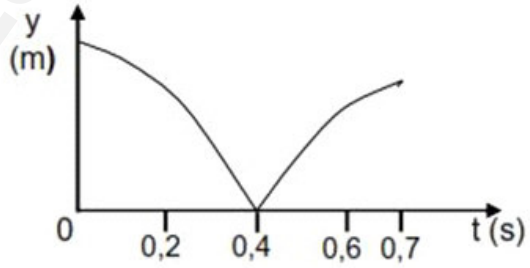
t = 0 s 0,4 s:
Falls at constant acceleration

t = 0,4 s:
Reaches the floor at 4 m·s-1 (or 4 m·s-1 downwards)

t = 0,4 s:
Bounces back at -3 m·s-1 (or 3 m·s-1 upwards)

1.2 Δy = area of triangle = = ½ bh
= ½ (0,4) 9 (4)
= 0,8 m

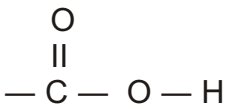
1.3



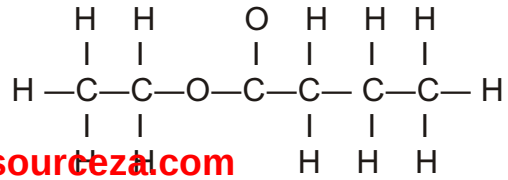
1.4 Inelastic
Decrease/change in speed (from 4 ms^{-1} to 3 ms^{-1})

QUESTION 2 (TASK 3)

2.1.1 D
2.1.2 C
2.2.1 4-methylpentanal
2.2.2 prop-1-yne OR propyne OR 1-propyne
2.3 H_2O / water
CO_2 / carbon dioxide
2.4.1 Esters
2.4.1



2.4.3 Butanoic acid
2.4.4



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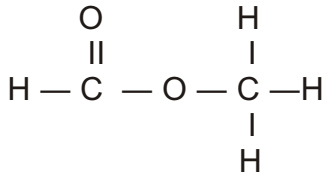
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TASK 4 SOLUTION

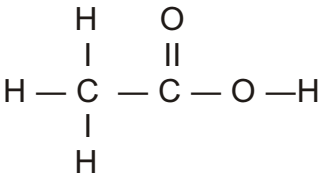
QUESTION 1

.1.1 Compounds that have the same molecular formula but different structural formulae

1.2



methylmethanoate



ethanoic acid

1.3.1 Ethanoic acid

- The hydrogen bonds between ethanoic acid molecules are stronger than Van der Waals forces between the ester molecules
- More energy needed to break bonds between ethanoic acid molecules

1.3.2 Methylmethanoate

- The Van der Waals forces between the ester molecules are weaker than the hydrogen bonds between ethanoic acid molecules
- less energy is needed to break bonds between the ester molecules

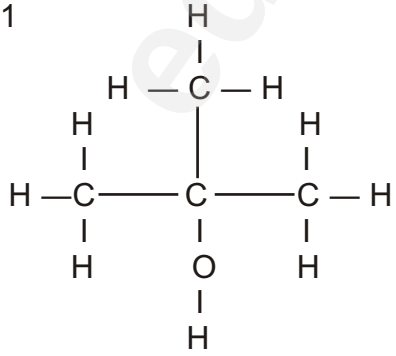
1.4 Decrease.

Van der Waals forces increase with molecular size

QUESTION 2

2.1 D

2.2.1



2.2.2 D

2..3.1

Example:

What is the relationship between viscosity and chain length of alcohols?

2.3.2 C

Longest flow time

2.3.3 Increase in chain length from A to C.

Increase in strength of intermolecular forces .

2.3.4 C

2.4 D

2.5 The more branched alcohol E has a smaller surface area over which the intermolecular forces act.

Decrease in strength of intermolecular forces reduces resistance to flow (and thus lower viscosity).

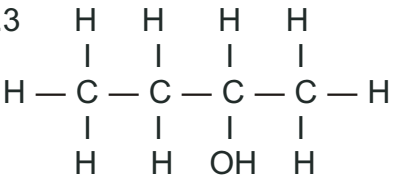
TASK 5 SOLUTION

1.1 III - elimination/dehydration

1.2 I hydration

II hydrohalogenation

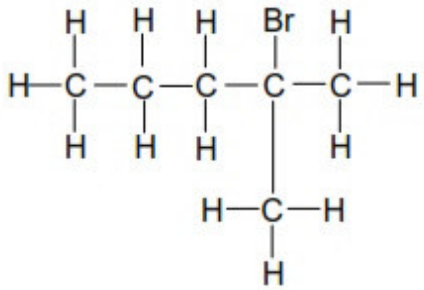
1.3



2-butanol/butan-2-ol

1.4 H_2SO_4

1.5



2-bromo-2-methylpentane

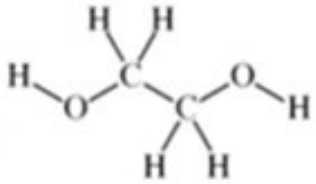
1.6 Alkenes

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TASK 6 SOLUTION

1.1 The monomer with two hydroxyl groups is:



The monomer with two carboxylic acid groups is:



1.2 Examples of natural polymers: cotton, silk, natural rubber, cellulose, wool, and DNA

Examples of synthetic polymers: Kevlar, vinyl, nylon, Dacron, polyethylene, polypropylene and synthetic rubber

SOLUTION 2

2.1 chloroethene

2.2
2.2.1 addition polymerization
2.2.2 condensation polymerization

TASK 7 SOLUTION

SOLUTION 1

1.1 0 (N)/Zero
no acceleration/constant velocity

1.2 0 (J)/Zero

1.3.1 $U_i + K_i + W_{friction} + W_{applied} = U_f + U_f$

$0 + f\Delta x\cos\theta + W_{applied} = mgh\ (K_i = K_f)$

$0 + (50)(10)(-1) + W_{applied} = (120)(9.8)(1.5)$

$W_{applied} = 2264J$

1.3.2 $W_{applied} = F\Delta x\cos\theta$

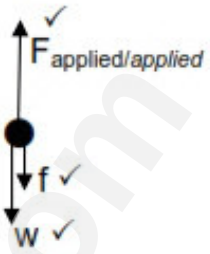
$2264 = F(10)(1)$

$F = 226.4N$

SOLUTION 2

2.1 The net (total) work (done on an object)
is equal to the change in kinetic energy (of the object.)

2.2



2.3 Gravitational force/weight (of soldier)

2.4 $W_{net} = \Delta K$

$F\Delta y\cos\theta + Fw\Delta y\cos\theta + Wf = \Delta K$

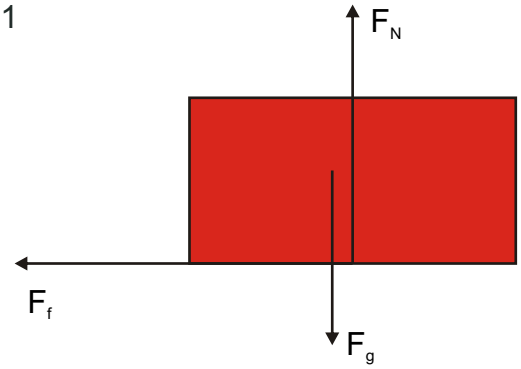
$(960)(20)\cos0° 3+ (80)(9,8)(20)\cos180° + Wf = 0$

$19\ 200 - 15\ 680 + Wf = 0$

$Wf = - 3\ 520\ J$

SOLUTION 3

3.1



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3.2

Data Given

$m = 0.080kg$
$M = 4.5kg$
$\Delta x = 0.9m$
$V_i = 300m.s^{-1}$
$V_f = 0m.s^{-1}$

$W_{net} = \Delta E_k = ½ mv^2_f - ½ mv^2_i$
$= ½ (0.080)(0)^2 - ½ (0.080)(300)^2$
$= 0 - 3600$
$= -3600J$

But $W_{net} = F_{net} x \Delta x$
$= F_{net} x 0.9$

Therefore $F_{net} x 0.9 = -3600J$

$F_{net} = - 5.18 \times 10^{10} N$
Or $F_{net} = 5.18 \times 10^{10} N$ backwards

TASK 8 SOLUTION

SOLUTION 1

1.1 Doppler effect

1.2

$$f_L = f_s \bullet \frac{v \pm v_L}{v \pm v_s}$$

OR

$$f_L = f_s \bullet \frac{v}{v + v_s}$$

But $f_L = \frac{90}{100} f_s$

$$\frac{90}{100} f_s = f_s \bullet \frac{340 - 0}{340 + v_s}$$

$v_s = 37.78m.s^{-1}$

SOLUTION 2

2.1 Doppler effect

2.2 $$f_L = f_s \bullet \frac{v \pm v_L}{v \pm v_s}$$

OR

$$f_L = f_s \bullet \frac{v + v_L}{v}$$

$$1000 = 960 \bullet \frac{340 + v_L}{340 - 0}$$

$v_L = 14.17m.s^{-1}$

2.3 Higher than

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TASK 9 SOLUTION

1.1 1.1.1 Catalyst
1.1.2 Effective collision
1.1.3 Surface area
1.1.4 Activated complex
1.1.5 Temperature
1.1.6 Heat of reaction

1.2.1 Example:
Reaction rate increases with increase in temperature.

1.2.2 Sulphur dioxide / SO_2
1.2.3 Concentration / mass / mol (of acid and sodium thiosulphate)
1.2.4 Sulphur / S
1.2.5 Different people have different sight abilities/reaction times.
1.2.6 Reaction rate
1.2.7 Example:
Reaction rate increases with increase in temperature.

TASK 10 SOLUTION

SOLUTION 1

1.1.1 When the equilibrium in a closed system is disturbed the system will shift the equilibrium position as to favour the reaction that will oppose the disturbance.

1.1.2 Decreases
When the pressure is increased, the reverse reaction (The reaction that produced the smaller volume/amount of gas) is favoured.

1.1.3 Products form at faster rate.
Higher yield of products.

1.2.1

	H_2	CO_2	H_2O	CO	
Initial quantity (mol) *Aanvangshoeveelheid (mol)*	x	0,3	0	0	
Change (mol) *Verandering (mol)*	- 0,2	-0,2	+ 0,2	+ 0,2	ratio ✓ *verhouding*
Quantity at equilibrium (mol)/ *Hoeveelheid by ewewig(mol)*	x -0,2	0,1 ✓	0,2	0,2✓	
Equilibrium concentration ($mol \cdot dm^{-3}$) *Ewewigskonsentrasie ($mol \cdot dm^{-3}$)*	$\frac{x-0,2}{10}$	0,01	0,02	0,02	Divide by 10✓ *Deel deur 10*

$$K_C = \frac{[CO][H_2O]}{[H_2][CO_2]} \checkmark \therefore \frac{(0,02)(0,02)}{\left(\frac{x-0,2}{10}\right)(0,01)} \checkmark = 4 \checkmark \therefore x = 0,3 \therefore n(H_2) = 0,3 \text{ mol} \checkmark$$

1.2.2 Exothermic A decrease in Kc implies: Lower product concentration
Reverse reaction favoured. This means the forward reaction is exothermic.

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QUESTION 2 (TASK 10)

2.1 2.2.1 Increases
2.2.2 Decreases

	SO_2	O_2	SO_3	
Molar ratio	2	1	2	
Initial quantity (mol)	4	$\frac{x}{32}$ ✓✓	0	
Change (mol)	3	1,5	3	Ratio ✓
Quantity at equilibrium (mol)	1	$\frac{x}{32} - 1,5$ ✓	3✓	
Concentration ($mol \cdot dm^{-3}$)	0,5	$\frac{x-48}{64}$	1,5	Divide by 2 ✓

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]} \checkmark \therefore 4,5 = \frac{(1,5)^2}{(0,5)^2(\frac{x-48}{64})} \checkmark \therefore x = 176\ g \checkmark$$

TASK 11 SOLUTIONS

SOLUTION 1

1.1

1.1.1 HCO_3^- (base) and $CO_2 + H_2O$ (acid), H_3O^+ (acid) and H_2O (base)

1.1.2 H_2SO_4 (acid) and HSO_4^- (base), HNO_3 (base) and $NO_2^+ + H_2O$ (acid)

1.2

1.2.1 $pH = -\log_{10}(0.001) = 3.00$

1.2.2 $pOH = -\log_{10}(0.002) = 2.70$

$pH = 14 - pOH$

$= 14 - 2.70$

$= 11.30$

1.3

1.3.1 $pH = 3$

$-\log_{10}([H^+]) = 3$

$[H^+] = (10^{-1})^3 = 1x10^{-3}\ mol.dm^{-3}$

1.3.2 $pH = 14 - pOH$

$= 14 - 11 = 3$

$-\log_{10}([H^+]) = 3$

$[H^+] = (10^{-1}) = 1.0 \times 10^{-3}\ mol.dm^{-3}$

2.1 HCl is a strong acid and hence it completely dissociate in water according to the following equation:

$HCl + H_2O \rightarrow H_3O^+ + Cl^-$

$HCl : H_3O^+$

$1 : 1$

$[HCl] = 0.1\ M \leftrightarrow [H_3O^+] = 0.1M$

$[OH^-] = \frac{K_w}{[H_3O^+]} = \frac{1.0 \times 10^{-14}}{0.1}$

$[OH^-] = 1.0 \times 10^{-13}\ M$

$Ba(OH)_2$ is a strong base therefore it completely dissociate in water solutions according to the following equation:

$Ba(OH)_2 \rightarrow Ba^{2+} + 2OH^-$

$Ba(OH)_2 : OH^-$

$1 : 2$

Therefore:

$[OH^-] = 2x\ [Ba(OH)_2] = 2x0.1 = 0.2M$

$[H_3O^+] = \frac{K_w}{[OH^-]} = \frac{1.0 \times 10^{-14}}{0.2}$

$[H_3O^+] = 5.0 \times 10^{-14}\ M$

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TASK 12 SOLUTION

1.1 12 V 1.2.1 $emf = Ir_{ext} + Ir$

$12 = I(2,4) + 2,4 \quad \therefore I = 4\ A$

1.2.2 $emf = IR_{ext} + Ir \quad \leftrightarrow \quad 12 = 9,6 + 4r \quad \therefore\ r = 0,6\ \Omega$

1.2.3 $emf = I(R_{ext} + r)$

$12 = 6(R_{ext} + 0,6)$

$R_{ext} = 1,4\ \Omega$

$$\frac{1}{R_{ext}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{1,4} = \frac{1}{2,4} + \frac{1}{R}$$

$\therefore R = 3,36\ \Omega$

1.4 Increases Resistance increases, current decreases Ir (lost volts) decreases

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TASK 13 SOLUTION

1.1.1 Electrical (energy) to mechanical (energy)
1.1.2 Mechanical (energy) to electrical (energy)

1.1.3 Motor effect
1.1.4 Electromagnetic induction
1.2 BC / conductor is parallel to the magnetic field. OR Open switch , no current.

1.3

$$V_{rms} = \frac{V_{max}}{\sqrt{2}} \checkmark$$
$$= \frac{311}{\sqrt{2}} \checkmark$$
$$= 219{,}91 \text{ V}$$
$$I_{rms} = \frac{I_{max}}{\sqrt{2}} \checkmark$$
$$= \frac{21}{\sqrt{2}} \checkmark$$
$$= 14{,}85 \text{ A}$$
$$P_{ave} = V_{rms}I_{rms} \checkmark$$
$$= (219{,}91)(14{,}85)$$
$$= 3\,265{,}66 \text{ W} \checkmark$$

TASK 14 SOLUTION

1.1 Photo-electric effect
1.2 Work function

1.3

$$c = f\lambda$$
$$3 \times 10^{8} = f(330 \times 10^{-9})$$
$$\therefore f = 9{,}09 \times 10^{14} \text{ Hz}$$

1.4

$$\left.\begin{aligned} E &= W_o + K \\ \frac{hc}{\lambda} &= W_o + K \end{aligned}\right\}$$
$$\therefore \frac{(6{,}63 \times 10^{-34})(3 \times 10^{8})}{330 \times 10^{-9}}$$
$$\therefore K = 2{,}53 \times 10^{-19} \text{ J} \checkmark$$

1.5
1.5.1 Remains the same
1.5.2 Increases 1.6
1.6.1 Ultraviolet radiation
1.6.2 High energy / high frequency

TASK 15 SOLUTION

1.1 Chemical (energy) to electrical (energy)

1.2 Completes the circuit.

OR
Maintains electrical neutrality.

1.3 $Pb \rightarrow Pb^{2+} + 2e^-$

1.4 Pb to Cu

1.5 $Pb + Cu^{2+} \rightarrow Pb^{2+} + Cu$ Balancing

1.6 Exothermic

1.7 $E^{\theta}_{cell} = E^{\theta}_{cathode} - E^{\theta}_{anode}$
$= 0{,}34 - (-0{,}13)$

$E^{\theta}_{cell} = 0{,}47$ V

1.8 Measurements not done at:
Temperature of 25 °C / 298 K
Concentration of 1 moldm^{-3}

SOLUTION 2

2.1 A liquid solution that conducts electricity through the movement of free ions.

2.2.1 $2C\ell^- \rightarrow C\ell_2 + 2e^-$
2.2.2 $Cu^{2+} + 2e^- \rightarrow Cu$

2.3 Q
Reduction takes place.

2.4.1 Cu is a stronger reducing agent than the $C\ell^-$ ions.
Cu will be oxidised / loses electrons, resulting in the plate becoming eroded.

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TASK 16 SOLUTION

1.1

1.1.1 Fractional distillation of liquid air

1.1.2 $N_2 + 3H_2 \rightarrow 2NH_3$

1.1.3 Nitric acid / HNO_3

1.1.4 $H_2SO_4 + 2NH_3 \rightarrow (NH_4)_2SO_4$

1.1.5 Nitrogen / N

1.2 Any ONE:

- Enhance growth of crops/plants to produce more food for humans /food security for humans.
- Production/application of fertiliser results in job creation.
- Selling of fertilisers stimulates the economy.

1.3

Any TWO:

- (Excessive) nitrates in water (eutrophication) can result in blue-baby syndrome / cancer.
- (Excessive) nitrates/ammonium ions in water can result in poor quality drinking water.
- (Excessive) nitrates / ammonium ions in water cause death of fish (eutrophication) can result in less food.
- (Excessive) nitrates /ammonium ions in water (eutrophication) can result in poorer water recreational facilities.
- (Excessive) nitrates in soil kill plants/crops resulting in food shortages/famine.
- (Excessive) ammonium ions in soil increases the acidity of the soil limiting food production.

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DATA

SHEETS

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DATA FOR PHYSICAL SCIENCES GRADE 12
PAPER 1 (PHYSICS)

GEGEWENS VIR FISIESE WETENSKAPPE GRAAD 12
VRAESTEL 1 (FISIKA)

TABLE 1: PHYSICAL CONSTANTS/*TABEL 1: FISIESE KONSTANTES*

NAME/*NAAM*	SYMBOL/*SIMBOOL*	VALUE/*WAARDE*
Acceleration due to gravity *Swaartekragversnelling*	g	9,8 $m \cdot s^{-2}$
Speed of light in a vacuum *Spoed van lig in 'n vakuum*	c	$3,0 \times 10^{8}$ $m \cdot s^{-1}$
Planck's constant *Planck se konstante*	h	$6,63 \times 10^{-34}$ $J \cdot s$
Coulomb's constant *Coulomb se konstante*	k	$9,0 \times 10^{9}$ $N \cdot m^{2} \cdot C^{-2}$
Charge on electron *Lading op elektron*	e	$-1,6 \times 10^{-19}$ C
Electron mass *Elektronmassa*	m_e	$9,11 \times 10^{-31}$ kg
Permittivity of free space *Permittiwiteit van vry ruimte*	ε_0	$8,85 \times 10^{-12}$ $F \cdot m^{-1}$

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TABLE 2: FORMULAE/*TABEL 2: FORMULES*

MOTION/*BEWEGING*

$v_f = v_i + a\,\Delta t$	$\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2$ or/*of* $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$
$v_f^{\,2} = v_i^{\,2} + 2a\Delta x$ or/*of* $v_f^{\,2} = v_i^{\,2} + 2a\Delta y$	$\Delta x = \left(\frac{v_i + v_f}{2}\right)\Delta t$ or/*of* $\Delta y = \left(\frac{v_i + v_f}{2}\right)\Delta t$

FORCE/*KRAG*

$F_{net} = ma$	$p = mv$
$F_{net}\Delta t = \Delta p$ $\Delta p = mv_f - mv_i$	$w = mg$

WORK, ENERGY AND POWER/*ARBEID, ENERGIE EN DRYWING*

$W = F\Delta x\cos\theta$	$U = mgh$	or/*of* $E_P = mgh$
$K = \frac{1}{2}mv^2$ or/*of* $E_k = \frac{1}{2}mv^2$	$W_{net} = \Delta K$	or/*of* $W_{net} = \Delta E_k$
	$\Delta K = K_f - K_i$	or/*of* $\Delta E_k = E_{kf} - E_{ki}$
$P = \frac{W}{\Delta t}$	$P = Fv$	

WAVES, SOUND AND LIGHT/*GOLWE, KLANK EN LIG*

$v = f\lambda$	$T = \frac{1}{f}$
$f_L = \frac{v \pm v_L}{v \pm v_s}f_s$ or/*of* $f_L = \frac{v \pm v_L}{v \pm v_b}f_b$	$E = hf$ $E = h\frac{c}{\lambda}$
$\sin\theta = \frac{m\lambda}{a}$	$E = W_o + E_k$ where/*waar* $E = hf$ and/*en* $W_0 = hf_0$ and/*en* $E_k = \frac{1}{2}mv^2$

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ELECTROSTATICS/*ELEKTROSTATIKA*

$F = \frac{kQ_1Q_2}{r^2}$	$E = \frac{kQ}{r^2}$
$E = \frac{V}{d}$	$E = \frac{F}{q}$
$U = \frac{kQ_1Q_2}{r}$	$V = \frac{W}{q}$
$C = \frac{Q}{V}$	$C = \frac{\varepsilon_0 A}{d}$

ELECTRIC CIRCUITS/*ELEKTRIESE STROOMBANE*

$R = \frac{V}{I}$	emf (ε) = I(R + r) emk (ε) = I(R + r)
$R_s = R_1 + R_2 + \ldots$ $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$	$q = I\,\Delta t$
W = Vq W = VIΔt W= $I^2R\Delta t$ W= $\frac{V^2\Delta t}{R}$	$P = \frac{W}{\Delta t}$ P = VI P = I^2R P = $\frac{V^2}{R}$

ALTERNATING CURRENT/*WISSELSTROOM*

$I_{rms} = \frac{I_{max}}{\sqrt{2}}$	/	$I_{wgk} = \frac{I_{maks}}{\sqrt{2}}$	$P_{average} = V_{rms}I_{rms}$ / $P_{gemiddeld} = V_{wgk}I_{wgk}$
			$P_{average} = I_{rms}^2R$ / $P_{gemiddeld} = I_{wgk}^2R$
$V_{rms} = \frac{V_{max}}{\sqrt{2}}$	/	$V_{wgk} = \frac{V_{maks}}{\sqrt{2}}$	$P_{average} = \frac{V_{rms}^2}{R}$ / $P_{gemiddeld} = \frac{V_{wgk}^2}{R}$

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DATA FOR PHYSICAL SCIENCES GRADE 12
PAPER 2 (CHEMISTRY)

GEGEWENS VIR FISIESE WETENSKAPPE GRAAD 12
VRAESTEL 2 (CHEMIE)

TABLE 1: PHYSICAL CONSTANTS/*TABEL 1: FISIESE KONSTANTES*

NAME/*NAAM*	SYMBOL/*SIMBOOL*	VALUE/*WAARDE*
Standard pressure *Standaarddruk*	p^{θ}	$1{,}013 \times 10^5$ Pa
Molar gas volume at STP *Molêre gasvolume by STD*	V_m	$22{,}4\ dm^3 \cdot mol^{-1}$
Standard temperature *Standaardtemperatuur*	T^{θ}	273 K
Charge on electron *Lading op elektron*	e	$-1{,}6 \times 10^{-19}$ C

TABLE 2: FORMULAE/*TABEL 2: FORMULES*

$n = \frac{m}{M}$	$c = \frac{n}{V}$ or/*of* $c = \frac{m}{MV}$
$q = I\Delta t$ $W = Vq$	$E^{\theta}_{cell} = E^{\theta}_{cathode} - E^{\theta}_{anode}$ / $E^{\theta}_{sel} = E^{\theta}_{katode} - E^{\theta}_{anode}$ or/*of* $E^{\theta}_{cell} = E^{\theta}_{reduction} - E^{\theta}_{oxidation}$ / $E^{\theta}_{sel} = E^{\theta}_{reduksie} - E^{\theta}_{oksidasie}$ or/*of* $E^{\theta}_{cell} = E^{\theta}_{oxidising\ agent} - E^{\theta}_{reducing\ agent}$ / $E^{\theta}_{sel} = E^{\theta}_{oksideermiddel} - E^{\theta}_{reduseermiddel}$

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TABLE 4A: STANDARD REDUCTION POTENTIALS
TABEL 4A: STANDAARD- REDUKSIEPOTENSIALE

Increasing oxidising ability/*Toenemende oksiderende vermoë* ↑

Half-reactions/*Halfreaksies*			$E^{\ominus}$ (V)
$F_2(g) + 2e^-$	$\rightleftharpoons$	$2F^-$	+ 2,87
$Co^{3+} + e^-$	$\rightleftharpoons$	Co^{2+}	+ 1,81
$H_2O_2 + 2H^+ + 2e^-$	$\rightleftharpoons$	$2H_2O$	+1,77
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	+ 1,51
$C\ell_2(g) + 2e^-$	$\rightleftharpoons$	$2C\ell^-$	+ 1,36
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	$\rightleftharpoons$	$2Cr^{3+} + 7H_2O$	+ 1,33
$O_2(g) + 4H^+ + 4e^-$	$\rightleftharpoons$	$2H_2O$	+ 1,23
$MnO_2 + 4H^+ + 2e^-$	$\rightleftharpoons$	$Mn^{2+} + 2H_2O$	+ 1,23
$Pt^{2+} + 2e^-$	$\rightleftharpoons$	Pt	+ 1,20
$Br_2(\ell) + 2e^-$	$\rightleftharpoons$	$2Br^-$	+ 1,07
$NO_3^- + 4H^+ + 3e^-$	$\rightleftharpoons$	$NO(g) + 2H_2O$	+ 0,96
$Hg^{2+} + 2e^-$	$\rightleftharpoons$	$Hg(\ell)$	+ 0,85
$Ag^+ + e^-$	$\rightleftharpoons$	Ag	+ 0,80
$NO_3^- + 2H^+ + e^-$	$\rightleftharpoons$	$NO_2(g) + H_2O$	+ 0,80
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	+ 0,77
$O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O_2	+ 0,68
$I_2 + 2e^-$	$\rightleftharpoons$	$2I^-$	+ 0,54
$Cu^+ + e^-$	$\rightleftharpoons$	Cu	+ 0,52
$SO_2 + 4H^+ + 4e^-$	$\rightleftharpoons$	$S + 2H_2O$	+ 0,45
$2H_2O + O_2 + 4e^-$	$\rightleftharpoons$	$4OH^-$	+ 0,40
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	Cu	+ 0,34
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(g) + 2H_2O$	+ 0,17
$Cu^{2+} + e^-$	$\rightleftharpoons$	Cu^+	+ 0,16
$Sn^{4+} + 2e^-$	$\rightleftharpoons$	Sn^{2+}	+ 0,15
$S + 2H^+ + 2e^-$	$\rightleftharpoons$	$H_2S(g)$	+ 0,14
$2H^+ + 2e^-$	**$\rightleftharpoons$**	**$H_2(g)$**	**0,00**
$Fe^{3+} + 3e^-$	$\rightleftharpoons$	Fe	– 0,06
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	Pb	– 0,13
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	Sn	– 0,14
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	Ni	– 0,27
$Co^{2+} + 2e^-$	$\rightleftharpoons$	Co	– 0,28
$Cd^{2+} + 2e^-$	$\rightleftharpoons$	Cd	– 0,40
$Cr^{3+} + e^-$	$\rightleftharpoons$	Cr^{2+}	– 0,41
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	Fe	– 0,44
$Cr^{3+} + 3e^-$	$\rightleftharpoons$	Cr	– 0,74
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	Zn	– 0,76
$2H_2O + 2e^-$	$\rightleftharpoons$	$H_2(g) + 2OH^-$	– 0,83
$Cr^{2+} + 2e^-$	$\rightleftharpoons$	Cr	– 0,91
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	Mn	– 1,18
$A\ell^{3+} + 3e^-$	$\rightleftharpoons$	$A\ell$	– 1,66
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	Mg	– 2,36
$Na^+ + e^-$	$\rightleftharpoons$	Na	– 2,71
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	Ca	– 2,87
$Sr^{2+} + 2e^-$	$\rightleftharpoons$	Sr	– 2,89
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	Ba	– 2,90
$Cs^+ + e^-$	$\rightleftharpoons$	Cs	- 2,92
$K^+ + e^-$	$\rightleftharpoons$	K	– 2,93
$Li^+ + e^-$	$\rightleftharpoons$	Li	– 3,05

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TABLE 4B: STANDARD REDUCTION POTENTIALS
TABEL 4B: STANDAARD- REDUKSIEPOTENSIALE

Half-reactions/*Halfreaksies*	$E^{\ominus}$ (V)
$Li^+ + e^- \rightleftharpoons Li$	– 3,05
$K^+ + e^- \rightleftharpoons K$	– 2,93
$Cs^+ + e^- \rightleftharpoons Cs$	– 2,92
$Ba^{2+} + 2e^- \rightleftharpoons Ba$	– 2,90
$Sr^{2+} + 2e^- \rightleftharpoons Sr$	– 2,89
$Ca^{2+} + 2e^- \rightleftharpoons Ca$	– 2,87
$Na^+ + e^- \rightleftharpoons Na$	– 2,71
$Mg^{2+} + 2e^- \rightleftharpoons Mg$	– 2,36
$A\ell^{3+} + 3e^- \rightleftharpoons A\ell$	– 1,66
$Mn^{2+} + 2e^- \rightleftharpoons Mn$	– 1,18
$Cr^{2+} + 2e^- \rightleftharpoons Cr$	– 0,91
$2H_2O + 2e^- \rightleftharpoons H_2(g) + 2OH^-$	– 0,83
$Zn^{2+} + 2e^- \rightleftharpoons Zn$	– 0,76
$Cr^{3+} + 3e^- \rightleftharpoons Cr$	– 0,74
$Fe^{2+} + 2e^- \rightleftharpoons Fe$	– 0,44
$Cr^{3+} + e^- \rightleftharpoons Cr^{2+}$	– 0,41
$Cd^{2+} + 2e^- \rightleftharpoons Cd$	– 0,40
$Co^{2+} + 2e^- \rightleftharpoons Co$	– 0,28
$Ni^{2+} + 2e^- \rightleftharpoons Ni$	– 0,27
$Sn^{2+} + 2e^- \rightleftharpoons Sn$	– 0,14
$Pb^{2+} + 2e^- \rightleftharpoons Pb$	– 0,13
$Fe^{3+} + 3e^- \rightleftharpoons Fe$	– 0,06
$2H^+ + 2e^- \rightleftharpoons H_2(g)$	**0,00**
$S + 2H^+ + 2e^- \rightleftharpoons H_2S(g)$	+ 0,14
$Sn^{4+} + 2e^- \rightleftharpoons Sn^{2+}$	+ 0,15
$Cu^{2+} + e^- \rightleftharpoons Cu^+$	+ 0,16
$SO_4^{2-} + 4H^+ + 2e^- \rightleftharpoons SO_2(g) + 2H_2O$	+ 0,17
$Cu^{2+} + 2e^- \rightleftharpoons Cu$	+ 0,34
$2H_2O + O_2 + 4e^- \rightleftharpoons 4OH^-$	+ 0,40
$SO_2 + 4H^+ + 4e^- \rightleftharpoons S + 2H_2O$	+ 0,45
$Cu^+ + e^- \rightleftharpoons Cu$	+ 0,52
$I_2 + 2e^- \rightleftharpoons 2I^-$	+ 0,54
$O_2(g) + 2H^+ + 2e^- \rightleftharpoons H_2O_2$	+ 0,68
$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$	+ 0,77
$NO_3^- + 2H^+ + e^- \rightleftharpoons NO_2(g) + H_2O$	+ 0,80
$Ag^+ + e^- \rightleftharpoons Ag$	+ 0,80
$Hg^{2+} + 2e^- \rightleftharpoons Hg(\ell)$	+ 0,85
$NO_3^- + 4H^+ + 3e^- \rightleftharpoons NO(g) + 2H_2O$	+ 0,96
$Br_2(\ell) + 2e^- \rightleftharpoons 2Br^-$	+ 1,07
$Pt^{2+} + 2e^- \rightleftharpoons Pt$	+ 1,20
$MnO_2 + 4H^+ + 2e^- \rightleftharpoons Mn^{2+} + 2H_2O$	+ 1,23
$O_2(g) + 4H^+ + 4e^- \rightleftharpoons 2H_2O$	+ 1,23
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O$	+ 1,33
$C\ell_2(g) + 2e^- \rightleftharpoons 2C\ell^-$	+ 1,36
$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$	+ 1,51
$H_2O_2 + 2H^+ + 2e^- \rightleftharpoons 2H_2O$	+1,77
$Co^{3+} + e^- \rightleftharpoons Co^{2+}$	+ 1,81
$F_2(g) + 2e^- \rightleftharpoons 2F^-$	+ 2,87

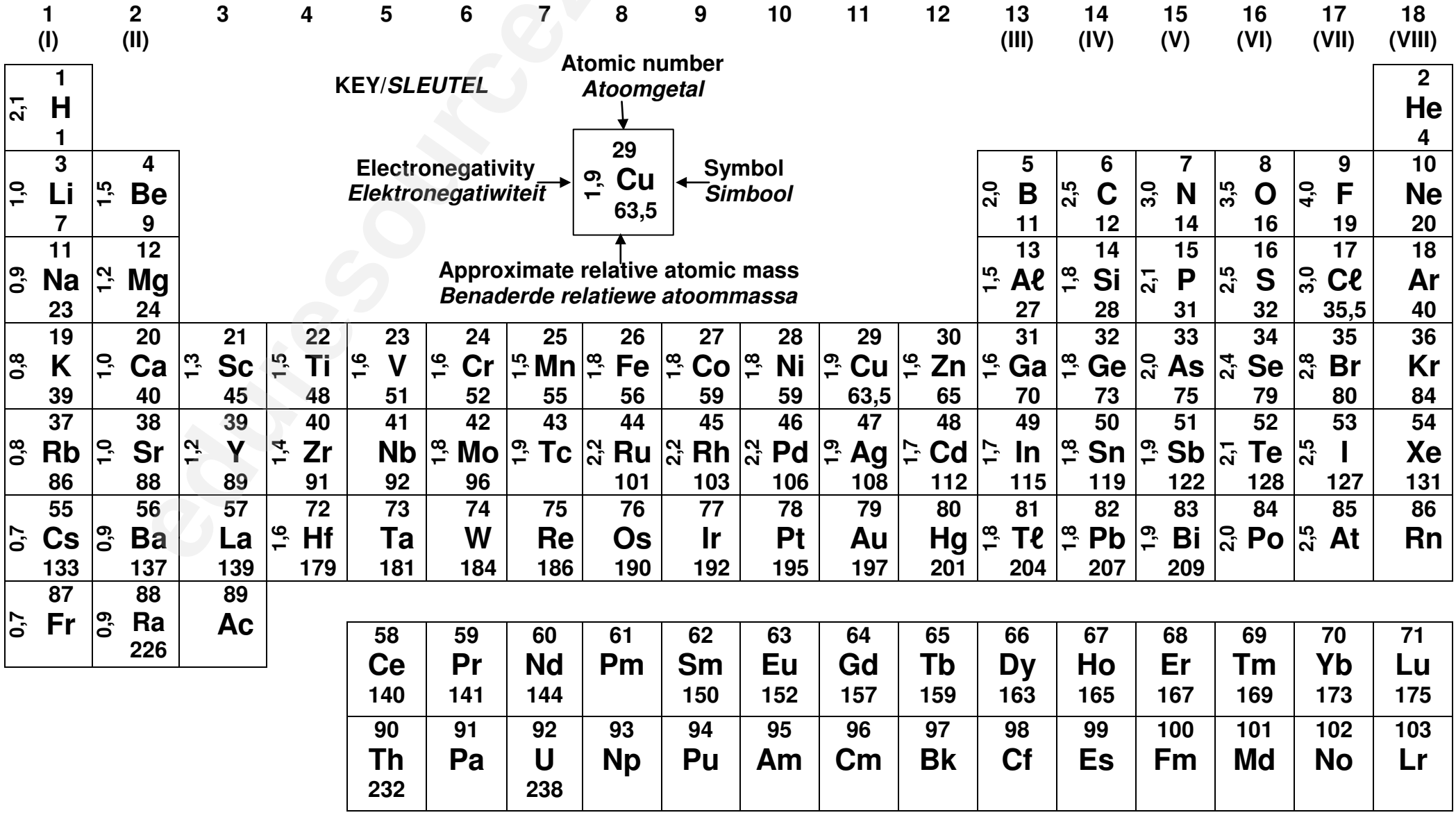
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TABLE 3: THE PERIODIC TABLE OF ELEMENTS
TABEL 3: DIE PERIODIEKE TABEL VAN ELEMENTE



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