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GRADE 12

PHYSICAL SCIENCES

CRASH COURSE

BY NAEEM MOHAMED

NAME: _____

MODULE 0: IMPORTANT INFORMATION

A. CONTENTS

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B. GENERAL ADVICE FOR 2021 MATRICULANTS

2021 – The year you write your final school examinations! Those who excel during this vital year will open up your learning and earning opportunities. Use your final year of study well. Attend all your classes in school and any extra tuition offered to you, both privately and by your school. Eat healthy, play sports and avoid any activity that undermines your studying and preparation. At the same time, remain calm as stressing too much can work against you.

Keep up to date with the latest matric news in newspapers and on the internet. Work through previous year's examination papers, exemplar papers as well as departmental papers and any sample papers prepared for you by your tutors and teachers. Ask your tutors / teachers to work through the questions, answers and examination technique with you.

Do everything you possibly can to convert twelve years of school into a National Senior Certificate with excellent marks, while making the most of probably the most enjoyable year of your schooling life.

Good luck!



Naeem Mohamed

C. COURSE STRUCTURE

The physical science course accompanying this booklet is focused on preparing you for the trial and final examinations. Theory and questions from national, IEB and exemplar papers are worked through during the course. Please note that the theory presented is a summary and does not replace your textbook.

D. MATRIC HELP ON THE INTERNET

Visit the following websites regularly to download past papers, media publications, workbooks and other valuable physics resources:

<https://education.gauteng.gov.za/pages/Exam-Papers.aspx>
https://www.docscientia.co.za/index.php?option=com_content&view=article&id=134
<https://www.stanmorephysics.com/>

E. FORMAT OF PHYSICS AND CHEMISTRY PAPER

Duration: 3 hours	Marks
SECTION A: Multiple-choice questions	20
SECTION B: Longer questions assessing all themes	130
Total	150

F. MARK DISTRIBUTION FOR PHYSICAL SCIENCE CAPS GRADE 12

Paper 1:

Knowledge Area	Theme	Marks
Mechanics	Momentum, Impulse and change in momentum	±42%
	Vertical projectile motion	
	Work, power and energy	
	Newton's Laws Grade 11	
Waves, sound and light	Doppler effect	±11%
Electricity and magnetism	Electrostatics Grade 11	±37%
	Electric circuits (including Grade 11)	
	Electrodynamics	
Matter and materials	Optical phenomena and properties of materials	±10%

Paper 2:

Knowledge Area	Theme	Marks
Matter and materials	Organic Chemistry	±38%
Chemical Change	Rates of Reaction and Chemical Equilibrium	±62%
	Acids and Bases	
	Electrochemical Reactions	

G. PRIOR KNOWLEDGE REQUIRED FROM GRADES 10 AND 11

Physics from grade 11	Chemistry from grades 10 and 11
Newton's Laws (Newton 1, 2, 3 and Newton's Law of Universal Gravitation) and Application of Newton's Laws.	Representing chemical change (grade 10)
Electrostatics (Coulomb's Law and Electric field)	Intermolecular forces (grade 11)
Electric circuits (Ohm's Law, Power and Energy)	Stoichiometry (grade 11)
	Energy and Change (grade 11)

MODULE 1: MECHANICS

1. WORK, ENERGY AND POWER

- Work** - work is done when a resultant force moves an object. **Unit:** Joules (J)

$$W = F\Delta x \cos \theta$$

Work is not done by a body circulating a planet a constant distance away from its centre since the distance remains the same, and also when applying a force on an object which does not move.

- Energy** - Energy is the capacity for doing work. **Unit:** Joules (J). Types of energy:
 - Potential energy** - energy that a body has as a result of its state or position. **Unit:** Joules (J)

$$U = E_p = mgh$$
 - Kinetic energy** - Energy that a body has as a result of its motion. **Unit:** Joules(J)

$$K = E_k = \frac{1}{2}mv^2$$
 - Mechanical Energy (M.E.)** – is the sum of the potential energy and the kinetic energy of a body.
- Conservative forces** – a force is conservative if the net work done by a force in moving an object around a closed path, starting and ending at the same point is zero. The gravitational force is an example of a conservative force. Examples of non-conservative forces include air resistance, friction, tension and applied forces.
- Law of conservation of Mechanical Energy** – the total Mechanical Energy (M.E) is conserved in an isolated system. If there is no work done by external forces (W), then: $M.E_{\text{Before}} = M.E_{\text{after}}$
When work is done by non conservative forces such as heat, sound or friction: $W_{nc} = \Delta E_k + \Delta E_p$
- The **Work – Energy Theorem** states that the net work done on an object is equal to the change in the object's kinetic energy: $W_{net} = \Delta K = \Delta E_k = E_{kf} - E_{ki}$
- Power:** Power is the rate at which work is done or energy is expended. **Unit:** Watts (W)

$$P = \frac{W}{\Delta t}$$

If an object travels at a **known constant velocity**, use: $P_{ave} = Fv_{ave}$

The inclined plane diagram – we often use the inclined plane diagram to solve problems based on work and energy.

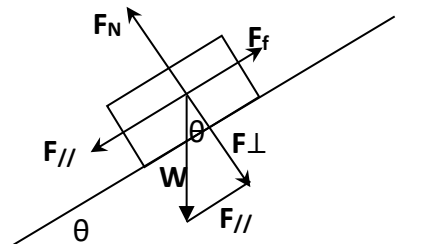
$F_{//}$ = force parallel to the surface: $F_{//} = mg \sin \theta$

F_f = force of friction that keeps the object stationary.

W = Weight of the Object.

$F_{\perp}$ = force perpendicular to surface: $F_{\perp} = mg \cos \theta$

F_N = Normal Force.



**** Note that the force of friction acts downwards if the object is moving up the plane, but upwards if the object moves down the plane or is stationary.**

- Newton's 1st Law of Motion** - A body will remain in a state of rest or uniform motion in a straight line unless an unbalanced force acts on it.
 - Inertia** - is that property of a body that resists any change to its state of rest or motion. It is an application of Newton's 1st law (it is not a law).
- Newton's 2nd Law of Motion** – The acceleration of a body is directly proportional to the net (resultant) force exerted on it and inversely proportional to its mass, in the direction of the applied force.

$$F_{NET} = ma$$

where F_{NET} = net force (N), m = mass (kg) and a =acceleration ($m \cdot s^{-2}$)

- **Newton's 3rd Law of Motion** - if Body A exerts a force on Body B, then Body B will exert an equal but opposite force on Body A.
- **Newton's Law of Gravitation** – every particle in the universe exerts a gravitational force of attraction on every other particle. The force is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

$$F = \frac{Gm_1m_2}{r^2} \quad g = \frac{Gm}{r^2}$$

Where $G = 6,67 \times 10^{-11} \text{N} \cdot \text{m}^2 \cdot \text{kg}^{-2}$, F = force(N), m_1 and m_2 = mass(kg) and r = distance(m)

- **Coefficient of static friction (μ_s – stationary objects) and kinetic friction (μ_k – moving objects)**
 $f_{s(\text{max})} = \mu_s N$ $f_k = \mu_k N$ where f = limiting or kinetic frictional force (N) and N = Normal force (N)

2. MOMENTUM

- **Momentum** is the quantity measured by the product of its mass and velocity. It is a vector quantity. **Unit:** $\text{kg} \cdot \text{m} \cdot \text{s}^{-1}$ **$p = mv$**
- **Law of conservation of momentum** - In an isolated or closed system (absence of external forces) the total linear momentum remains the same.
- Types of collisions and applicable equations:
 - **Elastic collisions** – Kinetic energy before and after the collision is the same.
 - **Inelastic collisions** – Kinetic energy during the collision is not conserved.
 - If objects collide and separate after the collision: $m_1v_{1i} + m_2v_{2i} = m_1v_{1f} + m_2v_{2f}$
 - If objects stick together after collision: $m_1v_{1i} + m_2v_{2i} = (m_1 + m_2)v_f$ If objects together before collision: $(m_1 + m_2)v_i = m_1v_{1f} + m_2v_{2f}$
- **IMPULSE (Newton's 2nd Law in terms of momentum)** – $\Delta p = m(v_f - v_i)$.
- **Net force** is the rate of change of momentum: $F_{\text{net}} = \frac{m(v_f - v_i)}{\Delta t}$

3. FALLING BODIES

- Formulae:

$$v_f = v_i + g\Delta t$$

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

$$v_f^2 = v_i^2 + 2g\Delta y$$

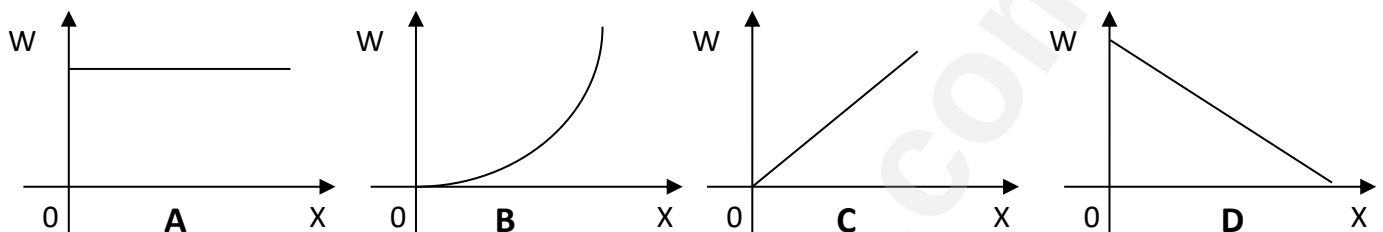
$$\Delta y = \left(\frac{v_i + v_f}{2} \right) \Delta t$$

Δy = displacement in meters (m)
 v_i = initial velocity ($\text{m} \cdot \text{s}^{-1}$)
 v_f = final velocity ($\text{m} \cdot \text{s}^{-1}$)
 g = gravitational acceleration ($\text{m} \cdot \text{s}^{-2}$)
 Δt = time in seconds(s)

EXAM / EXAM TYPE QUESTIONS

MULTIPLE CHOICE QUESTIONS

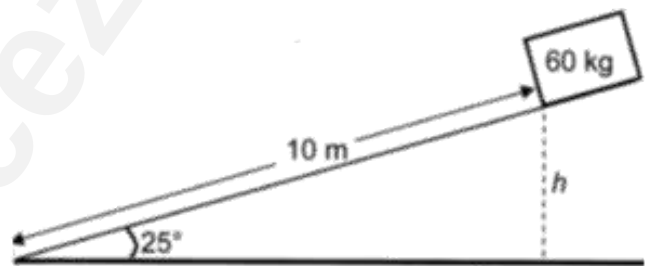
1. A constant resultant force acts on a body moving from rest in a straight line. Which one of the following graphs best represents the work done (W) on the body as a function of the displacement of the body (X)?



[A 2003]

LONG QUESTIONS

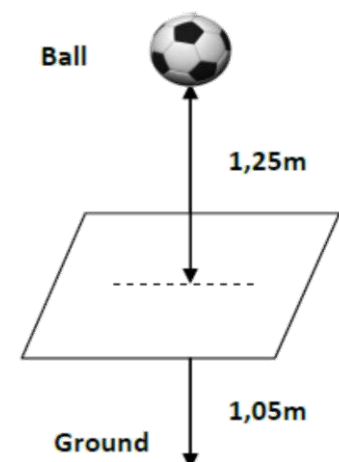
1. A box of mass 60 kg starts from rest at height h and slides down a rough slope of length 10 m , which makes an angle of 25° with the horizontal. It undergoes a constant acceleration of magnitude $2\text{ m}\cdot\text{s}^{-2}$ while sliding down the slope.



- Draw a free-body diagram to show all forces acting on the box while it slides down the slope. The box reaches the bottom of the slope. Calculate the following:
- The kinetic energy of the box, using equations of motion.
- The work done on the box by the gravitational force.
- The work done on the box by the frictional force, using the work-energy theorem.
- The magnitude of the frictional force acting on the box.

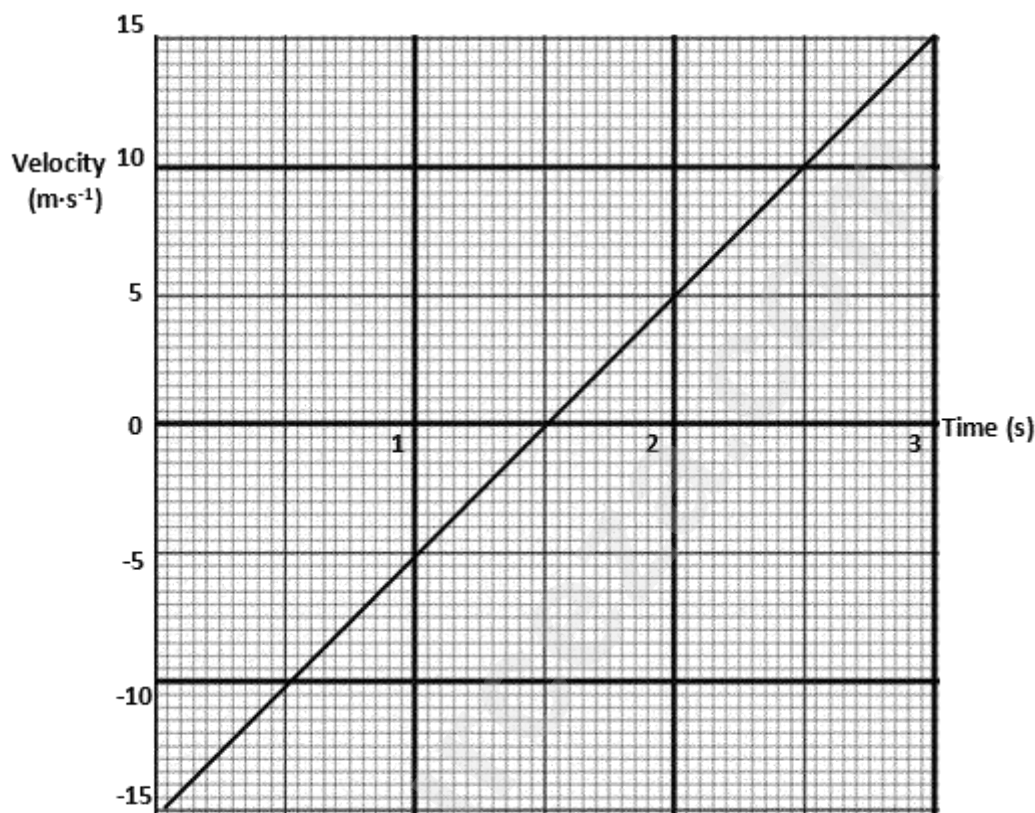
[NM 2010]

2. A glass plate is mounted horizontally $1,05\text{ m}$ above the ground. An iron ball of mass $0,40\text{ kg}$ is released from rest and falls a distance of $1,25\text{ m}$ before striking the glass plate and breaking it. The total time taken from release to hitting the ground is recorded as $0,81\text{ s}$. Assume that the time taken to break the plate is negligible.



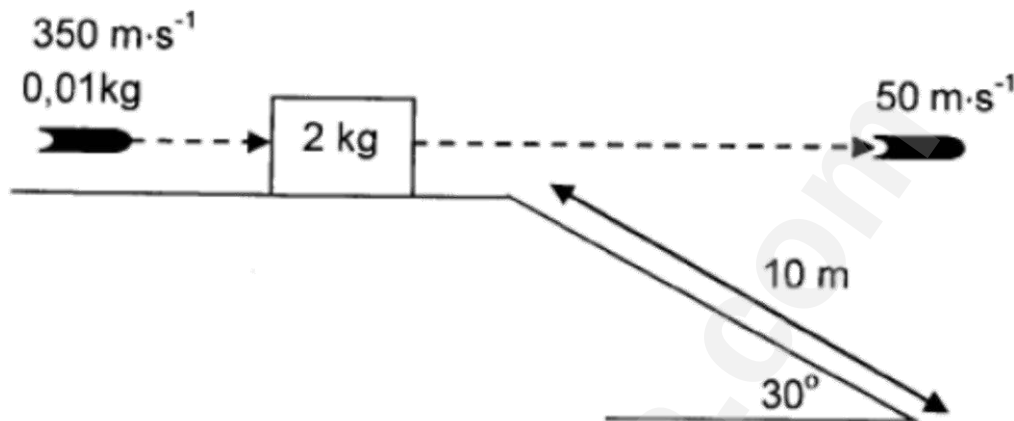
- Calculate the speed at which the ball strikes the glass plate.
- Show that the ball's speed immediately after breaking the plate is $2,03\text{ m}\cdot\text{s}^{-1}$.
- Calculate the magnitude and give the direction of the change of momentum which the ball experiences during its contact with the glass plate.
- Give the magnitude and the direction of the impulse which the glass plate experiences when the ball hits it.
- Calculate the work done in breaking the glass plate.
- Explain whether the mechanical energy of the ball is conserved or not during its fall to the ground.

3. Mehul throws a ball with a mass of 200g vertically upward with an initial velocity of $15\text{m}\cdot\text{s}^{-1}$. The ball falls back in his hand. The following velocity / time graph represents the motion of the ball.

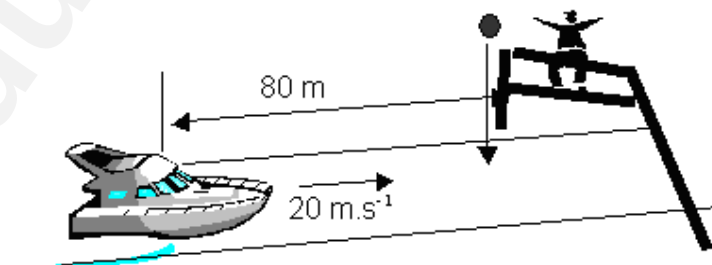


- How long was the ball in the air?
 - What is the velocity of the ball after 3s?
 - What will
 - the velocity; and
 - the acceleration of the ball be at its maximum height?
 - Use the graph to calculate the total distance the ball travelled in the air.
 - Draw a sketch graph of the position vs. time graph for the above. Show relevant values on both axes of the graph and use the starting point of the ball as a reference point. [NN 2000]
4. The earth has a mass of $5,98 \times 10^{24}\text{kg}$ and the moon has a mass of $7,35 \times 10^{22}\text{kg}$. The distance from the centre of the moon to the centre of the earth is $3,84 \times 10^8\text{m}$. A rocket with a total mass of 1200kg is $3 \times 10^8\text{m}$ from the centre of the earth and directly in between the earth and the moon. Find the net gravitational force on the rocket from the earth and moon.

5. A 0,01 kg bullet travelling at $350\text{ m}\cdot\text{s}^{-1}$ passes horizontally through 2kg block that rests on a frictionless surface. The bullet emerges with a speed of $50\text{ m}\cdot\text{s}^{-1}$.



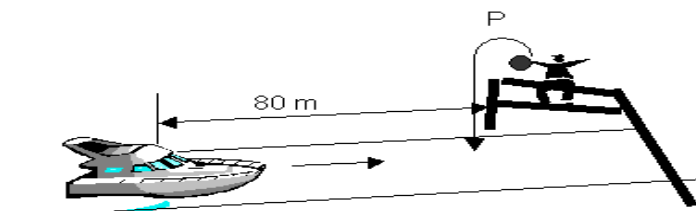
- Determine the speed of the 2kg block after the collision.
The 2kg block slides across the horizontal surface and then moves down a rough 30° incline, causing it to experience a constant frictional force of 1,95 N. The length of the incline is 10m.
 - Draw a labelled free-body diagram to show ALL the forces acting on the block while it slides down the slope.
 - Determine the net work done by the block.
 - Determine the speed of the block at the bottom of the incline using work and energy methods.
6. Rayhaan is driving his new BMW X5 of mass $2,5 \times 10^4\text{ kg}$ and is approaching a stationary SLK of mass $2,5 \times 10^4\text{ kg}$ at $1\text{ m}\cdot\text{s}^{-1}$. Ameera walks by and Rayhaan accidentally collides with the SLK. Calculate the velocity of each vehicle after the collision if they move apart after the collision with equal momenta. [DNGr11 2009]
7. A man holding a parcel is standing on a bridge 40 m above the level at which a boat, approaching the bridge, will pass. The boat is travelling at a velocity of $20\text{ m}\cdot\text{s}^{-1}$. The man must drop the parcel such that the pilot of the boat catches the parcel as he passes underneath the bridge.



- If the parcel was dropped from rest from the edge of the bridge, show that the time for the parcel to fall 40m, would be 2,86 seconds.
- The boat is 80m from the bridge. What magnitude of acceleration should the boat produce to
- enable the pilot to catch the parcel if it was dropped **from rest**?

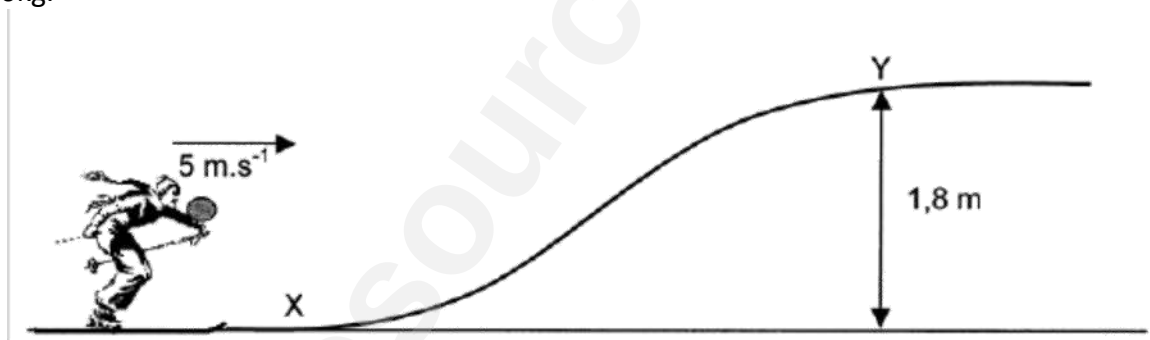
The man, however, needs to get rid of the parcel while the boat is still 80m from the foot of the bridge and still travelling at a constant velocity. He therefore projects it vertically upwards

at $10\text{m}\cdot\text{s}^{-1}$ so that the parcel is in the air for a longer period of time.



- d. What is the magnitude of the acceleration of the parcel at its maximum height (point P)?
- e. Predict, by doing appropriate calculations **to the nearest second**, whether or not the pilot will be able to catch the package while passing underneath the bridge if he is 80 m away from the edge of the bridge at the time of projection.

8. Electronic equipment being transported on trucks and ships is often wrapped in bubble plastic (plastic filled with air bubbles). Use physics principles to explain why bubble plastic is preferred to ordinary plastic. [NA 2008]
9. Zainab is skiing to the right towards point X at the bottom of a snow slope which is 1,8m high, carrying a 10kg parcel. Her velocity is $5\text{m}\cdot\text{s}^{-1}$ and the total mass of Raeesa, her skis and the parcel is 80kg.



Before she reaches the beginning of the slope, she is uncertain whether she will reach point Y, at the top of the slope, while still holding the parcel. Being a physics student, she decides to throw the parcel horizontally with a velocity v to increase her forward speed. Ignore all friction.

- a. In which direction must Raeesa throw the parcel to assist her forward speed?
- b. Name 2 principles / laws Raeesa can apply to calculate her new forward speed.
- c. Calculate the magnitude of the minimum velocity with which she must throw the parcel in order to reach the top of the slope at point Y.
- d. By calculation, determine if the collision is elastic or inelastic. [NN 2004]

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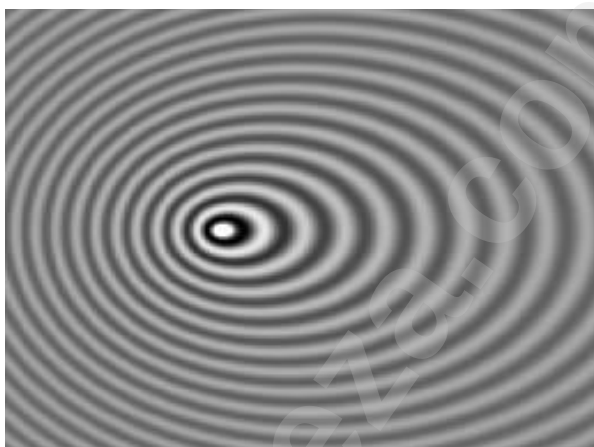
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MODULE 2: WAVES, SOUND AND LIGHT

1. THE DOPPLER EFFECT

- The **Doppler Effect** is experienced whenever the speed of an object is slower than the speed of sound it emits e.g. when a car passes you, the pitch of the sound it makes seems to drop.



- As the distance between the object moving and the listener increases, so does the wavelength, and thus the frequency of waves produced decreases. This means that the pitch will be lower.

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

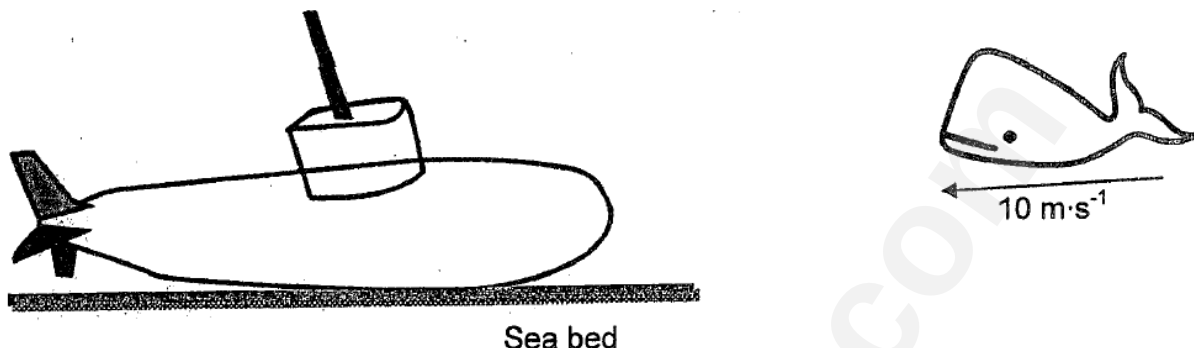
- The speed of sound is usually close to $340\text{m}\cdot\text{s}^{-1}$ but varies according to different factors. Use the value given in the question.
- Use:
 - $v + v_L$ – Listener moving towards source.
 - $v - v_L$ – Listener moving away from source.
 - $v + v_s$ – Source moving away from listener.
 - $v - v_s$ – Source moving towards listener.

MULTIPLE CHOICE QUESTIONS

3. Astronomers analyse the spectrum of light from a star. They have found that the light from other galaxies moving away from us has a red shift. Which of the following statements are **FALSE**?
- Light shifts to red since red has the lowest frequency of visible light.
 - Light shifts to red since red has the longest wavelength of visible light.
 - Red shift is due to the Doppler Effect of electromagnetic waves.
 - An increase in red shift implies that galaxies are receding slowly and that the universe is expanding.

LONG QUESTIONS

1. A submarine is stationary on the sea bed as shown in the diagram. The sonar system of the submarine detects a whale moving straight towards the submarine at a velocity of $10\text{m}\cdot\text{s}^{-1}$.



The sonar system operates at a frequency of $2,3 \times 10^4$ Hz. If the speed of the sonar wave in water is $1435 \text{ m} \cdot \text{s}^{-1}$, calculate the frequency of the signal received by the submarine after being reflected from the whale. [GDE Sep 2013]

2. Hearing the siren of an approaching fire truck, you pull over to the side of the road and stop. As the truck approaches, you hear a tone of 470 Hz; as the truck recedes, you hear a tone of 400 Hz. How much time will it take the truck to get to the fire 2.5 km away assuming it maintain a constant speed?

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MODULE 3: ELECTRICITY

1. ELECTROSTATICS AND ELECTRIC FIELDS

- **Coulombs Law:** The force of attraction or repulsion between two charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them.

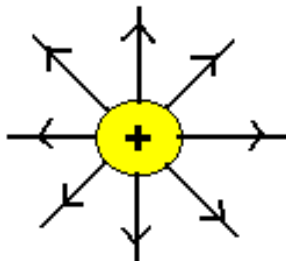
$$F = \frac{k Q_1 Q_2}{r^2}$$

Where F = force (N), $k = 9 \times 10^9 \text{ N}\cdot\text{m}^2\cdot\text{C}^{-2}$

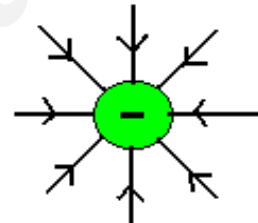
Q is the charge of the objects (C), r is the distance (m)

- **Electric Field:** is the region around a charged object in which other charged objects experience a force. The following are electric field patterns for various configurations of charges:

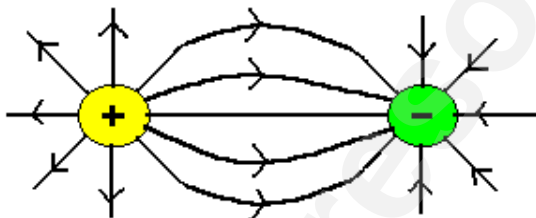
Positive Charge:



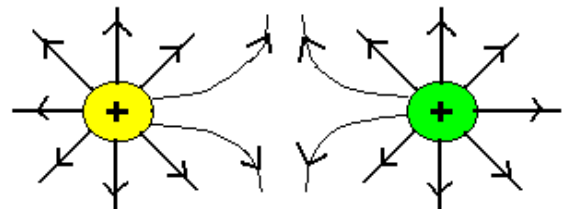
Negative Charge:



Unlike Charges:



Like Charges



The further away a test charge is placed in the field, the smaller the force experienced.

- **Electric Field Strength** – at a point is the force which 1 unit of positive charge possesses at that point. We can calculate the strength of the electric field as follows:

$$E = \frac{F}{Q}$$

Where E = Electric Field Strength ($\text{N}\cdot\text{C}^{-1}$), F is the Force (N) and Q is the charge (C)

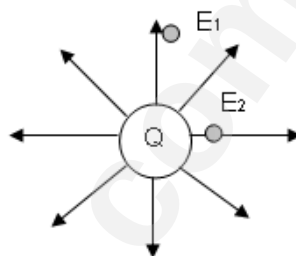
When determining the field strength at a point that is a certain distance from a point charge, use

$$E = \frac{k Q}{r^2} \quad \text{Where } k = 9 \times 10^9 \text{ N}\cdot\text{m}^2\cdot\text{C}^{-2}, Q = \text{Charge (C)}, r = \text{distance away from charge (m)}$$

EXAM / EXAM TYPE QUESTIONS

MULTIPLE CHOICE QUESTIONS

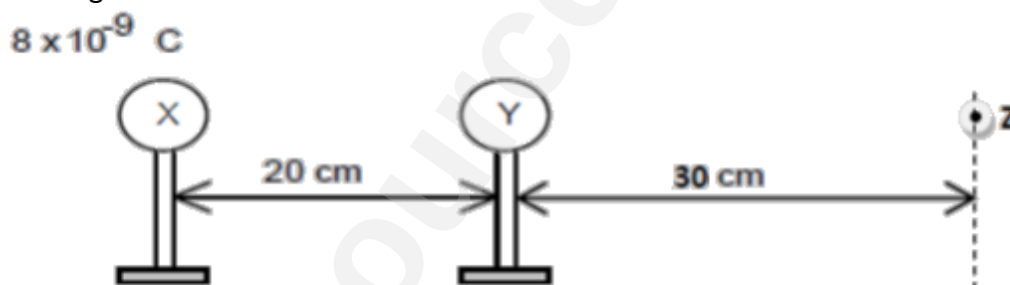
1. The magnitude of the electric field intensities at two points in the electric field of a large positive charge Q are measured and found to be E_1 and E_2 respectively. How do the magnitudes of the electric fields E_1 and E_2 compare?
- $E_1 < E_2$
 - $E_1 = E_2$
 - $E_1 > E_2$
 - Magnitudes cannot be compared without further information.



[WCJ 2008]

LONG QUESTIONS

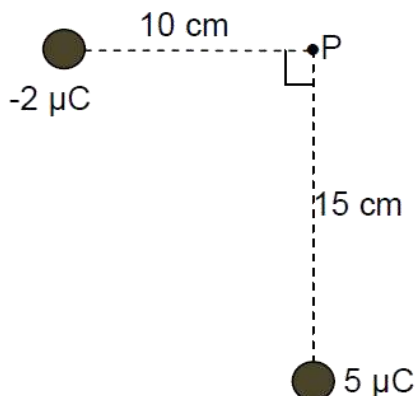
1. Two identical very small charged spheres X and Y on insulated stands are placed 20 cm apart as indicated on diagram. X has a charge of $8 \times 10^{-9} \text{ C}$ and the attractive electrostatic force between the two charges are $7 \times 10^{-6} \text{ N}$.



- Calculate the charge on Y.
The charge Y is brought closer towards X and is made to touch X. Sphere Y is then moved back to its original position.
- Will the charge on X be **smaller, the same or greater than** before it was moved?
- Now calculate the net electric field at point Z due to the presence of both X and Y.

[YE 2012 NM]

2. A positive charge of $5 \mu\text{C}$ is positioned 15 cm from point P while a negative charge of $2 \mu\text{C}$ is positioned 10 cm away, as shown in the diagram below.



Calculate the magnitude of the electric field at point P due to both charges.

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2. ELECTRIC CIRCUITS

- Current** – is the rate at which charges flow.

$$I = \frac{Q}{t}$$

Where I is the current in amperes (A), Q is the charge in Coulombs(C),
t is the time in seconds(s).

- Ohm's Law** – The current in conductor is directly proportional to the potential difference across it provided that the temperature remains constant.

$$R = \frac{V}{I}$$

Where R = resistance in ohms (Ω), V = potential difference (V),
I = current in amperes (A).

- Ohmic conductors** follow ohms law and non ohmic do not. A filament bulb is a non-ohmic conductor because it releases heat. A diode is a further example of a non-ohmic conductor. Circuits containing no capacitances or inductances are examples of ohmic conductors.
- The Heating Effect of an Electric Current** – Electrical energy (J) is converted into kinetic energy of the particles in the conductor. As the kinetic energy increases, the temperature of the conductor increases. Formulae:

$$W = VQ$$

$$W = VIt$$

$$W = \frac{V^2 t}{R}$$

$$W = I^2 R t$$

- Electrical Power** – Power is the rate at which work is done. The greater the power in a bulb, the brighter the bulb will glow. Unit: Watts. Formulae:

$$P = VI$$

$$P = \frac{V^2}{R}$$

$$P = I^2 R$$

- Resistance** – is the measure of difficulty that a charge experience when passing through a conductor.

- In a Series Circuit: $R = R_1 + R_2 + R_3$

- In a Parallel Circuit:

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \dots$$

Invert the result to find total resistance.

- Behaviour of **current and voltage** is series / parallel:

	Series	Parallel
Current	Remains the same	Is divided
Voltage	Is divided	Remains the same

- **Internal Resistance** – The resistance that the cells offer towards charge in the circuit is known as internal resistance. When it is given that the EMF of the cells differs from the potential difference across the cells, some internal resistance exists. This difference is known as lost volts. Real batteries always have internal resistance.
- The voltmeter reading across the cells when the **circuit is open is the EMF** of the cells and the voltmeter reading when the **circuit is closed the potential difference**.

$$\text{lost volts} = \text{emf} - \text{pd}$$

$$r = \frac{\text{'lost volts'}}{I}$$

$$\text{emf} = I(R + r)$$

where emf = voltage when circuit is open (V), r = internal resistance of the cells (Ω)

I = current (A), R = total resistance of the external circuit (Ω)

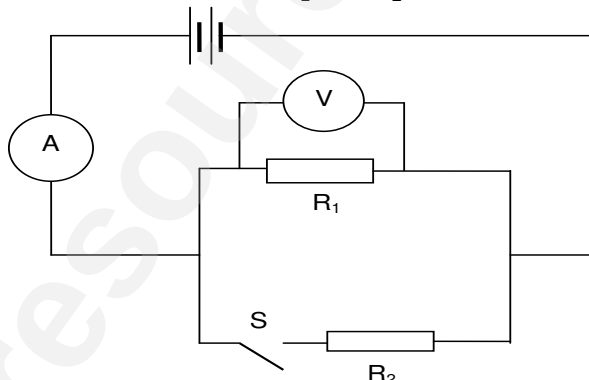
EXAM / EXAM TYPE QUESTIONS

ONE WORD ITEMS

1. Work done in moving electric charge from a high potential to a low potential in an electric field. [WCS 2008]

MULTIPLE CHOICE QUESTIONS

1. Consider the following electric circuit. When switch S is open the reading on the voltmeter is V and the reading on the ammeter is A. The resistors R_1 and R_2 are identical.

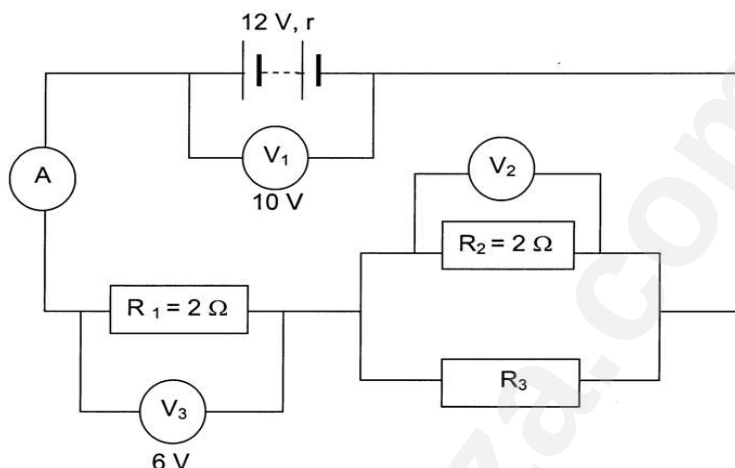


When switch S is closed how will the readings on the voltmeter and ammeter change? [WCS 2008]

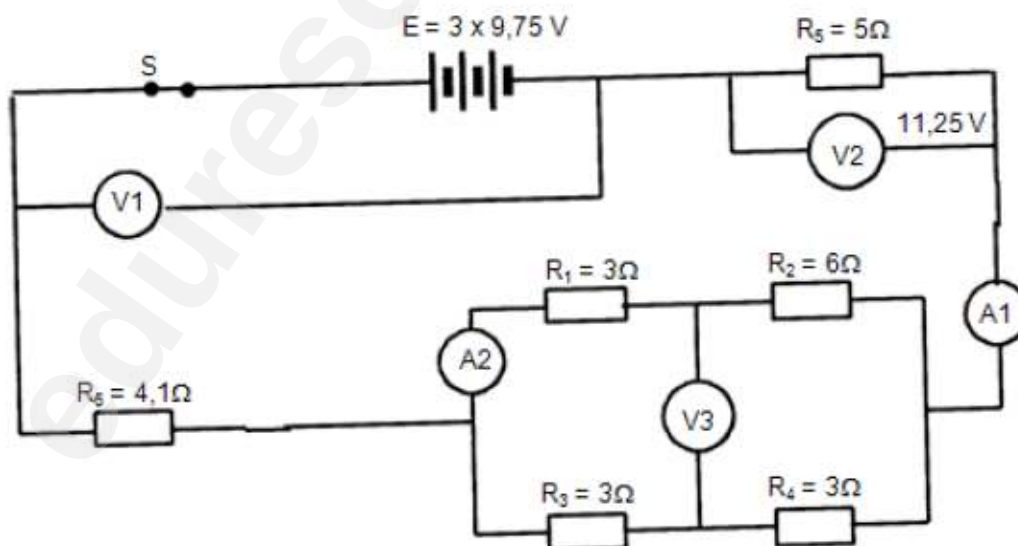
	READING ON AMMETER	READING ON VOLTMETER
A	less than A	equal to V
B	less than A	more than V
C	greater than A	less than V
D	greater than A	equal to V

LONG QUESTIONS

1. In the circuit below, the battery has an EMF of 12V and an unknown internal resistance. The resistance of resistor R_3 is also unknown. Voltmeters V_1 and V_3 have readings of 10V and 6V respectively.



- Calculate the current in the circuit.
 - Calculate the current in resistor R_2 .
 - Calculate the resistance of resistor R_3 .
 - Calculate the internal resistance of the battery.
- [NN 2007]
2. Peter connects electrical components as shown in the circuit diagram. The three cells have an EMF of 9,75 V each. The voltmeters have a very high internal resistance, while the internal resistance of the ammeters can be ignored. The reading on V_2 is 11,25 V.



Calculate the following when the switch S is closed:

- The reading on ammeter A_1 .
- The total resistance of the circuit
- The reading on voltmeter V_1 .
- The reading on ammeter A_2 .
- The reading on voltmeter V_3 .

3. In the two circuits represented below, the same battery is used. The emf of the battery and its internal resistance, r , are unknown. When Katleho connects three resistors, 4Ω , 10Ω and 20Ω in parallel, as shown in Figure 1, the voltmeter reads 10V . Prishanca then disconnects the parallel combination and instead connects a resistor of $5,5\Omega$ in series with the same battery as shown in Figure 2. The voltmeter then reads 11V .

Figure 1

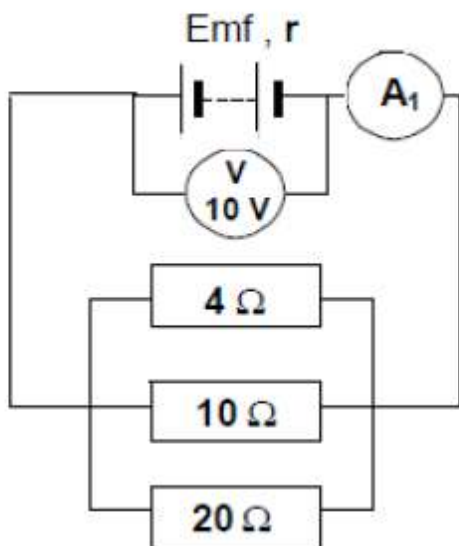
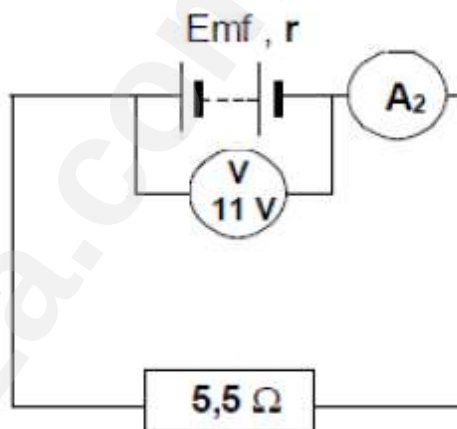


Figure 2



- Calculate the effective resistance of the three external resistors in Figure 1.
- Explain why the voltmeter reading in Figure 2 is greater than that in Figure 1.
- Calculate the reading on ammeter A_1 in Figure 1.
- Calculate the reading on ammeter A_2 in Figure 2.
- Calculate the internal resistance, r , of the battery.
- Calculate the emf of the battery.

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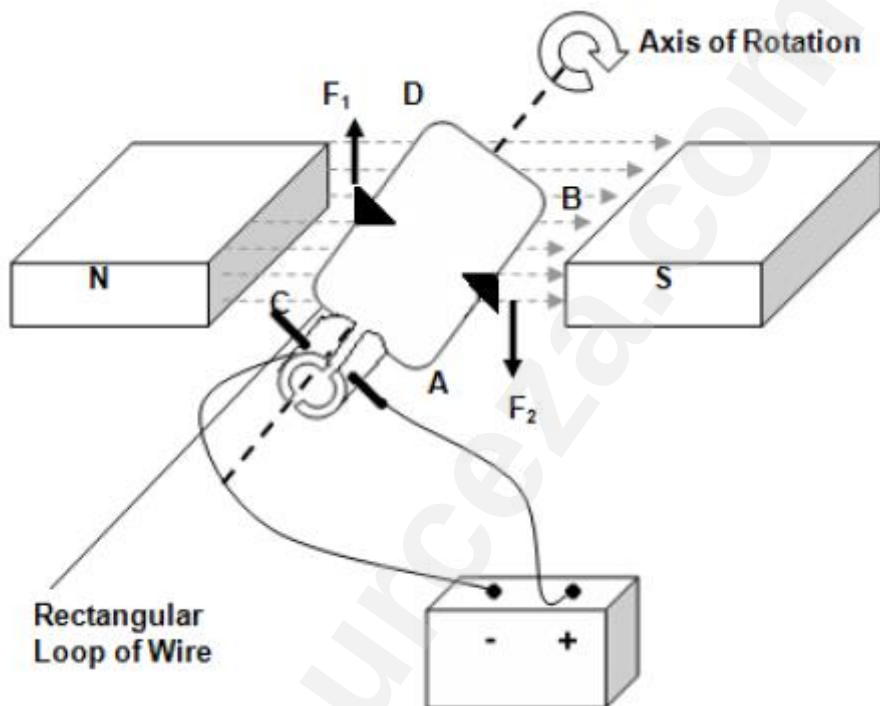
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3. ELECTRODYNAMICS

- **THE DIRECT CURRENT MOTOR** - In an electric motor, a current carrying loop rotates in a magnetic field so that **electrical energy is converted into mechanical energy**. The motor is constructed by placing a rectangular loop of wire between the poles of a magnet, and connecting the loop to a battery by means of **brushes** (contacts) and a **split ring commutator**.

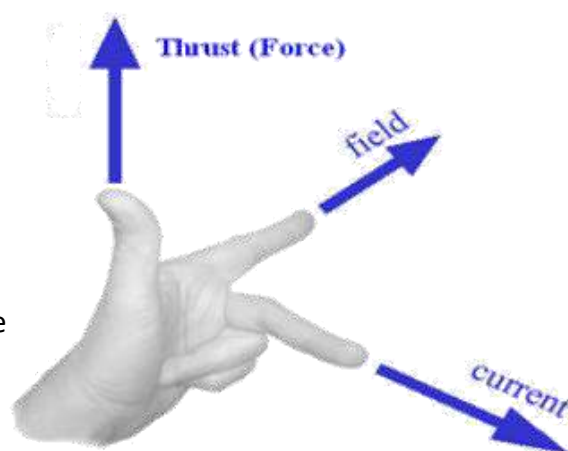


The **speed of rotation of the motor** can be increased by:

- Increasing the number of coils (armature).
- Increasing the strength of the magnetic field.
- Increasing the current in the coils.

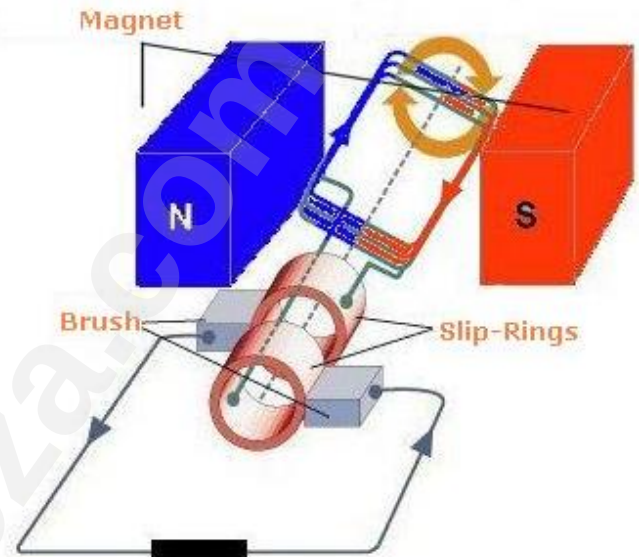
F_1 and F_2 can be determined using: **Fleming's left hand motor rule**: This rule helps us to predict the direction of the force which acts on a current that passes through a magnetic field.

- Place the **Forefinger, Centre(middle) finger and Thumb** of the left hand at right angles.
- Point the **Forefinger** in the direction of the **Field**.
- Point the **Centre finger** in the direction of the conventional **Current**.
- The **Thumb** will point in the direction of the **Thrust**.

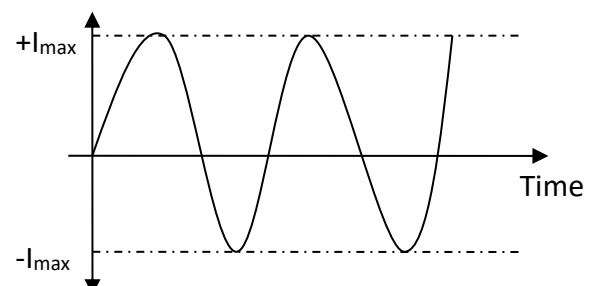
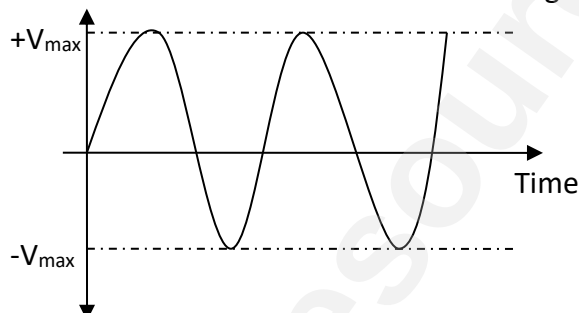


- **THE ALTERNATING CURRENT GENERATOR** - A generator (or **alternator**) is a device used to **convert mechanical energy into electrical energy**. A coil is magnetically turned in a magnetic field causing a current to be induced in the coil because of the magnetic flux linkage through the coil changes as it rotates (**Faraday's Law of electromagnetic induction**).

The generator is constructed by placing a rectangular loop of wire between the poles of a magnet, and connecting the loop to 2 metal ring called **slip rings** using **brushes** for contact.



ALTERNATING CURRENT: Current and voltage vary according to the sine graph as shown below.



Current reaches zero approximately 100 times a second in rapid succession so that lights in our homes and places of work appear on continuously.

The average power in an ac circuit is taken as half the maximum power:

$$P_{ave} = \frac{1}{2} P_{max} = \frac{1}{2} V_{max} I_{max} = V_{rms} I_{rms}$$

$$V_{rms} = \frac{V_{max}}{\sqrt{2}} \quad I_{rms} = \frac{I_{max}}{\sqrt{2}} \quad \text{where rms = root mean square.}$$

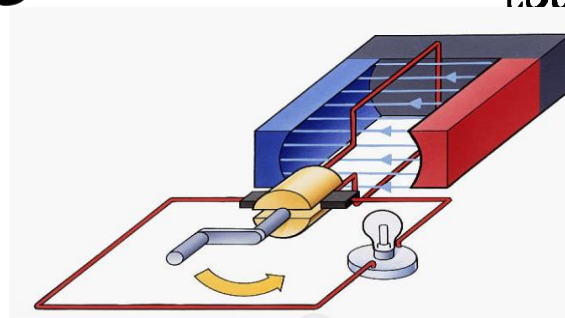
The power formula and Ohm's Law are stated as:

$$V_{rms} = I_{rms} R$$

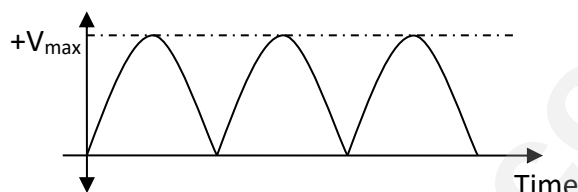
and

$$\begin{aligned} P_{ave} &= V_{rms} I_{rms} \\ &= I_{rms}^2 R \\ &= \frac{V_{rms}^2}{R} \end{aligned}$$

THE DIRECT CURRENT GENERATOR – can be constructed by replacing the slip rings with a split ring commutator.

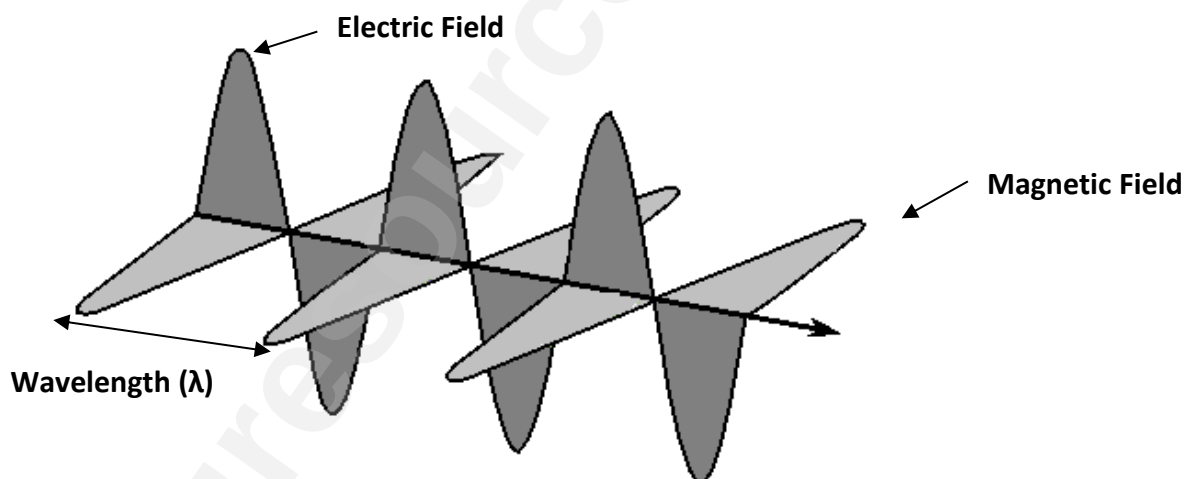


The voltage will now vary according to the graph as shown below:



4. ELECTROMAGNETIC RADIATION

- **ELECTROMAGNETIC WAVES:** Electromagnetic waves form when electrical charges oscillate rapidly. The oscillating charge is changing its position and velocity so the electric and magnetic fields it produces change continuously. The changing fields produce other fields nearby and the disturbance travels outwards.



- As the **electric field** increases, it induces an increasing **magnetic field** at **right angles** to it, and vice-versa. The waves, in the absence of any intervening absorbing medium, propagate indefinitely. Being a wave, the radiation is represented as a wavelength, λ having frequency, f . The speed of light (c) has a value of $3 \times 10^8 \text{ m.s}^{-1}$:
$$c = f \lambda$$
- Electromagnetic waves are transverse and can travel both in a material medium and in a vacuum.
- Light behaves as a wave and a particle.

De Broglie wavelength – $E = hf$ and $E = h \frac{c}{\lambda}$ where Planck's constant = $6,6 \times 10^{-34} \text{ J.s}$

- **The electromagnetic spectrum** - This is an arrangement of different electromagnetic radiations arranged in order of decreasing wavelength. (See inside of covers for diagram)
 - **Gamma rays** – These are high energy electromagnetic waves that are given off when a radioactive nucleus decays. Gamma rays are used in medicine to kill cancerous cells and for sterilization of equipment, in engineering to examine steel rods inside concrete and also to create pictures of the universe in astronomy. These can be harmful in large doses.

- **X-Rays** – are produced when fast moving electrons are slowed down suddenly. Bone and teeth absorb x-rays and thus appear easily on x-ray film. X-rays, however, pass easily through skin and muscle tissue. They are used by doctors to view bones, at airports to view the contents of luggage, etc. They can be harmful in high doses causing cancer.
- **Ultraviolet (UV) Rays** – can be produced by the discharge of an electric arc. The wavelength is shorter than that of visible light. They are used in energy-saving fluorescent tubes, on money-detectors to detect genuine notes and in scientific instruments.
- **Visible Rays** – Light is given off by excited electrons returning to their ground state. These are emitted by the sun as well as fire. This type of light is responsible for life on Earth.
- **Infrared Rays** – These result from the changes in the vibrational energy of molecules. They are invisible to humans. As the temperature increases, shorter waves are produced. Infrared can cause an increase in temperature when absorbed by matter. They are used in conventional ovens, optical fibres to carry signals, remote controls and for data transfer in mobile phones.
- **Microwaves** – These are produced by oscillations of free electrons in matter. They are used in satellite communications, radar speed trapping and vibrate water molecules to cook or warm up food.
- **Radiowaves** – These are produced by oscillations of free electrons in matter. They extend spherically from the point of transmission. Radio and television transmission use either AM, FM or TV radio waves. Cellular phones use radio waves with smaller wavelengths than TV and FM waves to transmit information.



EXAM / EXAM TYPE QUESTIONS

ONE WORD ITEMS

- The component needed to ensure continuous rotation in the DC electric motor.
- The fundamental principle on which electric generators work. [NM 2010]

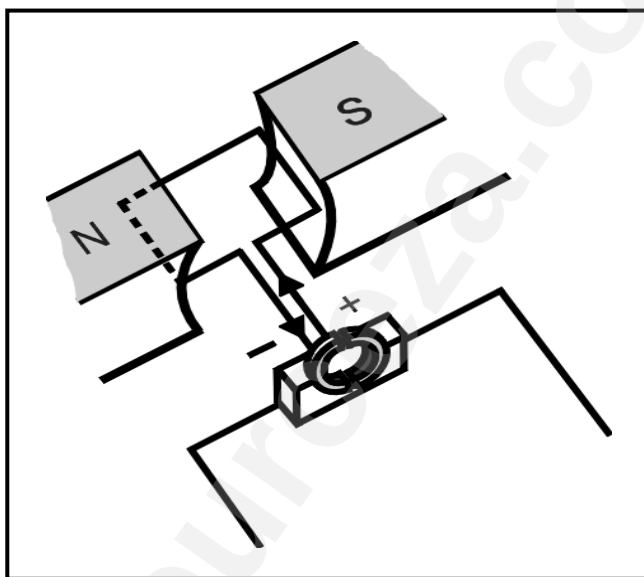
MULTIPLE CHOICE QUESTIONS

- Which electromagnetic wave in column X matches the everyday context described in column Y?

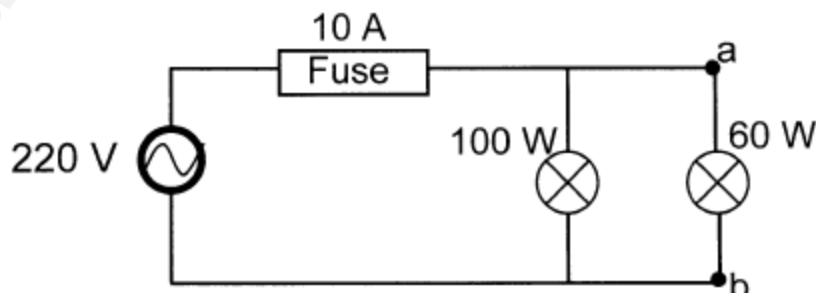
	Column X	Column Y
A	Microwaves	Can pass through metals
B	Radio Waves	Is diffracted round hills
C	Gamma Rays	Used in remote controls
D	Visible light	Used to kill cancer cells

LONG QUESTIONS

1. Electric motors are an important component of many modern electrical appliances. Electric motors are described as DC motors or as AC motors.
 - a. What energy conversion takes place in all electric motors?
 - b. What is the essential difference between DC motors and AC motors with regard to key components?
 - c. Consider the diagram below.



- i. In which direction (clockwise or anti-clockwise) will the coiled armature rotate if the switch is closed?
 - ii. Which law was used to determine the direction in (a) above?
 - iii. Why does the armature continue moving once the coiled armature has reached the vertical position?
2. Lights in most households are connected in parallel, as shown in the simplified circuit below. Two light bulbs rated at 100W; 220V and 60W; 220V respectively are connected to an AC source of rms value 220V. The fuse in the circuit can allow a maximum current of 10A.



- a. Calculate the peak voltage of the source.
- b. Calculate the resistance of the 100W light bulb, when operating at optimal conditions.
- c. An electric iron, with a power rating of 2200W, is now connected across points a and b. Explain, with the aid of a calculation, why this is not advisable. [NM 2010]

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MODULE 4: OPTICAL PHENOMENA AND PROPERTIES OF MATERIAL

1. EMISSION AND ABSORPTION SPECTRA

- For an electron to move between the orbitals in an atom, it must either release or absorb energy. If an object is heated, the electrons gain energy and may move to higher orbitals, placing the atom in an **excited state**. The electron cannot stay in the higher energy level and so drops back to the lower orbital. This is called **ground state** where it releases the excess energy. If electrons remain in the excited state they are said to be in the **metastable state**.
- Since energy is proportional to frequency different amounts of energy released are related to the colour of the light. A **continuous spectrum**, where colours fade into each other, is emitted by glowing solids, or liquids and gases under high pressure.
- Gases under low pressures will only emit a few frequencies of light and only a few lines of colour will be seen. This is called a **line emission spectrum** (coloured lines on dark background). (See diagram 5 inside cover)
- When light is passed through a cold gas before being shone through a prism and split into different colours and frequencies, the cooler gas absorbs certain frequencies of light. These then appear as black lines on the spectrum called **line absorption spectra** (black lines on a colour background). These lines appear in the Sun. (See diagram 5 inside cover)
- Absorption and emission spectra are used for identifying or **fingerprinting** an element. For a particular element, the colours in the emission spectrum correspond to the black lines in the absorption spectrum.

2. TRANSMISSION AND SCATTERING OF LIGHT

- **The interaction of light with metals:** When visible light strikes a metallic surface, **all frequencies that make up visible light are absorbed** by electrons to achieve different electron transitions. The electrons that are excited by resonating photons are usually very unstable in the higher energy levels, and tend to **drop back to their ground states**. In the process, photons of energy with the same wavelength, and hence colour, are **re-emitted**. This accounts for the good reflecting properties of metals and their shiny / silvery appearance.
- **Why is the sky blue?** When visible light moves through the atmosphere, the wavelengths hit water droplets and dust particles which are **much larger**, and are thus reflected, or bounced off in all directions. The different colours are all reflected equally and thus appear as **white light in clouds**. Gas molecules, on the other hand, are much smaller than the wavelength of visible light and thus absorb high frequency blue light. The blue light is then remitted in all directions by the gas molecule in a process called **Rayleigh scattering**. The lower frequency red light is unaffected and thus passes straight through. When we look at the sky, the blue light is reflected, thus giving the sky a blue colour.

3. THE PHOTOELECTRIC EFFECT

- The **photoelectric effect** occurs when electrons are ejected from metals if electromagnetic radiation with a high enough energy is shone onto the surface of metals.
- If **electrons are not ejected**, this means that the electromagnetic radiation does not have enough energy. Changing to a brighter light does not affect the energy of the light and will thus not cause any electrons to be ejected.
- If the **frequency of light shone on the metal is greater than the threshold frequency of the metal**, electrons will be ejected from the metal. This is because if an electron absorbs enough energy, it will jump up to the next level but if it absorbs a lot more energy, it will jump up out of the highest energy level and out of the atom altogether. The greater the intensity (brightness) of the light, the faster electrons are ejected, i.e. there more **photons** (packets of energy) in the beam.
- Each photon has a specific amount of energy, given by:

$$E = hf$$
 where E = energy of the photon (J), h = Planck's constant ($6,63 \times 10^{-34}$)
Work function is the minimum amount of energy required to remove an electron from the surface of a metal. Einstein formulated the photoelectric equation as:

$$hf = W + \frac{1}{2}mv^2$$
 where W = Work function (J), m = mass (kg) and v = velocity ($m.s^{-2}$)
- The photoelectric effect thus proves that **light is of a particle nature**, since photons can eject electrons from a metal. These electrons are called **photoelectrons**.
 It has also contributed to the **quantum theory** – a theory of matter and radiation. According to quantum theory, measurable physical variables such as energy and momentum can have only a discrete set of values (and hence are said to be quantized).

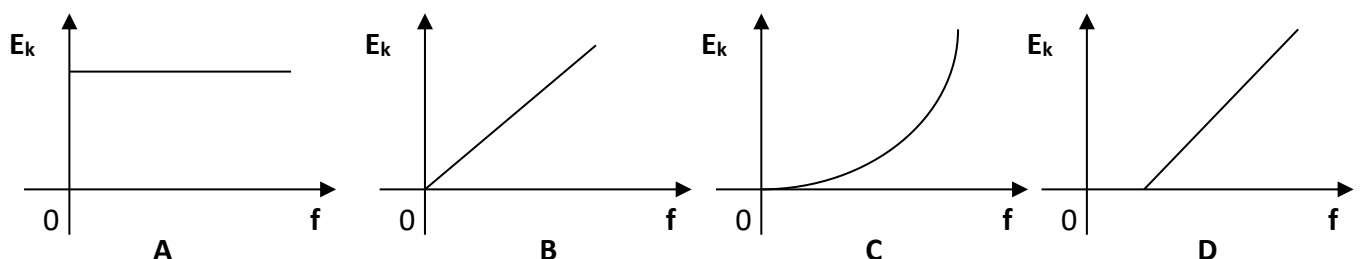
EXAM / EXAM TYPE QUESTIONS

ONE WORD ITEMS

- The minimum amount of energy required to remove an electron from a metal surface.

MULTIPLE CHOICE QUESTIONS

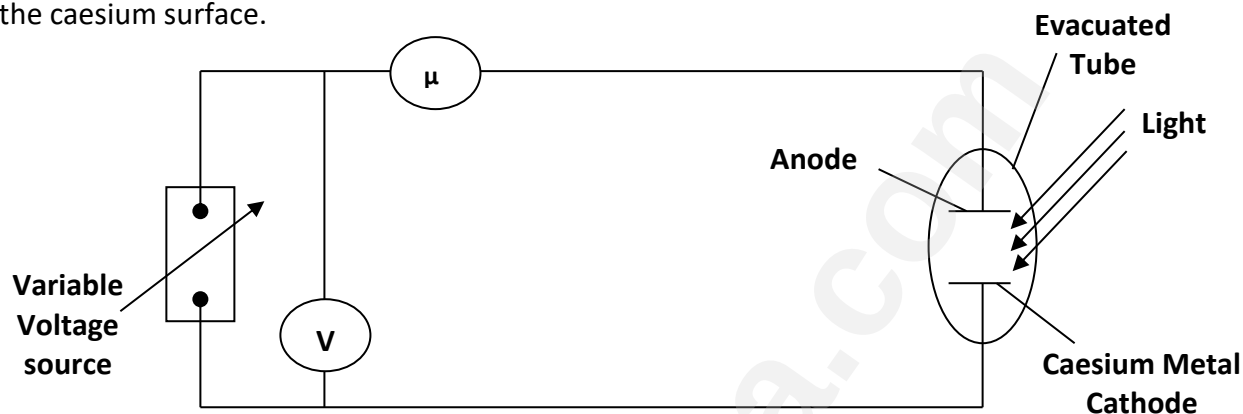
- A metal is illuminated with light of frequency f and the electrons emitted have a maximum kinetic energy of E_k . Which ONE of the following graphs best illustrates the relationship between kinetic energy (E_k) of the emitted electrons and frequency (f) of the incident light?



[NA 2008]

LONG QUESTIONS

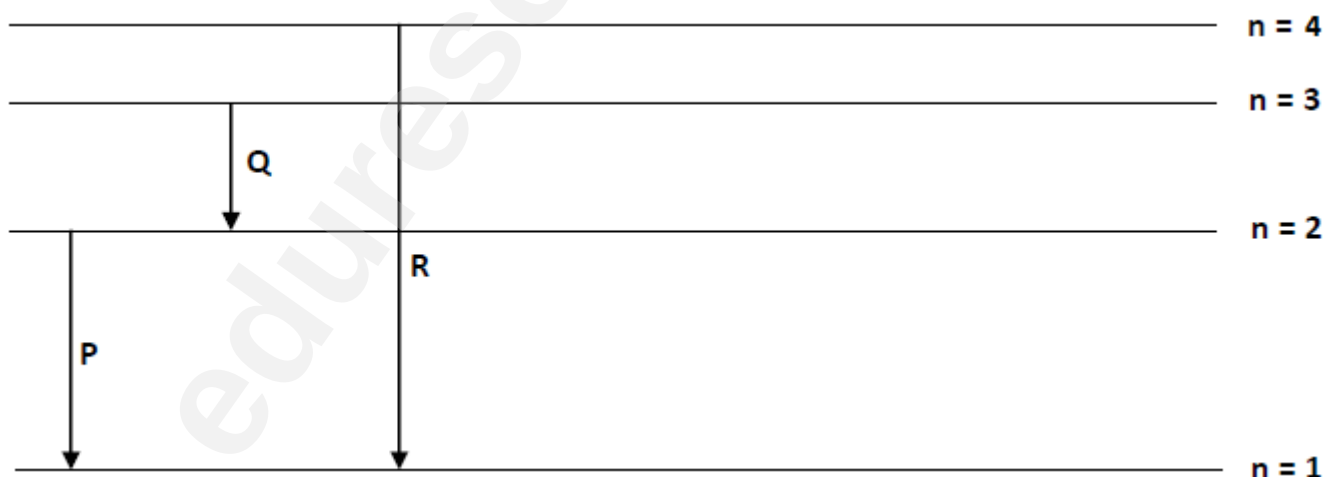
1. A photoelectric cell is connected into a circuit. The lowest frequency of light that will emit electrons from its caesium surface is $5,1 \times 10^4$ Hz. Violet light of wavelength 400nm is incident on the caesium surface.



- Calculate the work function of caesium.
 - Calculate the amount of energy carried by the incident photons of violet light.
 - Calculate the kinetic energy of the fastest photoelectrons emitted from the caesium surface when violet light shines on it.
- [IEBE 2008]

HOMEWORK / ADVANCED QUESTIONS

2. The diagram shows four energy levels corresponding to four shells in an atom. When an electron 'jumps' from an outer shell to an inner shell, it emits all energy in the form of waves.



In the 3 transitions, which one has:

- The highest energy?
- The lowest energy?
- The highest frequency?
- The lowest frequency?
- The longest wavelength?
- The shortest wavelength?

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MODULE 6: ORGANIC CHEMISTRY REVISION

1. SUMMARY OF IMPORTANT CONCEPTS

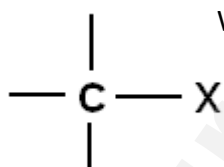
NUMBERING SYSTEM

ALIPHATIC HYDROCARBONS				
No. of Carbon's	Main Chain			Side Chain
	Alkanes (-)	Alkenes (=)	Alkynes ($\equiv$)	Alkyl Groups
	Single Bond	Double Bond	Triple Bond	
1	Methane	-	-	Methyl-
2	Ethane	Ethene	Ethyne	Ethyl-
3	Propane	Propene	Propyne	
4	Butane	Butene	Butyne	
5	Pentane	Pentene	Pentyne	
6	Hexane	Hexene	Hexyne	
7	Heptane	Heptene	Heptyne	
8	Octane	Octene	Octyne	
General formula	C_nH_{2n+2}	C_nH_{2n}	C_nH_{2n-2}	

Functional Groups

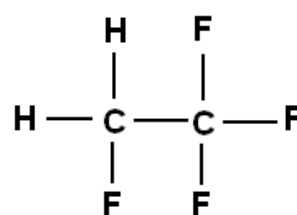
- The Halo – alkanes / alkyl halides

- Functional Group:



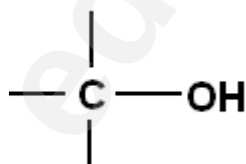
Where X = Fluorine (F - Fluoro),
Chlorine (Cl - Chloro),
Bromine (Br - Bromo) or
Iodine (I - Iodo)

E.g. 1,1,1,2 – tetrafluoroethane

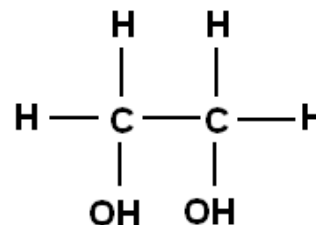


- The Alcohols (-OH Group)

- Functional Group:

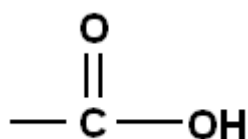


E.g. 1,2 – diethanol

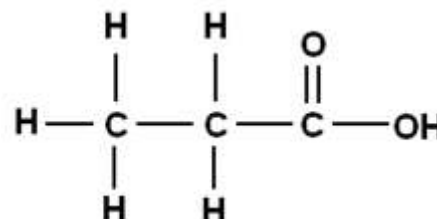


- The Carboxylic Acids

- Functional Group:

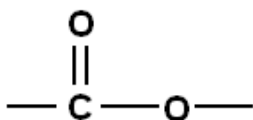


E.g. Propanoic acid

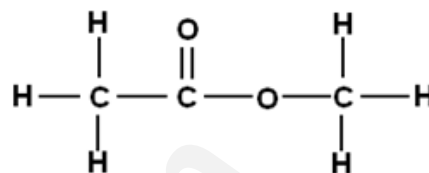


- **The Esters**

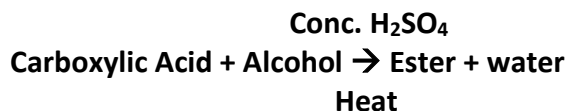
- **Functional Group:**



E.g. Methyl Ethanoate

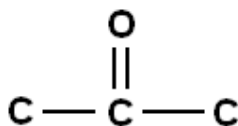


- **Esterification** is the process of producing an ester by an acid catalysed condensation:

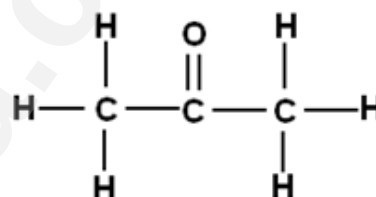


- **The Ketones**

- **Functional Group:**

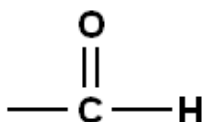


E.g. Propanone

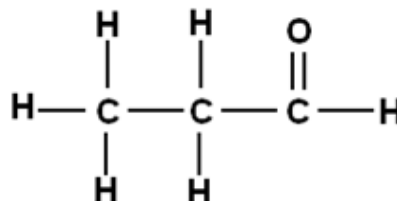


- **The Aldehydes**

- **Functional Group:**



E.g. Propanal



Types of Reactions

Markovnikov's rule: The **hydrogen** atom attaches to the **carbon atom** already having the **greater number of hydrogen atoms**. The **halogens** (i.e. Cl, Br) attaches to the **more substituted carbon atom**.

- **ADDITION REACTIONS**

- Occur in **alkenes, cycloalkenes or alkynes** (unsaturated compounds) and involve the **breaking of a double or triple bond**. Types of addition reactions:
 - **Hydrohalogenation** – **No water** must be present. **Markovnikov's rule applies**.
 - **Hydrogenation** – **Catalyst required:** Platinum (Pt), Palladium (Pd) or Nickel (Ni). The alkene must be **dissolved in a non-polar solvent**
 - **HALOGENATION**
 - **HYDRATION** – **Catalyst required:** a small amount of **HX** or **other strong acid** (e.g. H_2SO_4 , H_3PO_4). **Markovnikov's rule applies**.

- **SUBSTITUTION REACTIONS**

- These involve the **replacing of atoms** within the molecule. Types of substitution reactions:
 - **REACTIONS OF HX (X = Cl, Br) WITH ALCOHOLS TO PRODUCE HALOALKANES.**
 - **Tertiary alcohols** - are converted into **haloalkanes** at room temperature.
 - **Primary and secondary bromoalkanes** - treat **primary and secondary alcohols** with concentrated H_2SO_4 and **solid NaBr** (or KBr).
 - **HYDROLYSIS: REACTIONS OF BASES WITH HALOALKANES TO PRODUCE ALCOHOLS**
 - The **haloalkane** must be dissolved in **ethanol** first.
 - Thereafter it is treated with **aqueous NaOH** and **heated**.
 - **FORMING HALOALKANES FROM ALKANES**

- **Reaction conditions:** must be done in the presence of light or heat.

Zaitsev's rule: If more than one elimination product is possible, the major product is the one where the **hydrogen atom** is removed from the **carbon atom** with the **least number of hydrogen atoms**.

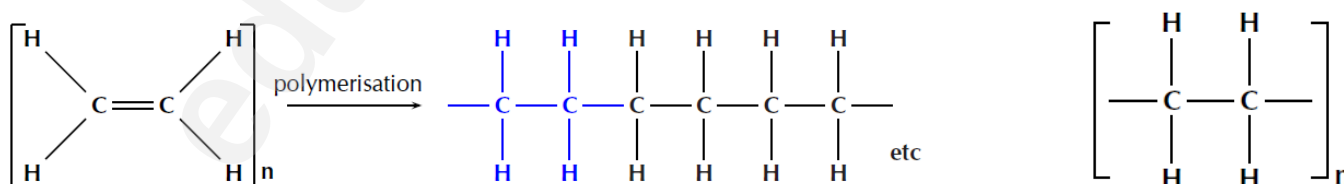
• ELIMINATION REACTIONS

- **Halo alkanes, alcohols, alkanes (saturated compounds)** undergo elimination reactions.
- These are the opposite of an addition reaction. Types of eliminations reactions:
- **DEHYDROHALOGENATION: ELIMINATION OF HX FROM A HALOALKANE**
 - **Reaction conditions: Heat under reflux** – this is where vapours condensate and return to reaction vessel during heating. Reaction must occur in **concentrated NaOH or KOH** in **pure ethanol** as the solvent i.e. **hot ethanolic NaOH / KOH**. **Zaitsev's rule applies**.
- **DEHYDRATION OF ALCOHOLS: ELIMINATION OF H₂O FROM AN ALCOHOL**
 - **Catalyst required:** An acid catalysed dehydration – heating of alcohol with an excess of **concentrated H₂SO₄ (or H₃PO₄)**. **Zaitsev's rule applies**.
- **CRACKING OF HYDROCARBONS**
 - Breaking up large hydrocarbon molecules into smaller and more useful bits.

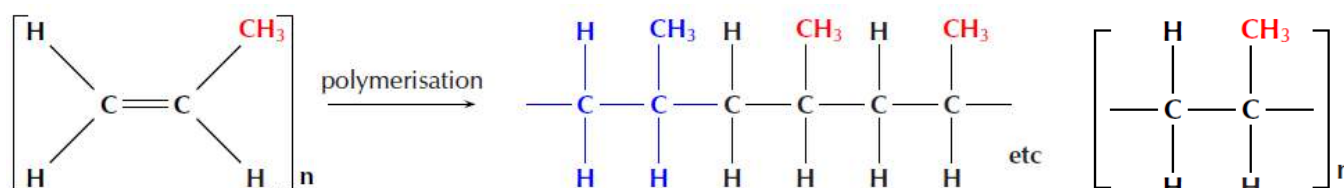
6. PLASTICS AND POLYMERS

- **Monomer** – is the basic structural unit (a small molecule) from which a polymer is made.
- **Polymers** - Are substances that have a molecular structure built up from a large number of monomers to form **polymer chains**. Most polymers are **macromolecules**.
- A **chain** is a macromolecule formed when monomers attach one at a time to the end of a growing polymer.
- **Plastics** – a subgroup of organic polymers that can be moulded. Plastics may contain more than one organic polymer as well as other additives.
- **Polymerisation** is a process of bonding monomers, or single units together to form longer chains called polymers. Polymers can form in 2 ways:
 - **Addition polymerisation (plastics)** – we examine 5 major examples of addition polymers:

1. The polymerization of ethene in the formation of polyethene (polyethylene) –

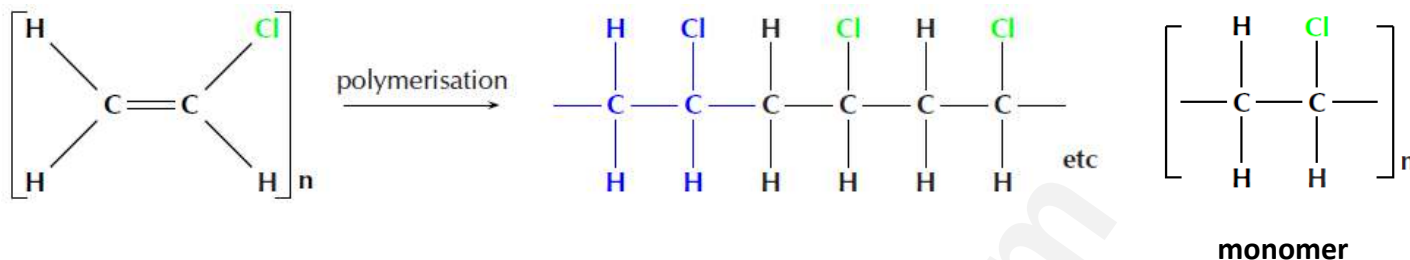


2. Polypropene (polypropylene) – is formed using the monomer propene as shown:

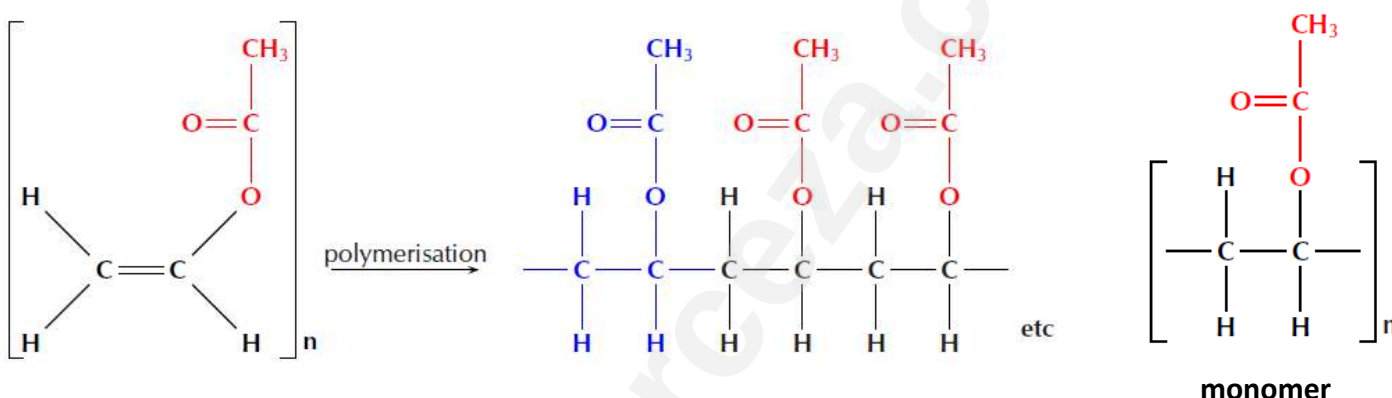


monomer

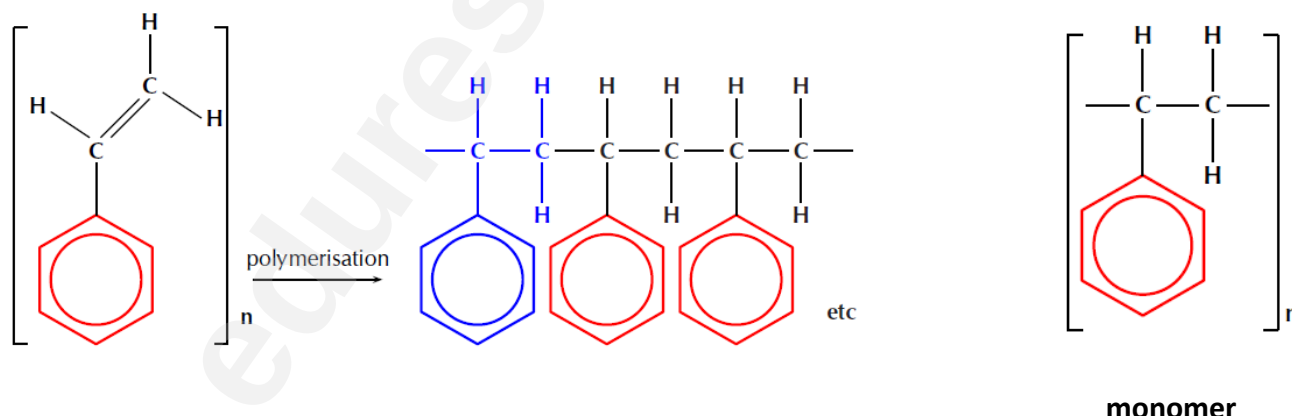
3. **Polyvinyl chloride (PVC)** – is formed from the monomer chloroethene (vinyl chloride).



4. **Polyvinyl Acetate (PVA)** – is formed from the monomer ethenyl ethanoate (vinyl acetate).

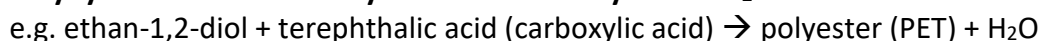


5. **Polystyrene** – is formed from the monomer styrene which consists of a **benzene ring** (a six membered ring with three double bonds) bonded to an ethene chain. Polystyrene is a liquid petrochemical.



- **Condensation polymerisation (fibres)** – two monomer molecules combine by means of a covalent bond and a small molecule such as water is **eliminated** in the bonding process to form **polyester**.

- **Polyethylene terephthalate (PET)** – although there are many forms of polyesters, the term polyester usually refers to polyethylene terephthalate (PET). The esterification reaction is represented below:

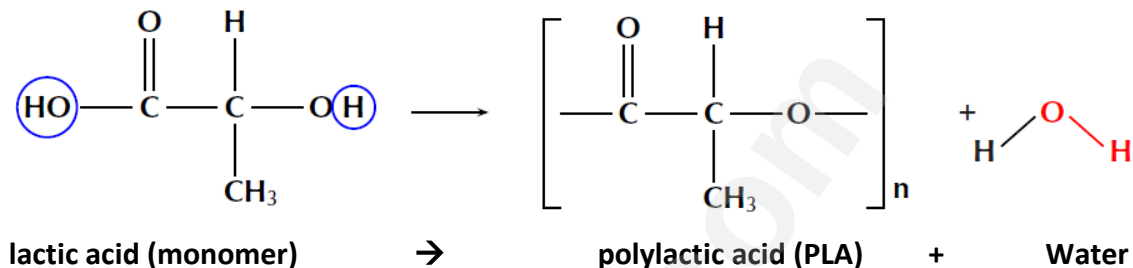


Examples of specific polyesters:

- Kevlar
- Mylar

▪ **Poly(lactic acid (PLA))**

The reaction to produce PLA is:



EXAM / EXAM TYPE QUESTIONS

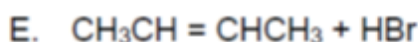
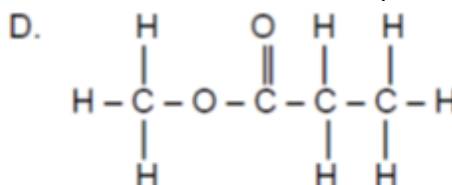
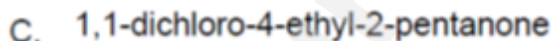
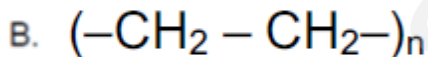
MULTIPLE CHOICE QUESTIONS

1. Which one of the following pairs of compounds contains members of the same homologous series?
- C_2H_4 and C_3H_8
 - C_3H_6 and C_4H_6
 - CH_4O and $\text{C}_2\text{H}_6\text{O}_2$
 - $\text{C}_2\text{H}_4\text{O}_2$ and $\text{C}_3\text{H}_6\text{O}_2$

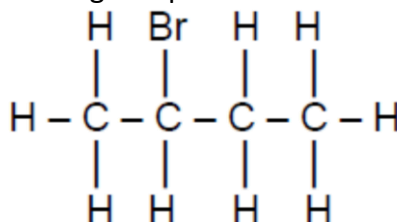
[NEN 2003]

LONG QUESTIONS

2. Consider the organic compounds labelled B to D and the reaction products A and E:



- Write down the IUPAC name of compound B.
- Draw the structural formula of compound C.
- Draw the structural formula of the monomer of B.
- Choose one of the letters A or E that represents the major products formed in the dehydrohalogenation of the following compound:



- Write down the IUPAC name of compound D.

[WCJ 2008]

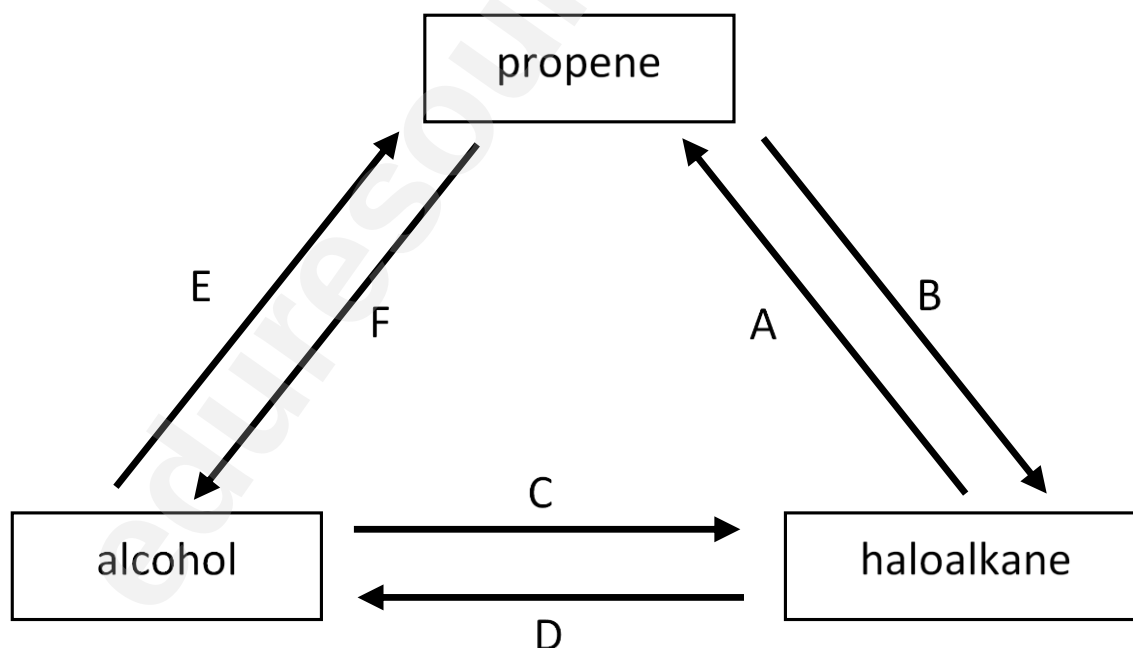
1. Halo alkanes play an important role in the chemical industry. Halo alkanes can be made from alcohols. The following tables can be used to compare the boiling points of some halo alkanes:

TABLE 1		
Systematic Name	Formula	Boiling point (°C)
chloromethane	CH ₃ Cl	-24,1
dichloromethane	CH ₂ Cl ₂	40,1
trichloromethane	CHCl ₃	61,8
tetrachloromethane	CCl ₄	76,6

TABLE 2		
Systematic name	Formula	Boiling point (K)
fluoromethane	CH ₃ F	194.7
chloromethane	CH ₃ Cl	248.9
bromomethane	CH ₃ Br	276.7
iodomethane	CH ₃ I	315.5

Use the information given in these tables to answer questions 'a' to 'c'.

- Write down the FORMULA of two halo alkanes that you think are the most dangerous at 25°C. Give a reason for your answer.
 - Describe the trend in boiling point illustrated by Table 2. Give an explanation for this trend.
 - Predict the relationship between the number of chlorine atoms and boiling point illustrated in Table 2. State what should be constant. [WCJ 2008]
3. The flow diagram below shows the inter conversion between alcohols, alkenes and halo alkanes. The letters A, B, C, D, E, and F represent addition or substitution or elimination reactions.



- What type of reaction is represented by F? Choose from ADDITION or SUBSTITUTION or ELIMINATION.
- Use structural formulae and write a balanced equation for reaction F to show the formation of the major product.
- Reaction E is sometimes referred to as a dehydration. Write down the FORMULA of the substance eliminated during dehydration.

- [FSJ 2008]

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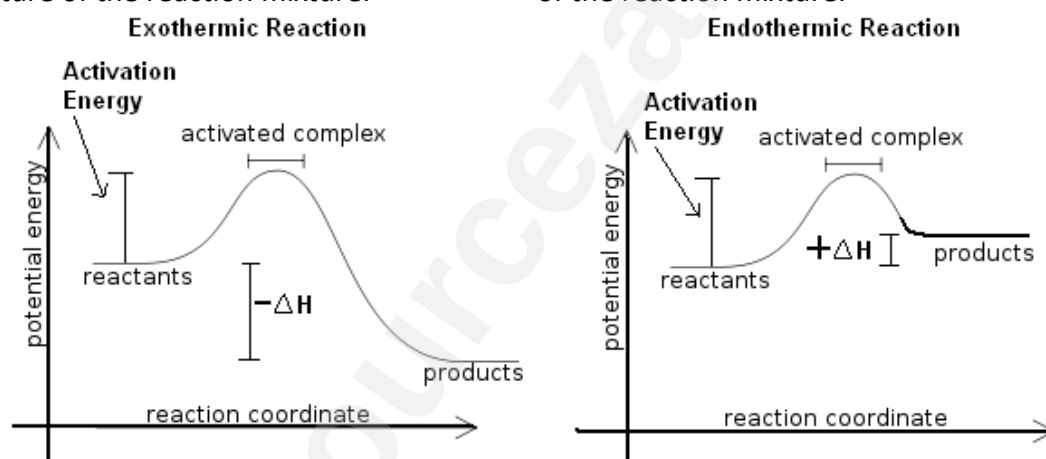
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MODULE 7: CHEMICAL CHANGE

1. ENERGY CHANGES IN REACTIONS

- **Enthalpy** – is the heat of a reaction (ΔH) – the energy that is needed to break bonds or the energy that is liberated when new bonds are formed.
- **Activation energy** – the minimum amount of energy that must be supplied to the reactants in order to start the chemical reaction.
- **Activated Complex** – is an intermediate, short-lived group of atoms formed in between the reactants and products.
- **Exothermic reaction** - is one in which energy is released, resulting in a decrease in temperature of the reaction mixture.

Endothermic reaction – is one in which energy is absorbed, resulting in a rise in temperature of the reaction mixture.



2. RATE OF REACTIONS

- **Rate of a chemical reaction** - is a measure of how fast a reaction takes to reach completion.
- **Collision Theory** – particles can only react if they collide. The greater the number of effective collisions (when molecules move faster and have sufficient energy), the faster the reaction rate.
For a reaction to take place, colliding molecules must have:
 - the **correct orientation**,
 - **sufficient kinetic energy**
- **Factors affecting rates of reaction**
 - **Surface area (solids)** – the greater the surface area of the solid, the faster reaction rate, e.g. when reactants are powdered instead of in pieces, they will react faster.
 - **Concentration (solutions)** - the greater the concentration of the solution, the more particles there are and thus more collisions will occur, and so the faster the reaction rate.
 - **Pressure (gases)** – an increase in the pressure, moves molecules closer together and thus increases the number of collisions, and so increases the reaction rate.
 - **Temperature** - the higher the temperature of the reactant, the more energy the particles have which increases their speed, and so the faster the reaction rate.
 - **Catalyst** – a positive catalyst increases the reaction rate. The catalyst itself remains chemically unchanged. They decrease the amount of activation needed for the reaction to

take place.

3. CHEMICAL EQUILIBRIUM

- **Dynamic equilibrium** – The rate of the forward reaction equals the rate of the reverse reaction, indicated by the double arrows.
- **Le Chatelier's Principle** – In a closed system (closed container), if one of the conditions affecting equilibrium changes, the equilibrium shifts in such a direction so as to cancel the effect of the change.

Condition change	Equilibrium shift
Concentration - increase on left	To the right
Concentration - decrease on left	To the left
Concentration – increase on right	To the left
Concentration – decrease on right	To the right
Temperature increase endothermic	Heat is on the left – shift to the right
Temperature decrease endothermic	Heat is on the left - shift to the left
Temperature increase exothermic	Heat is on the right – shift to the left
Temperature decrease exothermic	Heat is on the right – shift to the right
Pressure increase (by decreasing volume)	In the direction of smaller number of moles.
Pressure decrease (by increasing volume)	In the direction of greater number of moles.

- A catalyst has no effect on equilibrium.
- **The Equilibrium Constant (K_c)**
 - Given the balanced equation: $aA + bB \rightleftharpoons cC + dD$. The equilibrium constant is:

$$K_c = \frac{[\text{Products}]}{[\text{Reactants}]} = \frac{C^c D^d}{A^a B^b}$$

- **Solids** and **pure liquids** are not included in the equilibrium equation.
- $K_c > 1$, indicates a relatively high concentration of products as compared to reactants.
- $K_c < 1$, indicates a relatively low concentration of products as compared to reactants.
- K_c will only remain constant for a **particular temperature**.

EXAM / EXAM TYPE QUESTIONS

MULTIPLE CHOICE QUESTIONS

1. Consider the following reaction equation: $\text{N}_{2(g)} + 3\text{H}_{2(g)} \rightarrow 2\text{NH}_{3(g)}$ $\Delta H = -92\text{kJ}$
According to Le Chatelier's Principle, the conditions of temperature and pressure at which the highest yield will be obtained are:

	Temperature	Pressure
a.	Low	Low
b.	High	High
c.	High	Low
d.	Low	High

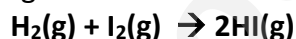
[NN 2001]

2. A strip of zinc metal is placed in a solution of HCl of concentration $4\text{mol}\cdot\text{dm}^{-3}$. Which one of the following will not affect the rate at which hydrogen gas is liberated from the beaker?
- The use of powdered zinc instead of the strip.
 - The addition of another strip of zinc.
 - The addition of more $4\text{mol}\cdot\text{dm}^{-3}$ $\text{HCl}_{(aq)}$.
 - Using $2\text{mol}\cdot\text{dm}^{-3}$ $\text{HCl}_{(aq)}$ instead of $4\text{mol}\cdot\text{dm}^{-3}$ $\text{HCl}_{(aq)}$.

[GN1996]

LONG QUESTIONS

1. Consider the following reversible reaction in a sealed container:



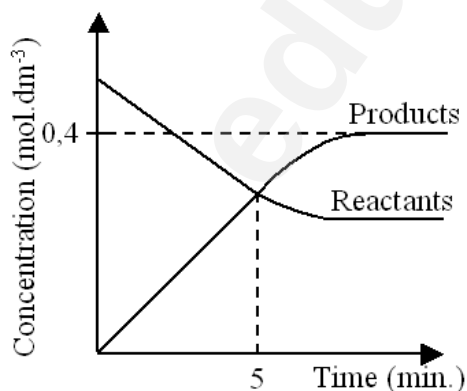
The experiments were repeated three times under different conditions. In each case $0,50\text{ mol H}_2$ and $0,50\text{ mol I}_2$ reacted in a $1,0\text{ dm}^3$ container.

The sketch graphs of concentration versus time for the three investigations are shown below.

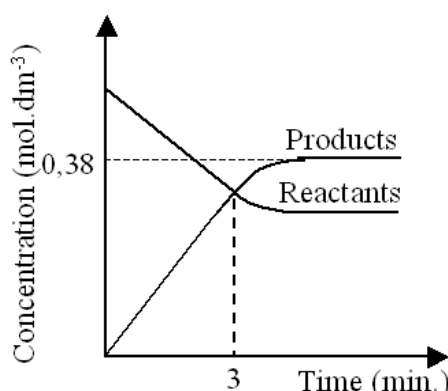
Graph A was obtained at 500°C .

Graph B was obtained under the same conditions as graph A, but at a temperature of 600°C .

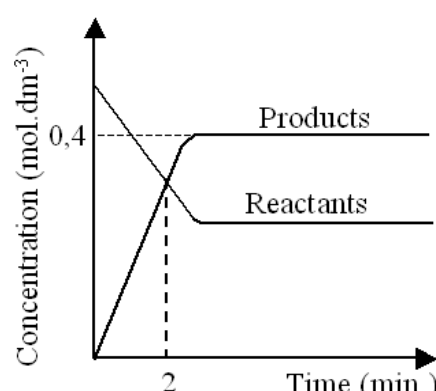
Graph C was also obtained at 500°C , but under different conditions than graph A.



GRAPH A



GRAPH B



GRAPH C

- What factor is responsible for the difference between graph A and graph C?
 - Give an explanation for the answer to a.
 - Is the reaction in this experiment exothermic or endothermic?
 - Give an explanation for the answer to c.
 - Use the supplied information to calculate the equilibrium constant at 500 °C.
2. 2mol of $\text{NO}_{2(g)}$ and an unknown amount of $\text{N}_2\text{O}_{4(g)}$ are sealed in a 2dm^3 container, that is fitted with a plunger, at a certain temperature. The following reaction takes place:
- $$2\text{NO}_{2(g)} \rightleftharpoons \text{N}_2\text{O}_{4(g)}$$
- At equilibrium it is found that the NO_2 concentration is $0,4\text{mol}\cdot\text{dm}^{-3}$. The equilibrium constant at this temperature is 2.
- Calculate the initial amount (in mol) of $\text{N}_2\text{O}_{4(g)}$ that was sealed in the container.
- The plunger now pushed into the container causing the pressure of the enclosed gas to increase by decreasing the volume.
- How will this change influence the amount of nitrogen dioxide at equilibrium? Only write down INCREASES, DECREASES or REMAINS THE SAME. [NM 2010]
3. 1g of Calcium Carbonate is sealed off in a $0,50\text{dm}^3$ metal flask. A pressure gauge is connected to the metal flask. The flask is placed in an oven and instantaneously heated to a temperature of 800°C . After some time equilibrium was reached in the flask according to the following equation:
- $$\text{CaCO}_3(s) + \text{CaO}(s) \rightleftharpoons \text{CO}_2(g) \quad \Delta H \leq 0$$
- How can it be observed that equilibrium has been reached?
 - Draw a sketch-graph to show how the mass of CaCO_3 changes with time until equilibrium has been established.
 - During a power failure the temperature drops to 500°C . Using Le Chatelier's principle, explain what happens to the mass of CO_2 .
 - When equilibrium has been established at 800°C , the number of particles of CaCO_3 present is $1,9264 \times 10^{21}$ molecules. Calculate the equilibrium constant (K_c) at 800°C for this reaction. [AO Test]

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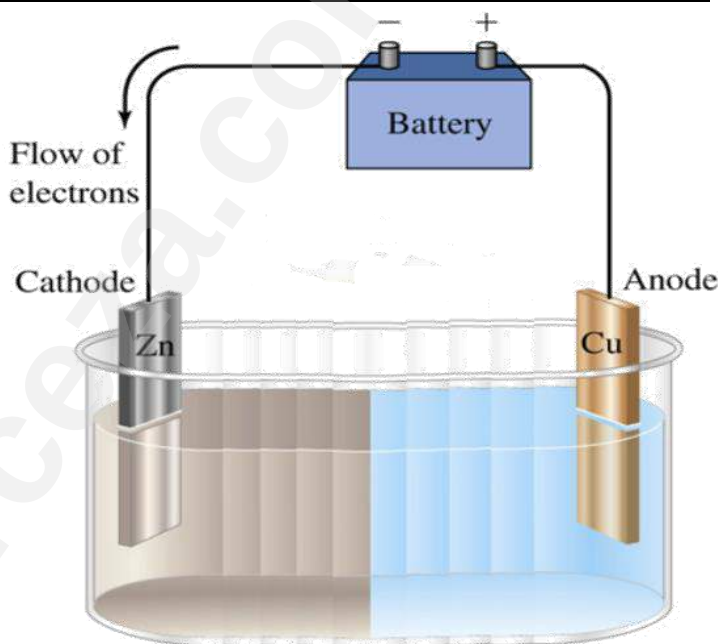
MODULE 7: ELECTROCHEMICAL CELLS

1. DEFINITIONS

- **REDOX REACTIONS** – This is a reaction where electron transfer takes place.
- **OXIDATION** – is the **loss of electrons**. The **reducing agent** is the substance that loses electrons.
- **REDUCTION** – is the **gain of electrons**. The **oxidizing agent** is the substance that gains electrons.

2. PROPERTIES OF ELECTROLYTIC CELLS

- Electrical energy is converted into chemical energy.
- The cell is sustained by a battery.
- The reaction is **endothermic**.
- The solution that conducts electricity is called an **electrolyte**.
- Reduction takes place at the **cathode (negative electrode)**, while oxidation takes place at the **anode (positive electrode)**.

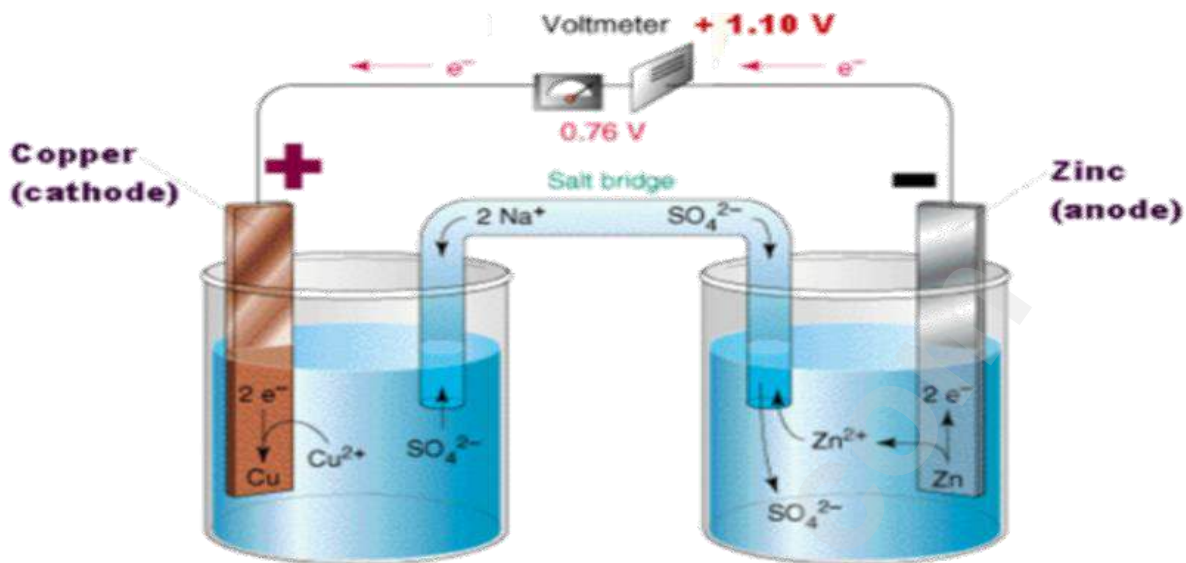


3. PROPERTIES OF GALVANIC / VOLTAIC CELLS

- Chemical energy is converted into electrical energy.
- The cell is self sustaining.
- The reaction is **exothermic**.
- The chemical reactions take place in 2 separate containers joined by a **salt bridge**.
- The oxidation half-reaction takes place in one container (anode) while the reduction half-reaction takes place in the other (cathode).

Anode	Cathode
1. Always the top half-reaction (Table 4B).	1. Always the bottom half-reaction (Table 4B).
2. Oxidation (stronger reducing agent)	2. Reduction (stronger oxidising agent)
3. Read from right to left.	3. Read from left to right.
4. Negative electrode.	4. Positive electrode.
5. Decreases in mass.	5. Increases in mass.

- **Standard conditions**
 - **Temperature** 298k (25°C)
 - **Pressure** 101.3 kpa
 - **Concentration** 1mol.dm⁻³

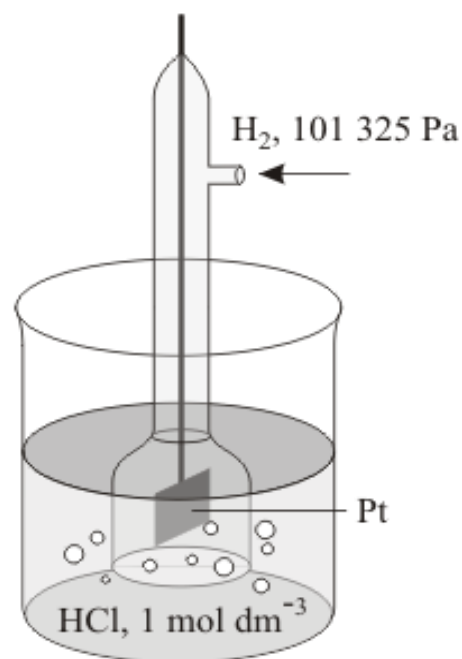


- **The emf of a cell:** $E^{\circ}_{\text{cell}} = e^{\circ}_{\text{cathode}} - e^{\circ}_{\text{anode}}$
 - A positive emf indicates that the cell reaction occurs spontaneously from left to right.
- **The salt bridge** – the salt bridge keeps the 2 electrolytes separate and at the same time completes the circuit. It also absorbs excess ions to ensure electrical neutrality.
- **Cell notation:**

electrode/electrolyte (ANODE)	//	electrolyte/electrode (CATHODE)
	↑ SALT BRIDGE	
- **Relation of current and potential to rate and equilibrium**
 - The potential difference of the cell is related to the extent to which the spontaneous cell reaction has reached equilibrium.
 - V_{cell} decreases as the concentration of product ions increases and the concentration of reactant ions decreases until equilibrium is reached at which the $V_{\text{cell}} = 0$ (cell is 'flat').
- **Electrons** in the external cell flow from the anode to the cathode.

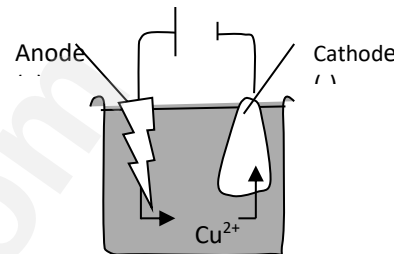
4. THE STANDARD HYDROGEN ELECTRODE

- The standard hydrogen electrode:
- Standard hydrogen electrode is a system in which hydrogen ion and gaseous hydrogen are present in their standard states. The convention is to designate the cell so that the standard hydrogen electrode is written first.
- The electrode is used as a **reference (of zero)** for the values of other standard electrode potentials.



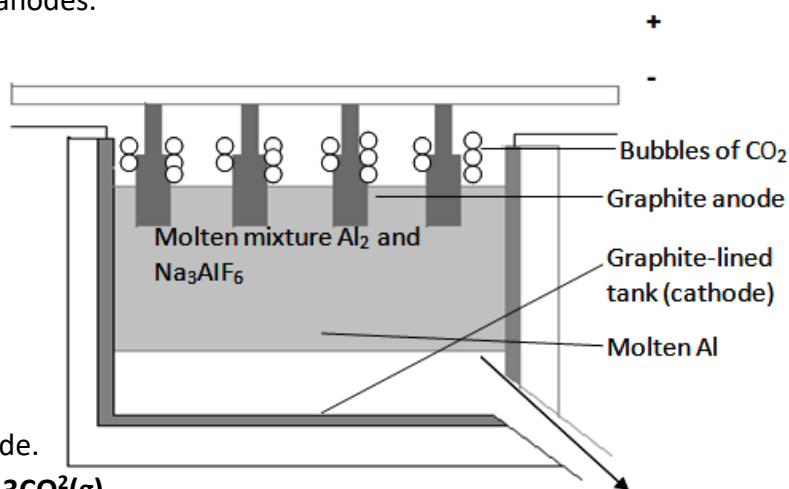
5. ELECTRO REFINING OF COPPER

- **At the anode**
 - Impure copper is oxidised
 - Goes into solution as Cu^{2+} ions
 - Precious metals such as gold and silver are not oxidised and sinks to the bottom along with other impurities such as zinc and iron.
 - $\text{Cu} \rightarrow \text{Cu}^{2+} + 2\text{e}^-$
- **At the cathode**
 - Cu^{2+} ions are reduced to pure copper metal
 - Less easily reduced ions (Zn^{2+} , Fe^{2+} , etc) remain in solution.
 - $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$
 - Net cell reaction involves transfer of copper metal from impure anode to pure cathode.



6. THE EXTRACTION OF ALUMINIUM

- Electrolysis is the most powerful way to decompose ionic compounds therefore it is used to extract reactive metals such as aluminium from their ores.
- It is industrially electrolysed from its ore **bauxite** which consists of 60% aluminium oxide, and the rest being silicon oxide and iron oxide.
- **The Hall- Heroult process**
 - Bauxite is treated with sodium hydroxide forming pure aluminium oxide (Al_2O_3).
 - The waste produced (iron(III) oxide) is pumped into red mud dams.
 - Alumina dissolves into molten cryolite (Na_3AlF_6).
 - Al_2O_3 is dissolved in cryolite which reduces the temperature of a melting point from 2000°C to about 950°C (saving on energy costs.)
- **The electrolytic cell**
 - Contains a series of carbon (graphite) anodes.
 - Cathode consists of carbon and lines the inside of the cell.
- **At the cathode**
 - Aluminium is formed
 - $\text{Al}^{3+} + 3\text{e}^- \rightarrow \text{Al}$
 - Aluminium is molten due to high temperature and is easily tapped off.
- **At the anode**
 - At $1\,000^\circ\text{C}$ released oxygen gas reacts with the graphite to form carbon dioxide.
 - $\text{C} + \text{O}_2 \rightarrow \text{CO}_2(\text{g})$
- **Properties of aluminium**
 - Malleable and can be rolled into thin foil
 - Excellent electric conductor



EXAM / EXAM TYPE QUESTIONS

ONE WORD ANSWERS

- In a standard copper-zinc electrochemical cell, what is the copper metal called?
- In the following reaction: $2\text{Fe}^{3+}(\text{aq}) + \text{Zn}(\text{s}) \rightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{Fe}^{2+}(\text{aq})$
The substance that is oxidised is _____.

FALSE ITEMS

- The stronger an oxidising agent, the stronger its ability to lose electrons.

MULTIPLE CHOICE QUESTIONS

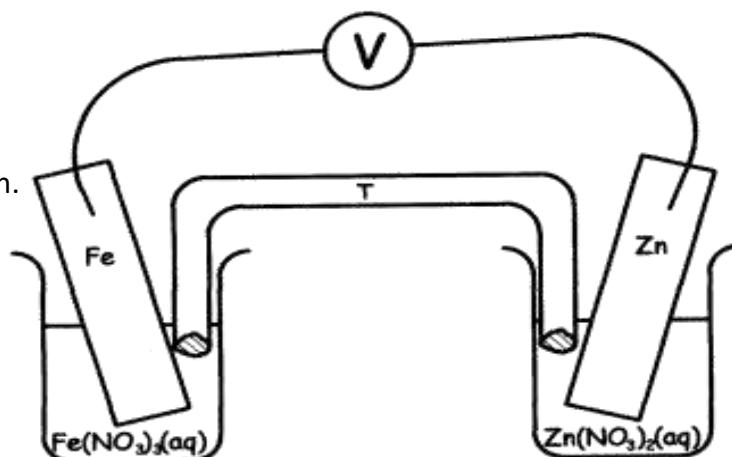
- Which one of the following reactions CANNOT occur spontaneously under standard conditions?
 - $2\text{Fe}^{3+}(\text{aq}) + \text{Mn}(\text{s}) \rightarrow \text{Mn}^{2+}(\text{aq}) + 2\text{Fe}^{2+}(\text{aq})$
 - $\text{Fe}(\text{s}) + 2\text{Fe}^{3+}(\text{aq}) \rightarrow 3\text{Fe}^{2+}(\text{aq})$
 - $\text{Cd}(\text{s}) + \text{Sn}^{4+}(\text{aq}) \rightarrow \text{Cd}^{2+}(\text{aq}) + \text{Sn}^{2+}(\text{aq})$
 - $\text{Ag}(\text{s}) + \text{CuCl}_2(\text{aq}) \rightarrow \text{AgCl}(\text{s}) + \text{CuCl}(\text{aq})$
- Which one of the following is a redox reaction?
 - $\text{Na}_2\text{SO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + \text{H}_2\text{O} + \text{SO}_2$
 - $\text{Cu} + \text{conc H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + 2\text{H}_2\text{O} + \text{SO}_2$
 - $\text{H}_2\text{O} + \text{SO}_2 \rightarrow \text{H}_2\text{SO}_3$
 - $\text{CuSO}_4 + \text{H}_2\text{S} \rightarrow \text{CuS} + \text{H}_2\text{SO}_4$

LONG QUESTIONS

- The two half-cells, $\text{Fe}(\text{s})/\text{Fe}^{2+}(\text{aq})$, and $\text{O}_2(\text{g})/\text{H}_2\text{O}(\text{l})$ in acid solution, are used to set up an electrochemical cell. The cell operates under standard conditions.
 - Write down the standard conditions, which apply to this electrochemical cell.
 - Which half-cell represents the anode?
 - Write down the balanced equation for the oxidation and reduction half-reactions.
 - Write down the balanced equation for the overall net reaction.
 - Calculate the EMF of the cell.
- A standard zinc/iron electrochemical cell is set up as shown below:

[NEN 2003]

- Write down the appropriate iron half reaction.
It is given that the EMF of the cell is 0,72 V.
- Which electrode is the cathode?
- Write down the half reaction that occurs at the anode.
- Write down the balanced, net ionic equation of the cell.



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PHYSICS GRADE 12 CAPS

MODULE 7: ACIDS AND BASES AND STOICHIOMETRY

1. REVISION OF CONCEPTS

- **The Arrhenius theory**
 - An **acid** is a substance that releases **hydronium ions (H_3O^+)** in an aqueous solution.
 - A **base** is a substance that forms **hydroxyl ions (OH^-)** in an aqueous solution.
- **Brønsted-lowry theory**
 - An acid is a **proton (H^+) donor**.
 - A base is a **proton (H^+) acceptor**.

Conjugate acid base pairs show proton transfer in pairs of acids and bases

- To calculate the **concentration** of any solution, use the formulae:

$$C = \frac{n}{V} \qquad C = \frac{m}{MV}$$

where C = concentration ($\text{mol} \cdot \text{dm}^{-3}$), n = number of moles (mol), m = mass (g), V = Volume (dm^3),
 M = Molar Mass ($\text{g} \cdot \text{mol}^{-1}$)

When **diluting solutions**, use the formula: $C_1V_1 = C_2V_2$

- **Titration** – this is a reaction where a **standard acidic solution** is gradually added to a basic solution of unknown concentration, until they neutralize each other completely and **end point** is reached. A balanced equation must be obtained to get the ratio of the number of moles.

$$\frac{c_a V_a}{c_b V_b} = \frac{n_a}{n_b}$$

Where c_a / c_b = concentration ($\text{mol} \cdot \text{dm}^{-3}$); v_a / v_b = volume
 n_a / n_b = number of moles of acid and base (mol) from the balanced equation.

- **The pH scale** – this indicates the degree of acidity or alkalinity of a solution.

$$\text{pH} = -\log [\text{H}_3\text{O}^+]$$

0 – 6: Acid 7: Neutral 8 – 14: Base

The ionic product of Water – $K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14}$ at 25°C .

- **Calculating the number of moles (n)** - use one of the following formulae depending on the given information:

$$n = \frac{N}{N_A} \qquad n = \frac{m}{M_r} \qquad n = \frac{V}{V_m}$$

Where n = number of moles (mol), N = number of particles, m = mass (g), V = Volume (dm^3)
 $N_A = 6,02 \times 10^{23}$ (**Avogadro's Number**), $V_m = 22,4 \text{ dm}^3$ (**molar volume at STP**)

- **Stoichiometry** – using the mole ratio from a balanced equation to perform chemical calculations.
Concepts used in stoichiometric calculations:

- **Limiting Reagent** – is the reactant that is completely used up during the chemical reaction.
- The **reactant that is in excess** is the reactant that left over at the end of the reaction.

- Calculating percentage yield: $\text{percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$

- Calculating the percentage purity of a sample as:

$$\text{percentage purity} = \frac{\text{mass of pure compound in the sample}}{\text{total mass of sample}} \times 100$$

EXAM / EXAM TYPE QUESTIONS

LONG QUESTIONS

1. A certain antacid tablet contains 22,0 g of baking soda (NaHCO_3). It is used to neutralise the excess hydrochloric acid in the stomach. The balanced equation for the reaction is:



The hydrochloric acid in the stomach has a concentration of $1,0 \text{ mol} \cdot \text{dm}^{-3}$. Calculate the volume of the hydrochloric acid that can be neutralised by the antacid tablet. [N2007 11]

2. When 2g of Magnesium combines with 0,65g of oxygen it forms magnesium oxide.

- Write a balanced equation for the reaction.
- Determine which reactant is in excess.
- What mass of the reactants in excess?

[N2009 11]

3. When Sechaba and Thabang carried out a titration experiment they found that the products which were obtained using a diprotic acid with sodium hydroxide were sodium sulphate and water. The titration was carried out by placing $20,0 \text{ cm}^3$ acid in an Erlenmeyer flask and adding the base from a burette.

- Write down a balanced chemical equation for the reaction that occurred.
- If the concentration of the acid was $0,20 \text{ mol} \cdot \text{dm}^{-3}$ and that of the base $0,6 \text{ mol} \cdot \text{dm}^{-3}$ calculate the volume of the base that is necessary to just neutralise 20 cm^3 of the solution. [N2009 11]

3. The following solutions are provided:

Solution A: $0,1 \text{ mol} \cdot \text{dm}^{-3} \text{ H}_2\text{SO}_4$

Solution B: $0,1 \text{ mol} \cdot \text{dm}^{-3} \text{ HCl}$

Solution C: $0,1 \text{ mol} \cdot \text{dm}^{-3} \text{ Na}_2\text{SO}_4$

Solution D: $0,1 \text{ mol} \cdot \text{dm}^{-3} \text{ Na}_2\text{CO}_3$

Solution E: $0,1 \text{ mol} \cdot \text{dm}^{-3} \text{ NaOH}$

- Use the symbols A, B, C, D or E to indicate the solution that:

- may have a $\text{pH} = 7$
- has the highest concentration of H_3O^+ .
- is a strong base.
- is a monoprotic acid.

- Calculate the pH of solution E (assuming the temperature of the solution is 298 K).

- When a piece of litmus paper is placed in solution D, it turns blue. Write down the equation for the reaction of this compound (D) with water that explains this observation. [ECJ 2014]

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TABLE 4B: STANDARD REDUCTION POTENTIALS
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Half-reactions/Halfreaksies	E^{θ} (V)
$\text{Li}^{+} + \text{e}^{-} = \text{Li}$	-3,05
$\text{K}^{+} + \text{e}^{-} = \text{K}$	-2,93
$\text{Cs}^{+} + \text{e}^{-} = \text{Cs}$	-2,92
$\text{Ba}^{2+} + 2\text{e}^{-} = \text{Ba}$	-2,90
$\text{Sr}^{2+} + 2\text{e}^{-} = \text{Sr}$	-2,89
$\text{Ca}^{2+} + 2\text{e}^{-} = \text{Ca}$	-2,87
$\text{Na}^{+} + \text{e}^{-} = \text{Na}$	-2,71
$\text{Mg}^{2+} + 2\text{e}^{-} = \text{Mg}$	-2,36
$\text{Al}^{3+} + 3\text{e}^{-} = \text{Al}$	-1,66
$\text{Mn}^{2+} + 2\text{e}^{-} = \text{Mn}$	-1,18
$\text{Cr}^{2+} + 2\text{e}^{-} = \text{Cr}$	-0,91
$2\text{H}_2\text{O} + 2\text{e}^{-} = \text{H}_2(\text{g}) + 2\text{OH}^{-}$	-0,83
$\text{Zn}^{2+} + 2\text{e}^{-} = \text{Zn}$	-0,76
$\text{Cr}^{3+} + 3\text{e}^{-} = \text{Cr}$	-0,74
$\text{Fe}^{2+} + 2\text{e}^{-} = \text{Fe}$	-0,44
$\text{Cr}^{3+} + \text{e}^{-} = \text{Cr}^{2+}$	-0,41
$\text{Cd}^{2+} + 2\text{e}^{-} = \text{Cd}$	-0,40
$\text{Co}^{2+} + 2\text{e}^{-} = \text{Co}$	-0,28
$\text{Ni}^{2+} + 2\text{e}^{-} = \text{Ni}$	-0,27
$\text{Sn}^{2+} + 2\text{e}^{-} = \text{Sn}$	-0,14
$\text{Pb}^{2+} + 2\text{e}^{-} = \text{Pb}$	-0,13
$\text{Fe}^{3+} + 3\text{e}^{-} = \text{Fe}$	-0,06
$2\text{H}^{+} + 2\text{e}^{-} = \text{H}_2(\text{g})$	0,00
$\text{S} + 2\text{H}^{+} + 2\text{e}^{-} = \text{H}_2\text{S}(\text{g})$	+0,14
$\text{Sn}^{4+} + 2\text{e}^{-} = \text{Sn}^{2+}$	+0,15
$\text{Cu}^{2+} + \text{e}^{-} = \text{Cu}^{+}$	+0,16
$\text{SO}_4^{2-} + 4\text{H}^{+} + 2\text{e}^{-} = \text{SO}_2(\text{g}) + 2\text{H}_2\text{O}$	+0,17
$\text{Cu}^{2+} + 2\text{e}^{-} = \text{Cu}$	+0,34
$2\text{H}_2\text{O} + \text{O}_2 + 4\text{e}^{-} = 4\text{OH}^{-}$	+0,40
$\text{SO}_2 + 4\text{H}^{+} + 4\text{e}^{-} = \text{S} + 2\text{H}_2\text{O}$	+0,45
$\text{Cu}^{+} + \text{e}^{-} = \text{Cu}$	+0,52
$\text{I}_2 + 2\text{e}^{-} = 2\text{I}^{-}$	+0,54
$\text{O}_2(\text{g}) + 2\text{H}^{+} + 2\text{e}^{-} = \text{H}_2\text{O}_2$	+0,68
$\text{Fe}^{3+} + \text{e}^{-} = \text{Fe}^{2+}$	+0,77
$\text{NO}_3^{-} + 2\text{H}^{+} + \text{e}^{-} = \text{NO}_2(\text{g}) + \text{H}_2\text{O}$	+0,80
$\text{Ag}^{+} + \text{e}^{-} = \text{Ag}$	+0,80
$\text{Hg}^{2+} + 2\text{e}^{-} = \text{Hg}(\text{l})$	+0,85
$\text{NO}_3^{-} + 4\text{H}^{+} + 3\text{e}^{-} = \text{NO}(\text{g}) + 2\text{H}_2\text{O}$	+0,96
$\text{Br}_2(\text{l}) + 2\text{e}^{-} = 2\text{Br}^{-}$	+1,07
$\text{Pt}^{2+} + 2\text{e}^{-} = \text{Pt}$	+1,20
$\text{MnO}_2 + 4\text{H}^{+} + 2\text{e}^{-} = \text{Mn}^{2+} + 2\text{H}_2\text{O}$	+1,23
$\text{O}_2(\text{g}) + 4\text{H}^{+} + 4\text{e}^{-} = 2\text{H}_2\text{O}$	+1,23
$\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^{+} + 6\text{e}^{-} = 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$	+1,33
$\text{Cl}_2(\text{g}) + 2\text{e}^{-} = 2\text{Cl}^{-}$	+1,36
$\text{MnO}_4^{-} + 8\text{H}^{+} + 5\text{e}^{-} = \text{Mn}^{2+} + 4\text{H}_2\text{O}$	+1,51
$\text{H}_2\text{O}_2 + 2\text{H}^{+} + 2\text{e}^{-} = 2\text{H}_2\text{O}$	+1,77
$\text{Co}^{3+} + \text{e}^{-} = \text{Co}^{2+}$	+1,81
$\text{F}_2(\text{g}) + 2\text{e}^{-} = 2\text{F}^{-}$	+2,87

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