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PHYSICAL SCIENCES

PAPER 1 (PHYSICS)

GRADE 12

TERMS & DEFINITIONS

QUESTIONS & ANSWERS PER TOPIC

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TERMS AND DEFINITIONS

MECHANICS: NEWTON'S LAWS	
Static frictional force (f_s)	The force that opposes the tendency of motion of a STATIONARY object relative to a surface.
Kinetic frictional force (f_k)	The force that opposes the motion of a MOVING object relative to a surface.
Maximum static frictional force ($f_s^{\max}$)	The static frictional force is a maximum ($f_s^{\max}$) just before the object starts to move across the surface.
Free-body diagrams	This is a diagram that shows the relative magnitudes and directions of forces acting on a body/particle that has been isolated from its surroundings
Newton's first law of motion	A body will remain in its state of rest or motion at constant velocity unless a non-zero resultant/net force acts on it.
Inertia	The resistance of a body to a change in its state of rest or uniform motion in a straight line. Mass is a measure of an object's inertia.
Newton's second law of motion	When a resultant/net force acts on an object, the object will accelerate in the direction of the force at an acceleration directly proportional to the force and inversely proportional to the mass of the object. In symbols: $F_{\text{net}} = ma$
Newton's Third Law of motion	When object A exerts a force on object B, object B SIMULTANEOUSLY exerts a force equal in magnitude but opposite in direction on object A.
Newton's law of universal gravitation	Each body in the universe attracts every other body with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres. In symbols: $F = \frac{Gm_1m_2}{r^2}$
Normal force	The force or the component of a force which a surface exerts on an object with which it is in contact, and which is perpendicular to the surface.
Mass	The amount of matter in a body measured in kilogram (kg).
Weight	The gravitational force, in newton (N), exerted on an object.
Weightlessness	The sensation experienced when all contact forces are removed i.e. no external objects touch one's body.

MECHANICS: MOMENTUM AND IMPULSE	
Contact forces	Contact forces arise from the physical contact between two objects (e.g. a soccer player kicking a ball.)
Non-contact forces	Non-contact forces arise even if two objects do not touch each other (e.g. the force of attraction of the earth on a parachutist even when the earth is not in direct contact with the parachutist.)
Momentum	Linear momentum is the product of an object's mass and its velocity. In symbols: $p = mv$ Unit: $\text{N}\cdot\text{s}$ or $\text{kg}\cdot\text{m}\cdot\text{s}^{-1}$
Newton's Second Law of motion in terms of momentum	The net (or resultant) force acting on an object is equal to the rate of change of momentum of the object in the direction of the net force. In symbols: $F_{\text{net}} = \frac{\Delta p}{\Delta t}$
Principle of conservation of linear momentum	The TOTAL linear momentum in an isolated system remains constant (is conserved). In symbols: $\Sigma p_{\text{before}} = \Sigma p_{\text{after}}$
Closed system	A system in which the net external force acting on the system is zero.
Impulse	The product of the resultant/net force acting on an object and the time the resultant/net force acts on the object. In symbols: $\text{Impulse} = F_{\text{net}}\Delta t$ Unit: $\text{N}\cdot\text{s}$ or $\text{kg}\cdot\text{m}\cdot\text{s}^{-1}$



Impulse-momentum theorem	In symbols: $F_{\text{net}}\Delta t = m\Delta v = m(v_f - v_i)$ Unit: $\text{N}\cdot\text{s}$ or $\text{kg}\cdot\text{m}\cdot\text{s}^{-1}$
Elastic collision	A collision in which both total momentum and total kinetic energy are conserved.
Inelastic collision	A collision during which kinetic energy is not conserved.

MECHANICS: VERTICAL PROJECTILE MOTION	
1-D motion	One-dimensional motion. Linear motion. Motion in one line.
Acceleration	The rate of change of velocity. Symbol: a Unit: meters per second squared ($\text{m}\cdot\text{s}^{-2}$)
Gravitational acceleration (g)	The acceleration of a body due to the force of attraction of the earth.
Displacement	Change in position. Symbol: Δx (horizontal displacement) or Δy (vertical displacement) Unit: meters (m)
Free fall	The type of motion in which the only significant vertical force acting on the body is the body's weight.
Gravitational force	A force of attraction of one body on another due to their masses.
Position	Where an object is relative to a reference point. Symbol: x (horizontal position) or y (vertical position) Unit: meters (m)
Projectile	An object in free fall.
Velocity	The rate of change of position. Symbol: v Unit: meters per second ($\text{m}\cdot\text{s}^{-1}$)

MECHANICS: WORK, ENERGY AND POWER	
Work	Work done on an object by a constant force is the product of the magnitude of the force, the magnitude of the displacement and the angle between the force and the displacement. In symbols: $W = F \Delta x \cos \theta$
Positive work	The kinetic energy of the object increases.
Negative work	The kinetic energy of the object decreases.
Work-energy theorem	The net/total work done on an object is equal to the change in the object's kinetic energy OR the work done on an object by a resultant/net force is equal to the change in the object's kinetic energy. In symbols: $W_{\text{net}} = \Delta K = K_f - K_i$.
Principle of conservation of mechanical energy	The total mechanical energy (sum of gravitational potential energy and kinetic energy) in an isolated system remains constant. (A system is isolated when the resultant/net external force acting on the system is zero.) In symbols: $E_M(\text{initial}) = E_M(\text{final})$ OR $(E_p + E_k)_{\text{initial}} = (E_p + E_k)_{\text{final}}$
Conservative force	A force for which the work done in moving an object between two points is independent of the path taken. Examples are gravitational force, the elastic force in a spring and electrostatic forces (coulomb forces).
Non-conservative force	A force for which the work done in moving an object between two points depends on the path taken. Examples are frictional force, air resistance, tension in a chord, etc.
Power	The rate at which work is done or energy is expended. In symbols: $P = \frac{W}{\Delta t}$ Unit: watt (W)

WAVES, SOUND AND LIGHT: DOPPLER EFFECT	
Doppler Effect	The change in frequency (or pitch) of the sound detected by a listener because the sound source and the listener have different velocities relative to the medium of sound propagation.
Red shift	Observed when light from an object increased in wavelength (decrease in frequency). A red shift occurs when a light source moves away from an observer.
Blue shift	Observed when light from an object decreased in wavelength (increase in frequency). A blue shift occurs when a light source moves towards an observer.
Frequency	The number of vibrations per second. Symbol: f Unit: hertz (Hz) or per second (s^{-1})
Wavelength	The distance between two successive points in phase. Symbol: λ Unit: meter (m)
Wave equation	Speed = frequency x wavelength

ELECTRICITY AND MAGNETISM: ELECTROSTATICS	
Coulomb's law	The magnitude of the electrostatic force exerted by one point charge on another point charge is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance (r) between them. In symbols: $F = \frac{kQ_1Q_2}{r^2}$
Electric field	A region of space in which an electric charge experiences a force.
Electric field at a point	The electric field at a point is the electrostatic force experienced per unit positive charge placed at that point. In symbols: $E = \frac{F}{q}$ Unit: $N \cdot C^{-1}$
Direction of electric field	The direction of the electric field at a point is the direction that a positive test charge would move if placed at that point.

ELECTRICITY AND MAGNETISM: ELECTRIC CIRCUITS	
Ohm's law	The potential difference across a conductor is directly proportional to the current in the conductor at constant temperature. In symbols: $R = \frac{V}{I}$
Ohmic conductors	A conductor that obeys Ohm's law. The resistance of the conductor remains constant.
Non-ohmic conductors	A conductor that does not obey Ohm's law. The resistance of the conductor does not remain constant, but increases as the current increases. Example: A bulb
Power	Rate at which work is done. In symbols: $P = \frac{W}{\Delta t}$ Unit: watt (W) Other formulae: $P = VI$; $P = I^2R$; $P = \frac{V^2}{R}$
kilowatt hour (kWh)	The use of 1 kilowatt of electricity for 1 hour.
Internal resistance	The resistance within a battery that causes a drop in the potential difference of the battery when there is a current in the circuit.
emf	Maximum energy provided (work done) by a battery per coulomb/unit charge passing through it. (It is the potential difference across the ends of a battery when there is NO current in the circuit.)

Terminal potential difference	The energy transferred to or the work done per coulomb of charge passing through the battery when the battery delivers a current. (It is the potential difference across the ends of a battery when there is a current in the circuit.)
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ELECTRICITY AND MAGNETISM: ELECTRICAL MACHINES

Generator	A device that transfers mechanical energy into electrical energy.
Faraday's law of electromagnetic induction	The magnitude of the induced emf across the ends of a conductor is directly proportional to the rate of change in the magnetic flux linkage with the conductor. (When a conductor is moved in magnetic field, a potential difference is induced across the conductor.)
Fleming's Right Hand Rule for generators	Hold the thumb, forefinger and second finger of the RIGHT hand at right angles to each other. If the forefinger points in the direction of the magnetic field (N to S) and the thumb points in the direction of the force (movement), then the second finger points in the direction of the induced current.
Electric motor	A device that transfers electrical energy into mechanical energy.
Fleming's Left Hand Rule for electric motors	Hold the thumb, forefinger and second finger of the LEFT hand at right angles to each other. If the forefinger points in the direction of the magnetic field (N to S) and the second finger points in the direction of the conventional current, then the thumb will point in the direction of the force (movement).
Conventional current	Flow of electric charge from positive to negative.
AC	Alternating current The direction of the current changes each half cycle.
DC	Direct current The direction of the current remains constant. (The direction of conventional current is from the positive to the negative pole of a battery. The direction of electron current is from the negative to the positive pole of the battery.)
Root-mean-square potential difference (V_{rms})	The root-mean-square potential difference is the AC potential difference that dissipates the same amount of energy (gives the same heating effect) as an equivalent DC potential difference.
Peak potential difference (V_{max})	The maximum potential difference value reached by the alternating current as it fluctuates i.e. the peak of the sine wave representing an AC potential difference.
Root-mean-square current (I_{rms})	Root-mean-square current is the alternating current that dissipates the same amount of energy (gives the same heating effect) as an equivalent DC current.
Peak current (I_{max})	The maximum current value reached by the alternating current as it fluctuates i.e. the peak of the sine wave representing an AC current.

MATTER AND MATERIALS: OPTICAL PHENOMENA AND PROPERTIES OF MATERIALS

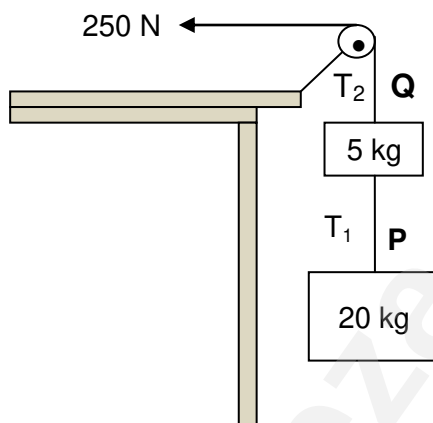
Photo-electric effect	The process whereby electrons are ejected from a metal surface when light of suitable frequency is incident on that surface.
Threshold frequency (f_0)	The minimum frequency of light needed to emit electrons from a certain metal surface.
Work function (W_0)	The minimum energy that an electron in the metal needs to be emitted from the metal surface.
Photo-electric equation	$E = W_0 + K_{max}$, where $E = hf$ and $W_0 = hf_0$ and $K_{max} = \frac{1}{2}mv_{max}^2$
Atomic absorption spectrum	Formed when certain frequencies of electromagnetic radiation that passes through a medium, e.g. a cold gas, is absorbed.
Atomic emission spectrum	Formed when certain frequencies of electromagnetic radiation are emitted due to an atom's electrons making a transition from a high-energy state to a lower energy state.

QUESTIONS

NEWTON'S LAWS

QUESTION 1

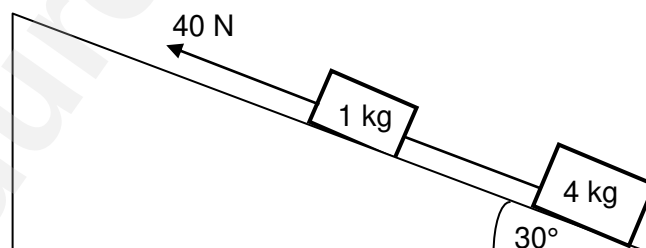
Two blocks of masses 20 kg and 5 kg respectively are connected by a light inextensible string, **P**. A second light inextensible string, **Q**, attached to the 5 kg block, runs over a light frictionless pulley. A constant horizontal force of 250 N pulls the second string as shown in the diagram below. The magnitudes of the tensions in **P** and **Q** are T_1 and T_2 respectively. Ignore the effects of air friction.



- 1.1 State Newton's second law of motion in words. (2)
 - 1.2 Draw a labelled free-body diagram indicating ALL the forces acting on the **5 kg block**. (3)
 - 1.3 Calculate the magnitude of the tension T_1 in string **P**. (6)
 - 1.4 When the 250 N force is replaced by a sharp pull on the string, one of the two strings break. Which ONE of the two strings, **P** or **Q**, will break? (1)
- [12]

QUESTION 2

A block of mass 1 kg is connected to another block of mass 4 kg by a light inextensible string. The system is pulled up a rough plane inclined at 30° to the horizontal, by means of a constant 40 N force parallel to the plane as shown in the diagram below.



The magnitude of the kinetic frictional force between the surface and the 4 kg block is 10 N. The coefficient of kinetic friction between the 1 kg block and the surface is 0,29.

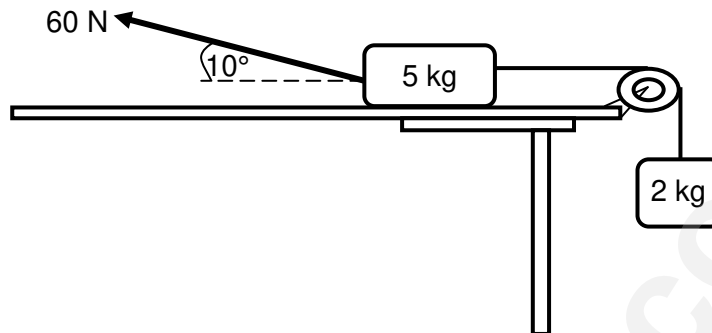
- 2.1 State Newton's third law of motion in words. (2)
- 2.2 Draw a labelled free-body diagram showing ALL the forces acting on the **1 kg block** as it moves up the incline. (5)
- 2.3 Calculate the magnitude of the:
 - 2.3.1 Kinetic frictional force between the 1 kg block and the surface (3)
 - 2.3.2 Tension in the string connecting the two blocks (6)

[16]

QUESTION 3

A 5 kg block, resting on a rough horizontal table, is connected by a light inextensible string passing over a light frictionless pulley to another block of mass 2 kg. The 2 kg block hangs vertically as shown in the diagram below.

A force of 60 N is applied to the 5 kg block at an angle of 10° to the horizontal, causing the block to accelerate to the left.

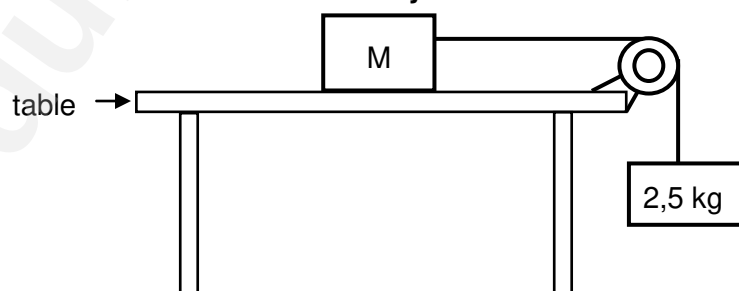


The coefficient of kinetic friction between the 5 kg block and the surface of the table is 0,5. Ignore the effects of air friction.

- 3.1 Draw a labelled free-body diagram showing ALL the forces acting on the 5 kg block. (5)
 - 3.2 Calculate the magnitude of the:
 - 3.2.1 Vertical component of the 60 N force (2)
 - 3.2.2 Horizontal component of the 60 N force (2)
 - 3.3 State Newton's Second Law of Motion in words. (2)
- Calculate the magnitude of the:
- 3.4 Normal force acting on the 5 kg block (2)
 - 3.5 Tension in the string connecting the two blocks (7)
- [20]**

QUESTION 4

- 4.1 Two blocks of mass M kg and 2,5 kg respectively are connected by a light, inextensible string. The string runs over a light, frictionless pulley, as shown in the diagram below. The blocks are **stationary**.



- 4.1.1 State Newton's THIRD law of motion in words. (2)
- 4.1.2 Calculate the tension in the string. (3)

The coefficient of static friction (μ_s) between the unknown mass M and the surface of the table is 0,2.

- 4.1.3 Calculate the minimum value of M that will prevent the blocks from moving. (5)

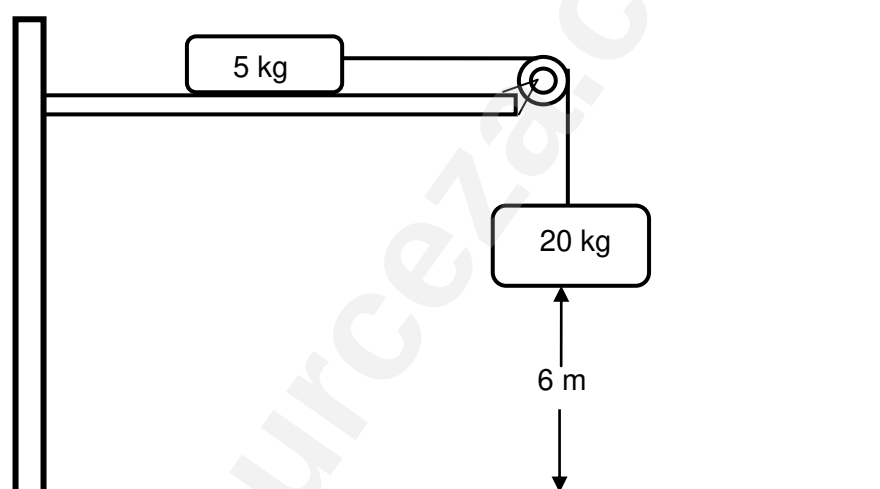
The block of unknown mass M is now replaced with a block of mass 5 kg. The 2,5 kg block now accelerates downwards. The coefficient of kinetic friction (μ_k) between the 5 kg block and the surface of the table is 0,15.

4.1.4 Calculate the magnitude of the acceleration of the 5 kg block. (5)

4.2 A small hypothetical planet **X** has a mass of $6,5 \times 10^{20}$ kg and a radius of 550 km. Calculate the gravitational force (weight) that planet **X** exerts on a 90 kg rock on this planet's surface. (4)
[19]

QUESTION 5

5.1 A 5 kg mass and a 20 kg mass are connected by a light inextensible string which passes over a light frictionless pulley. Initially, the 5 kg mass is held stationary on a horizontal surface, while the 20 kg mass hangs vertically downwards, 6 m above the ground, as shown in the diagram below. The diagram is not drawn to scale.



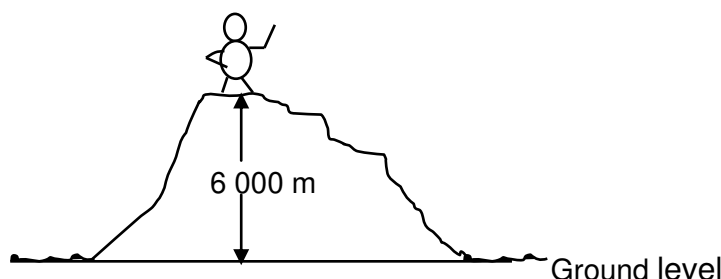
When the *stationary* 5 kg mass is released, the two masses begin to move. The coefficient of kinetic friction, μ_k , between the 5 kg mass and the horizontal surface is 0,4. Ignore the effects of air friction.

5.1.1 Calculate the acceleration of the 20 kg mass. (5)

5.1.2 Calculate the speed of the 20 kg mass as it strikes the ground. (4)

5.1.3 At what minimum distance from the pulley should the 5 kg mass be placed initially, so that the 20 kg mass just strikes the ground? (1)

5.2 A person of mass 60 kg climbs to the top of a mountain which is 6 000 m above ground level.

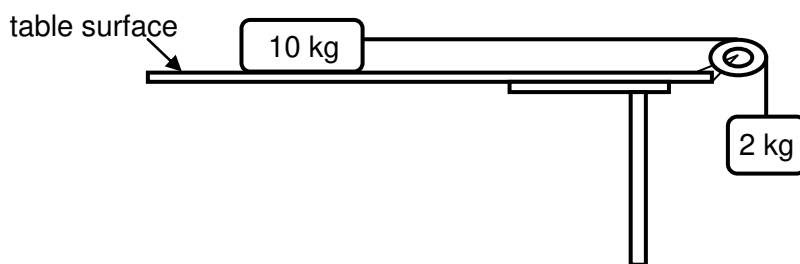


5.2.1 State Newton's Law of Universal Gravitation in words. (2)

5.2.2 Calculate the *difference* in the weight of the climber at the top of the mountain and at ground level. (6)
[18]

QUESTION 6

The diagram below shows a 10 kg block lying on a flat, rough, horizontal surface of a table. The block is connected by a light, inextensible string to a 2 kg block hanging over the side of the table. The string runs over a light, frictionless pulley. The blocks are **stationary**.



- 6.1 State Newton's FIRST law of motion in words. (2)
- 6.2 Write down the magnitude of the NET force acting on the 10 kg block. (1)

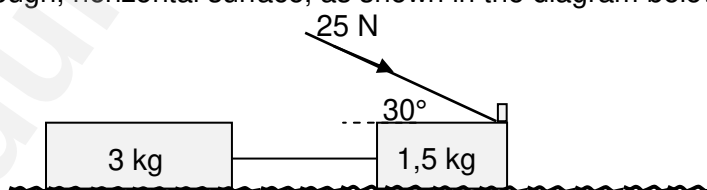
When a 15 N force is applied vertically downwards on the 2 kg block, the 10 kg block accelerates to the right at $1,2 \text{ m} \cdot \text{s}^{-2}$.

- 6.3 Draw a free-body diagram for the 2 kg block when the 15 N force is applied to it. (3)
- 6.4 Calculate the coefficient of kinetic friction between the 10 kg block and the surface of the table. (7)
- 6.5 How does the value, calculated in QUESTION 6.4, compare with the value of the coefficient of STATIC friction for the 10 kg block and the table? Write down only LARGER THAN, SMALLER THAN or EQUAL TO. (1)
- 6.6 If the 10 kg block had a larger surface area in contact with the surface of the table, how would this affect the coefficient of kinetic friction calculated in QUESTION 6.4? Assume that the rest of the system remains unchanged. Write down only INCREASES, DECREASES or REMAINS THE SAME. Give a reason for the answer. (2)

[16]

QUESTION 7

A learner constructs a push toy using two blocks with masses 1,5 kg and 3 kg respectively. The blocks are connected by a massless, inextensible cord. The learner then applies a force of 25 N at an angle of 30° to the 1,5 kg block by means of a light rigid rod, causing the toy to move across a flat, rough, horizontal surface, as shown in the diagram below.



The coefficient of kinetic friction (μ_k) between the surface and each block is 0,15.

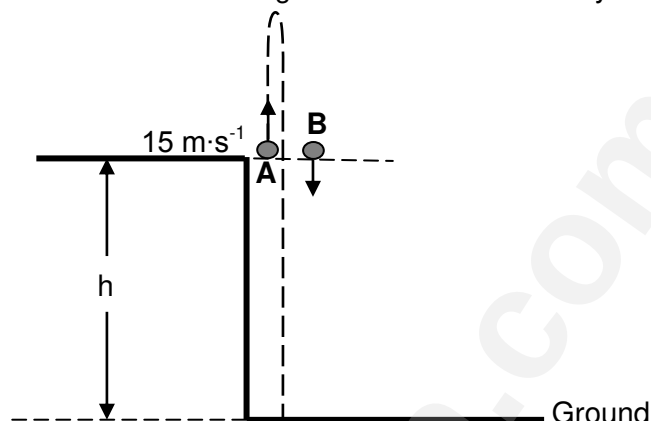
- 7.1 State Newton's Second Law of Motion in words. (2)
- 7.2 Calculate the magnitude of the kinetic frictional force acting on the 3 kg block. (3)
- 7.3 Draw a labelled free-body diagram showing ALL the forces acting on the 1,5 kg block. (5)
- 7.4 Calculate the magnitude of the:
- 7.4.1 Kinetic frictional force acting on the 1,5 kg block (3)
- 7.4.2 Tension in the cord connecting the two blocks (5)

[18]

VERTICAL PROJECTILE MOTION

QUESTION 1

A ball, **A**, is thrown vertically upward from a height, h , with a speed of $15 \text{ m}\cdot\text{s}^{-1}$. AT THE SAME INSTANT, a second identical ball, **B**, is dropped from the same height as ball **A** as shown in the diagram below. Both balls undergo free fall and eventually hit the ground.

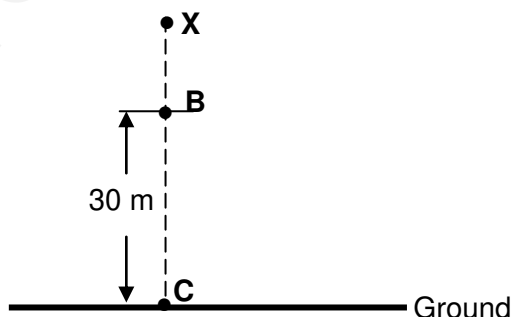


- 1.1 Explain the term *free fall*. (2)
 - 1.2 Calculate the time it takes for ball **A** to return to its starting point. (4)
 - 1.3 Calculate the distance between ball **A** and ball **B** when ball **A** is at its maximum height. (7)
 - 1.4 Sketch a velocity-time graph in the ANSWER BOOK for the motion of ball **A** from the time it is projected until it hits the ground. Clearly show the following on your graph: (4)
- The initial velocity
 - The time it takes to reach its maximum height
 - The time it takes to return to its starting point

[17]

QUESTION 2

An object is released from rest from a point **X**, above the ground as shown in the diagram below. It travels the last 30 m (**BC**) in 1,5 s before hitting the ground. Ignore the effects of air friction.



- 2.1 Name the type of motion described above. (1)
- 2.2 Calculate the:
 - 2.2.1 Magnitude of the velocity of the object at point **B** (4)
 - 2.2.2 Height of point **X** above the ground (5)

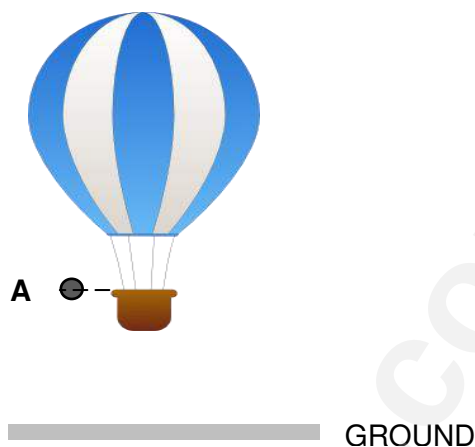
After hitting the ground, the object bounces once and then comes to rest on the ground.

- 2.3 Sketch an acceleration-time graph for the entire motion of the object. (3)

[13]

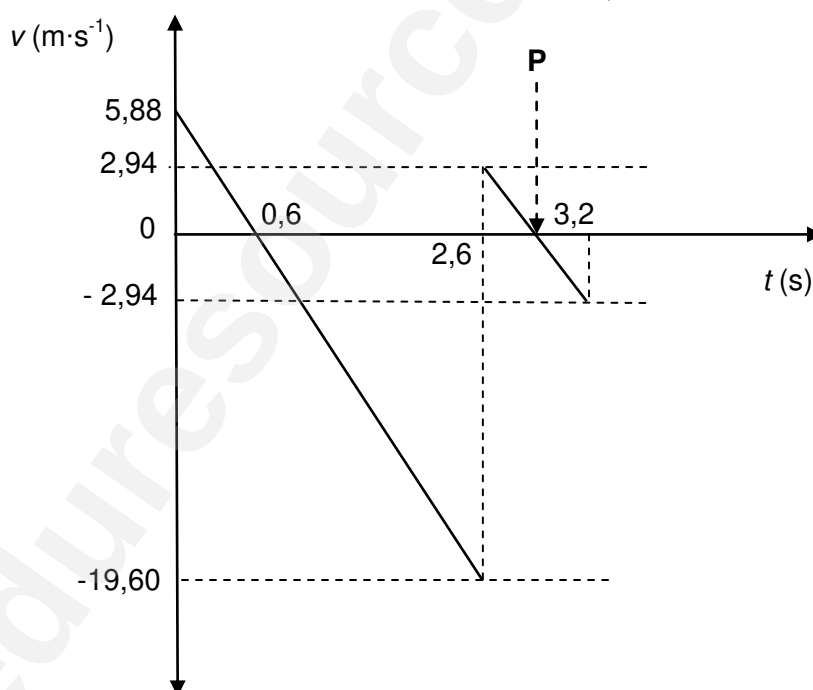
QUESTION 3

A hot air balloon is rising vertically at a constant velocity. When the hot air balloon reaches point **A** a few metres above the ground, a man in the hot air balloon drops a ball which hits the ground and bounces. Ignore the effects of friction.



The velocity-time graph below represents the motion of the ball from the instant it is dropped until after it bounces for the first time. The time interval between bounces is ignored. THE UPWARD DIRECTION IS TAKEN AS POSITIVE.

USE INFORMATION FROM THE GRAPH TO ANSWER THE QUESTIONS THAT FOLLOW.



3.1 Write down the magnitude of the velocity of the hot air balloon. (1)

3.2 Calculate the height above the ground from which the ball was dropped. (3)

Calculate the:

3.3 Time at the point **P** indicated on the graph (2)

3.4 Maximum height the ball reaches after the first bounce (3)

3.5 Distance between the ball and hot air balloon when the ball is at its maximum height after the first bounce (4)

[13]

QUESTION 4

Ball **A** is projected vertically upwards at a velocity of $16 \text{ m}\cdot\text{s}^{-1}$ from the ground. Ignore the effects of air resistance. **Use the ground as zero reference.**

4.1 Calculate the time taken by ball **A** to return to the ground. (4)

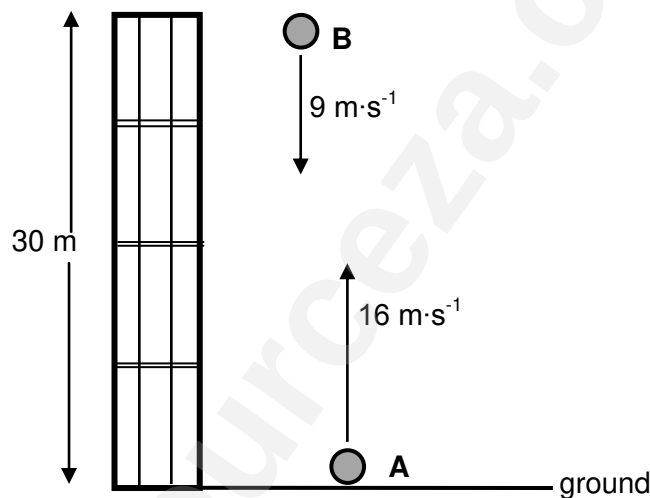
4.2 Sketch a velocity-time graph for ball **A**.

Show the following on the graph:

- Initial velocity of ball **A**
- Time taken to reach the highest point of the motion
- Time taken to return to the ground

(3)

ONE SECOND after ball **A** is projected upwards, a second ball, **B**, is thrown vertically downwards at a velocity of $9 \text{ m}\cdot\text{s}^{-1}$ from a balcony 30 m above the ground. Refer to the diagram below.



4.3 Calculate how high above the ground ball **A** will be at the instant the two balls pass each other. (6)

[13]

QUESTION 5

A man throws ball **A** downwards with a speed of $2 \text{ m}\cdot\text{s}^{-1}$ from the edge of a window, 45 m above a dam of water. One second later he throws a second ball, ball **B**, downwards and observes that both balls strike the surface of the water in the dam at the same time. Ignore air friction.

5.1 Calculate the:

5.1.1 Speed with which ball **A** hits the surface of the water (3)

5.1.2 Time it takes for ball **B** to hit the surface of the water (3)

5.1.3 Initial velocity of ball **B** (5)

5.2 On the same set of axes, sketch a velocity versus time graph for the motion of balls **A** and **B**. Clearly indicate the following on your graph:

- Initial velocities of both balls **A** and **B**
- The time of release of ball **B**
- The time taken by both balls to hit the surface of the water

(5)

[16]

QUESTION 6

Ball **A** is projected vertically upwards from the ground, near a tall building, with a speed of $30 \text{ m}\cdot\text{s}^{-1}$. Ignore the effects of air friction.

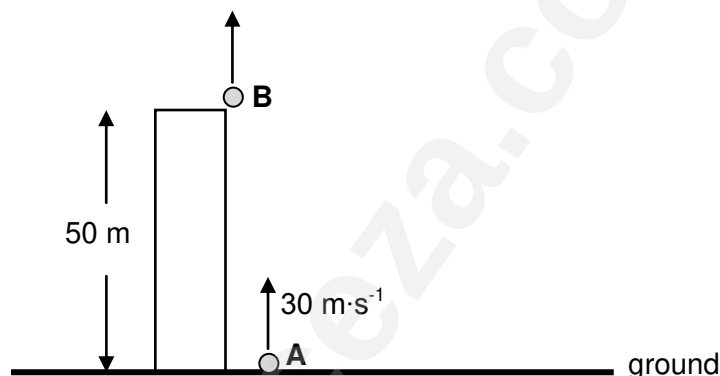
6.1 Explain what is meant by a *projectile*. (2)

6.2 Calculate:

6.2.1 The total time that ball **A** will be in the air (4)

6.2.2 The distance travelled by ball **A** during the last second of its fall (4)

6.3 TWO SECONDS after ball **A** is projected upwards, ball **B** is projected vertically upwards from the roof of the same building. The roof the building is 50 m above the ground. Both balls **A** and **B** reach the ground *at the same time*. Refer to the diagram below. Ignore the effects of air friction.



Calculate the speed with which ball **B** was projected upwards from the roof. (4)

6.4 Sketch velocity-time graphs for the motion of both balls **A** and **B** on the *same set of axes*. Clearly label the graphs for balls **A** and **B** respectively.

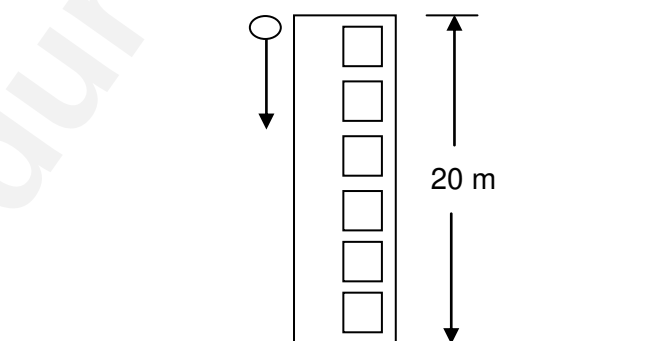
Indicate the following on the graphs:

- (a) Time taken by both balls **A** and **B** to reach the ground
- (b) Time taken by ball **A** to reach its maximum height

(4)
[18]

QUESTION 7

A ball is dropped from the top of a building 20 m high. Ignore the effects of air resistance.



7.1 Define the term *free fall*. (2)

7.2 Calculate the:

7.2.1 Speed at which the ball hits the ground (4)

7.2.2 Time it takes the ball to reach the ground (3)

7.3 Sketch a velocity-time graph for the motion of the ball (no values required). (2)

[11]

MOMENTUM AND IMPULSE

QUESTION 1

Dancers have to learn many skills, including how to land correctly. A dancer of mass 50 kg leaps into the air and lands feet first on the ground. She lands on the ground with a velocity of $5 \text{ m}\cdot\text{s}^{-1}$. As she lands, she bends her knees and comes to a complete stop in 0,2 seconds.

- 1.1 Calculate the momentum with which the dancer reaches the ground. (3)
- 1.2 Define the term *impulse* of a force. (2)
- 1.3 Calculate the magnitude of the net force acting on the dancer as she lands. (3)

Assume that the dancer performs the same jump as before but lands without bending her knees.

- 1.4 Will the force now be GREATER THAN, SMALLER THAN or EQUAL TO the force calculated in QUESTION 1.3? (1)
 - 1.5 Give a reason for the answer to QUESTION 1.4. (3)
- [12]**

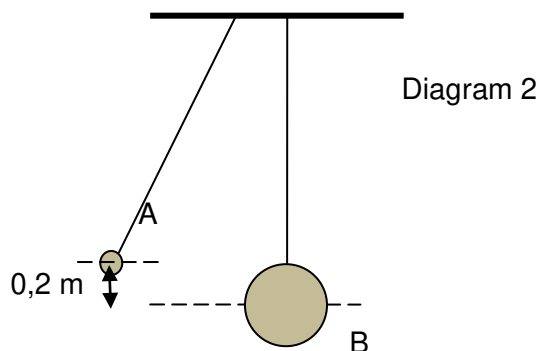
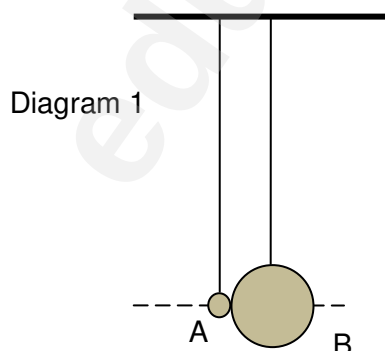
QUESTION 2

Percy, mass 75 kg, rides at $20 \text{ m}\cdot\text{s}^{-1}$ on a quad bike (motorcycle with four wheels) with a mass of 100 kg. He suddenly applies the brakes when he approaches a red traffic light on a wet and slippery road. The wheels of the quad bike lock and the bike slides forward in a straight line. The force of friction causes the bike to stop in 8 s.

- 2.1 Define the concept *momentum* in words. (2)
 - 2.2 Calculate the change in momentum of Percy and the bike, from the moment the brakes lock until the bike comes to a stop. (4)
 - 2.3 Calculate the average frictional force exerted by the road on the wheels to stop the bike. (4)
- [10]**

QUESTION 3

Two stationary steel balls, **A** and **B**, are suspended next to each other by massless, inelastic strings as shown in Diagram 1 below.



Ball **A** of mass 0,2 kg is displaced through a vertical distance of 0,2 m, as shown in Diagram 2 above. When ball **A** is released, it collides elastically and head-on with ball **B**. Ignore the effects of air friction.

- 3.1 What is meant by an *elastic collision*? (2)

Immediately after the collision, ball **A** moves horizontally backwards (to the left). Ball **B** acquires kinetic energy of 0,12 J and moves horizontally forward (to the right).

Calculate the:

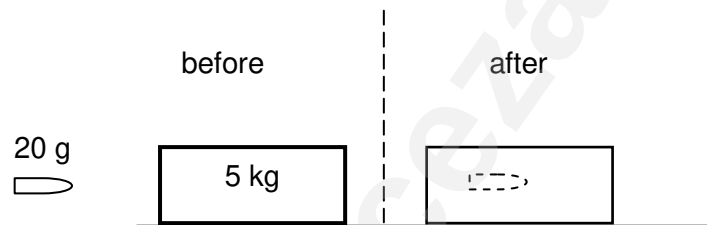
- 3.2 Kinetic energy of ball **A** just before it collides with ball **B** (Use energy principles only.) (3)
- 3.3 Speed of ball **A** immediately after the collision (4)
- 3.4 Magnitude of the impulse on ball **A** during the collision (5)
- [14]**

QUESTION 4

A bullet of mass 20 g is fired from a stationary rifle of mass 3 kg. Assume that the bullet moves horizontally. Immediately after firing, the rifle recoils (moves back) with a velocity of $1,4 \text{ m}\cdot\text{s}^{-1}$.

- 4.1 Calculate the speed at which the bullet leaves the rifle. (4)

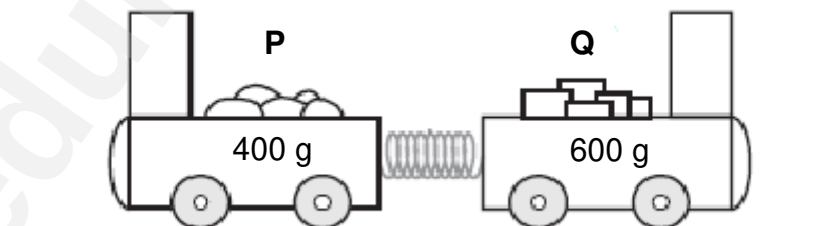
The bullet strikes a stationary 5 kg wooden block **fixed** to a flat, horizontal table. The bullet is brought to rest after travelling a distance of 0,4 m **into the block**. Refer to the diagram below.



- 4.2 Calculate the magnitude of the average force exerted by the block on the bullet. (5)
- 4.3 How does the magnitude of the force calculated in QUESTION 3.2 compare to the magnitude of the force exerted by the bullet on the block? Write down only LARGER THAN, SMALLER THAN or THE SAME. (1)
- [10]**

QUESTION 5

The diagram below shows two trolleys, **P** and **Q**, held together by means of a compressed spring on a flat, frictionless horizontal track. The masses of **P** and **Q** are 400 g and 600 g respectively.



When the trolleys are released, it takes 0,3 s for the spring to unwind to its natural length. Trolley **Q** then moves to the right at $4 \text{ m}\cdot\text{s}^{-1}$.

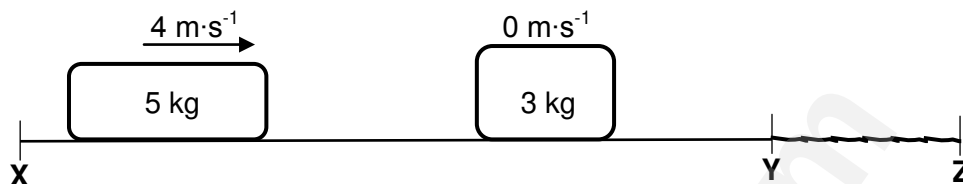
- 5.1 State the *principle of conservation of linear momentum* in words. (2)
- 5.2 Calculate the:
- 5.2.1 Velocity of trolley **P** after the trolleys are released (4)
- 5.2.2 Magnitude of the average force exerted by the spring on trolley **Q** (4)
- 5.3 Is this an elastic collision? Only answer YES or NO. (1)
- [11]**

QUESTION 6

The diagram below shows two sections, **XY** and **YZ**, of a horizontal, flat surface. Section **XY** is smooth, while section **YZ** is rough.

A 5 kg block, moving with a velocity of $4 \text{ m}\cdot\text{s}^{-1}$ to the right, collides head-on with a stationary 3 kg block. After the collision, the two blocks stick together and move to the right, past point **Y**.

The combined blocks travel for 0,3 s from point **Y** before coming to a stop at point **Z**.



6.1 State the *principle of conservation of linear momentum* in words. (2)

6.2 Calculate the magnitude of the:

6.2.1 Velocity of the combined blocks at point **Y** (4)

6.2.2 Net force acting on the combined blocks when they move through section **YZ** (4)
[10]

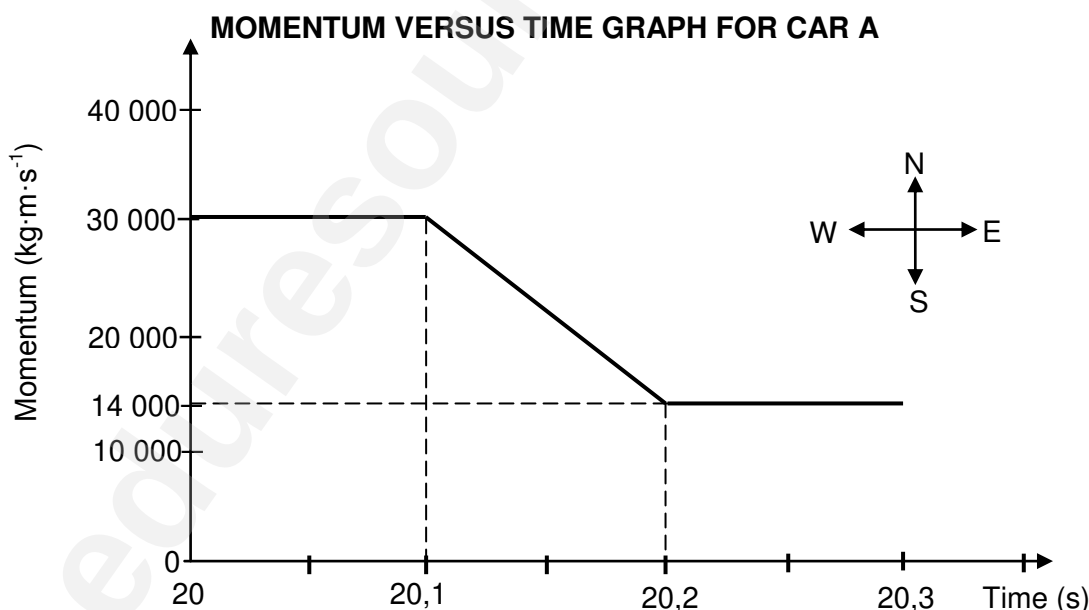
QUESTION 7

The graph below shows how the momentum of car **A** changes with time *just before* and *just after* a head-on collision with car **B**.

Car **A** has a mass of 1 500 kg, while the mass of car **B** is 900 kg.

Car **B** was travelling at a constant velocity of $15 \text{ m}\cdot\text{s}^{-1}$ west before the collision.

Take east as positive and consider the system as isolated.



7.1 What do you understand by the term *isolated system* as used in physics? (1)

Use the information in the graph to answer the following questions.

7.2 Calculate the:

7.2.1 Magnitude of the velocity of car **A** just before the collision (3)

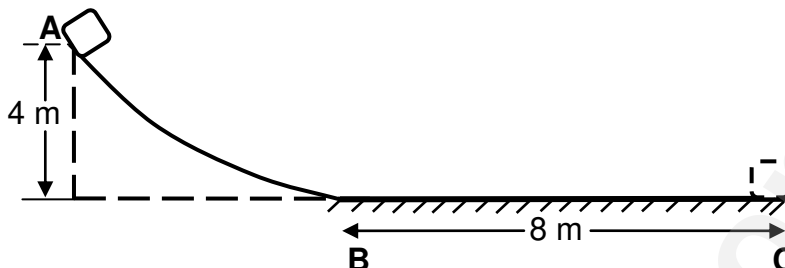
7.2.2 Velocity of car **B** just after the collision (5)

7.2.3 Magnitude of the net average force acting on car **A** during the collision (4)
[13]

WORK, ENERGY AND POWER

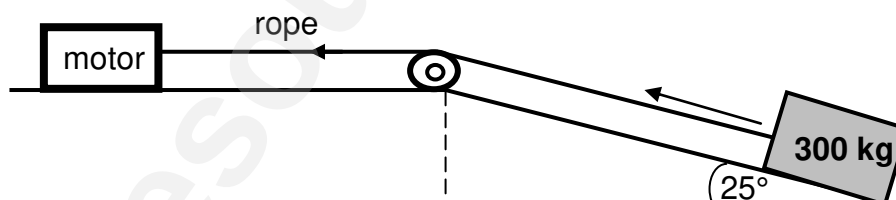
QUESTION 1

- 1.1 The diagram below shows a track, **ABC**. The curved section, **AB**, is frictionless. The rough horizontal section, **BC**, is 8 m long.



An object of mass 10 kg is released from point **A** which is 4 m above the ground. It slides down the track and comes to rest at point **C**.

- 1.1.1 State the *principle of conservation of mechanical energy* in words. (2)
- 1.1.2 Is mechanical energy conserved as the object slides from **A** to **C**? Write only YES or NO. (1)
- 1.1.3 Using ENERGY PRINCIPLES only, calculate the magnitude of the frictional force exerted on the object as it moves along **BC**. (6)
- 1.2 A motor pulls a crate of mass 300 kg with a constant force by means of a light inextensible rope running over a light frictionless pulley as shown below. The coefficient of kinetic friction between the crate and the surface of the inclined plane is 0,19.



- 1.2.1 Calculate the magnitude of the frictional force acting between the crate and the surface of the inclined plane. (3)

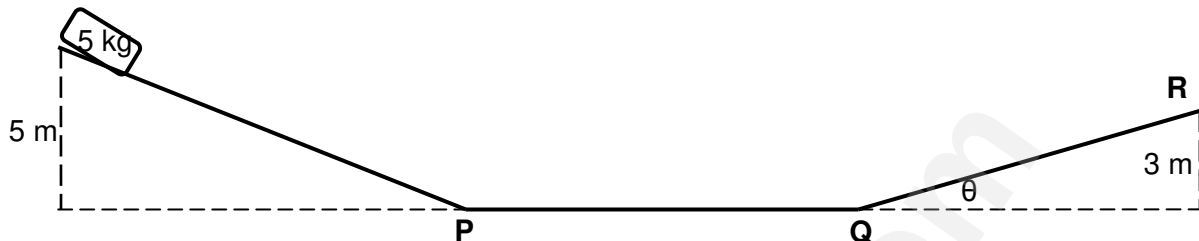
The crate moves up the incline at a constant speed of $0,5 \text{ m}\cdot\text{s}^{-1}$.

- 1.2.2 Calculate the average power delivered by the motor while pulling the crate up the incline. (6)
- [18]**



QUESTION 2

A 5 kg block is released from rest from a height of 5 m and slides down a frictionless incline to point **P** as shown in the diagram below. It then moves along a frictionless horizontal portion **PQ** and finally moves up a second rough inclined plane. It comes to a stop at point **R** which is 3 m above the horizontal.

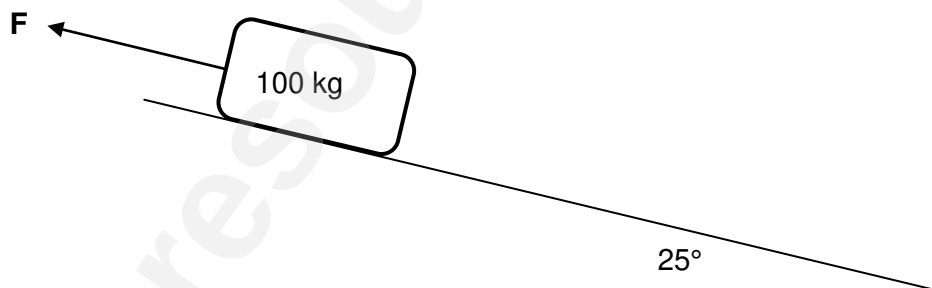


The frictional force, which is a non-conservative force, between the surface and the block is 18 N.

- 2.1 Using ENERGY PRINCIPLES only, calculate the speed of the block at point **P**. (4)
 - 2.2 Explain why the kinetic energy at point **P** is the same as that at point **Q**. (2)
 - 2.3 Explain the term *non-conservative force*. (2)
 - 2.4 Calculate the angle (θ) of the slope **QR**. (7)
- [15]

QUESTION 3

The diagram below shows a heavy block of mass 100 kg sliding **down** a rough 25° inclined plane. A constant force **F** is applied on the block parallel to the inclined plane as shown in the diagram below, so that the block slides down at a **constant velocity**.



The magnitude of the kinetic frictional force (f_k) between the block and the surface of the inclined plane is 266 N.

- 3.1 Friction is a non-conservative force. What is meant by the term *non-conservative force*? (2)
 - 3.2 A learner states that the net work done on the block is greater than zero.
 - 3.2.1 Is the learner correct? Answer only YES or NO. (1)
 - 3.2.2 Explain the answer to QUESTION 3.2.1 using physics principles. (2)
 - 3.3 Calculate the magnitude of the force **F**. (4)
- If the block is released from rest without the force **F** being applied, it moves 3 m down the inclined plane.
- 3.4 Calculate the speed of the block at the bottom of the inclined plane. (6)
- [15]

QUESTION 4

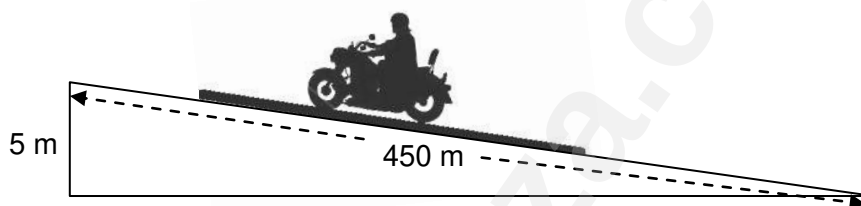
The track for a motorbike race consists of a straight, horizontal section that is 800 m long.



A participant, such as the one in the picture above, rides at a certain average speed and completes the 800 m course in 75 s. To maintain this speed, a constant driving force of 240 N acts on the motorbike.

- 4.1 Calculate the average power developed by the motorbike for this motion. (3)

Another person practises on the same motorbike on a track with an incline. Starting from rest, the person rides a distance of 450 m up the incline which has a vertical height of 5 m, as shown below.



The total frictional force acting on the motorbike is 294 N. The combined mass of rider and motorbike is 300 kg. The average driving force on the motorbike as it moves up the incline is 350 N. Consider the motorbike and rider as a single system.

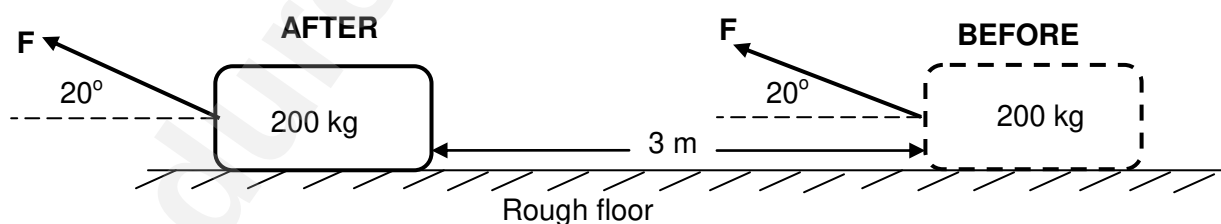
- 4.2 Draw a labelled free-body diagram for the motorbike-rider system on the incline. (4)

- 4.3 State the WORK-ENERGY theorem in words. (2)

- 4.4 Use energy principles to calculate the speed of the motorbike at the end of the 450 m ride. (6)
[15]

QUESTION 5

A constant force F , applied at an angle of 20° above the horizontal, pulls a 200 kg block, over a distance of 3 m, on a rough, horizontal floor as shown in the diagram below.



The coefficient of kinetic friction, μ_k , between the floor surface and the block is 0,2.

- 5.1 Give a reason why the coefficient of kinetic friction has no units. (1)

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

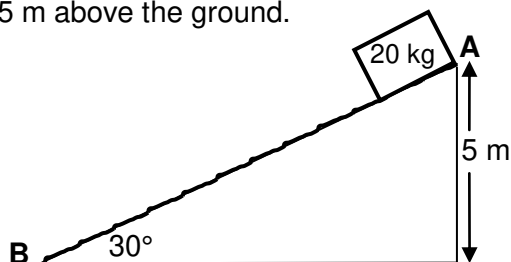
- 5.3 Draw a free-body diagram indicating ALL the forces acting on the block while it is being pulled. (4)

- 5.4 Show that the work done by the kinetic frictional force (W_{fk}) on the block can be written as $W_{fk} = (-1\,176 + 0,205 F)$ J. (4)

- 5.5 Calculate the magnitude of the force F that has to be applied so that the net work done by all forces on the block is zero. (4)
[15]

QUESTION 6

A 20 kg block is released from rest from the top of a ramp at point **A** at a construction site as shown in the diagram below. The ramp is inclined at an angle of 30° to the horizontal and its top is at a height of 5 m above the ground.

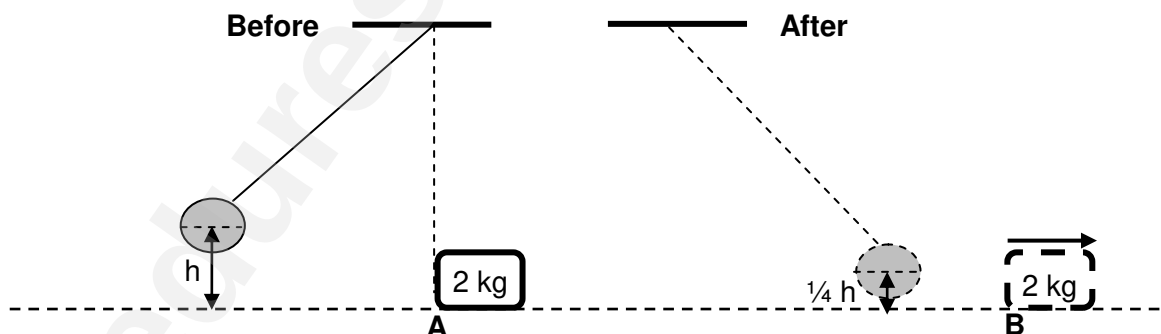


- 6.1 State the *principle of conservation of mechanical energy* in words. (2)
- 6.2 The kinetic frictional force between the 20 kg block and the surface of the ramp is 30 N. Use *energy principles* to calculate the:
- 6.2.1 Work done by the kinetic frictional force on the block (3)
- 6.2.2 Speed of the block at point **B** at the bottom of the ramp (5)
- 6.3 A 100 kg object is pulled up the SAME RAMP at a constant speed of $2 \text{ m} \cdot \text{s}^{-1}$ by a small motor. The kinetic frictional force between the 100 kg object and the surface of the ramp is 25 N. Calculate the average power delivered by the small motor in the pulling of the object up the incline. (4)

[14]

QUESTION 6

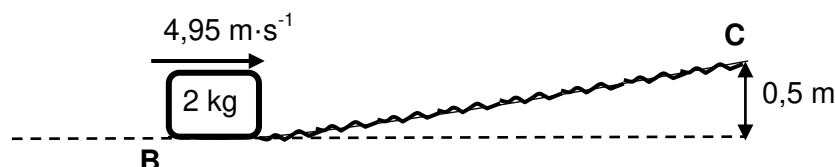
A pendulum with a bob of mass 5 kg is held stationary at a height h metres above the ground. When released, it collides with a block of mass 2 kg which is stationary at point **A**. The bob swings past **A** and comes to rest momentarily at a position $\frac{1}{4}h$ above the ground. The diagrams below are NOT drawn to scale.



Immediately after the collision the 2 kg block begins to move from **A** to **B** at a constant speed of $4,95 \text{ m} \cdot \text{s}^{-1}$. Ignore frictional effects and assume that no loss of mechanical energy occurs during the collision.

- 6.1 Calculate the:
- 6.1.1 Kinetic energy of the block immediately after the collision (3)
- 6.1.2 Height h (4)

The block moves from point **B** at a velocity of $4,95 \text{ m}\cdot\text{s}^{-1}$ up a rough inclined plane to point **C**. The speed of the block at point **C** is $2 \text{ m}\cdot\text{s}^{-1}$. Point **C** is $0,5 \text{ m}$ above the horizontal, as shown in the diagram below. During its motion from **B** to **C** a uniform frictional force acts on the block.

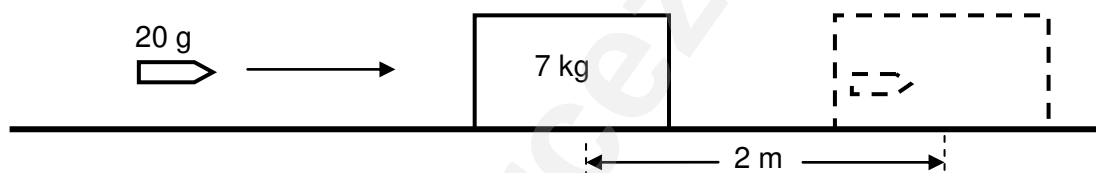


6.2 State the work-energy theorem in words. (2)

6.3 Use energy principles to calculate the work done by the frictional force when the 2 kg block moves from point **B** to point **C**. (4)
[13]

QUESTION 8

The diagram below shows a bullet of mass 20 g that is travelling horizontally. The bullet strikes a stationary 7 kg block and becomes embedded in it. The bullet and block together travel on a rough horizontal surface a distance of 2 m before coming to a stop.



8.1 Use the work-energy theorem to calculate the magnitude of the velocity of the bullet-block system immediately after the bullet strikes the block, given that the frictional force between the block and surface is 10 N . (5)

8.2 State the *principle of conservation of linear momentum* in words. (2)

8.3 Calculate the magnitude of the velocity with which the bullet hits the block. (4)
[11]



DOPPLER EFFECT

QUESTION 1

- 1.1 The siren of a stationary ambulance emits a note of frequency 1 130 Hz. When the ambulance moves at a constant speed, a stationary observer detects a frequency that is 70 Hz **higher** than that emitted by the siren.

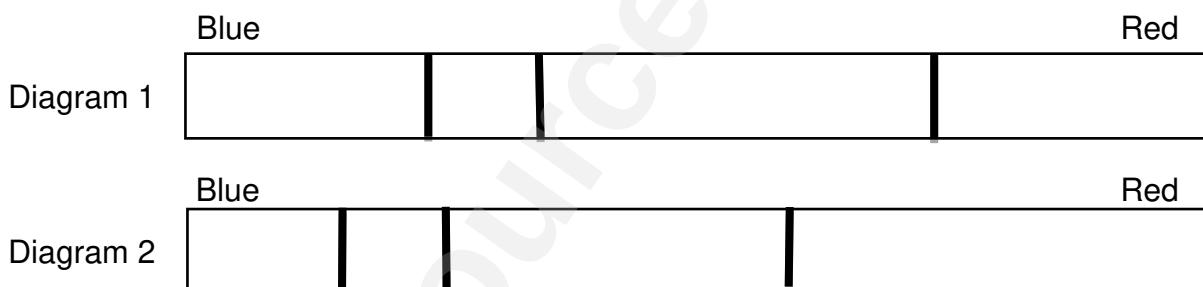
1.1.1 State the Doppler effect in words. (2)

1.1.2 Is the ambulance moving *towards* or *away from* the observer? Give a reason for the answer. (2)

1.1.3 Calculate the speed at which the ambulance is travelling. Take the speed of sound in air as $343 \text{ m}\cdot\text{s}^{-1}$. (5)

- 1.2 A study of spectral lines obtained from various stars can provide valuable information about the movement of the stars.

The two diagrams below represent different spectral lines of an element. Diagram 1 represents the spectrum of the element in a laboratory on Earth. Diagram 2 represents the spectrum of the same element from a distant star.



Is the star moving *towards* or *away from* the Earth? Explain the answer by referring to the shifts in the spectral lines in the two diagrams above.

(2)
[11]

QUESTION 2

The Doppler effect is applicable to both sound and light waves. It also has very important applications in our everyday lives.

- 2.1 A hooter on a stationary train emits sound with a frequency of 520 Hz, as detected by a person standing on the platform. Assume that the speed of sound is $340 \text{ m}\cdot\text{s}^{-1}$ in still air. Calculate the:

2.1.1 Wavelength of the sound detected by the person (2)

2.1.2 Wavelength of the sound detected by the person when the train moves towards him/her at a constant speed of $15 \text{ m}\cdot\text{s}^{-1}$ with the hooter still emitting sound (6)

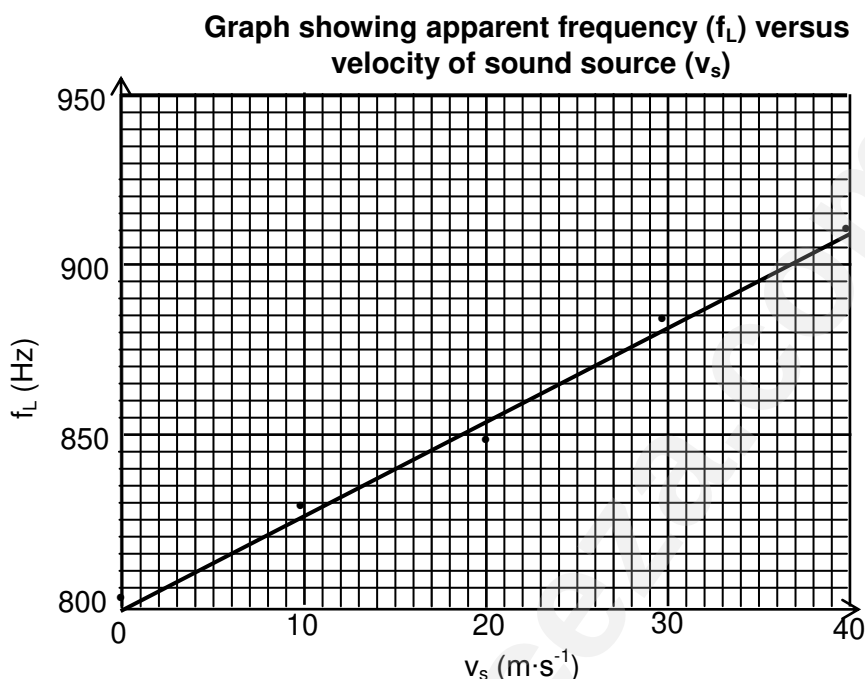
- 2.2 Explain why the wavelength calculated in QUESTION 2.1.1 differs from that obtained in QUESTION 2.1.2. (2)

- 2.3 Use your knowledge of the Doppler effect to explain *red shifts*. (2)

[12]

QUESTION 3

The graph below shows the relationship between the apparent frequency (f_L) of the sound heard by a STATIONARY listener and the velocity (v_s) of the source travelling TOWARDS the listener.



- 3.1 State the Doppler effect in words. (2)
- 3.2 Use the information in the graph to calculate the speed of sound in air. (5)
- 3.3 Sketch a graph of apparent frequency (f_L) versus velocity (v_s) of the sound source if the source was moving AWAY from the listener. It is not necessary to use numerical values for the graph. (2)
- [9]**

QUESTION 4

- 4.1 The data below was obtained during an investigation into the relationship between the different velocities of a moving sound source and the frequencies detected by a stationary listener for **each** velocity. The effect of wind was ignored in this investigation.

Experiment number	1	2	3	4
Velocity of the sound source ($\text{m}\cdot\text{s}^{-1}$)	0	10	20	30
Frequency (Hz) of the sound detected by the stationary listener	900	874	850	827

- 4.1.1 Write down the dependent variable for this investigation. (1)
- 4.1.2 State the Doppler effect in words. (2)
- 4.1.3 Was the sound source moving TOWARDS or AWAY FROM the listener? Give a reason for the answer. (2)
- 4.1.4 Use the information in the table to calculate the speed of sound during the investigation. (5)
- 4.2 The spectral lines of a distant star are shifted towards the longer wavelengths of light. Is the star moving TOWARDS or AWAY FROM the Earth? (1)
- [11]**



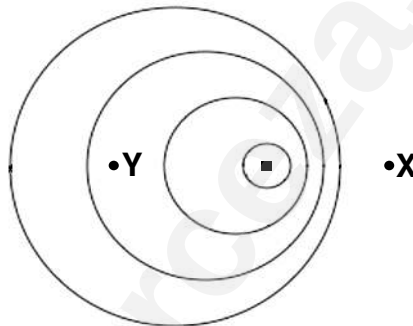
QUESTION 5

Reflection of sound waves enables bats to hunt for moths. The sound wave produced by a bat has a frequency of 222 kHz and a wavelength of $1,5 \times 10^{-3}$ m.

- 5.1 Calculate the speed of this sound wave through the air. (3)
- 5.2 A stationary bat sends out a sound signal and receives the same signal reflected from a moving moth at a frequency of 230,3 kHz.
- 5.2.1 Is the moth moving TOWARDS or AWAY FROM the bat? (1)
- 5.2.2 Calculate the magnitude of the velocity of the moth, assuming that the velocity is constant. (6)
- [10]**

QUESTION 6

An ambulance is travelling towards a hospital at a constant velocity of $30 \text{ m}\cdot\text{s}^{-1}$. The siren of the ambulance produces sound of frequency 400 Hz. Take the speed of sound in air as $340 \text{ m}\cdot\text{s}^{-1}$. The diagram below shows the wave fronts of the sound produced from the siren as a result of this motion.



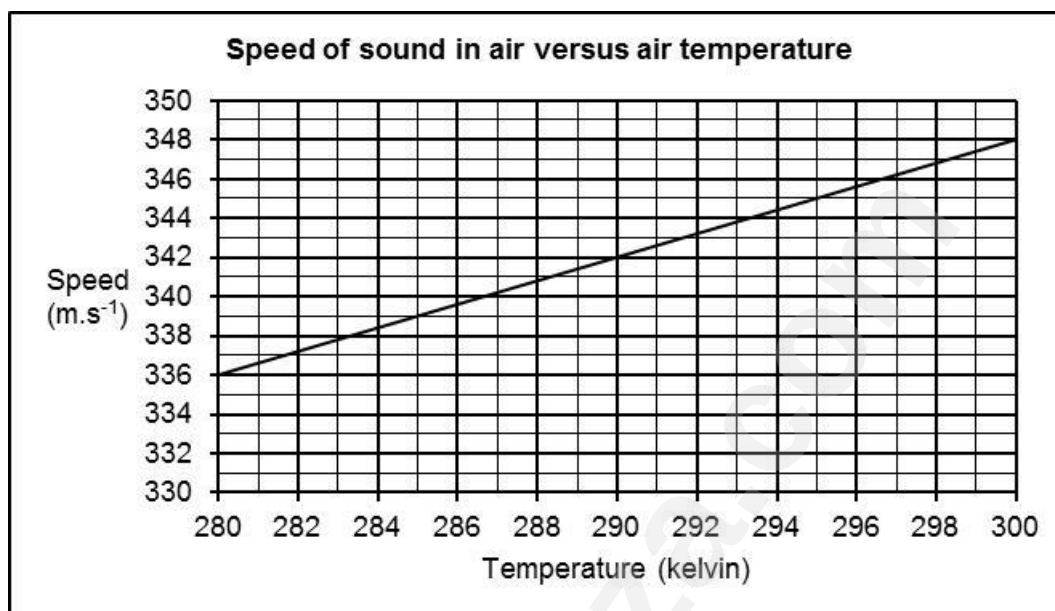
- 6.1 At which side of the diagram, **X** or **Y**, is the hospital situated? (1)
- 6.2 Explain the answer to QUESTION 6.1. (3)
- 6.3 Calculate the frequency of the sound of the siren heard by a person standing at the hospital. (5)
- 6.4 A nurse is sitting next to the driver in the passenger seat of the ambulance as it approaches the hospital. Calculate the wavelength of the sound heard by the nurse. (3)
- [12]**

QUESTION 7

- 7.1 An ambulance is moving towards a stationary listener at a constant speed of $30 \text{ m}\cdot\text{s}^{-1}$. The siren of the ambulance emits sound waves having a wavelength of 0,28 m. Take the speed of sound in air as $340 \text{ m}\cdot\text{s}^{-1}$.
- 7.1.1 State the Doppler effect in words. (2)
- 7.1.2 Calculate the frequency of the sound waves emitted by the siren as heard by the ambulance driver. (3)
- 7.1.3 Calculate the frequency of the sound waves emitted by the siren as heard by the listener. (5)
- 7.1.4 How would the answer to QUESTION 7.1.3 change if the speed of the ambulance were LESS THAN $30 \text{ m}\cdot\text{s}^{-1}$? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1)
- 7.2 An observation of the spectrum of a distant star shows that it is moving away from the earth. Explain, in terms of the frequencies of the spectral lines, how it is possible to conclude that the star is moving away from the earth. (2)
- [13]**

QUESTION 8

The speed of sound in air depends among others on the air temperature. The following graph shows this relationship.



8.1 Which one of temperature or speed is the dependent variable? (1)

8.2 The gradient of this graph is equal to $0,6 \text{ m}\cdot\text{s}^{-1}\cdot\text{K}^{-1}$. With how much does the speed, in $\text{m}\cdot\text{s}^{-1}$, increase for every 5 K increase in temperature? (1)

8.3 Two experiments are done to verify the Doppler effect. In the first experiment, an object approaches a stationary observer **X** at a constant speed of $57,5 \text{ m}\cdot\text{s}^{-1}$. The object is equipped with a siren that emits sound waves at a fixed frequency of 1 000 Hz. The motion takes place in still air at a temperature of 295 K.

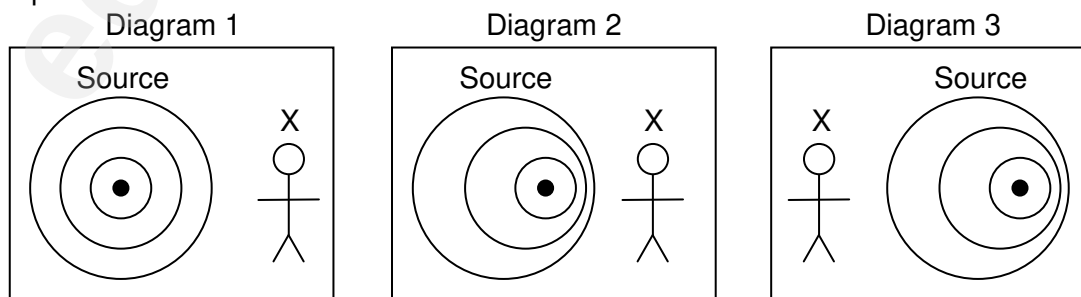
8.3.1 Describe what the *Doppler effect* is. (2)

8.3.2 What is the speed of sound, in $\text{m}\cdot\text{s}^{-1}$, in air at 295 K?
HINT: Use the graph. (1)

8.3.3 Calculate the frequency measured by observer **X**. (4)

8.3.4 In the second experiment, the object moves away from observer **X** at the same constant speed as before. What should the air temperature, in kelvin, be to make it a fair test between the two experiments? (1)

8.4 Consider the three diagrams below. Each one represents the source (with the siren) and observer **X**. Two of the diagrams are applicable on the above-mentioned experiments.



8.3.3 Which diagram is applicable to experiment 2? (1)

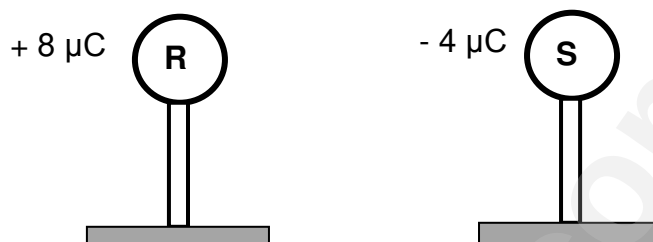
8.3.4 Which diagram is NOT applicable to any of the experiments?
Give a reason for your answer. (2)

[13]

ELECTROSTATICS

QUESTION 1

The diagram below shows two small identical metal spheres, **R** and **S**, each placed on a wooden stand. Spheres **R** and **S** carry charges of $+8\ \mu\text{C}$ and $-4\ \mu\text{C}$ respectively. Ignore the effects of air.



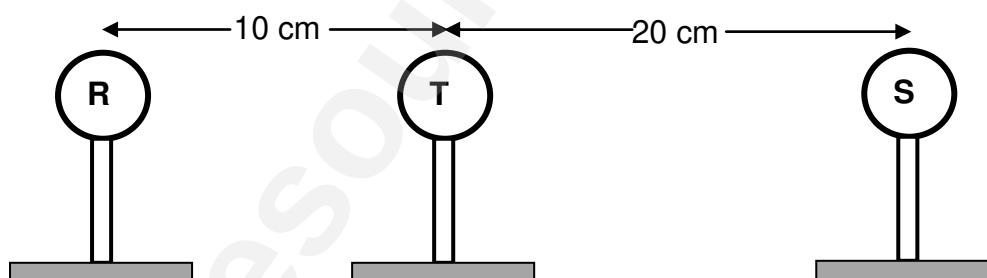
- 1.1 Explain why the spheres were placed on wooden stands. (1)

Spheres **R** and **S** are brought into contact for a while and then separated by a small distance.

- 1.2 Calculate the net charge on each of the spheres. (2)

- 1.3 Draw the electric field pattern due to the two spheres **R** and **S**. (3)

After **R** and **S** have been in contact and separated, a third sphere, **T**, of charge $+1\ \mu\text{C}$ is now placed between them as shown in the diagram below.



- 1.4 Draw a free-body diagram showing the electrostatic forces experienced by sphere **T** due to spheres **R** and **S**. (2)

- 1.5 Calculate the net electrostatic force experienced by **T** due to **R** and **S**. (6)

- 1.6 Define the *electric field at a point*. (2)

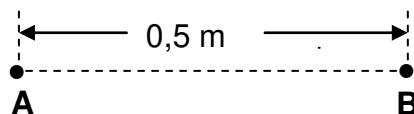
- 1.7 Calculate the magnitude of the net electric field at the location of **T** due to **R** and **S**. (Treat the spheres as if they were point charges.) (3)

[19]



QUESTION 2

Two identical negatively charged spheres, **A** and **B**, having charges of the **same magnitude**, are placed 0,5 m apart in vacuum. The magnitude of the electrostatic force that one sphere exerts on the other is $1,44 \times 10^{-1}$ N.



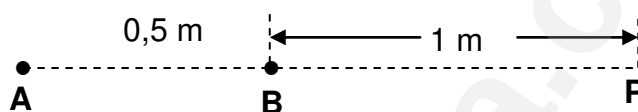
2.1 State Coulomb's law in words. (2)

2.2 Calculate the:

2.2.1 Magnitude of the charge on each sphere (4)

2.2.2 Excess number of electrons on sphere **B** (3)

2.3 **P** is a point at a distance of 1 m from sphere **B**.



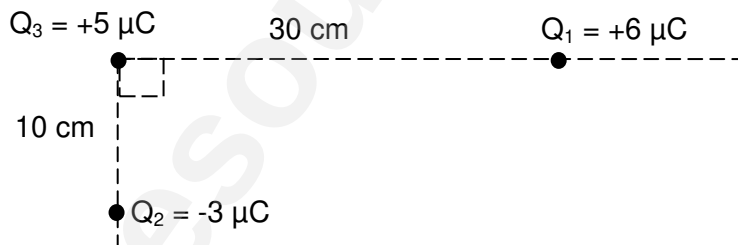
2.3.1 What is the direction of the net electric field at point **P**? (1)

2.3.2 Calculate the number of electrons that should be removed from sphere **B** so that the net electric field at point **P** is $3 \times 10^4 \text{ N} \cdot \text{C}^{-1}$ to the right. (8)

[18]

QUESTION 3

Three point charges, **Q₁**, **Q₂** and **Q₃**, carrying charges of $+6 \mu\text{C}$, $-3 \mu\text{C}$ and $+5 \mu\text{C}$ respectively, are arranged in space as shown in the diagram below. The distance between **Q₃** and **Q₁** is 30 cm and that between **Q₃** and **Q₂** is 10 cm.



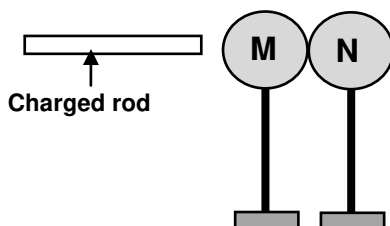
3.1 State Coulomb's law in words. (2)

3.2 Calculate the net force acting on charge Q₃ due to the presence of **Q₁** and **Q₂**. (7)

[9]

QUESTION 4

Two identical neutral spheres, **M** and **N**, are placed on insulating stands. They are brought into contact and a charged rod is brought near sphere **M**.

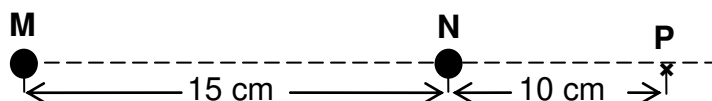


When the spheres are separated it is found that 5×10^6 electrons were transferred from sphere **M** to sphere **N**.

4.1 What is the net charge on sphere **N** after separation? (3)

- 4.2 Write down the net charge on sphere **M** after separation. (2)

The charged spheres, **M** and **N**, are now arranged along a straight line, in space, such that the distance between their centres is 15 cm. A point **P** lies 10 cm to the right of **N** as shown in the diagram below.



- 4.3 Define the *electric field* at a point. (2)

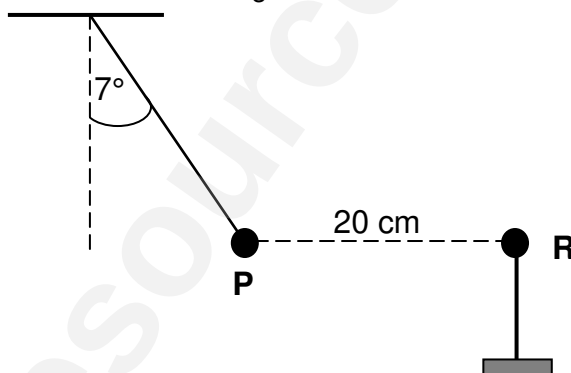
- 4.4 Calculate the net electric field at point **P** due to **M** and **N**. (6)
[13]

QUESTION 5

A very small graphite-coated sphere **P** is rubbed with a cloth. It is found that the sphere acquires a charge of $+0,5 \mu\text{C}$.

- 5.1 Calculate the number of electrons removed from sphere **P** during the charging process. (3)

Now the charged sphere **P** is suspended from a light, inextensible string. Another sphere, **R**, with a charge of $-0,9 \mu\text{C}$, on an insulated stand, is brought close to sphere **P**. As a result sphere **P** moves to a position where it is 20 cm from sphere **R**, as shown below. The system is in equilibrium and the angle between the string and the vertical is 7° .



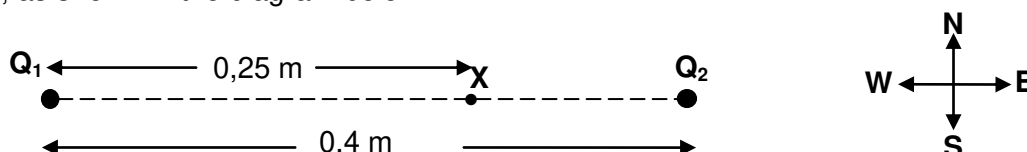
- 5.2 Draw a labelled free-body diagram showing ALL the forces acting on sphere **P**. (3)

- 5.3 State Coulomb's law in words. (2)

- 5.4 Calculate the magnitude of the tension in the string. (5)
[13]

QUESTION 6

Two charged particles, **Q₁** and **Q₂**, are placed 0,4 m apart along a straight line. The charge on **Q₁** is $+2 \times 10^{-5} \text{ C}$, and the charge on **Q₂** is $-8 \times 10^{-6} \text{ C}$. Point **X** is 0,25 m east of **Q₁**, as shown in the diagram below.



Calculate the:

- 6.1 Net electric field at point **X** due to the two charges (6)

- 6.2 Electrostatic force that a $-2 \times 10^{-9} \text{ C}$ charge will experience at point **X** (4)

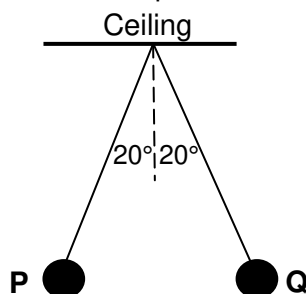
The -2×10^{-9} C charge is replaced with a charge of -4×10^{-9} C at point **X**.

- 6.3 **Without any further calculation**, determine the magnitude of the force that the -4×10^{-9} C charge will experience at point **X**.

(1)
[11]

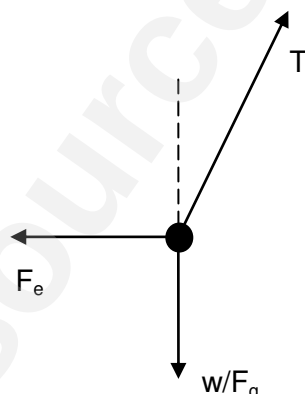
QUESTION 7

Two identical spherical balls, **P** and **Q**, each of mass 100 g, are suspended at the same point from a ceiling by means of identical light, inextensible insulating strings. Each ball carries a charge of $+250$ nC. The balls come to rest in the positions shown in the diagram below.



- 7.1 In the diagram, the angles between each string and the vertical are the same. Give a reason why the angles are the same.
- 7.2 State Coulomb's law in words.
- 7.3 The free-body diagram, not drawn to scale, of the forces acting on ball **P** is shown below.

(1)
(2)



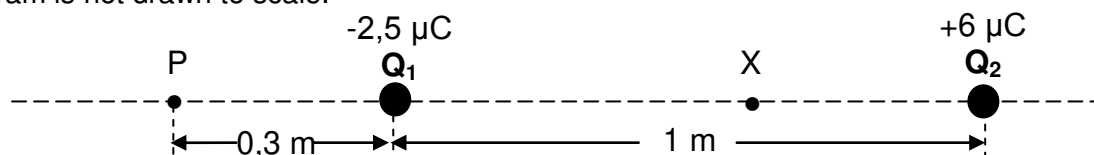
Calculate the:

- 7.3.1 Magnitude of the tension (**T**) in the string
- 7.3.2 Distance between balls **P** and **Q**

(3)
(5)
[11]

QUESTION 8

A sphere **Q₁**, with a charge of $-2,5 \mu\text{C}$, is placed 1 m away from a second sphere **Q₂**, with a charge $+6 \mu\text{C}$. The spheres lie along a straight line, as shown in the diagram below. Point **P** is located a distance of 0,3 m to the left of sphere **Q₁**, while point **X** is located between **Q₁** and **Q₂**. The diagram is not drawn to scale.

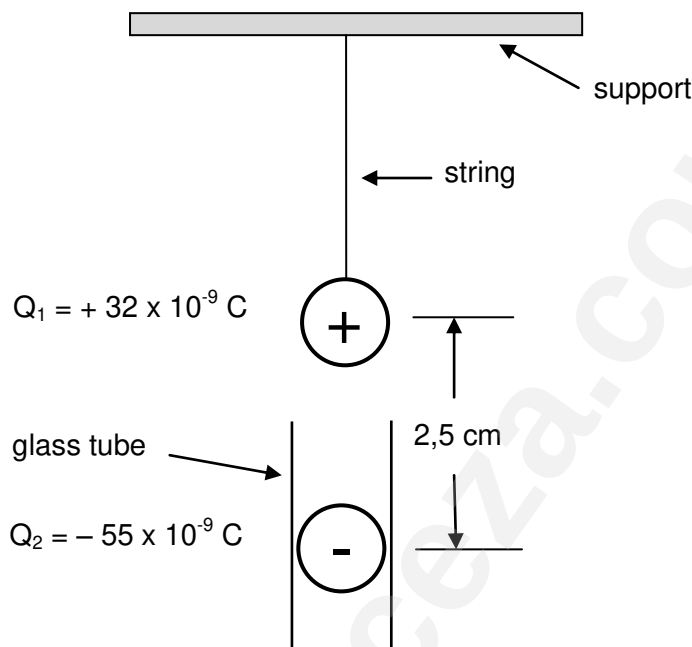


- 8.1 Show, with the aid of a **VECTOR DIAGRAM**, why the net electric field at point **X** *cannot be zero*.
- 8.2 Calculate the net electric field at point **P**, due to the two charged spheres **Q₁** and **Q₂**.

(4)
(6)
[10]

QUESTION 9

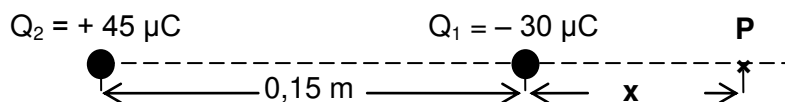
A small sphere, Q_1 , with a charge of $+ 32 \times 10^{-9} \text{ C}$, is suspended from a light string secured to a support. A second, identical sphere, Q_2 , with a charge of $- 55 \times 10^{-9} \text{ C}$, is placed in a narrow, cylindrical glass tube vertically below Q_1 . Each sphere has a mass of 7 g. Both spheres come to equilibrium when Q_2 is 2,5 cm from Q_1 , as shown in the diagram. Ignore the effects of air friction.



- 9.1 Calculate the number of electrons that were removed from Q_1 to give it a charge of $+ 32 \times 10^{-9} \text{ C}$. Assume that the sphere was neutral before being charged. (3)
 - 9.2 Draw a labelled free-body diagram showing all the forces acting on sphere Q_1 . (3)
 - 9.3 Calculate the magnitude of the tension in the string. (5)
- [11]

QUESTION 10

- 10.1 Define *electric field at a point* in words. (2)
- 10.2 Draw the electric field pattern for two identical positively charged spheres placed close to each other. (3)
- 10.3 A $- 30 \mu\text{C}$ point charge, Q_1 , is placed at a distance of 0,15 m from a $+ 45 \mu\text{C}$ point charge, Q_2 , in space, as shown in the diagram below. The net electric field at point **P**, which is on the same line as the two charges, is zero. (5)



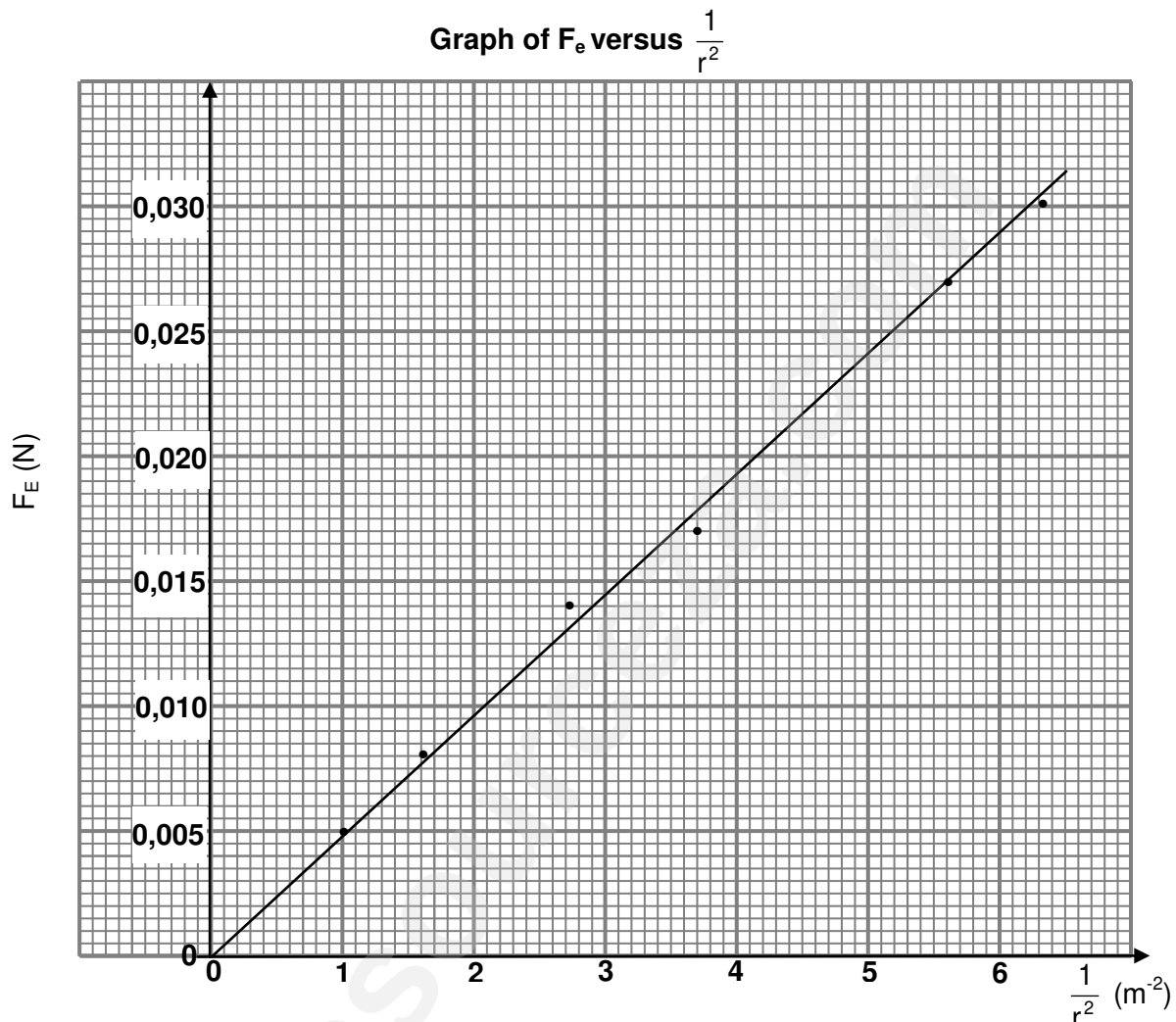
Calculate **x**, the distance of point **P** from charge Q_1 .

(5)
[10]



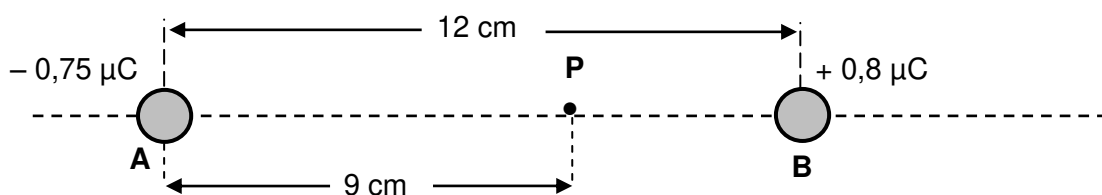
QUESTION 11

- 11.1 In an experiment to verify the relationship between the electrostatic force, F_E , and distance, r , between two **identical**, positively charged spheres, the graph below was obtained.



- 11.1.1 State Coulomb's law in words. (2)
- 11.1.2 Write down the dependent variable of the experiment. (1)
- 11.1.3 What relationship between the electrostatic force F_E and the square of the distance, r^2 , between the charged spheres can be deduced from the graph? (1)
- 11.1.4 Use the information in the graph to calculate the charge on each sphere. (6)
- 11.2 A charged sphere, **A**, carries a charge of $-0,75 \mu\text{C}$.
- 11.2.1 Draw a diagram showing the electric field lines surrounding sphere **A**. (2)

Sphere **A** is placed 12 cm away from another charged sphere, **B**, along a straight line in a vacuum, as shown below. Sphere **B** carries a charge of $+0,8 \mu\text{C}$. Point **P** is located 9 cm to the right of sphere **A**.



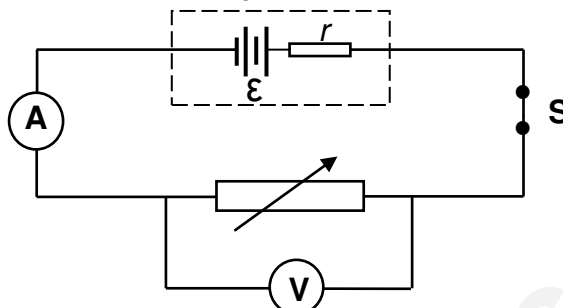
- 11.2.2 Calculate the magnitude of the net electric field at point **P**. (5)

[17]

ELECTRIC CIRCUITS

QUESTION 1

- 1.1 A group of learners conduct an experiment to determine the emf ($\mathcal{E}$) and internal resistance (r) of a battery. They connect a battery to a rheostat (variable resistor), a low-resistance ammeter and a high-resistance voltmeter as shown in the diagram below.

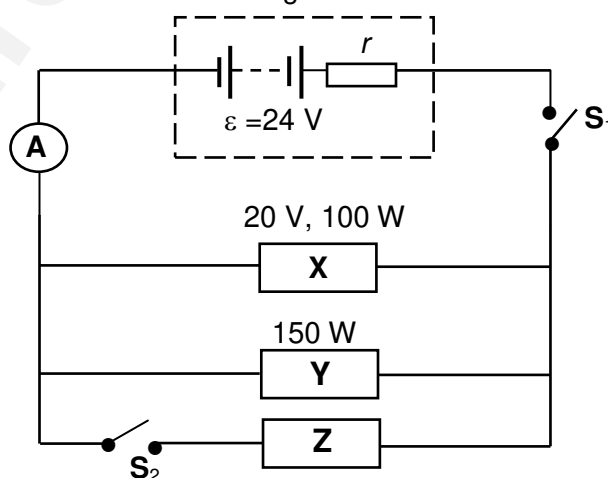


The data obtained from the experiment is displayed in the table below.

READING ON VOLTMETER (V)	READING ON AMMETER (A)
2	0,58
3	0,46
4	0,36
5	0,24
6	0,14

- 1.1.1 State ONE factor which must be kept constant during the experiment. (1)
- 1.1.2 Using the information in the table above, plot the points and draw the line of best fit on a graph paper. (3)
- Use the graph drawn in QUESTION 1.1.2 to determine the following:
- 1.1.3 Emf ($\mathcal{E}$) of the battery (1)
- 1.1.4 Internal resistance of the battery, WITHOUT USING ANY FORM OF THE EQUATION $\mathcal{E} = I(R + r)$ (3)

- 1.2 Three electrical devices, X, Y and Z, are connected to a 24 V battery with internal resistance r as shown in the circuit diagram below. The power rating of each of the devices X and Y are indicated in the diagram.



With switch S_1 closed and S_2 open, the devices function as rated. Calculate the:

- 1.2.1 Current in X (3)
- 1.2.2 Resistance of Y (3)
- 1.2.3 Internal resistance of the battery (5)

Now switch S_2 is also closed.

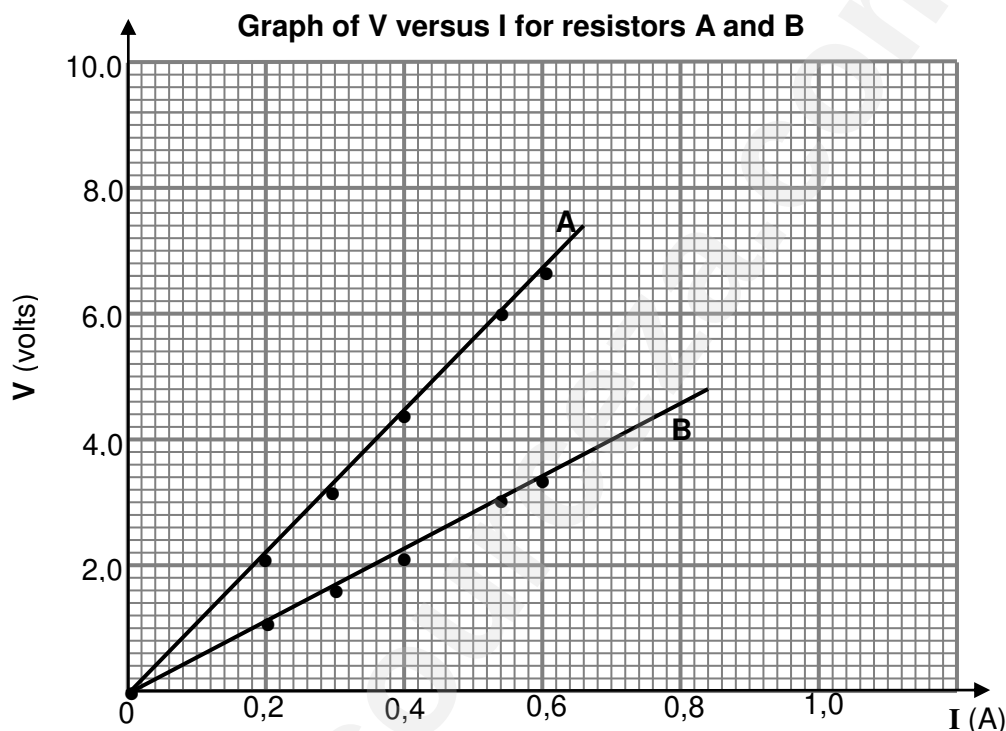
1.2.4 Identify device **Z** which, when placed in the position shown, can still enable **X** and **Y** to operate as rated. Assume that the resistances of all the devices remain unchanged. (1)

1.2.5 Explain how you arrived at the answer to QUESTION 1.2.4. (2)

[22]

QUESTION 2

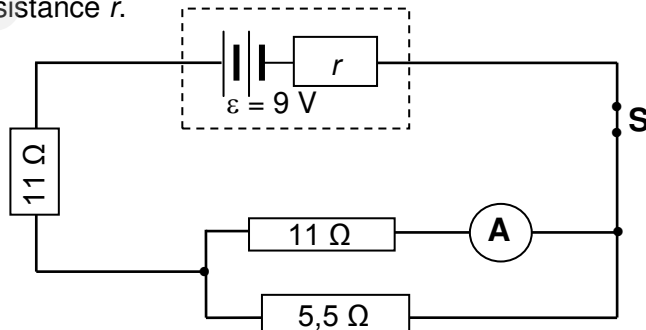
2.1 Learners want to construct an electric heater using one of two wires, **A** and **B**, of different resistances. They conduct experiments and draw the graphs as shown below.



2.1.1 Apart from temperature, write down TWO other factors that the learners should consider to ensure a fair test when choosing which wire to use. (2)

2.1.2 Assuming all other factors are kept constant, state which ONE of the two wires will be the most suitable to use in the heater. Use suitable calculations to show clearly how you arrive at the answer. (8)

2.2 In the circuit below the reading on ammeter **A** is 0,2 A. The battery has an emf of 9 V and internal resistance r .



2.2.1 Calculate the current through the 5,5 Ω resistor. (3)

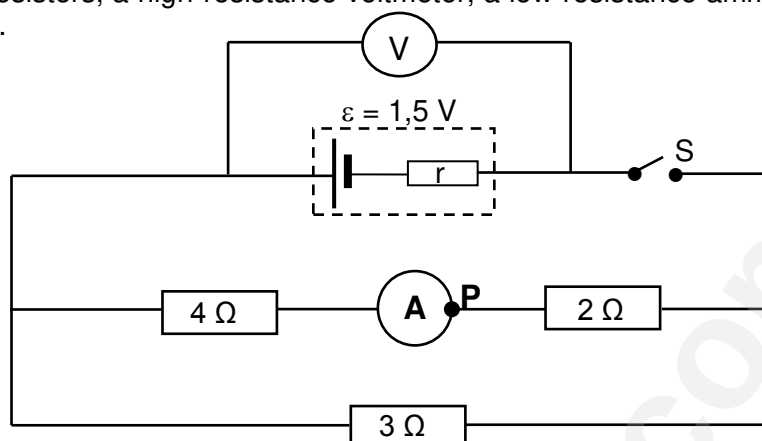
2.2.2 Calculate the internal resistance of the battery. (7)

2.2.3 Will the ammeter reading INCREASE, DECREASE or REMAIN THE SAME if the 5,5 Ω resistor is removed? Give a reason for the answer. (2)

[22]

QUESTION 3

A cell of unknown internal resistance, r , has emf (ε) of 1,5 V. It is connected in a circuit to three resistors, a high-resistance voltmeter, a low-resistance ammeter and a switch S as shown below.



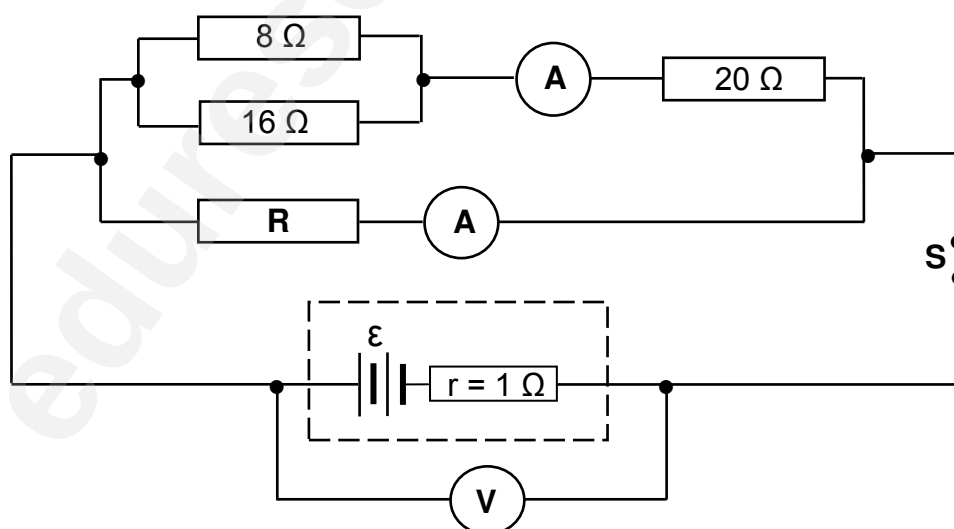
When switch S is closed, the voltmeter reads 1,36 V.

- 3.1 Which terminal of the ammeter is represented by point **P**?
Write down only POSITIVE or NEGATIVE. (1)
- 3.2 Calculate the ammeter reading. (3)
- 3.3 Determine the internal resistance of the cell. (7)
- 3.4 An additional resistor X is connected parallel to the 3 Ω resistor in the circuit.
Will the reading on the ammeter INCREASE, DECREASE or REMAIN UNCHANGED? Give a reason for the answer. (4)

[15]

QUESTION 4

A battery with an internal resistance of 1 Ω and an unknown emf (ε) is connected in a circuit, as shown below. A high-resistance voltmeter (V) is connected across the battery. **A₁** and **A₂** represent ammeters of negligible resistance.



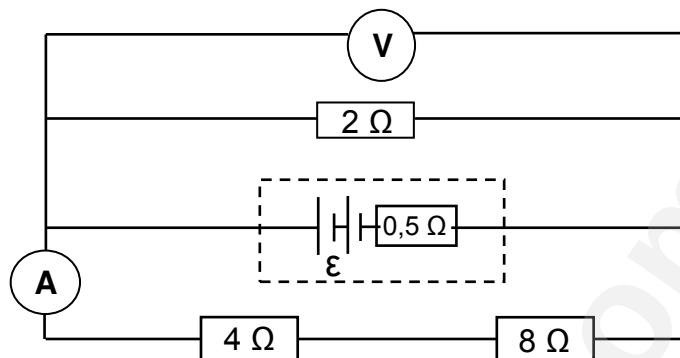
With switch **S** closed, the current passing through the 8 Ω resistor is 0,5 A.

- 4.1 State Ohm's law in words. (2)
- 4.2 Calculate the reading on ammeter **A₁**. (4)
- 4.3 If device **R** delivers power of 12 W, calculate the reading on ammeter **A₂**. (5)
- 4.4 Calculate the reading on the voltmeter when switch **S** is open. (3)

[14]

QUESTION 5

A battery of an unknown emf and an internal resistance of $0,5 \Omega$ is connected to three resistors, a high-resistance voltmeter and an ammeter of negligible resistance, as shown below.

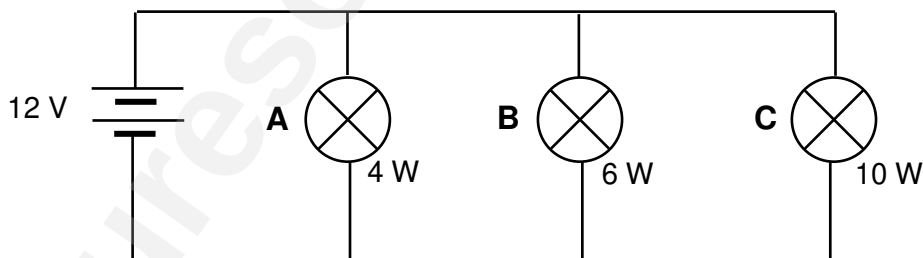


The reading on the ammeter is $0,2 \text{ A}$.

- 5.1 Calculate the:
- 5.1.1 Reading on the voltmeter (3)
 - 5.1.2 Total current supplied by the battery (4)
 - 5.1.3 Emf of the battery (5)
- 5.2 How would the voltmeter reading change if the 2Ω resistor is removed? Write down INCREASE, DECREASE or REMAIN THE SAME. Explain the answer. (3)
- [15]**

QUESTION 6

- 6.1 In the diagram below, three light bulbs, **A**, **B** and **C**, are connected in parallel to a 12 V source of negligible internal resistance. The bulbs are rated at 4 W , 6 W and 10 W respectively and are all at their maximum brightness.

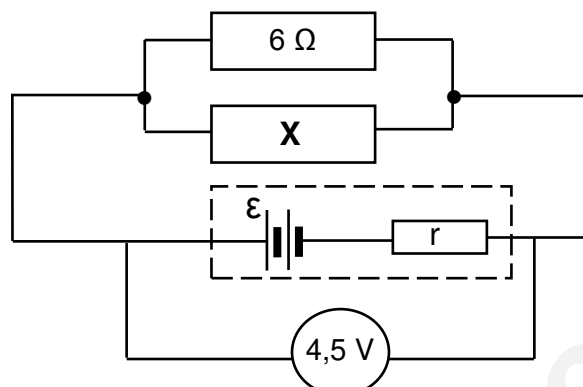


- 6.1.1 Calculate the resistance of the 4 W bulb. (3)
 - 6.1.2 How will the equivalent resistance of the circuit change if the 6 W bulb burns out? Write down only INCREASES, DECREASES or NO CHANGE. (1)
 - 6.1.3 How will the power dissipated by the 10 W bulb change if the 6 W bulb burns out? Write down only INCREASES, DECREASES or NO CHANGE. Give a reason for the answer. (2)
- 6.2 A learner connects a high-resistance voltmeter across a battery. The voltmeter reads 6 V . She then connects a 6Ω resistor across the battery. The voltmeter now reads 5 V .
- 6.2.1 Calculate the internal resistance of the battery. (4)



The learner now builds the circuit below, using the same 6 V battery and the 6 Ω resistor. She connects an unknown resistor **X** in parallel with the 6 Ω resistor. The voltmeter now reads 4,5 V.

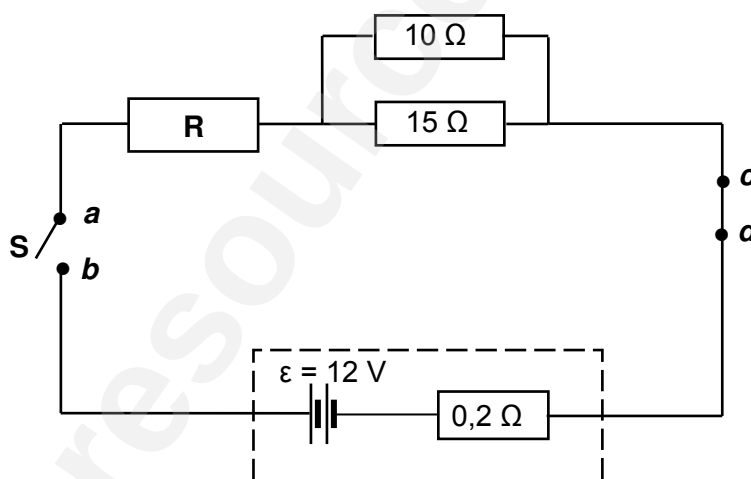
6.2.2 Define the term *emf* of a cell. (2)



6.2.3 Calculate the resistance of **X** when the voltmeter reads 4,5 V. (5)
[17]

QUESTION 7

7.1 In the circuit below the battery has an emf (ϵ) of 12 V and an internal resistance of 0,2 Ω . The resistances of the connecting wires are negligible.



7.1.1 Define the term *emf* of a battery. (2)

7.1.2 Switch **S** is open. A high-resistance voltmeter is connected across points **a** and **b**. What will the reading on the voltmeter be? (1)

7.1.3 Switch **S** is now closed. The same voltmeter is now connected across points **c** and **d**. What will the reading on the voltmeter be? (1)

When switch **S** is closed, the potential difference across the terminals of the battery is 11,7 V. Calculate the:

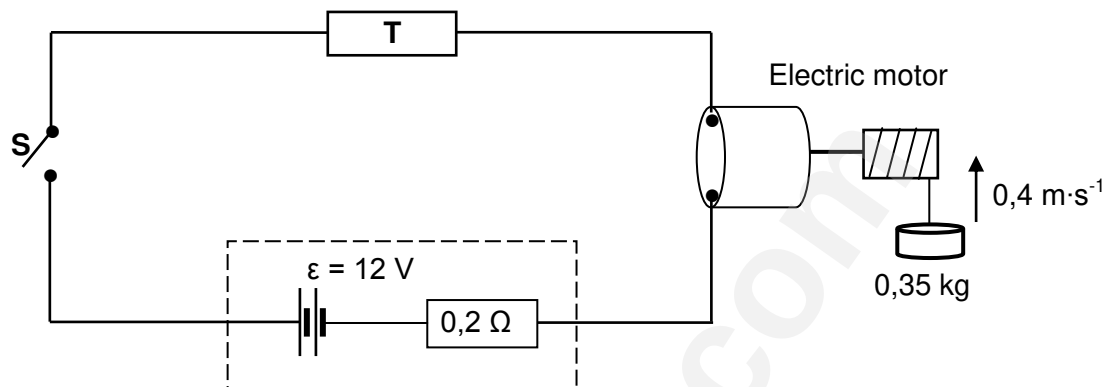
7.1.4 Current in the battery (3)

7.1.5 Effective resistance of the **parallel** branch (2)

7.1.6 Resistance of resistor **R** (4)

- 7.2 A battery with an emf of 12 V and an internal resistance of $0,2 \Omega$ are connected in series to a very small electric motor and a resistor, **T**, of unknown resistance, as shown in the circuit below.

The motor is rated **X** watts, 3 volts, and operates at optimal conditions.



When switch **S** is closed, the motor lifts a 0,35 kg mass vertically upwards at a constant speed of $0,4 \text{ m} \cdot \text{s}^{-1}$. Assume that there is no energy conversion into heat and sound.

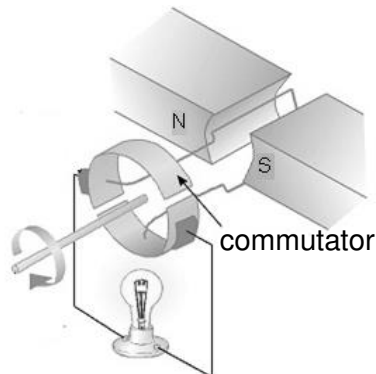
Calculate the value of:

- 7.2.1 **X** (3)
- 7.2.2 The resistance of resistor **T** (5)
- [21]

ELECTRICAL MACHINES

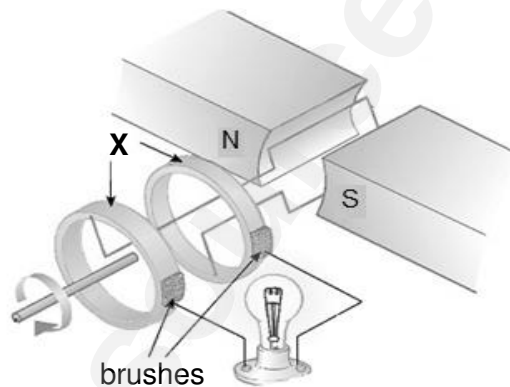
QUESTION 1

The diagram below represents a simplified version of an electrical machine used to light up a bulb.

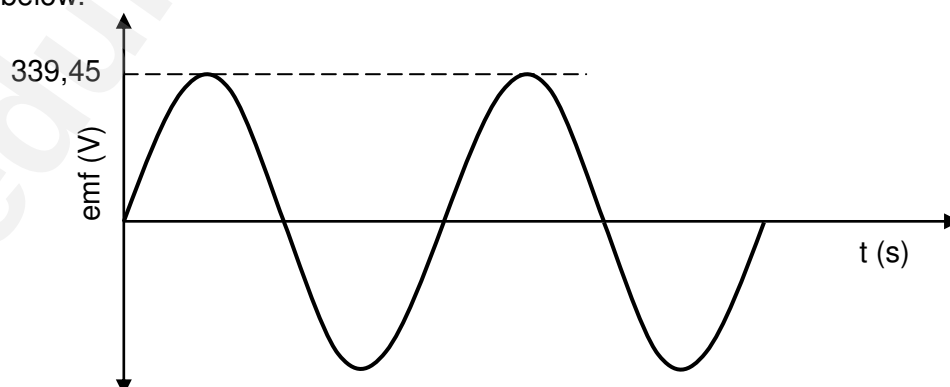


- 1.1 Name the principle on which the machine operates. (1)
- 1.2 State ONE way in which to make this bulb burn brighter. (1)

Some changes have been made to the machine and a new device is obtained as shown below.



- 1.3 Name part **X** in the new device. (1)
- 1.4 The graph of output emf versus time obtained using the device in QUESTION 9.3 is shown below.

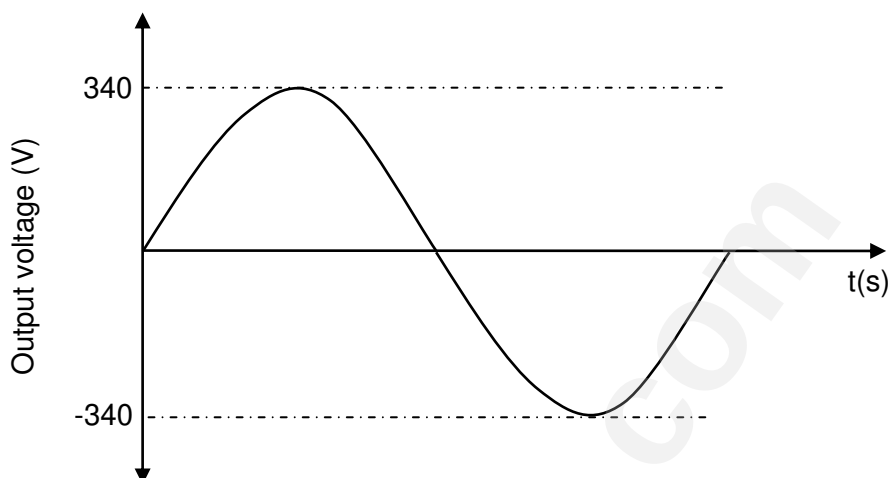


- 1.4.1 Define the term *root mean square value* of an AC voltage. (2)
- 1.4.2 Calculate the rms voltage. (3)

[8]

QUESTION 2

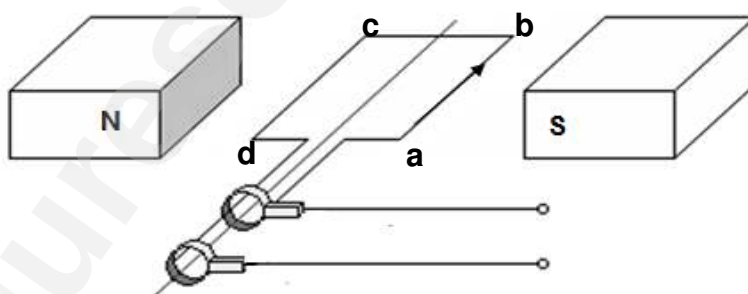
The graph below shows the output voltage from a household AC generator for one cycle of rotation of the coils.



- 2.1 A 100 W light bulb is connected to this generator and it glows at its maximum brightness. Use the information from the graph to calculate the:
- 2.1.1 Resistance of the bulb (5)
- 2.1.2 rms current through the bulb (3)
- 2.2 Give ONE reason why AC voltage is preferred to DC voltage for everyday use. (1)
- [9]**

QUESTION 3

- 3.1 The output potential difference of an AC generator is 100 V at 20 Hz. A simplified diagram of the generator is shown below. The direction of the current in the coil is from **a** to **b**.

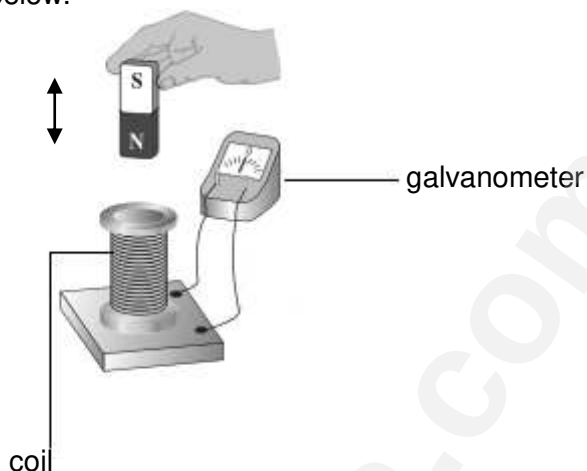


- 3.1.1 In which direction is the coil rotating? Write only CLOCKWISE or ANTICLOCKWISE. (1)
- 3.1.2 Starting from the position shown in the diagram, sketch a graph of the output potential difference versus time when the coil completes TWO full cycles. On the graph, clearly indicate the maximum potential difference (100 V) and the time taken to complete the two cycles. (3)
- 3.1.3 State ONE way in which this AC generator can be used to produce a lower output potential difference. (1)
- 3.2 An electrical device is rated 220 V, 1 500 W.
- Calculate the maximum current output for the device when it is connected to a 220 V alternating current source. (5)

[10]

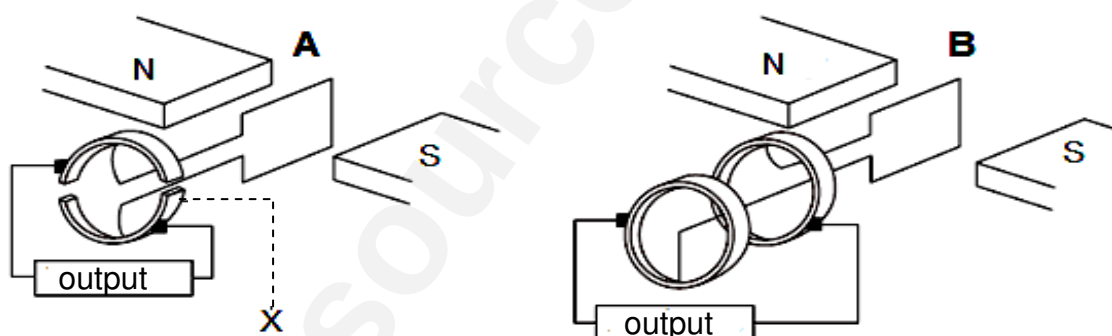
QUESTION 4

- 4.1 A teacher demonstrates how current can be obtained using a bar magnet, a coil and a galvanometer. The teacher moves the bar magnet up and down, as shown by the arrow in the diagram below.



- 4.1.1 Briefly describe how the magnet must be moved in order to obtain a LARGE deflection on the galvanometer. (2)

The two devices, **A** and **B**, below operate on the principle described in QUESTION 4.1.1 above.

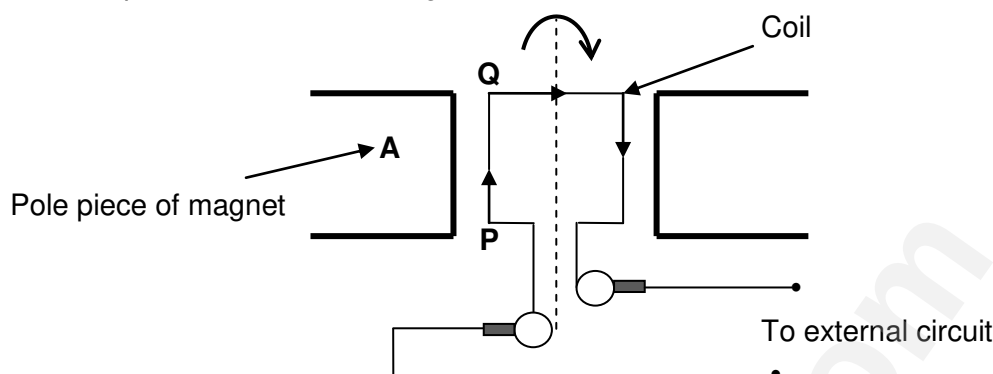


- 4.1.2 Write down the name of the principle. (1)
- 4.1.3 Write down the name of part **X** in device **A**. (1)
- 4.2 A 220 V, AC voltage is supplied from a wall socket to an electric kettle of resistance $40,33 \, \Omega$. Wall sockets provide rms voltages and currents.
- Calculate the:
- 4.2.1 Electrical energy consumed by the kettle per second (4)
- 4.2.2 Maximum (peak) current through the kettle (3)

[11]

QUESTION 5

5.1 A simplified sketch of an AC generator is shown below.



The coil of the generator rotates clockwise between the pole pieces of two magnets. At a particular instant, the current in the segment **PQ** has the direction shown above.

5.1.1 Identify the magnetic pole **A**.
Only write NORTH POLE or SOUTH POLE. (1)

5.1.2 The coil is rotated through 180° .
Will the direction of the current in segment **PQ** be from **P** to **Q** or **Q** to **P**? (1)

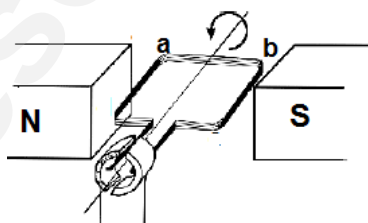
5.2 An electrical device is connected to a generator which produces an rms potential difference of 220 V. The maximum current passing through the device is 8 A. Calculate the:

5.2.1 Resistance of the device (5)

5.2.2 Energy the device consumes in two hours (5)
[12]

QUESTION 6

6.1 A part of a simplified DC motor is shown in the sketch below.



6.1.1 In which direction (**a** to **b**, OR **b** to **a**) is the current flowing through the coil if the coil rotates anticlockwise as indicated in the diagram? (1)

6.1.2 Name the rule you used to answer QUESTION 6.1.1. (1)

6.1.3 Which component in the diagram must be replaced in order for the device to operate as an AC generator? (1)

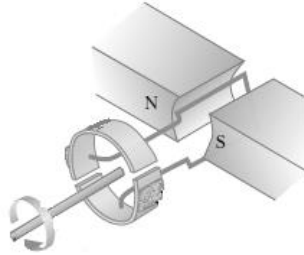
6.2 An electrical device of resistance $400\ \Omega$ is connected across an AC generator that produces a maximum emf of 430 V. The resistance of the coils of the generator can be ignored.

6.2.1 State the energy conversion that takes place when the AC generator is in operation. (2)

6.2.2 Calculate the root mean square value of the current passing through the resistor. (5)
[10]

QUESTION 7

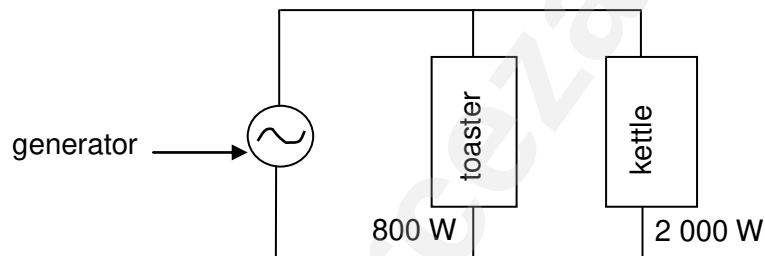
- 7.1 A generator is shown below. Assume that the coil is in a vertical position.



- 7.1.1 Is the generator above AC or DC? Give a reason for the answer. (2)

- 7.1.2 Sketch an induced emf versus time graph for ONE complete rotation of the coil. (The coil starts turning from the vertical position.) (2)

- 7.2 An AC generator is operating at a maximum emf of 340 V. It is connected across a toaster and a kettle, as shown in the diagram below.



The toaster is rated at 800 W, while the kettle is rated at 2 000 W. Both are working under optimal conditions.

Calculate the:

- 7.2.1 rms current passing through the toaster (3)

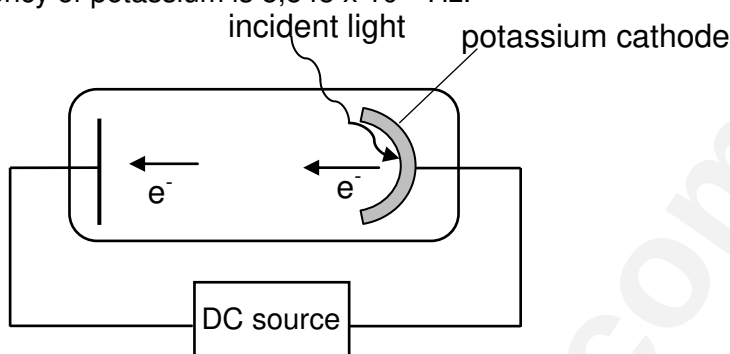
- 7.2.2 Total rms current delivered by the generator (4)

[11]

OPTICAL PHENOMENA AND PROPERTIES OF MATERIALS

QUESTION 1

Ultraviolet light is incident onto a photocell with a potassium cathode as shown below.
The threshold frequency of potassium is $5,548 \times 10^{14}$ Hz.



1.1 Define the term *threshold frequency (cut-off frequency)*. (2)

The maximum speed of an ejected photoelectron is $5,33 \times 10^5$ m·s⁻¹.

1.2 Calculate the wavelength of the ultraviolet light used. (5)

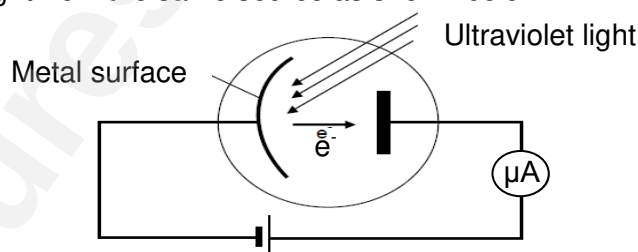
The photocell is now replaced by another photocell with a rubidium cathode. The maximum speed of the ejected photoelectron is $6,10 \times 10^5$ m·s⁻¹ when the same ultraviolet light source is used.

1.3 How does the work function of rubidium compare to that of potassium?
Write down only GREATER THAN, SMALLER THAN or EQUAL TO. (1)

1.4 Explain the answer to QUESTION 1.3. (3)
[11]

QUESTION 2

A learner uses photocells to determine the maximum kinetic energy of ejected photoelectrons. One photocell has a caesium cathode and the other has a sodium cathode. Each photocell is radiated by ultraviolet light from the same source as shown below.



The incomplete results obtained are shown in the table below.

NAME OF THE METAL	WORK FUNCTION OF THE METAL (J)	MAXIMUM KINETIC ENERGY OF PHOTOELECTRONS (J)
Caesium	$3,36 \times 10^{-19}$	$2,32 \times 10^{-19}$
Sodium	$3,65 \times 10^{-19}$	E_K

2.1 Define the term *work function of a metal*. (2)

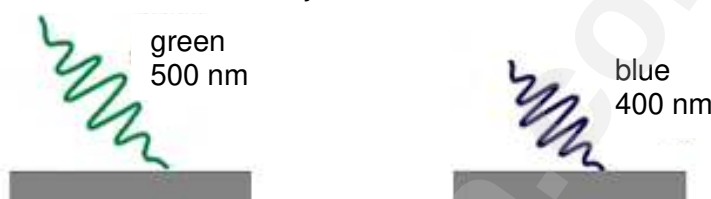
2.2 Use the information in the table to calculate the wavelength of the ultraviolet light used in the experiment. (4)

2.3 Calculate the maximum kinetic energy, E_K , of an electron ejected from the sodium metal. (4)

- 2.4 The intensity of the incident ultraviolet light was then increased.
- 2.4.1 Give a reason why this change does NOT affect the maximum kinetic energy of the ejected photoelectrons. (1)
- 2.4.2 How does the increased intensity affect the reading on the ammeter? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1)
- 2.4.3 Explain the answer to QUESTION 2.4.2. (2)
- [14]**

QUESTION 3

- 3.1 In the diagram below, green and blue light are successively shone on a metal surface. In each case, electrons are ejected from the surface.



- 3.1.1 What property of light is illustrated by the photoelectric effect? (1)
- 3.1.2 Without any calculation, give a reason why the maximum kinetic energy of an ejected electron, using blue light, is GREATER THAN that obtained using green light, for the same metal surface. (2)
- 3.2 The wavelength associated with the cut-off (threshold) frequency of a certain metal is 330 nm. Calculate:
- 3.2.1 The work function of the metal (4)
- 3.2.2 The maximum speed of an electron ejected from the surface of the metal when light of frequency $1,2 \times 10^{15}$ Hz is shone on the metal (5)
- [12]**

QUESTION 4

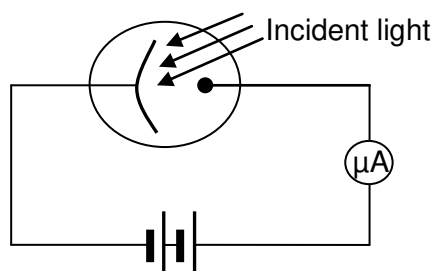
In an experiment to demonstrate the photoelectric effect, light of different wavelengths was shone onto a metal surface of a photoelectric cell. The maximum kinetic energy of the emitted electrons was determined for the various wavelengths and recorded in the table below.

INVERSE OF WAVELENGTH $\frac{1}{\lambda} (\times 10^6 \text{ m}^{-1})$	MAXIMUM KINETIC ENERGY $E_{k(\text{max})} (\times 10^{-19} \text{ J})$
5,00	6,60
3,30	3,30
2,50	1,70
2,00	0,70

- 4.1 What is meant by the term *photoelectric effect*? (2)
- 4.2 Draw a graph of $E_{k(\text{max})}$ (y-axis) versus $\frac{1}{\lambda}$ (x-axis) on a graph paper. (3)
- 4.3 USE THE GRAPH to determine:
- 4.3.1 The threshold frequency of the metal in the photoelectric cell (4)
- 4.3.2 Planck's constant (4)
- [13]**

QUESTION 5

An investigation was conducted to determine the effects of changes in frequency AND intensity on the current generated in a photoelectric cell when light is incident on it. The apparatus used in the investigation is shown in the simplified diagram below.



The results of the experiment are shown in the table below.

EXPERIMENT	FREQUENCY (Hz)	INTENSITY (Cd)	CURRENT (μA)
A	$4,00 \times 10^{14}$	10	0
B	$4,50 \times 10^{14}$	10	0
C	$5,00 \times 10^{14}$	10	0
D	$5,01 \times 10^{14}$	10	20
E	$5,01 \times 10^{14}$	20	40
F	$6,50 \times 10^{14}$	10	30

5.1 Define the term *work function*. (2)

5.2 Identify an independent variable. (1)

The threshold frequency for the metal used in the photocell is $5,001 \times 10^{14}$ Hz.

5.3 Define the term *threshold frequency*. (2)

5.4 Calculate the maximum speed of an emitted electron in experiment **F**. (5)

In experiments **D** and **E**, the current doubled when the intensity was doubled at the same frequency.

5.5 What conclusion can be made from this observation? (2)
[12]



QUESTION 6

- 6.1 In an experiment on the photoelectric effect, light is incident on the surface of a metal and electrons are ejected.

6.1.1 What does the photoelectric effect indicate about the nature of light? (1)

6.1.2 The intensity of the light is increased. Will the maximum speed of the ejected electrons INCREASE, DECREASE or REMAIN THE SAME? Give a reason for the answer. (2)

The wavelength corresponding with the threshold frequency is referred to as *threshold wavelength*.

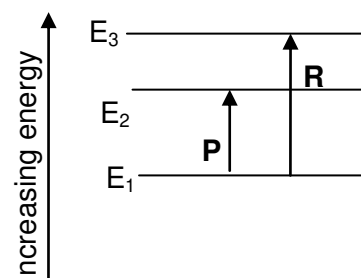
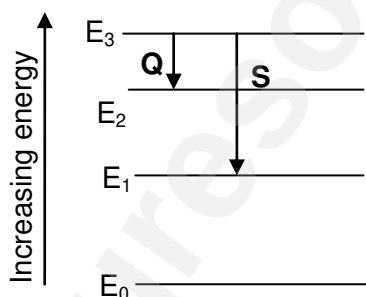
The table below gives the values of threshold wavelengths for three different metals.

METAL	THRESHOLD WAVELENGTH (λ_0) IN METRES
Silver	$2,88 \times 10^{-7}$
Calcium	$4,32 \times 10^{-7}$
Sodium	$5,37 \times 10^{-7}$

In the experiment using one of the metals above, the maximum speed of the ejected electrons was recorded as $4,76 \times 10^5 \text{ m}\cdot\text{s}^{-1}$ for light of wavelength 420 nm.

6.1.3 Identify the metal used in the experiment by means of suitable calculations. (5)

- 6.2 The simplified energy diagrams showing the possible electron transitions in an atom are shown below.

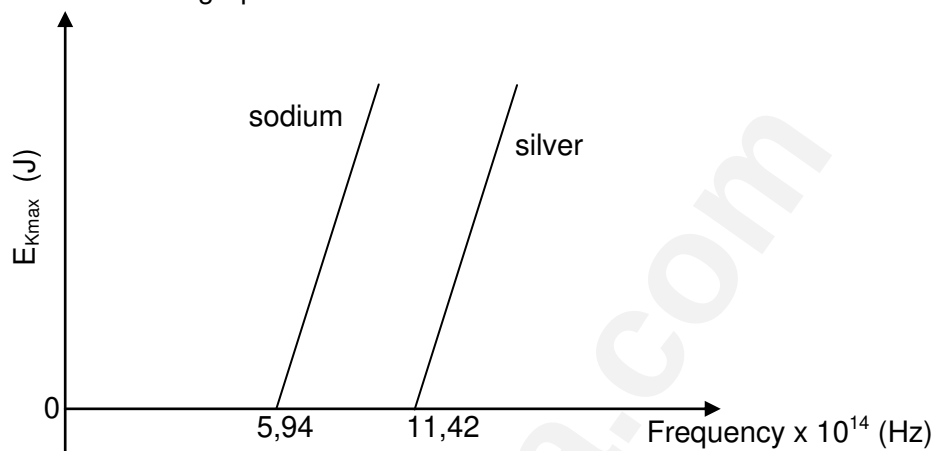


Using the letters **P**, **Q**, **R** and **S**, identify the lines that CORRECTLY show transitions that will result in the atom giving off an EMISSION SPECTRUM. Give a reason for the answer.

(4)
[12]

QUESTION 7

- 7.1 A learner is investigating the photoelectric effect for two different metals, silver and sodium, using light of different frequencies. The maximum kinetic energy of the emitted photoelectrons is plotted against the frequency of the light for each of the metals, as shown in the graphs below.



- 7.1.1 Define the term *threshold frequency*. (2)
- 7.1.2 Which metal, sodium or silver, has the larger work function? Explain the answer. (3)
- 7.1.3 Name the physical constant represented by the slopes of the graphs. (1)
- 7.1.4 If light of the same frequency is shone on each of the metals, in which metal will the ejected photoelectrons have a larger maximum kinetic energy? (1)
- 7.2 In a different photoelectric experiment blue light obtained from a light bulb is shone onto a metal plate and electrons are released.
- The wavelength of the blue light is $470 \times 10^{-9} \text{ m}$ and the bulb is rated at 60 mW. The bulb is only 5% efficient.
- 7.2.1 Calculate the number of photons that will be incident on the metal plate per second, assuming all the light from the bulb is incident on the metal plate. (5)
- 7.2.2 **Without any further calculation**, write down the number of electrons emitted per second from the metal. (1)
- [13]**

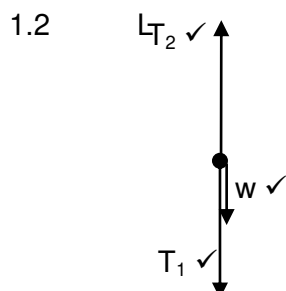


ANSWERS TO QUESTIONS

NEWTON'S LAWS

QUESTION 1

- 1.1 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. ✓ (2)



Accepted Labels	
w	F_g / F_w / force of earth on block / weight / 49 N / mg / gravitational force
T_2	Tension 2 / F_Q / 250 N / F_{T2} / F_{app}
T_1	Tension 1 / F_{T1} / F_P

(3)

1.3 OPTION 1

$$F_{net} = ma \checkmark$$

For 5 kg block:

$$T_2 + (-mg) + (-T_1) = ma$$

$$250 - (5)(9,8) - T_1 \checkmark = 5a$$

$$201 - T_1 = 5a$$

$$T_1 = 201 - 5a \dots (1)$$

For 20 kg block:

$$T_1 + (-mg) = ma \dots (2)$$

$$T_1 + [-20(9,8)] \checkmark = 20a$$

$$5 = 25a$$

$$a = 0,2 \text{ m} \cdot \text{s}^{-2} \text{ upwards}$$

$$\therefore T_1 = \underline{201 - 5(0,2)} \checkmark$$

$$= 200 \text{ N} \checkmark$$

$$\text{OR } T_1 = \underline{20(9,8) + 20(0,2)} \checkmark$$

$$= 200 \text{ N} \checkmark$$

✓ for either 5a or 20a

(6)

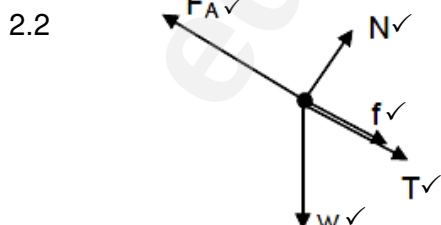
- 1.4 **Q** ✓

(1)

[12]

QUESTION 2

- 2.1 When body A exerts a force on body B, body B exerts a force of equal magnitude ✓ in the opposite direction ✓ on body A. (2)



Accepted labels	
w	F_g / F_w / force of earth on block / weight / mg / gravitational force
N	Normal force / F_N
T	Tension / F_T
F_A	F / $F_{applied}$ / 40 N
f	Frictional force / F_f

(5)

2.3

2.3.1

OPTION 1/OPSIE 1

For the 1 kg block/Vir die 1 kg blok;

$$\begin{aligned} f_k &= \mu_k N \\ &= \mu_k mg \cos \theta \checkmark \\ &= 0,29 (1 \times 9,8 \cos 30^\circ) \checkmark \\ &= 2,46 \text{ N} \checkmark \end{aligned}$$

OPTION 2/OPSIE 2

BY PROPORTION:/DEUR EWEREDIGHEID

The smaller mass = $\frac{1}{4}$ of the larger mass $\checkmark$

Die kleiner massa = $\frac{1}{4}$ die groter massa

$$\begin{aligned} \therefore \text{frictional force/wrywingskrag} &= \frac{1}{4} (10) \checkmark \\ &= 2,5 \text{ N} \checkmark \end{aligned}$$

(3)

2.3.2

POSITIVE MARKING FROM QUESTION 2.2

POSITIEWE NASIEN VANAF VRAAG 2.2

OPTION 1/OPSIE 1

$$F_{\text{net}} = ma \checkmark$$

For 1 kg block/Vir 1 kg blok

$$F_A - \{(T + f_k) + mg \sin \theta\} = ma$$

$$40 - \{T + 2,46 + 1(9,8)(\sin 30^\circ)\} \checkmark = (1 \text{ x}) a \checkmark$$

$$40 - T - 7,36 = a$$

$$32,64 - T = a \dots \dots (1)$$

For 4 kg block/Vir 4 kg blok

$$T - (mg \sin \theta + f_k) = 4a$$

$$T - (4 \times 9,8 \sin 30^\circ + 10) = 4a \checkmark$$

$$T - 29,6 = 4a \dots \dots (2)$$

From (1) and (2)/Vanaf (1) en (2)

$$a = 0,61 \text{ m} \cdot \text{s}^{-2}$$

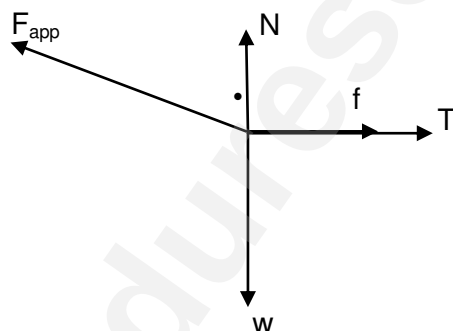
$$T = 29,6 + (4(0,61)) \checkmark$$

$$T = 32,04 \text{ N} \checkmark$$

(6)
[16]

QUESTION 3

3.1



Accepted labels		
w	✓	F_g / F_w / weight / mg / gravitational force
T	✓	F_T / tension
F	✓	F_a / F_{60} / 60 N / F_{applied} / F_t /
N	✓	F_N
f	✓	F_f

(5)

3.2

3.2.1

$$\begin{aligned} F_{60y} &= F_{60} \sin \theta \checkmark & F_{60y} &= F_{60} \cos \theta \checkmark \\ F_{60y} &= 60 \sin 10^\circ \checkmark & \text{OR } F_{60y} &= 60 \cos 80^\circ \checkmark \\ &= 10,42 \text{ N} \checkmark \end{aligned}$$

(2)

3.2.2

$$\begin{aligned} F_{60x} &= F_{60} \cos \theta \checkmark & F_{60x} &= F_{60} \sin \theta \checkmark \\ F_{60x} &= 60 \cos 10^\circ \checkmark & \text{OR } F_{60x} &= 60 \sin 80^\circ \checkmark \\ &= 59,09 \text{ N} \checkmark \end{aligned}$$

(2)

3.3

When a resultant/net force acts on an object, the object will accelerate in the direction of the force at an acceleration directly proportional to the force $\checkmark$ and inversely proportional to the mass of the object. $\checkmark$

(2)



3.4

POSITIVE MARKING FROM 3.2. $N = mg - F_{60y}$ $N = \{5(9,8) - 10,42\}$ ✓ $= 38,58 \text{ N}$ ✓	OR $F_y + N = w$ $N = w - F_y = mg - F_y$ $= \{5(9,8) - 10,42\}$ ✓ $= 38,58 \text{ N}$ ✓
--	---

(2)

3.5

POSITIVE MARKING FROM 3.2.2 AND 3.4.

$$\begin{aligned}
 F_{\text{net}} &= ma \\
 T - m_2g &= m_2a \\
 T - 2(9,8) &= 2a \\
 T - 19,6 &= 2a \dots\dots\dots(1) \\
 F_{60x} = (f + T) &= m_8a \\
 60\cos 10^\circ - (f + T) &= 5a \\
 60\cos 10^\circ - [(0,5N) + T] &= 5a \\
 59,09 - (0,5 \times 38,58) - T &= 5a \\
 39,8 - T &= 5a \dots\dots\dots(2) \\
 a &= 2,886 \text{ ms}^{-2} \\
 T - 19,6 &= 2(2,886) \checkmark \\
 T &= 25,37 \text{ N} \checkmark \\
 \text{OR} \\
 \text{From equation (2)} \\
 T &= 25,37 \text{ N} \\
 \text{OR} \\
 T - 19,6 &= 2a \dots\dots\dots(1) \times 5 \\
 59,09 - 19,29 - T &= 5a \dots\dots\dots(2) \times 2 \\
 7T - 177,6 &= 0 \checkmark \\
 T &= 25,37 \text{ N} \checkmark
 \end{aligned}$$

$$\text{OR } 60 \sin 80^\circ - [f + T] = 5a$$

(7)
[20]

QUESTION 4

4.1

4.1.1 When body A exerts a force on body B, body B exerts a force of equal magnitude ✓ in the opposite direction ✓ on body A. (2)

4.1.2

For 2,5 kg block $T = mg$ ✓ $\therefore T = (2,5)(9,8)$ ✓ $= 24,5 \text{ N}$ ✓	OR $F_{\text{net}} = ma$ $T - mg = (2,5)(0)$ ✓ $T - (2,5)(9,8) = 0$ ✓ $T = 24,5 \text{ N}$ ✓	OR $F_{\text{net}} = ma$ $mg - T = (2,5)(0)$ ✓ $(2,5)(9,8) - T = 0$ ✓ $T = 24,5 \text{ N}$ ✓
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(3)

4.1.3

POSITIVE MARKING FROM 4.1.2. For mass M $f_s = \mu_s N$ ✓ ✓ $\therefore N = \frac{24,5}{0,2} = 122,5 \text{ N}$ $N = Mg = 122,5 \text{ N}$ $M(9,8) = 122,5 \text{ N}$ ✓ $M = 12,5 \text{ kg}$ ✓	OR $\mu_s N = \mu_s Mg$ $24,5 = (0,2) M(9,8)$ ✓ $M = 12,5 \text{ kg}$ ✓
--	---

(5)

4.1.4

For the 5 kg block:

$$\begin{aligned}
 f_k &= \mu_k N \\
 f_k &= (0,15)(5)(9,8) \checkmark \\
 &= 7,35 \text{ N} \\
 F_{\text{net}} &= ma \\
 T - f_k &= ma \\
 T - 7,35 &= 5a \checkmark
 \end{aligned}$$

For the 2,5 kg block:

$$\begin{aligned}
 w - T &= ma \\
 (2,5)(9,8) - T &= 2,5a \checkmark \\
 17,15 &= 7,5 \\
 a &= 2,29 \text{ m} \cdot \text{s}^{-2} \checkmark
 \end{aligned}$$

(5)

4.2

$$F = G \frac{m_1 m_2}{r^2} \checkmark$$

$$F = \frac{(6,67 \times 10^{-11})(6,5 \times 10^{20})(90)}{(550 \times 10^3)^2} \checkmark$$

$$= 12,90 \text{ N} \checkmark (12,899 \text{ N})$$

OR

$$g = \frac{Gm}{r^2} \checkmark$$

$$g = \frac{(6,67 \times 10^{-11})(6,5 \times 10^{20})}{(550 \times 10^3)^2} \checkmark$$

$$= 0,143 \dots \text{m} \cdot \text{s}^{-2}$$

$$w = mg$$

$$= (90)(0,143 \dots) \checkmark$$

$$= 12,89 \text{ N} \checkmark (\text{downwards}) \quad (\text{Accept } 12,6 \text{ N} - 12,90 \text{ N})$$

Any one

(4)
[19]

QUESTION 5

5.1

5.1.1

For the 5 kg mass/Vir die 5 kg massa:

$$T - f = ma$$

$$T - \mu_k(mg) = ma \checkmark$$

$$T - (0,4)(5)(9,8) \checkmark = 5a \checkmark \dots\dots\dots(1)$$

For the 20 kg mass/Vir die 20 kg massa

$$mg - T = ma$$

$$20(9,8) - T = 20a \checkmark \dots\dots\dots(2)$$

$$176,4 = 25a \quad (1) + (2)$$

$$\therefore a = 7,06 (7,056) \text{ m} \cdot \text{s}^{-2} \checkmark$$

ACCEPT/AANVAAR (4 marks/4 punte)

$$F_{\text{net}} = ma$$

$$Mg - f = (M + m) a \checkmark$$

$$[20(9,8) - (0,4)(5)(9,8)] \checkmark = 25a \checkmark$$

$$\therefore a = 7,06 \text{ m} \cdot \text{s}^{-2} \checkmark$$

(5)

5.1.2

POSITIVE MARKING FROM QUESTION 5.1.1.

OPTION 1/OPSIE 1

$$v_f^2 = v_i^2 + 2a\Delta y \checkmark$$

$$= 0 \checkmark + (2)(7,056)(6) \checkmark$$

$$v_f = 9,20 \text{ m} \cdot \text{s}^{-1} \checkmark$$

OPTION 2/OPSIE 2

The 5 kg mass travels as fast as the 20 kg mass

Die 5 kg massa beweeg net so vinnig soos die 20 kg massa

$$W_{\text{net}} = \Delta K \checkmark$$

$$(5)(7,056)(6 \cos 0^\circ) \checkmark = \frac{1}{2}(5)(v_f^2 - 0) \checkmark$$

$$v_f = 9,20 \text{ m} \cdot \text{s}^{-1} \checkmark$$

(4)

5.1.3

$$6 \text{ m} \checkmark$$

(1)



5.2

- 5.2.1 Each body in the universe attracts every other body with a force that is directly proportional to the product of their masses ✓ and inversely proportional to the square of the distance between their centres. ✓ (2)

5.2.2

$$F = \frac{Gm_1m_2}{r^2} \checkmark$$

On the mountain/Op die berg

$$F_g = \frac{(6,67 \times 10^{-11})(5,98 \times 10^{24})(65)}{(6,38 \times 10^6 + 6 \times 10^3)^2} \checkmark$$

$$= 627,2 \text{ N}$$

On the ground/Op die grond

$$F_g = W = mg$$

$$= (65 \times 9,8) \checkmark$$

$$= 637 \text{ N}$$

$$F_g = \frac{(6,67 \times 10^{-11})(5,98 \times 10^{24})(65)}{(6,38 \times 10^6)^2}$$

$$= 636,94 \text{ N}$$

$$\text{Difference/Verskil} = (637 - 627,2) \checkmark$$

$$= 9,8 \text{ N} \checkmark$$

(6)
[19]

QUESTION 6

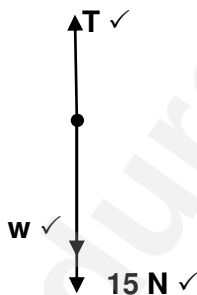
- 6.1 A body will remain in its state of rest or motion at constant velocity ✓ unless a resultant/net force ✓ acts on it.

OR

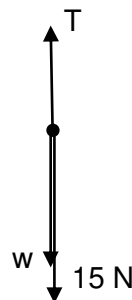
Every body continues in its state of rest or of uniform motion in a straight line ✓ unless a resultant/net force ✓ acts on it. (2)

- 6.2 0 (N) ✓ /zero (newton) (1)

6.3



OR



Accepted labels	
w	F_g / F_w / weight / mg / gravitational force
T	F_T / tension
15 N	F_a / F_{15N} / F_{applied} / F_t / / F

(3)

6.4

2 kg block

$$\begin{aligned} F_{\text{net}} &= ma \\ F_a + F_g + (-T) &= ma \\ F_a + mg + (-T) &= ma \\ [15 + (2)(9,8) - T] &= (2)(1,2) \\ T &= 32,2 \text{ N} \end{aligned}$$

10 kg block

$$\begin{aligned} T + (-f_k) &= ma \\ T - \mu_k N &= ma \\ T - \mu_k mg &= ma \\ 32,2 - (\mu_k)(10)(9,8) &= (10)(1,2) \\ \mu_k &= 0,21 \end{aligned}$$

(7)

6.5

Smaller than ✓

(1)

6.6

Remains the same ✓



The coefficient of kinetic friction is independent of the (apparent microscopic) surface areas in contact. ✓

OR

The coefficient of kinetic friction depends only on the type of materials used. ✓

(2)

[16]

QUESTION 7

7.1

When a resultant/net force acts on an object, the object will accelerate in the (direction of the net/resultant force). The acceleration is directly proportional to the net force ✓ and inversely proportional to the mass ✓ of the object.

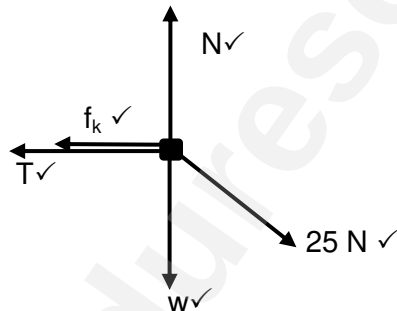
(2)

7.2

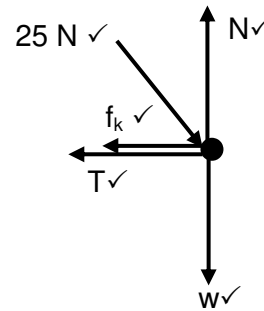
$$\begin{aligned} f_k &= \mu_k N = \mu_k mg \\ &= (0,15)(3)(9,8) \\ &= 4,41 \text{ N} \end{aligned}$$

(3)

7.3



OR



Accepted Labels	
w	F_g / F_w / force of earth on block / weight / 14,7 N / mg / gravitational force
N	F_N / F_{normal} / normal force
T	Tension / F_T
f_k	$f_{\text{kinetic friction}}$ / f / F_f / kinetic friction
25 N	F_{applied} / F_A / F

(5)



7.4

7.4.1

OPTION 1 $f_k = \mu_k N = \mu_k (25 \sin 30^\circ + mg)$ $= 0,15[(25 \sin 30^\circ) \checkmark + (1,5)(9,8) \checkmark]$ $= 4,08 \text{ N} \checkmark$	OPTION 2 $f_k = \mu_k N = \mu_k (25 \cos 60^\circ + mg)$ $= 0,15[(25 \cos 60^\circ) \checkmark + (1,5)(9,8) \checkmark]$ $= 4,08 \text{ N} \checkmark$
--	--

(3)

7.4.2

POSITIVE MARKING FROM Q7.2 & Q7.4.1. OPTION 1 For the 1,5 kg block $F_{\text{net}} = ma$ $F_x + (-T) + (-f_k) = ma$ } $25 \cos 30^\circ - T - f_k = 1,5a$ $(25 \cos 30^\circ - T) - 4,08 \checkmark = 1,5a$ $17,571 - T = 1,5a \dots\dots\dots(1)$ For the 3 kg block $T - f_k = 3a$ $T - 4,41 \checkmark = 3a \dots\dots\dots(2)$ $13,161 = 4,5a$ $a = 2,925 \text{ m} \cdot \text{s}^{-2}$ $T = 13,19 \text{ N} \checkmark$	OPTION 2 For the 1,5 kg block $F_{\text{net}} = ma$ $F_x + (-T) + (-f_k) = ma$ } $25 \cos 30^\circ - T - f_k = 1,5a$ $(25 \cos 30^\circ - T) - 4,08 \checkmark = 1,5a$ $17,571 - T = 1,5a \dots\dots\dots(1)$ $a = \frac{17,571 - T}{1,5}$ For the 3 kg block $T - f_k = 3a$ $T - 4,41 \checkmark = 3a \dots\dots\dots(2)$ $a = \frac{T - 4,41}{3}$ $\frac{17,571 - T}{1,5} = \frac{T - 4,41}{3}$ $T = 13,18 \text{ N} \checkmark$
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[18]



VERTICAL PROJECTILE MOTION

QUESTION 1

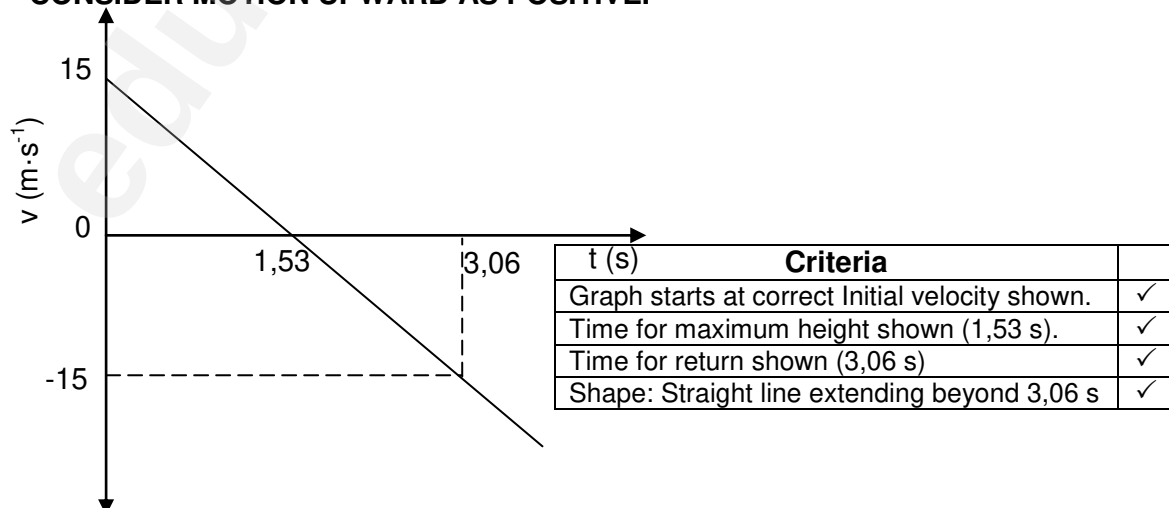
- 1.1 Motion under the influence of the gravitational force / weight ONLY. ✓✓ (There are no other forces such as friction.) (2)

1.2	OPTION 1 Upwards positive: $\Delta y = v_i \Delta t + \frac{1}{2} a \Delta t^2 \checkmark$ $0 \checkmark = 15 \Delta t + \frac{1}{2} (-9,8) \Delta t^2 \checkmark$ $\Delta t = 3,06 \text{ s}$ It takes 3,06 s ✓	Downwards positive: $\Delta y = v_i \Delta t + \frac{1}{2} a \Delta t^2 \checkmark$ $0 \checkmark = -15 \Delta t + \frac{1}{2} (9,8) \Delta t^2 \checkmark$ $\Delta t = 3,06 \text{ s}$ It takes 3,06 s ✓	(4)
	OPTION 2 Upwards positive: $v_f = v_i + a \Delta t \checkmark$ $0 \checkmark = 15 + (-9,8) \Delta t \checkmark$ $\Delta t = 1,53 \text{ s}$ It takes (2)(1,53) = 3,06 s ✓	Downwards positive: $v_f = v_i + a \Delta t \checkmark$ $0 \checkmark = -15 + (9,8) \Delta t \checkmark$ $\Delta t = 1,53 \text{ s}$ It takes (2)(1,53) = 3,06 s ✓	(4)

- 1.3 **POSITIVE MARKING FROM QUESTION 1.2**

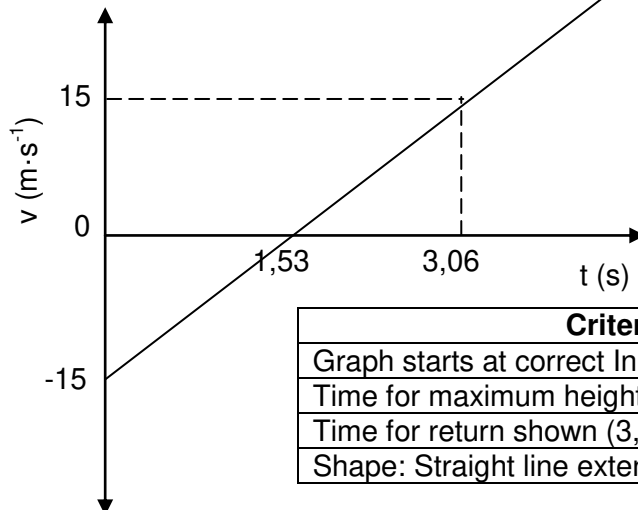
OPTION 1 Upwards positive: $v_f^2 = v_i^2 + 2a\Delta y \checkmark$ For ball A $0 = (15)^2 \checkmark + 2 (-9,8) \Delta y \checkmark$ $\Delta y_A = 11,48 \text{ m}$ <u>When A is at highest point:</u> $\Delta y_B = v_i \Delta t + \frac{1}{2} a \Delta t^2$ $= 0 + \frac{1}{2} (-9,8) (1,53)^2 \checkmark \checkmark$ $\Delta y_B = -11,47 \text{ m}$ $\Delta y_B = 11,47 \text{ m downward}$ $\text{Distance} = y_A + y_B$ $= 11,47 + 11,48 \checkmark$ $= 22,95 \text{ m} \checkmark$	Downwards positive: $v_f^2 = v_i^2 + 2a\Delta y \checkmark$ For ball A $0 = (-15)^2 \checkmark + 2 (9,8) \Delta y \checkmark$ $\Delta y_A = -11,48 \text{ m}$ <u>When A is at highest point:</u> $\Delta y_B = v_i \Delta t + \frac{1}{2} a \Delta t^2$ $= 0 + \frac{1}{2} (9,8) (1,53)^2 \checkmark \checkmark$ $\Delta y_B = 11,47 \text{ m}$ $\Delta y_B = 11,47 \text{ m downward}$ $\text{Distance} = y_A + y_B$ $= 11,48 + 11,47 \checkmark$ $= 22,95 \text{ m} \checkmark$
--	---

- 1.4 **POSITIVE MARKING FROM QUESTION 1.2.**
CONSIDER MOTION UPWARD AS POSITIVE.





CONSIDER MOTION DOWNWARD AS POSITIVE.



Criteria	
Graph starts at correct Initial velocity shown.	✓
Time for maximum height shown (1,53 s).	✓
Time for return shown (3,06 s)	✓
Shape: Straight line extending beyond 3,06 s	✓

(4)
[17]

QUESTION 2

2.1 Free fall ✓

(1)

2.2

2.2.1

Downward motion as positive
Afwaartse beweging as positief

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

$$30 \checkmark = v_i (1,5) + \frac{1}{2} (9,8) (1,5)^2 \checkmark$$

$$v_i = 12,65 \text{ m} \cdot \text{s}^{-1} \checkmark$$

Upward motion as positive
Opwaartse beweging as positief

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

$$-30 \checkmark = v_i (1,5) + \frac{1}{2} (-9,8) (1,5)^2 \checkmark$$

$$v_i = 12,65 \text{ m} \cdot \text{s}^{-1} \checkmark$$

(4)

2.2.2

POSITIVE MARKING FROM QUESTION 2.2.1.

Downward motion as positive
Afwaartse beweging as positief

$$v_f^2 = v_i^2 + 2a\Delta y \checkmark$$

$$12,65^2 \checkmark = 0 + 2(9,8) \Delta y \checkmark$$

$$\Delta y = 8,16 \text{ m} \checkmark$$

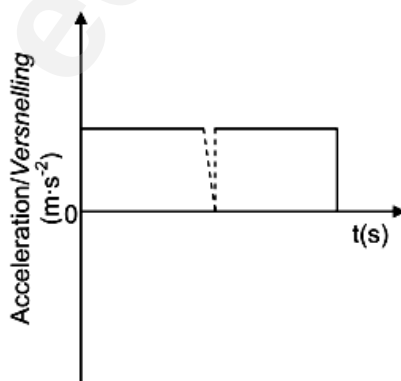
Height/Hoogte **XC = XB + BC**

$$(30 + 8,16) = 38,16 \text{ m}$$

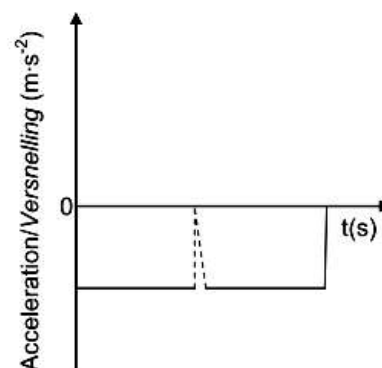
Height is/Hoogte is 38,16 m ✓

(5)

2.3



OR



(3)
[13]

QUESTION 3

3.1 $5,88 \text{ m} \cdot \text{s}^{-1}$ ✓ (1)

3.2 **POSITIVE MARKING FROM Q3.1**

OPTION 1
 $v_f^2 = v_i^2 + 2a\Delta y$ ✓
 $(-19,6)^2 = (5,88)^2 + 2(-9,8) \Delta y$ ✓
 $\Delta y = -17,84 \text{ m}$
Height above ground = 17,84 m ✓

OPTION 2
Area between graph and t-axis for 2,6 s
 $\Delta y = \frac{1}{2}bh + \frac{1}{2}bh$
 $= \frac{1}{2}(0,6)(5,88) + \frac{1}{2}(2,6 - 0,6)(-19,6)$ ✓
 $= -17,84 \text{ m}$
∴ Height above ground = 17,84 m ✓

OPTION 3
By symmetry ball returns to A at 1,2 s downward and $v = -5,88 \text{ m} \cdot \text{s}^{-1}$
 $\Delta y = \text{Area of trapezium}$
 $= \frac{1}{2}(\text{sum of parallel sides})(h)$ ✓
 $= \frac{1}{2}\{(-5,88) + (-19,6)\}(2,6 - 1,2)$ ✓ $= -17,84 \text{ m}$
∴ Height above ground = 17,84 m ✓

OPTION 4
 $\Delta y = \left(\frac{v_i + v_f}{2} \right) \Delta t$ ✓
 $\Delta y = \left(\frac{5,88 + (-19,6)}{2} \right) 2,6$ ✓ $= -17,836 \text{ m}$
∴ Height above ground = 17,84 m ✓

OPTION 5
 $\Delta y = v_i \Delta t + \frac{1}{2} a \Delta t^2$ ✓
 $\Delta y = (5,88)(2,6) + \frac{1}{2}(-9,8)(2,6)^2$ ✓
 $= 15,288 - 33,124 = -17,836$
∴ Height above ground = 17,84 m ✓ (3)

3.3

OPTION 1 $t_p = \left(\frac{3,2 - 2,6}{2} \right) + 2,6$ ✓ Time at P (t_p) = 2,9 s ✓	OPTION 2 $v_f = v_i + a\Delta t$ $0 = 2,94 + (-9,8)\Delta t$ ✓ $\Delta t = 0,3 \text{ s}$ <u>∴ $t_p = 2,6 + 0,3 = 2,9 \text{ s}$</u> ✓
--	--

OPTION 3
Gradient = -9,8
 $\frac{\Delta y}{\Delta t} = -9,8$
 $\frac{0 - 2,94}{\Delta t} = -9,8$ ✓
 $\Delta t = 0,3 \text{ s}$
Time at P (t_p) = $(2,6 + 0,3) = 2,9 \text{ s}$ ✓ (2)

3.4 **POSITIVE MARKING FROM Q3.3.**

OPTION 1 $\Delta y = \text{area under graph}$ ✓ $= \frac{1}{2}(0,3)(2,94)$ ✓ $= 0,44 \text{ m}$ ✓	OPTION 2 $\Delta y = v_i \Delta t + \frac{1}{2} a \Delta t^2$ ✓ $= (2,94)(0,3) + \frac{1}{2}(-9,8)(0,3)^2$ ✓ $= 0,44 \text{ m}$ ✓	OPTION 3 $v_f^2 = v_i^2 + 2a\Delta y$ ✓ $0 = 2,94^2 + 2(-9,8)\Delta y$ ✓ $\Delta y = 0,44 \text{ m}$ ✓
---	---	--

(3)



3.5 **POSITIVE MARKING FROM 3.1, 3.2, 3.3 AND 3.4.**

For $t = 2,9 \text{ s}$ $t_p = 2,9 \text{ s}$

Distance travelled by balloon since ball was dropped

$$\begin{aligned}\Delta y &= v\Delta t \\ &= (5,88)(2,9) \checkmark \\ &= 17,05 \text{ m}\end{aligned}$$

Height of balloon when ball was dropped = 17,84 m

Height of balloon after 2,9 s = $(17,05 + 17,84) \checkmark = 34,89 \text{ m}$

Maximum height of ball above ground = 0,44 m

$\therefore$ distance between balloon and ball = $(34,89 - 0,44) = 34,45 \text{ m} \checkmark$

(4)

[13]

QUESTION 4

4.1

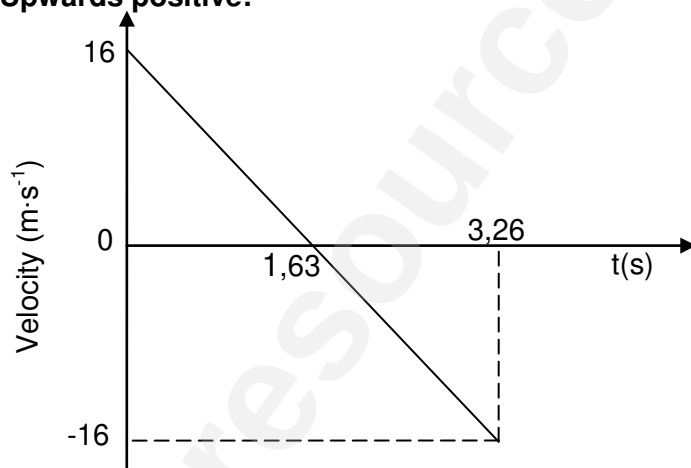
Upwards positive	Downwards positive
$v_f = v_i + a\Delta t \checkmark$	$v_f = v_i + a\Delta t \checkmark$
$-16 \checkmark = 16 - 9,8(\Delta t) \checkmark$	$16 \checkmark = -16 + 9,8(\Delta t) \checkmark$
$\Delta t = 3,27 \text{ s} \checkmark$	$\Delta t = 3,27 \text{ s} \checkmark$

(4)

4.2

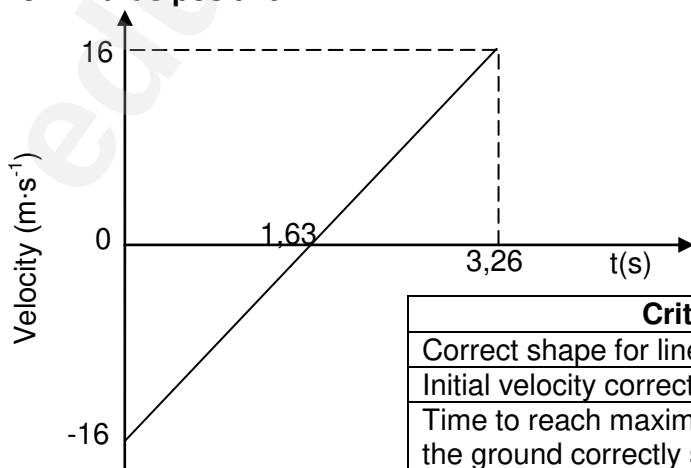
POSITIVE MARKING FROM 4.1.

Upwards positive:



POSITIVE MARKING FROM 4.2.

Downwards positive:



Criteria for graph	
Correct shape for line extending beyond $t = 1,63 \text{ s}$.	☒
Initial velocity correctly indicated as shown.	☒
Time to reach maximum height and time to return to the ground correctly shown.	☒

(3)



4.3

Marking criteria:

- Both equations ✓
- Equation for distance/displacement covered by A. ✓
- Equation for distance/displacement covered by B. ✓
 - One of equations to have time as $(\Delta t + 1)$ or $(\Delta t - 1)$. ✓
- Solution for $t = 2,24$ s. ✓
- Final answer: 11,25 m ✓

Upwards positive:

Take y_A as height of ball A from the ground:

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

$$y_A - 0 = 16\Delta t + \frac{1}{2}(-9,8)\Delta t^2$$

$$= 16\Delta t - 4,9\Delta t^2 \quad \checkmark$$

Take y_B as height of ball B from the ground:

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

$$y_B - 30 = (v_i \Delta t + \frac{1}{2} a \Delta t^2)$$

$$y_B = 30 - [-9(\Delta t - 1) + \frac{1}{2}(-9,8)(\Delta t - 1)^2] \quad \checkmark$$

$$= 34,1 + 0,8\Delta t - 4,9\Delta t^2 \quad \checkmark$$

$$y_A = y_B$$

$$\therefore 16\Delta t - 4,9\Delta t^2 = 34,1 + 0,8\Delta t - 4,9\Delta t^2$$

$$15,2\Delta t = 34,1$$

$$\Delta t = 2,24 \text{ s} \quad \checkmark$$

$$y_A = 16(2,24) - 4,9(2,24)^2 = 11,25 \text{ m} \quad \checkmark$$

✓ Both

Downwards positive:

Take y_A as height of ball A from the ground.

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

$$y_A - 0 = -16\Delta t + \frac{1}{2}(9,8)\Delta t^2$$

$$= -16\Delta t + 4,9\Delta t^2 \quad \checkmark$$

Take y_B as height of ball B from the ground.

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

$$y_B - 30 = -(v_i \Delta t + \frac{1}{2} a \Delta t^2)$$

$$y_B = 30 - [9(\Delta t - 1) + \frac{1}{2}(9,8)(\Delta t - 1)^2] \quad \checkmark$$

$$= 34,1 + 0,8\Delta t - 4,9\Delta t^2 \quad \checkmark$$

$$y_A = y_B$$

$$-16\Delta t + 4,9\Delta t^2 = 34,1 + 0,8\Delta t - 4,9\Delta t^2$$

$$15,2\Delta t = 34,1$$

$$\Delta t = 2,24 \text{ s} \quad \checkmark$$

$$\Delta y_A = (-16(2,24) + 4,9(2,24)^2) = 11,25 \text{ m} \quad \checkmark$$

✓ Both

(6)
[13]



QUESTION 5

5.1

5.1.1

OPTION 1/OPSIE 1 Upwards positive/Opwaarts positief: $v_f^2 = v_i^2 + 2a\Delta y$ ✓ $v_f^2 = (-2)^2 + 2(-9,8)(-45)$ ✓ $v_f = 29,76 \text{ m}\cdot\text{s}^{-1}$ ✓	Downwards positive/Afwaarts positief: $v_f^2 = v_i^2 + 2a\Delta y$ ✓ $v_f^2 = (2)^2 + 2(9,8)(45)$ ✓ $v_f = 29,76 \text{ m}\cdot\text{s}^{-1}$ ✓ (29,77 m·s⁻¹)
OPTION 2/OPSIE 2 Upwards positive/Opwaarts positief: $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$ ✓ for either equation/vir beide vergelykings $-45 = -2\Delta t + \frac{1}{2}(-9,8)\Delta t^2$ $-4,9\Delta t^2 - 2\Delta t + 45 = 0$ $4,9\Delta t^2 + 2\Delta t - 45 = 0$ ✓ $\Delta t = 2,83$ $v_f = v_i + a\Delta t$ $v_f = 0 + (-9,8)(2,83)$ $v_f = -29,73 \text{ m}\cdot\text{s}^{-1}$ ✓	Downwards positive/Afwaarts positief: $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$ ✓ for either equation/vir beide vergelykings $45 = 2\Delta t + \frac{1}{2}(9,8)\Delta t^2$ $4,9\Delta t^2 + 2\Delta t - 45 = 0$ ✓ $\Delta t = 2,83$ $v_f = v_i + a\Delta t$ $v_f = 0 + (9,8)(2,83)$ $v_f = 29,73 \text{ m}\cdot\text{s}^{-1}$ ✓

(4)

5.1.2

POSITIVE MARKING FROM Q5.1.1. OPTION 1/OPSIE 1 Upwards positive/Opwaarts positief: The balls hit the water at the same instant./Die balle tref die water gelyktydig $v_f = v_i + a\Delta t$ ✓ Ball/Bal A $-29,76 = -2 + (-9,8)\Delta t$ $\Delta t = 2,83 \text{ s}$ ✓ $\therefore$ for ball/vir bal B $\Delta t_B = 2,83 - 1 = 1,83 \text{ s}$ $\therefore$ for ball/vir bal B $\Delta t_B = 2,83 - 1 = 1,83 \text{ s}$ ✓	Downwards positive/Afwaarts positief The balls hit the water at the same instant./Die balle tref die water gelyktydig $v_f = v_i + a\Delta t$ ✓ Ball/Bal A $29,76 = 2 + (9,8)\Delta t$ $\Delta t = 2,83 \text{ s}$ ✓ $\therefore$ for ball/vir bal B $\Delta t_B = 2,83 - 1 = 1,83 \text{ s}$ $\therefore$ for ball/vir bal B $\Delta t_B = 2,83 - 1 = 1,83 \text{ s}$ ✓
OPTION 2 Upwards positive/Opwaarts positief: Ball/Bal A $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$ ✓ $-45 = -2\Delta t + \frac{1}{2}(-9,8)\Delta t^2$ $-4,9\Delta t^2 - 2\Delta t + 45 = 0$ $4,9\Delta t^2 + 2\Delta t - 45 = 0$ $\Delta t = 2,83$ ✓ $\therefore$ for ball/vir bal B $\Delta t_B = 2,83 - 1 = 1,83 \text{ s}$ ✓	Downwards positive/Afwaarts positief: $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$ ✓ $45 = 2\Delta t + \frac{1}{2}(9,8)\Delta t^2$ $4,9\Delta t^2 + 2\Delta t - 45 = 0$ $\Delta t = 2,83$ ✓ $\therefore$ for ball/vir bal B $\Delta t_B = 2,83 - 1 = 1,83 \text{ s}$ ✓

(4)

5.1.3

POSITIVE MARKING FROM Q5.1.2. Upwards positive/Opwaarts positief: $\Delta t_B = 1,83 \text{ s}$ ✓ $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$ ✓ $-45 \checkmark = v_i(1,83) + \frac{1}{2}(-9,8)(1,83)^2$ ✓ $v_i = -15,62 \text{ m}\cdot\text{s}^{-1}$ ✓	Downwards positive: $\Delta t_B = 1,83 \text{ s}$ $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$ $45 = v_i(1,83) + \frac{1}{2}(9,8)(1,83)^2$ $v_i = 15,62 \text{ m}\cdot\text{s}^{-1}$
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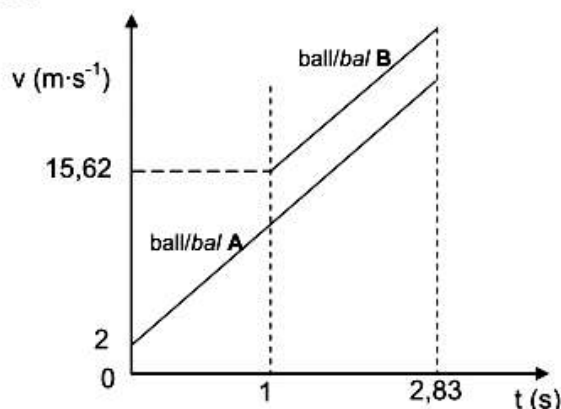
(4)



q
5.2

POSITIVE MARKING FROM Q5.1.2 & 5.1.3.

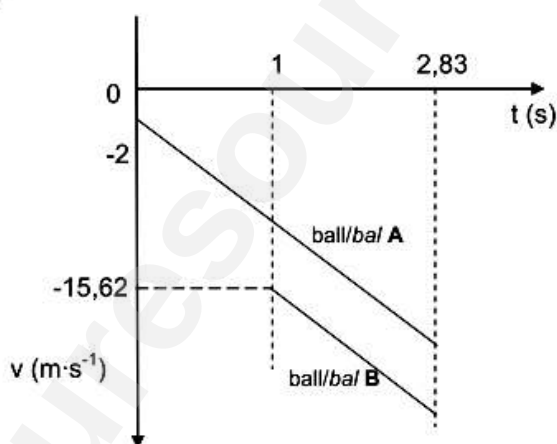
CONSIDER MOTION DOWNWARD AS POSITIVE/BESKOU BEWEGING AFWAARTS AS POSITIEF



CRITERIA FOR MARKING/KRITERIA VIR NASIEN	
1 mark for each initial velocity shown/1 punt vir elke beginsnelheid aangedui (For/Vir A $2 \text{ m}\cdot\text{s}^{-1}$ for/vir B $15,62 \text{ m}\cdot\text{s}^{-1}$)	✓✓
Time of release of ball/Tyd van vrystelling van bal B $t = 1 \text{ s}$	✓
Time of flight for both balls must be indicated as same on time axis/Vlugtyd van beide balle moet op dieselfde tyd as aangetoon word ($2,83 \text{ s}$)	✓
Shape: Lines must be parallel or nearly so/Vorm: Lyne moet parallel of amper parallel wees	✓

(4)

CONSIDER MOTION UPWARD AS POSITIVE/BESKOU OPWAARTSE BEWEGING AS POSITIEF



CRITERIA FOR MARKING/KRITERIA VIR NASIEN	
1 mark for each initial velocity shown/1 punt vir elke beginsnelheid aangedui (For/Vir A $-2 \text{ m}\cdot\text{s}^{-1}$ for/vir B $-15,62 \text{ m}\cdot\text{s}^{-1}$)	✓✓
Time of release of ball/Tyd van vrystelling van bal B $t = 1 \text{ s}$	✓
Time of flight for both balls must be indicated as same on time axis/Vlugtyd van beide balle moet op dieselfde tyd as aangetoon word ($2,83 \text{ s}$)	✓
Shape: Lines must be parallel or nearly so/Vorm: Lyne moet parallel of amper parallel wees	✓

(4)
[16]

QUESTION 6

6.1 An object upon which the only force acting is the force of gravity. ✓

(2)



6.2

6.2.1

OPTION 1	
Upward positive $v_f = v_i + a\Delta t \checkmark$ $-30 = 30 \checkmark + (-9,8)\Delta t \checkmark$ $\Delta t = 6,12 \text{ s} \checkmark$	Downward positive $v_f = v_i + a\Delta t \checkmark$ $30 = -30 \checkmark + (9,8)\Delta t \checkmark$ $\Delta t = 6,12 \text{ s} \checkmark$
OPTION 2	
Upward positive $v_f = v_i + a\Delta t \checkmark$ $0 = 30 \checkmark + (-9,8)\Delta t \checkmark$ $\Delta t = 3,06 \text{ s}$ Total time = $(2)(3,06) = 6,12 \text{ s} \checkmark$	Downward positive $v_f = v_i + a\Delta t \checkmark$ $0 = -30 \checkmark + (9,8)\Delta t \checkmark$ $\Delta t = 3,06 \text{ s}$ Total time = $(2)(3,06) = 6,12 \text{ s} \checkmark$
OPTION 3	
Upward positive $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2 \checkmark$ $0 = (30)\Delta t \checkmark + \frac{1}{2}(-9,8)\Delta t^2 \checkmark$ $\Delta t = 6,12 \text{ s} \checkmark$	Downward positive $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2 \checkmark$ $0 = (-30)\Delta t \checkmark + \frac{1}{2}(9,8)\Delta t^2 \checkmark$ $\Delta t = 6,12 \text{ s} \checkmark$

(4)

6.2.2

POSITIVE MARKING FROM QUESTION 6.2.1.

OPTION 1	
Upward positive } $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2 \checkmark$ $\Delta y_{\text{last}} = \Delta y_{(6,12)} - \Delta y_{(5,12)} \checkmark$ $= \{30(6,12) + \frac{1}{2}(-9,8)(6,12)^2\} \checkmark - \{30(5,12) + \frac{1}{2}(-9,8)(5,12)^2\} \checkmark$ $= -25,076$ Distance = $ \Delta y = 25,08 \text{ m} \checkmark$ OR Downward positive } $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2 \checkmark$ $\Delta y_{\text{last}} = \Delta y_{(6,12)} - \Delta y_{(5,12)} \checkmark$ $= \{-30(6,12) + \frac{1}{2}(9,8)(6,12)^2\} \checkmark - \{-30(5,12) + \frac{1}{2}(9,8)(5,12)^2\} \checkmark$ $= 25,076$ Distance = $ \Delta y = 25,08 \text{ m} \checkmark$	
OPTION 2	OPTION 2
Upward positive $v_f = v_i + a\Delta t$ $= 0 + (-9,8)(2,06) \checkmark$ $= -20,188 \text{ m}\cdot\text{s}^{-1}$ $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2 \checkmark$ $= \frac{(-20,188)(1) + \frac{1}{2}(-9,8)(1)^2}{1} \checkmark$ $= -25,09 \text{ m}$ Distance = $ \Delta y = 25,09 \text{ m} \checkmark$ OR $\Delta y = \left(\frac{v_f + v_i}{2}\right)\Delta t \checkmark$ $= \left(\frac{-20,188 + (-30)}{2}\right)(1) \checkmark$ $= -25,09 \text{ m}$ Distance = $ \Delta y = 25,09 \text{ m} \checkmark$ OR $v_f^2 = v_i^2 + 2a\Delta x \checkmark$ $(-30)^2 = (-20,188)^2 + 2(-9,8)\Delta x \checkmark$ $\Delta x = -25,12 \text{ m}$ Distance = $ \Delta y = 25,12 \text{ m} \checkmark$	Downward positive $v_f = v_i + a\Delta t$ $= 0 + (9,8)(2,06) \checkmark$ $= 20,188 \text{ m}\cdot\text{s}^{-1}$ $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2 \checkmark$ $= \frac{(20,188)(1) + \frac{1}{2}(9,8)(1)^2}{1} \checkmark$ $= 25,09 \text{ m}$ Distance = $ \Delta y = 25,09 \text{ m} \checkmark$ OR $\Delta y = \left(\frac{v_f + v_i}{2}\right)\Delta t \checkmark$ $= \left(\frac{20,188 + 30}{2}\right)(1) \checkmark$ $= 25,09 \text{ m}$ Distance = $ \Delta y = 25,09 \text{ m} \checkmark$ OR $v_f^2 = v_i^2 + 2a\Delta x \checkmark$ $(30)^2 = (20,188)^2 + 2(9,8)\Delta x \checkmark$ $\Delta x = 25,12 \text{ m}$ Distance = $ \Delta y = 25,12 \text{ m} \checkmark$

(4)



6.3

POSITIVE MARKING FROM QUESTION 6.2.1.

Upward positive

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

$$-50 \checkmark = [v_i (4,12)] + [\frac{1}{2} (-9,8)(4,12)^2] \checkmark$$

$$v_i = 8,05 \text{ m} \cdot \text{s}^{-1}$$

$$\text{speed} = 8,05 \text{ m} \cdot \text{s}^{-1} \checkmark$$

Downward positive

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

$$50 \checkmark = v_i (4,12) + [\frac{1}{2} (9,8)(4,12)^2] \checkmark$$

$$v_i = -8,05 \text{ m} \cdot \text{s}^{-1}$$

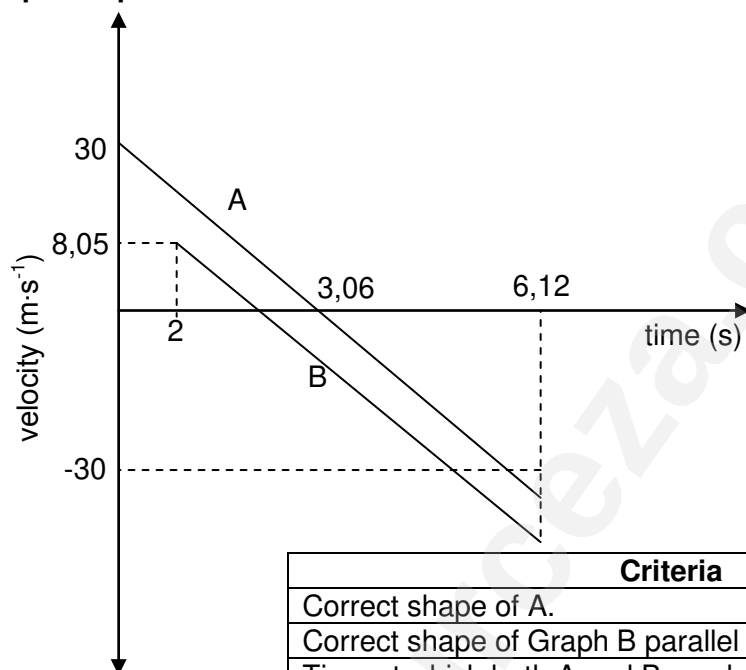
$$\text{speed} = 8,05 \text{ m} \cdot \text{s}^{-1} \checkmark$$

(4)

6.4

POSITIVE MARKING FROM QUESTIONS 6.2.1 AND 6.2.2.

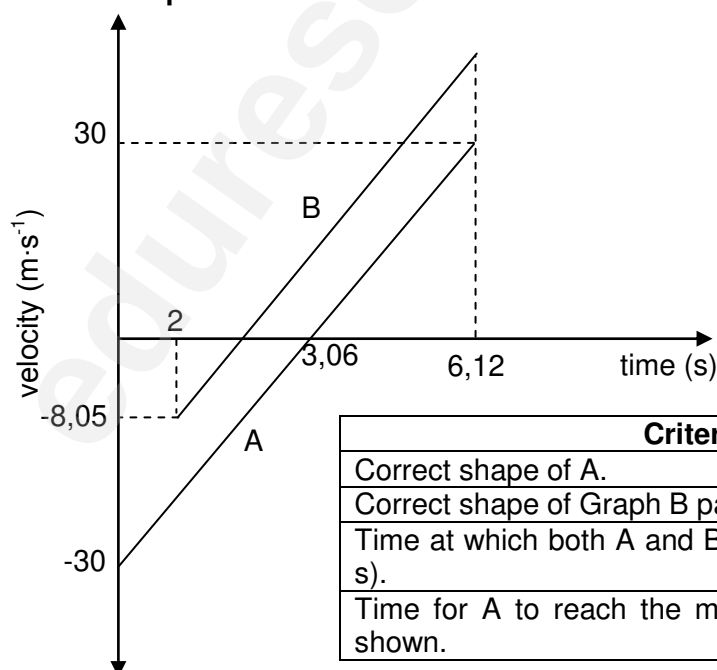
Upward positive.



Criteria	
Correct shape of A.	✓
Correct shape of Graph B parallel to A below A.	✓
Time at which both A and B reach the ground (6,12 s).	✓
Time for A to reach the maximum height (3,06 s) shown.	✓

POSITIVE MARKING FROM QUESTIONS 6.2.1 AND 6.2.2.

Downward positive.



Criteria	
Correct shape of A.	✓
Correct shape of Graph B parallel to A above A.	✓
Time at which both A and B reach the ground (6,12 s).	✓
Time for A to reach the maximum height (3,06 s) shown.	✓

(4)
[18]



QUESTION 7

- 7.1 The motion of an object under the influence of weight/ gravitational force only / Motion in which the only force acting is the gravitational force. ✓✓ (2)

7.2.1

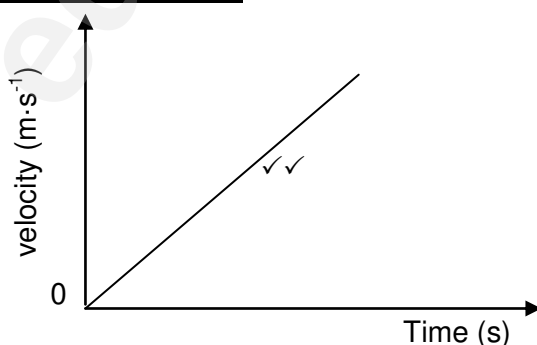
OPTION 1 Upwards positive: $v_f^2 = v_i^2 + 2a\Delta y$ ✓ $= 0^2 + (2)(-9,8)$ ✓ (-20) ✓ $v_f = 19,80 \text{ m}\cdot\text{s}^{-1}$ ✓ Downwards positive $v_f^2 = v_i^2 + 2a\Delta y$ ✓ $= 0^2 + (2)(9,8)$ ✓ (20) ✓ $v_f = 19,80 \text{ m}\cdot\text{s}^{-1}$ ✓	OPTION 2 Upwards positive: $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$ $-20 = 0 + \frac{1}{2}(-9,8)\Delta t^2$ ✓ $\Delta t = 2,02 \text{ s}$ $v_f = v_i + a\Delta t$ $= 0 + (-9,8)(2,02)$ ✓ $= -19,80 \text{ m}\cdot\text{s}^{-1}$ $= 19,80 \text{ m}\cdot\text{s}^{-1}$ ✓ Downwards positive $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$ $20 = 0 + \frac{1}{2}(9,8)\Delta t^2$ ✓ $\Delta t = 2,02 \text{ s}$ $v_f = v_i + a\Delta t$ $= 0 + (9,8)(2,02)$ ✓ $= 19,80 \text{ m}\cdot\text{s}^{-1}$ ✓
OPTION 3 $(E_{\text{mech}})_{\text{Top}} = (E_{\text{mech}})_{\text{Ground}}$ $(E_P + E_K)_{\text{Top}} = (E_P + E_K)_{\text{Bottom}}$ $(mgh + \frac{1}{2}mv^2)_{\text{Top}} = (mgh + \frac{1}{2}mv^2)_{\text{Bottom}}$ $(9,8)(20) + 0$ ✓ $= (0 + \frac{1}{2}v_f^2)$ ✓ $v_f = 19,80 \text{ m}\cdot\text{s}^{-1}$ ✓	
OPTION 4 $W_{\text{nc}} = \Delta E_p + \Delta E_k$ ✓ $0 = mg\Delta h + \frac{1}{2}m\Delta v^2$ 0 ✓ $= \frac{m(9,8)(0 - 20) + \frac{1}{2}m(v_f^2 - 0)}$ ✓ $v_f = 19,80 \text{ m}\cdot\text{s}^{-1}$ ✓	OPTION 5 $W_{\text{net}} = \Delta E_k$ ✓ $mg\Delta x \cos 0^\circ = \frac{1}{2}m(v_f^2 - 0)$ $\frac{m(9,8)(20)(1)}$ ✓ $= \frac{1}{2}mv_f^2$ ✓ $v_f = 19,80 \text{ m}\cdot\text{s}^{-1}$ ✓

7.2.2

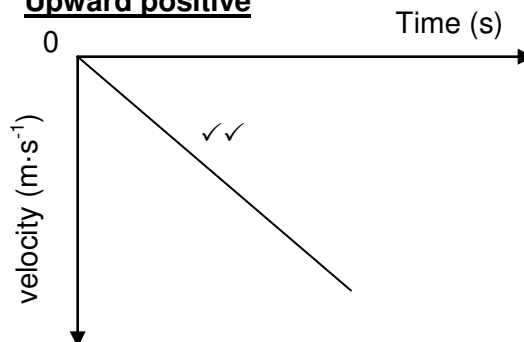
POSITIVE MARKING FROM QUESTION 7.2.1.	
OPTION 1 Upwards positive $v_f = v_i + a\Delta t$ ✓ $-19,80 = 0 + (-9,8)\Delta t$ ✓ $\therefore \Delta t = 2,02 \text{ s}$ ✓	Downwards positive $v_f = v_i + a\Delta t$ ✓ $19,80 = 0 + (9,8)\Delta t$ ✓ $\therefore \Delta t = 2,02 \text{ s}$ ✓
OPTION 2 Upwards positive: $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$ ✓ $-20 = 0 + \frac{1}{2}(-9,8)\Delta t^2$ ✓ $\therefore \Delta t = 2,02 \text{ s}$ ✓	Downwards positive: $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$ ✓ $20 = 0 + \frac{1}{2}(9,8)\Delta t^2$ ✓ $\therefore \Delta t = 2,02 \text{ s}$ ✓

7.3

Downward positive



Upward positive



✓✓	Straight line through the origin.
	Deduct 1 mark if axes are not labelled correctly.

(2)

[11]



MOMENTUM AND IMPULSE

QUESTION 1

- 1.1
- | | |
|--|--|
| $p = mv \checkmark$
$= 50(5) \checkmark$
$= 250 \text{ kg} \cdot \text{m} \cdot \text{s}^{-1} \checkmark$ (downward) | OR
$p = mv \checkmark$
$= 50(-5) \checkmark$
$= -250 \text{ kg} \cdot \text{m} \cdot \text{s}^{-1}$
$= 250 \text{ kg} \cdot \text{m} \cdot \text{s}^{-1} \checkmark$ (downward) |
|--|--|
- (3)
- 1.2 The product of the net force and the time interval during which the force acts. $\checkmark \checkmark$ (2)
- 1.3
- | | | |
|--|---|--|
| $\Delta p = F_{\text{net}} \Delta t \checkmark$
$0 - 250 \checkmark = F_{\text{net}}(0,2)$
$F_{\text{net}} = -1\,250 \text{ N}$
$= 1\,250 \text{ N} \checkmark$ | $\Delta p = F_{\text{net}} \Delta t \checkmark$
$250 - 0 \checkmark = F_{\text{net}}(0,2)$
$F_{\text{net}} = 1\,250 \text{ N} \checkmark$ | $\Delta p = F_{\text{net}} \Delta t \checkmark$
$50(0 - (-5)) \checkmark = F_{\text{net}}(0,2)$
$F_{\text{net}} = 1\,250 \text{ N} \checkmark$ |
|--|---|--|
- (3)
- 1.4 Greater than $\checkmark$ (1)
- 1.5 For the same momentum change, $\checkmark$
the stopping time (contact time) $\checkmark$ will be smaller (less) $\checkmark$ (3)
 $\therefore$ the (upward) force exerted (on her) is greater. (3)
- [12]**

QUESTION 2

- 2.1 Momentum is the product of an object's mass and its velocity. $\checkmark \checkmark$ (2)
- 2.2
- | | |
|---|--|
| Direction of motion positive:
$\Delta p = mv_f - mv_i \checkmark$
$= (175)(0 - (+20)) \checkmark$
$= -3\,500 \text{ kg} \cdot \text{m} \cdot \text{s}^{-1} \checkmark$
$\therefore \Delta p = 3\,500 \text{ kg} \cdot \text{m} \cdot \text{s}^{-1}$ opposite to direction of motion $\checkmark$ | Direction of motion negative:
$\Delta p = mv_f - mv_i \checkmark$
$= (175)(0 - (-20)) \checkmark$
$= 3\,500 \text{ kg} \cdot \text{m} \cdot \text{s}^{-1} \checkmark$
$\therefore \Delta p = 3\,500 \text{ kg} \cdot \text{m} \cdot \text{s}^{-1}$; opposite to direction of motion $\checkmark$ |
|---|--|
- (4)
- 2.3
- | | |
|--|--|
| Direction of motion positive:
$F_{\text{net}} \Delta t = \Delta p \checkmark$
$f(8) = -3\,500 \checkmark$
$f = -437,5 \text{ N} \checkmark$
$\therefore f = 437,5 \text{ N}$; opposite to direction of motion $\checkmark$ | Direction of motion negative:
$F_{\text{net}} \Delta t = \Delta p \checkmark$
$f(8) = 3\,500 \checkmark$
$f = 437,5 \text{ N} \checkmark$
$\therefore f = 437,5 \text{ N}$; opposite to direction of motion $\checkmark$ |
|--|--|
- (4)
- [10]**

QUESTION 3

- 3.1 A collision in which both total momentum and total kinetic energy are conserved. $\checkmark \checkmark$ (2)
- 3.2 **OPTION 1**
 For ball A
 $(E_{\text{mech}})_{\text{top}} = (E_{\text{mech}})_{\text{bottom}}$
 $(E_K + E_P)_{\text{top}} = (E_K + E_P)_{\text{bottom}}$
 $(\frac{1}{2}mv^2 + mgh)_{\text{top}} = (\frac{1}{2}mv^2 + mgh)_{\text{bottom}}$
 $\frac{1}{2}(0,2)(0)^2 + (0,2)(9,8)(0,2)_{\text{top}} = E_K + m(9,8)(0)_{\text{bottom}} \checkmark$
 $E_K = 0,39 \text{ J} \checkmark$
- } Any one $\checkmark$
- OPTION 2**
 $W_{\text{nc}} = \Delta E_p + \Delta E_k \checkmark$
 $0 = mg(h_f - h_i) + \frac{1}{2}m(v_f^2 - v_i^2)$
 $0 = (0,2)(9,8)(0,2 - 0) + \frac{1}{2}mv_f^2 - \frac{1}{2}(0,2)(0)^2 \checkmark$
 $\therefore E_k = 0,39 \text{ J} \checkmark$
- (3)



3.3 **POSITIVE MARKING FROM QUESTION 3.2.**

$$\left. \begin{aligned} \Sigma E_{K\text{before}} &= \Sigma E_{K\text{after}} \\ E_{KiA} + E_{KiB} &= E_{KfA} + E_{KfB} \\ E_{KiA} + E_{KiB} &= \frac{1}{2} m_A v_{fA}^2 + E_{KfB} \\ \underline{0,39 + 0} &= \frac{1}{2} (0,2) v_{fA}^2 + 0,12 \checkmark \\ v_{fA} &= 1,64 \text{ m} \cdot \text{s}^{-1} \checkmark \end{aligned} \right\} \checkmark \text{Any one}$$

(4)

3.4 **POSITIVE MARKING FROM QUESTION 3.2.**

$$\left. \begin{aligned} E_{K\text{before}} &= \frac{1}{2} m_A v_{iA}^2 \\ 0,39 &= \frac{1}{2} (0,2) v_{iA}^2 \checkmark \\ v_{iA} &= 1,98 \text{ m} \cdot \text{s}^{-1} \\ \text{Impulse} &= m(v_f - v_i) \\ \text{Impulse} &= m(v_{iA} - v_{fA}) \end{aligned} \right\} \checkmark \text{Any one}$$

$$\begin{aligned} &= 0,2(-1,64) \checkmark - (0,2)(1,98) \checkmark \\ &= 0,72 \text{ N} \cdot \text{s} \checkmark \end{aligned}$$

(5)
[14]

QUESTION 4

4.1 Take motion to the right as positive.

$$\left. \begin{aligned} \Sigma p_i &= \Sigma p_f \\ (m_1 + m_2)v_i &= m_1 v_{f1} + m_2 v_{f2} \\ (m_1 + m_2)v_i &= m_1 v_{f1} + m_2 v_{f2} \end{aligned} \right\} \checkmark \text{Any one}$$

$$\begin{aligned} (3 + 0,02)(0) \checkmark &= (3)(-1,4) + (0,02) v_{f2} \checkmark \\ v_{f2} &= 210 \text{ m} \cdot \text{s}^{-1} \checkmark \end{aligned}$$

OR

Take motion to the left as positive.

$$\left. \begin{aligned} \Sigma p_i &= \Sigma p_f \\ (m_1 + m_2)v_i &= m_1 v_{f1} + m_2 v_{f2} \\ (m_1 + m_2)v_i &= m_1 v_{f1} + m_2 v_{f2} \end{aligned} \right\} \checkmark \text{Any one}$$

$$\begin{aligned} (3 + 0,02)(0) \checkmark &= (3)(1,4) + (0,02) v_{f2} \checkmark \\ v_{f2} &= -210 \text{ m} \cdot \text{s}^{-1} \\ \text{Speed} &= 210 \text{ m} \cdot \text{s}^{-1} \checkmark \end{aligned}$$

(4)

4.2 **POSITIVE MARKING FROM 4.1.**

OPTION 1

$$\begin{aligned} v_f^2 &= v_i^2 + 2a\Delta x \checkmark \\ 0 &= 210^2 + 2a(0,4) \checkmark \\ a &= -55\,125 \text{ m} \cdot \text{s}^{-2} \end{aligned}$$

$$\begin{aligned} F_{\text{net}} &= ma \checkmark \\ &= (0,02)(-55\,125) \checkmark \\ &= -1\,102,5 \text{ N} \end{aligned}$$

$$\text{Magnitude of force} = 1\,102,5 \text{ N} \checkmark$$

OPTION 2

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

$$0,4 = \left(\frac{210 + 0}{2} \right) \Delta t \checkmark$$

$$\Delta t = 0,004 \text{ s } (0,00381 \text{ s})$$

$$F_{\text{net}} \Delta t = \Delta p = m \Delta v \checkmark$$

$$F_{\text{net}} = \frac{(0,02)(0 - 210)}{(0,004)} \checkmark$$

$$= -1\,050 \text{ N}$$

$$\text{Magnitude of force} = 1\,050 \text{ N} \checkmark$$

(5)

4.3 The same as/equal $\checkmark$

(1)
[10]



QUESTION 5

5.1 The total (linear) momentum of an isolated (closed) system ✓ is constant (is conserved). ✓ (2)

5.2

5.2.1 $\sum p_i = \sum p_f$ ✓
 $m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$
 $(m_1 + m_2) v_i = m_1 v_{1f} + m_2 v_{2f}$
 $0 = (0,4) v_{1f} + 0,6 (4)$ ✓
 $v_{1f} = -6 \text{ m} \cdot \text{s}^{-1}$
 $= 6 \text{ m} \cdot \text{s}^{-1}$ to the left/na links ✓ (4)

5.2.2

<u>OPTION 1/OPSIE 1</u>	<u>OPTION 2/OPSIE 2</u>	<u>OPTION 3/OPSIE 3</u>
$\Delta p = F_{\text{net}} \Delta t$ ✓ $[(0,6)(4) - 0] = F_{\text{net}} (0,3)$ ✓ $F_{\text{net}} = 8 \text{ N}$ ✓ <u>OR/OF</u> $m(v_f - v_i) = F_{\text{net}} \Delta t$ ✓ $0,6(4 - 0) = F_{\text{net}} (0,3)$ ✓ $F_{\text{net}} = 8 \text{ N}$ ✓	$v_f = v_i + a \Delta t$ $4 = 0 + a(0,3)$ $a = 13,33 \text{ m} \cdot \text{s}^{-2}$ $F_{\text{net}} = ma$ $= 0,6(13,33)$ $F_{\text{net}} = 8 \text{ N}$ ✓	$\Delta p = F_{\text{net}} \Delta t$ ✓ $[(0,4)(6) - 0] = F_{\text{net}} (0,3)$ ✓ $F_{\text{net}} = 8 \text{ N}$ ✓ <u>OR/OF</u> $m(v_f - v_i) = F_{\text{net}} \Delta t$ ✓ $0,4(6 - 0) = F_{\text{net}} (0,3)$ ✓ $F_{\text{net}} = 8 \text{ N}$ ✓

(4)

5.3 No ✓

(1)

[11]

QUESTION 6

6.1 The total (linear) momentum of an isolated (closed) system ✓ is constant (is conserved). ✓ (2)

6.2

6.2.1 $\sum p_i = \sum p_f$
 $m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$ } ✓ any one
 $m_1 v_{1i} + m_2 v_{2i} = (m_1 + m_2) v_f$
 $(5)(4) + (3)(0) = (5 + 3) v_f$ ✓
 $\therefore v = 2,5 \text{ m} \cdot \text{s}^{-1}$ ✓
OR
 $\Delta p_{5\text{kg}} = -\Delta p_{3\text{kg}}$ ✓
 $mv_f - mv_i = mv_f - mv_i$
 $5v_f - (5)(4) = 3v_f - (3)(0)$ ✓
 $v_f = 2,5 \text{ m} \cdot \text{s}^{-1}$ ✓ (4)

6.2.2 **POSITIVE MARKING FROM QUESTION 6.2.1.**

<u>OPTION 1</u> $F_{\text{net}} \Delta t = \Delta p = (p_f - p_i) = (mv_f - mv_i)$ ✓ $F_{\text{net}} (0,3) = 8 [(0) - (2,5)]$ ✓ $F_{\text{net}} = -66,67 \text{ N}$ $\therefore F_{\text{net}} = 66,67 \text{ N}$ ✓	
<u>OPTION 2</u> $F_{\text{net}} = ma$ ✓ $= \frac{m(v_f - v_i)}{\Delta t}$ $= \frac{8(0 - 2,5)}{0,3}$ ✓ $= -66,67 \text{ N}$ $\therefore F_{\text{net}} = 66,67 \text{ N}$ ✓	<u>OPTION 3</u> $v_f = v_i + a \Delta t$ $0 = 2,5 + a(0,3)$ ✓ $a = -8,333 \text{ m} \cdot \text{s}^{-2}$ $F_{\text{net}} = ma$ ✓ $= 8(-8,333)$ ✓ $= -66,67 \text{ N}$ $\therefore F_{\text{net}} = 66,67 \text{ N}$ ✓

(4)

[10]



QUESTION 7

- 7.1 A system on which the resultant/net external force is zero. ✓
A system which excludes external forces.

(1)

7.2

7.2.1

OPTION 1 $p = mv$ ✓ $30\,000 = (1\,500)v$ ✓ $v = 20\text{ m}\cdot\text{s}^{-1}$ ✓	OPTION 2 $\Delta p = mv_f - mv_i$ ✓ $0 = (1\,500)v_f - 30\,000$ ✓ $v = 20\text{ m}\cdot\text{s}^{-1}$ ✓
---	---

(3)

7.2.2

POSITIVE MARKING FROM QUESTION 7.2.1.

OPTION 1 $\sum p_i = \sum p_f$ $m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$ } ✓ for any $30\,000 + (900)(-15)$ ✓ = $14\,000 + 900v_B$ ✓ $\therefore v_B = 2,78\text{ m}\cdot\text{s}^{-1}$ ✓ east ✓	OPTION 2 $\Delta p_A = -\Delta p_B$ $p_f - p_i = -(mv_f - mv_i)$ } ✓ for any $14\,000 - 30\,000$ ✓ = $900v_f - 900(-15)$ ✓ $v_f = 2,78\text{ m}\cdot\text{s}^{-1}$ ✓ east
---	--

(5)

7.2.3

OPTION 1 $\text{Slope} = \frac{\Delta p}{\Delta t} = F_{\text{net}}$ ✓ $= \frac{(14\,000 - 30\,000)}{(20,2 - 20,1)}$ ✓ $= -160\,000$ $F_{\text{net}} = 160\,000\text{ N}$ ✓	OPTION 2 $F_{\text{net}}\Delta t = \Delta p$ ✓ $F_{\text{net}}(0,1)$ ✓ = $14\,000 - 30\,000$ ✓ $F_{\text{net}} = -160\,000\text{ N}$ $F_{\text{net}} = 160\,000\text{ N}$ ✓
--	--

POSITIVE MARKING FROM QUESTION 7.2.2.

OPTION 3 $F_{\text{net}}\Delta t = \Delta p$ ✓ $F_{\text{net}}(0,1)$ ✓ = $900[(2,78) - (-15)]$ ✓ $F_{\text{net}} = 160\,020\text{ N}$ $F_A = -F_B$ $F_{\text{net}} = 160\,020\text{ N}$ ✓	OPTION 4 $p = mv$ $14\,000 = 1\,500v_f$ ✓ $v_f = 9,33\text{ m}\cdot\text{s}^{-1}$
$F_{\text{net}} = \frac{m(v_f - v_i)}{\Delta t}$ ✓ = $\frac{1500(9,33 - 20)}{0,1}$ ✓ $= -160\,050$ $= 160\,050\text{ N}$ ✓	$v_f = v_i + a\Delta t$ $9,33 = 20 + a(0,1)$ $a = -106,7\text{ m}\cdot\text{s}^{-2}$ $F_{\text{net}} = ma$ ✓ $= 1\,500(-106,7)$ ✓ $F_{\text{net}} = -160\,050\text{ N}$ $F_{\text{net}} = 160\,050\text{ N}$ ✓

(4)

[13]



WORK, ENERGY AND POWER

QUESTION 1

1.1

1.1.1 In an isolated/closed system, ✓ the total mechanical energy is conserved / remains constant. ✓ (2)

1.1.2 No ✓ (1)

1.1.3

OPTION 1 Along AB $E_{\text{mechanical at A}} = E_{\text{mechanical at B}}$ $(E_p + E_k)_A = (E_p + E_k)_B$ $(mgh + \frac{1}{2}mv^2)_A = (mgh + \frac{1}{2}mv^2)_B$ $(10)(9,8)(4) + 0 = 0 + \frac{1}{2}(10)v_f^2$ $v_f = 8,85 \text{ m}\cdot\text{s}^{-1}$	OPTION 2 Along AB $W_{\text{net}} = \Delta E_k$ $F_g \Delta h \cos \theta = \frac{1}{2}m(v_f^2 - v_i^2)$ $(10)(9,8)(4) \cos 0^\circ = \frac{1}{2}(10)(v_f^2 - 0)$ $v_f = 8,85 \text{ m}\cdot\text{s}^{-1}$
OPTION 3 Along AB $W_{\text{nc}} = \Delta K + \Delta U$ $0 = \frac{1}{2}(10)(v_f^2 - 0) + 10(9,8)(4 - 0)$ $v_f = 8,85 \text{ m}\cdot\text{s}^{-1}$	
Substitute $8,85 \text{ m}\cdot\text{s}^{-1}$ in one of the following options	
Along BC $W_{\text{net}} = \Delta K$ $f \Delta x \cos \theta = \Delta K$ $\frac{f(8) \cos 180^\circ}{f} = \frac{\frac{1}{2}(10)(0 - 8,85^2)}{48,95}$ $f = 48,95 \text{ N}$	Along BC $W_{\text{nc}} = \Delta K + \Delta U$ $f \Delta x \cos \theta = \Delta K + \Delta U$ $\frac{f(8) \cos 180^\circ}{f} = \frac{\frac{1}{2}(10)(0 - 8,85^2) + 0}{48,95}$ $f = 48,95 \text{ N}$

1.2

1.2.1 $f_k = \mu_k N$ ✓
 $= \mu_k mg \cos \theta$
 $= \frac{(0,19)(300)(9,8) \cos 25^\circ}{506,26}$ ✓
 $= 506,26 \text{ N}$ ✓ (3)

1.2.2 **POSITIVE MARKING FROM QUESTION 1.2.1.**

$F_{\text{net}} = 0$
 $F_{\text{app}} + (-F_g \sin \theta) + (-f) = 0$ ✓
 $F_{\text{app}} - (300)(9,8) \sin 25^\circ - 506,26 = 0$ ✓
 $F_{\text{app}} = 1\,748,76 \text{ N}$

$P_{\text{ave}} = F v_{\text{ave}}$ ✓
 $= 1\,748,76 \times 0,5$ ✓
 $= 874,38 \text{ W}$ ✓

(6)
[18]

QUESTION 2

2.1 $\Delta U + \Delta K = 0 \checkmark$
 $(5)(9,8)(5) + 0 \checkmark + (0 + \frac{1}{2}(5v_f^2)) \checkmark = 0$
 $v_f = \sqrt{2 \times 9,8 \times 5}$
 $= 9,90 \text{ m} \cdot \text{s}^{-1} \checkmark (9,899 \text{ m} \cdot \text{s}^{-1})$ (4)

2.2 No friction/zero resultant force $\checkmark$ and thus no loss in energy. $\checkmark$
OR Only conservative forces are present. **OR** Mechanical energy is conserved. (2)

2.3 The force for which the work done is path dependent. $\checkmark \checkmark$ (2)

2.4 **OPTION 1/OPSIE 1**
 $W_{nc} = \Delta U + \Delta K \checkmark$
 $F \Delta x \cos \theta = \Delta U + \Delta K$
 $(18 \Delta x \cos 180^\circ) = (5)(9,8)(3 - 0) \checkmark + \frac{1}{2}(5)(0 - 9,90^2) \checkmark$
 $\Delta x = 5,4458 \text{ m} \checkmark$
 $\theta = \sin^{-1} \frac{3}{5,4458} \checkmark$
 $\theta = 33,43^\circ \checkmark$

OPTION 2/OPSIE 2
 $W_{net} = W_f + W_G \checkmark$
 $W_{net} = f \Delta x \cos \theta + mg \sin \theta \Delta x \cos \theta$
 $= [(18) \Delta x \cos 180^\circ] + 5(9,8) \frac{3}{\Delta x} (\Delta x) \cos 180^\circ \checkmark$
 $= -18 \Delta x - 147$
 $W_{net} = \Delta K \checkmark$
 $\Delta K = \frac{1}{2}(5)(0 - 9,90^2) \checkmark$
 $= -245,025$
 $-18 \Delta x - 147 = -245,025$
 $\Delta x = 5,4458 \text{ m} \checkmark$
 $\theta = \sin^{-1} \frac{3}{5,4458} \checkmark$
 $\theta = 39,43^\circ \checkmark$ (7)

[15]

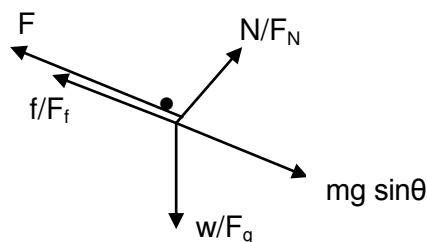
QUESTION 3

3.1 If the work done in moving an object between two points depends on the path taken (then the force applied is non-conservative). $\checkmark \checkmark$ (2)

3.2.1 No $\checkmark$ (1)

3.2.2 Since there is no acceleration, the net force is zero $\checkmark$ hence net work done $(F_{net} \Delta x \cos \theta)$ must be zero. $\checkmark$
OR
 $W_{net} = \Delta K$
 Since it is moving with constant velocity: $\checkmark$
 $\Delta K = 0 \therefore W_{net} = 0 \checkmark$ (2)

3.3 $F_{//} - (f + F) = 0 \checkmark$
OR
 $F = mg \sin \theta - f_k$
OR $F = mg \sin \theta - 266$
 $F = [100(9,8) \sin 25^\circ] \checkmark - 266 \checkmark$
 $414,167 - 266$
 $F = 148,17 \text{ N} \checkmark$ (4)





3.4

OPTION 1

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

$$W_{\text{net}} = W_f + W_g + W_N$$

$$W_{\text{net}} = f_k \Delta x \cos 180^\circ \checkmark + m g \sin \theta \Delta x \cos 0^\circ + 0 \quad \left. \vphantom{W_{\text{net}}} \right\} \checkmark \text{any of the three}$$

$$= (266)(3)(-1) \checkmark + [100(9,8) \sin 25^\circ (3)(1)] \checkmark + 0$$

$$= 444,5 \text{ J}$$

$$W_{\text{net}} = \Delta E_k / \Delta K = \frac{1}{2} m (v_f^2 - v_i^2) \checkmark$$

$$444,5 = \frac{1}{2} (100) (v_f^2 - 0) \checkmark$$

$$v_f = 2,98 \text{ m} \cdot \text{s}^{-1} \checkmark$$

OPTION 2

$$W_{\text{nc}} = \Delta E_p + \Delta E_k \checkmark$$

$$f \Delta x \cos \theta \checkmark = (m g h_f - m g h_i) + \left(\frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2 \right)$$

$$266 \Delta x \cos 180^\circ \checkmark = (0 - m g \sin 25^\circ \Delta x \cos 0^\circ) + \left(\frac{1}{2} m v_f^2 - 0 \right)$$

$$266(3)(-1) = [-100(9,8) \sin 25^\circ (3)(1)] \checkmark - \frac{1}{2} (100) (v_f^2 - 0) \checkmark$$

$$v_f = 2,98 \text{ m} \cdot \text{s}^{-1} \checkmark$$

OPTION 3 (POSITIVE MARKING FROM QUESTION 3.3.)

$$W_{\text{net}} = \Delta E_k \checkmark$$

$$F_{\text{net}} \Delta x \cos \theta \checkmark = \frac{1}{2} m (v_f^2 - v_i^2)$$

$$(148,17) \checkmark (3) \cos 0^\circ \checkmark = \frac{1}{2} (100) (v_f^2 - 0^2)$$

$$444,51 = 50 v_f^2 \checkmark$$

$$v_f = 2,98 \text{ m} \cdot \text{s}^{-1} \checkmark$$

OPTION 4 (POSITIVE MARKING FROM QUESTION 3.3.)

$$F_{\text{net}} = m a \checkmark$$

$$148,17 \checkmark = 100 a \checkmark$$

$$a = 1,48 \text{ m} \cdot \text{s}^{-2}$$

$$v_f^2 = v_i^2 + 2 a \Delta x \checkmark$$

$$= 2(1,48)(3) \checkmark$$

$$v_f = 2,98 \text{ m} \cdot \text{s}^{-1} \checkmark$$

OPTION 5 (POSITIVE MARKING FROM QUESTION 3.3.)

$$F_{\text{net}} = m a \checkmark$$

$$148,17 \checkmark = 100 a \checkmark$$

$$a = 1,48 \text{ m} \cdot \text{s}^{-2}$$

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

$$3 = 0 + \frac{1}{2} (1,48) \Delta t^2$$

$$\Delta t = 2,01 \text{ s}$$

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

$$= 0 + (1,48)(2,01) \checkmark$$

$$v_f = 2,97 \text{ m} \cdot \text{s}^{-1} \checkmark$$

OPTION 6 (POSITIVE MARKING FROM QUESTION 3.3.)

$$F_{\text{net}} = m a \checkmark$$

$$148,17 \checkmark = 100 a \checkmark$$

$$a = 1,48 \text{ m} \cdot \text{s}^{-2}$$

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

$$3 = 0 + \frac{1}{2} (1,48) \Delta t^2$$

$$\Delta t = 2,01 \text{ s}$$

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

$$3 = \left(\frac{0 + v_f}{2} \right) (2,01)$$

$$v_f = 2,99 \text{ m} \cdot \text{s}^{-1} \checkmark$$

(6)
[15]

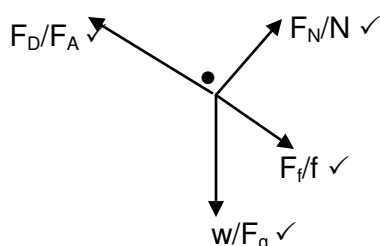
QUESTION 4

4.1

OPTION 1 $v_{ave} = \frac{800}{75} \checkmark = 10,67 \text{ m} \cdot \text{s}^{-1}$ $P_{ave} = Fv_{ave} \checkmark$ $P_{ave} = (240)(10,67)$ $= 2\,560,8 \text{ W (2,56 kW)} \checkmark$	OPTION 2 $v_{ave} = \frac{800}{75} \checkmark = 10,67 \text{ m} \cdot \text{s}^{-1}$ $\therefore \text{Distance covered in 1 s} = 10,67 \text{ m}$ $\therefore W(\text{Work done in 1 s}) = F\Delta x \cos \theta \checkmark$ $= (240)(10,67)(1)$ $= 2\,560,8 \text{ J s}^{-1}$ $\therefore P_{ave} = 2\,560,8 \text{ W (2,56 kW)} \checkmark$
OPTION 3 $P = \frac{W}{\Delta t} \checkmark$ $= \frac{F\Delta x \cos \theta}{\Delta t}$ $= \frac{(240)(800) \cos 0^\circ}{75} \checkmark$ $= 2\,560 \text{ W} \checkmark$	OPTION 4 $P = \frac{W}{\Delta t} \checkmark$ $= \frac{F\Delta x \cos \theta}{\Delta t}$ $= \frac{(240)(10,67) \cos 0^\circ}{1} \checkmark$ $= 2\,560 \text{ W} \checkmark$

(3)

4.2



Accepted labels	
w	$F_g / F_w / \text{weight} / mg / \text{gravitational force} / 2\,940 \text{ N}$
f	$F_{\text{friction}} / F_f / \text{friction} / 294 \text{ N} / f_k$
N	$F_N / F_{\text{normal}} / \text{normal force}$
F_D	$F_{\text{Applied}} / 350 \text{ N} / \text{Average driving force}$

(4)

4.3

The net/total work done on an object is equal $\checkmark$ to the change in the object's kinetic energy. $\checkmark$

OR

The work done on an object by a resultant/net force is equal $\checkmark$ to the change in the object's kinetic energy. $\checkmark$

(2)

4.4

OPTION 1 $W_{nc} = \Delta U + \Delta K \checkmark$ $W_f + W_D = \Delta U + \Delta K$ $f\Delta x \cos \theta + W_D = mg(h_f - h_i) + \frac{1}{2} (m)(v_f^2 - v_i^2)$ $(f\Delta x \cos \theta + F_D \Delta x \cos \theta = mg(h_f - h_i) + \frac{1}{2} m(v_f^2 - v_i^2)$ $(294)(450)(\cos 180^\circ) \checkmark + (350)(450) \cos 0^\circ \checkmark = (300)(9,8)(5 - 0) \checkmark + \frac{1}{2} (300)(v_f^2 - 0) \checkmark$ $v_f = 8,37 \text{ m} \cdot \text{s}^{-1} \checkmark$	OPTION 2 $W_{net} = \Delta K \checkmark$ $W_{net} = W_D + W_g + W_f + W_N$ $= (F_D \Delta x \cos \theta) + (mg \sin \alpha) \Delta x \cos \theta + (f \Delta x \cos \theta) + 0$ $W_{net} = [350(450)](\cos 0^\circ) \checkmark + (300)(9,8) \left(\frac{5}{450} (450)(\cos 180^\circ) \checkmark + 294(450)(\cos 180^\circ) \checkmark \right.$ $= 157\,500 - 14\,700 - 132\,300$ $= 10\,500 \text{ J}$ $W_{net} = \Delta K$ $10\,500 = \frac{1}{2} (300)(v_f^2 - 0) \checkmark \therefore v_f = 8,37 \text{ m} \cdot \text{s}^{-1} \checkmark$
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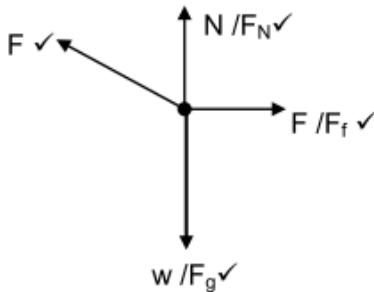
(6)
[15]

QUESTION 5

5.1 It is a ratio of two forces (hence units cancel). ✓ (1)

5.2 The net/total work done on an object is equal ✓ to the change in the object's kinetic energy. ✓ (2)

5.3



(4)

5.4

$$F \sin 20^\circ + N = mg \checkmark$$

$$N = mg - F \sin 20^\circ$$

$$W_{fk} = f_k \Delta x \cos \theta = \mu_k N \Delta x \cos \theta \checkmark$$

$$= \mu_k (mg - F \sin 20^\circ) (3) \cos \theta$$

$$= (0,2) [200(9,8) - F \sin 20^\circ] (3) \cos 180^\circ \checkmark$$

$$= (-1176 + 0,205 F) \text{ J} \checkmark$$

(4)

5.5

$$W_{\text{tot}} = [W_g] + W_f + W_F \checkmark$$

$$0 \checkmark = [0] + [-1176 + 0,205 F] + [F (\cos 20^\circ) (3) (\cos 0^\circ)] \checkmark$$

$$F = 388,88 \text{ N} \checkmark$$

(4)

[15]

QUESTION 6

6.1 The total mechanical energy in an isolated (closed) system ✓ remains constant (is conserved). ✓ (2)

6.2.1

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

$$= (30) \left(\frac{5}{\sin 30^\circ} \right) \cos \theta \checkmark$$

$$= (30)(10) \cos 180^\circ \checkmark$$

$$= (30)(10)(-1) \checkmark$$

$$= -300 \text{ J} \checkmark$$

(3)

6.2.2 **POSITIVE MARKING FROM 5.2.1**

OPTION 1

$$W_{nc} = \Delta E_p + \Delta E_k \checkmark$$

$$W_{nc} = mg(h_f - h_i) + \frac{1}{2}m(v_f^2 - v_i^2) \checkmark$$

$$-300 \checkmark = (20)(9,8)(0 - 5) \checkmark + \frac{1}{2}(20)(v_f^2 - 0) \checkmark$$

$$v = 8,25 \text{ m} \cdot \text{s}^{-1} \checkmark$$

OPTION 2

$$W_{\text{net}} = \Delta E_k \checkmark$$

$$W_g + W_f = \frac{1}{2}m(v_f^2 - v_i^2) \checkmark$$

$$W_g + (-300) = \frac{1}{2}(20)(v_f^2 - 0) \checkmark$$

$$[(20)(9,8) \sin 30^\circ \frac{5}{0,5} \cos 0^\circ] \checkmark + (-300) \checkmark = 10v_f^2$$

$$v_f = 8,25 \text{ m} \cdot \text{s}^{-1} \checkmark$$

(5)

6.3

$$\begin{aligned} F &= w_{\parallel} + f \\ &= (100)(9,8)\sin 30^{\circ} + 25 \checkmark \\ &= 515 \text{ N} \\ P_{\text{ave}} &= Fv_{\text{ave}} \checkmark \\ &= (515)(2) \checkmark \\ &= 1\,030 \text{ W} \checkmark \end{aligned}$$

(4)
[14]

QUESTION 7

7.1.1

$$\begin{aligned} E_{\text{K}}/K &= \frac{1}{2}mv^2 \checkmark \\ &= \frac{1}{2}(2)(4,95)^2 \checkmark \\ &= 24,50 \text{ J} \checkmark \end{aligned}$$

(3)

7.1.2

POSITIVE MARKING FROM QUESTION 5.1.1.

OPTION 1

$$\begin{aligned} E_{\text{mech before}} &= E_{\text{mech after}} \\ [(E_{\text{mech}})_{\text{bob}} + (E_{\text{mech}})_{\text{block}}]_{\text{before}} &= [(E_{\text{mech}})_{\text{block}} + (E_{\text{mech}})_{\text{bob}}]_{\text{after}} \quad \left. \vphantom{[(E_{\text{mech}})_{\text{bob}} + (E_{\text{mech}})_{\text{block}}]_{\text{before}}} \right\} \text{Any one } \checkmark \\ (mgh + \frac{1}{2}mv^2)_{\text{before}} &= (mgh + \frac{1}{2}mv^2)_{\text{after}} \\ (5)(9,8)h + 0 + 0 &\checkmark = 5(9,8)\frac{1}{4}h + 0 + 24,50 \checkmark \\ h &= 0,67 \text{ m} \checkmark \end{aligned}$$

OPTION 2

$$\begin{aligned} W_{\text{nc}} &= \Delta E_{\text{p}} + \Delta E_{\text{K}} \quad \left. \vphantom{W_{\text{nc}} = \Delta E_{\text{p}} + \Delta E_{\text{K}}} \right\} \text{Any one } \checkmark \\ 0 &= \Delta E_{\text{p}} + \Delta E_{\text{K}} \\ -\Delta E_{\text{p}} &= \Delta E_{\text{K}} \\ -[(5)(9,8)(\frac{1}{4}h) - (5)(9,8)h] &\checkmark = 24,50 \checkmark \\ h &= 0,67 \text{ m} \checkmark \end{aligned}$$

OPTION 3

$$\begin{aligned} \text{Loss } E_{\text{p bob}} &= \text{Gain in } E_{\text{K of block}} \checkmark \\ mg(\frac{3}{4}h) &= 24,5 \\ (5)(9,8)(\frac{3}{4}h) &\checkmark = 24,5 \checkmark \\ h &= 0,67 \text{ m} \checkmark \end{aligned}$$

(4)

7.2

The net/total work done on an object is equal $\checkmark$ to the change in the object's kinetic energy. $\checkmark$

(2)

7.3

OPTION 1

$$\begin{aligned} W_{\text{net}} &= \Delta E_{\text{K}} \checkmark \\ W_{\text{f}} + mg\Delta y \cos \theta &= \frac{1}{2}m(v_{\text{f}}^2 - v_{\text{i}}^2) \\ W_{\text{f}} + (2)(9,8)(0,5)\cos 180^{\circ} &\checkmark = \frac{1}{2}(2)(2^2 - 4,95^2) \checkmark \therefore W_{\text{f}} = -10,7 \text{ J} \checkmark \end{aligned}$$

OPTION 2

$$\begin{aligned} W_{\text{nc}} &= \Delta E_{\text{K}} + \Delta U \quad \left. \vphantom{W_{\text{nc}} = \Delta E_{\text{K}} + \Delta U} \right\} \checkmark \\ W_{\text{nc}} &= \Delta E_{\text{K}} + \Delta E_{\text{p}} \\ W_{\text{f}} &= \frac{1}{2}(2)(2^2 - 4,95^2) \checkmark + (2)(9,8)(0,5-0) \checkmark = -10,7 \text{ J} \checkmark \end{aligned}$$

(4)
[13]

QUESTION 8

8.1

$$\begin{aligned} W_{\text{net}} &= \Delta K \\ W_{\text{net}} &= \frac{1}{2}(M+m)(v_{\text{f}}^2 - v_{\text{i}}^2) \quad \checkmark \\ W_{\text{fr}} &= f\Delta x \cos \theta \checkmark = \frac{1}{2}(M+m)(v_{\text{f}}^2 - v_{\text{i}}^2) \\ \frac{10 \times 2 \cos 180^{\circ}}{v_{\text{bb}} = 2,39 \text{ m}\cdot\text{s}^{-1}} &\checkmark = \frac{\frac{1}{2}(7,02)(0 - v^2)}{(2,387) \text{ m}\cdot\text{s}^{-1}} \checkmark \end{aligned}$$

(5)

8.2

The total (linear) momentum of an isolated (closed) system $\checkmark$ is constant (is conserved). $\checkmark$

(2)

8.3

POSITIVE MARKING FROM QUESTION 8.1.

$$\begin{aligned} \Sigma p_{\text{i}} &= \Sigma p_{\text{f}} \checkmark \\ m_1v_{1\text{i}} + m_2v_{2\text{i}} &= (m_1 + m_2)v_{\text{f}} \\ 0,02v_{\text{i}} + (7)(0) &= (7,02)(2,39) \\ 0,02v_{\text{i}} &\checkmark = 7,02(2,39) \checkmark \\ v_{\text{i}} &= 838,89 \text{ m}\cdot\text{s}^{-1} \checkmark \end{aligned}$$

(4)
[11]

DOPPLER EFFECT

QUESTION 1

1.1

1.1.1 An (apparent) change in observed/detected frequency (or pitch or wavelength) ✓ as a result of the relative motion between a source and an observer. ✓ (2)

1.1.2 Towards ✓

Observed/detected frequency is greater than the actual frequency. ✓ (2)

1.1.3

$$f_L = \frac{v \pm v_L}{v \pm v_s} f_s \text{ OR/OR } f_L = \frac{v}{v - v_s} f_s \checkmark$$

$$(1200) \checkmark = \frac{343 \checkmark}{343 - v_s} 1130 \checkmark$$

$$v_s = 20,01 \text{ m} \cdot \text{s}^{-1} \checkmark$$

Accept/Aanvaar: (19,42 – 20,01 m·s⁻¹) (5)

1.2

- The star is approaching the earth. ✓

OR

The earth and the star are approaching (moving towards) each other.

- The spectral lines in diagram 2 are shifted towards the blue end/blue shifted. ✓ (2)
- [11]

QUESTION 2

2.1

2.1.1 $v = f\lambda \checkmark$
 $\lambda = \frac{340}{520}$
 $= 0,65 \text{ m} \checkmark$ (2)

2.1.2

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

$$f_L = \frac{340 \checkmark}{(340 - 15) \checkmark} (520) \checkmark$$

$$f_L = 544 \text{ Hz}$$

$$v = f\lambda$$

$$\lambda = \frac{340}{544} \checkmark$$

$$= 0,63 \text{ m} \checkmark$$
 (6)

2.2 The wavelength in QUESTION 1.1.2 is shorter because the waves are compressed as they approach the observer. ✓✓ (2)

2.3 The red shift occurs when the spectrum of a distant star moving away from the earth is shifted toward the red end of the spectrum. ✓✓ (2)
[12]



QUESTION 3

- 3.1 It is the (apparent) change in frequency (or pitch) of the sound detected ✓ by a listener because the sound source and the listener have different velocities relative to the medium of sound propagation. ✓

OR An (apparent) change in observed/detected frequency (pitch), (wavelength) ✓ as a result of the relative motion between a source and an observer ✓ (listener). (2)

3.2

$$f_L = \frac{v \pm v_L}{v \pm v_s} f_s \quad \text{OR} \quad f_L = \frac{v}{v - v_s} f_s \quad \checkmark$$

$$825 = \frac{v}{v - v_s} (800) \quad \checkmark$$

$$(1,03125)(v - 10) \checkmark = v$$

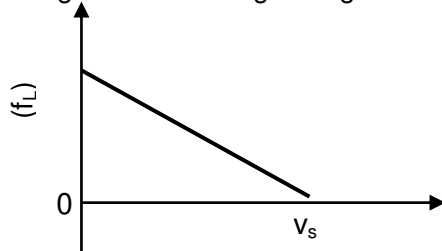
$$\therefore v = 330 \text{ m} \cdot \text{s}^{-1} \quad \checkmark$$

The following values are obtained using other points

$v_s (\text{m} \cdot \text{s}^{-1})$	Frequencies	$v (\text{m} \cdot \text{s}^{-1})$
$v_s = 20$	850	310
$v_s = 20$	845	375,56
$v_s = 30$	880	330
40	910	331

(5)

- 3.3 Straight line with negative gradient / frequency decreases (linearly). ✓✓



(2)

[9]

QUESTION 4

- 4.1.1 Frequency (of sound detected by the listener (observer)). ✓ (1)

- 4.1.2 The (apparent) change in frequency (or pitch) of the sound ✓ (detected) (by a listener) because the sound source and the listener have different velocities relative to the medium of sound propagation. ✓

OR

An (apparent) change in (observed/detected) frequency (pitch), (wavelength) ✓ as a result of the relative motion between a source and an observer ✓ (listener). (2)

- 4.1.3 Away ✓

Detected frequency of source decreases. ✓ (2)

4.1.4

EXPERIMENT 2

$$f_L = \frac{v \pm v_L}{v \pm v_s} f_s \quad \text{OR} \quad f_L = \frac{v}{v + v_s} f_s \quad \checkmark$$

$$874 = \frac{v}{v + 10} (900) \quad \checkmark$$

$$v = 336,15 \text{ m} \cdot \text{s}^{-1} \quad \checkmark$$

EXPERIMENT 3

$$f_L = \frac{v \pm v_L}{v \pm v_s} f_s \quad \text{OR/OF} \quad f_L = \frac{v}{v + v_s} f_s \quad \checkmark$$

$$850 = \frac{v}{v + 20} (900) \quad \checkmark$$

$$v = 340 \text{ m} \cdot \text{s}^{-1} \quad \checkmark$$

EXPERIMENT 4

$$f_L = \frac{v \pm v_L}{v \pm v_s} f_s \quad \text{OR} \quad f_L = \frac{v}{v + v_s} f_s \quad \checkmark$$

$$827 = \frac{v}{v + 30} (900) \quad \checkmark \quad \therefore v = 339,86 \text{ m} \cdot \text{s}^{-1} \quad \checkmark$$

(5)

- 6.2 Away from the earth. ✓

(1)

[11]



QUESTION 5

5.1 $v = f\lambda$ ✓
 $= (222 \times 10^3)(1,5 \times 10^{-3})$ ✓
 $= 333 \text{ m.s}^{-1}$ ✓ (3)

5.2

5.2.1 Towards the bat. ✓ (1)

5.2.2 $f_L = \frac{v \pm v_L}{v \pm v_s} f_s$ OR/OF $f_L = \frac{v}{v - v_s} f_s$ ✓
 $230,3 = \frac{333}{333 - v_s} (222)$ ✓
 $76689,9 - 230,3 v_s = 73\,926$
 $v = 12 \text{ m.s}^{-1}$ ✓ (towards bat/na die vlermuis toe) (6)
[10]

QUESTION 6

6.1 **X** ✓ (1)

6.2 As ambulance approaches the hospital the waves are compressed ✓ or wavelengths are shorter. Since the speed of sound is constant ✓ the observed frequency must increase. ✓ Therefore the hospital must be located on the side of X (from $v = f\lambda$)
OR
The number of wave fronts per second reaching the observer are more at X. ✓ ✓.
 For the same constant speed, this means that the observed frequency increases ✓
 therefore the hospital must be located on the side of X. (from $v = f\lambda$) (3)

6.3 $f_L = \frac{v \pm v_L}{v \pm v_s} f_s$ OR $f_L = \frac{v}{v - v_s} f_s$ ✓
 $f_L = \frac{340}{(340 - 30)} (400)$ ✓
 $f_L = 438,71 \text{ Hz}$ ✓ (5)

6.4 $v = f\lambda$ ✓
 $340 = 400\lambda$ ✓
 $\lambda = 0,85 \text{ m}$ ✓ (3)
[12]

QUESTION 7

7.1.1 It is the (apparent) change in frequency (or pitch) of the sound (detected by a listener) ✓ because the sound source and the listener have different velocities relative to the medium of sound propagation. ✓
OR
An (apparent) change in (observed/detected) frequency (pitch), (wavelength) ✓ as a result of the relative motion between a source and an observer ✓ (listener). (2)

7.1.2 $v = f\lambda$ ✓
 $340 = f(0,28)$ ✓
 $f_s = 1\,214,29 \text{ Hz}$ ✓ (3)



7.1.3 **POSITIVE MARKING FROM QUESTION 7.1.2.**

$$f_L = \frac{v \pm v_L}{v \pm v_s} f_s \quad \text{OR} \quad f_L = \frac{v \pm v_L}{v \pm v_s} \times \frac{v}{\lambda_s} \quad \text{OR} \quad f_L = \frac{v}{v - v_s} f_s \quad \text{OR} \quad f_L = \frac{f_s}{1 - \frac{v_s}{v}} \checkmark$$

$$f_L = \left(\frac{340}{340 - 30} \right) 1214,29 \quad \text{OR} \quad f_L = \left(\frac{340}{340 - 30} \right) \times \frac{340}{0,28} \quad \text{OR} \quad f_L = \frac{1214,29}{1 - \frac{30}{340}}$$

$$= 1\,331,80 \text{ Hz} \checkmark$$

(5)

7.1.4 Decreases $\checkmark$

(1)

7.2 The spectral lines of the star are/should be shifted towards the lower frequency $\checkmark$ end, which is the red end (red shift) of the spectrum. $\checkmark$

(2)

[13]

QUESTION 8

8.1 Speed $\checkmark$

(1)

8.2 $3 \checkmark (\text{m} \cdot \text{s}^{-1})$

(1)

8.3

8.3.1 It is the change in frequency (or pitch) of the sound detected by a listener $\checkmark$ because the sound source and the listener have different velocities relative to the medium of sound propagation. $\checkmark$

(2)

8.3.2 $345 \checkmark (\text{m} \cdot \text{s}^{-1})$

(1)

8.3.3

$$f_L = \left(\frac{v \pm v_L}{v \pm v_s} \right) f_s \checkmark$$

$$= \left(\frac{345 + 0}{345 - 57,5} \right) \left(\frac{1000}{1} \right) \checkmark$$

$$= 1200 \text{ Hz} \checkmark$$

(4)

8.3.4 $295 \checkmark (\text{K})$

(1)

8.4

8.4.1 Diagram 3 $\checkmark$

(1)

8.4.2

1 $\checkmark$  The source is stationary. $\checkmark$

(2)

[13]

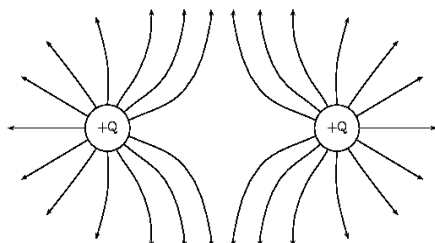
ELECTROSTATICS

QUESTION 1

1.1 To ensure that charge does not leak to the ground/insulated. ✓ (1)

1.2 Net charge = $\frac{Q_R + Q_S}{2} = \frac{+8 + (-4)}{2} \checkmark = 2 \mu\text{C} \checkmark$ (2)

1.3 **POSITIVE MARKING FROM QUESTION 1.2.**



Criteria for sketch:	
Correct direction of field lines	✓
Shape of the electric field	✓
No field line crossing each other / No field lines inside the spheres.	✓

(3)

1.4 (2)

1.5 **POSITIVE MARKING FROM QUESTION 1.2.**

Step 1:

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

$$F_{ST} = (9 \times 10^9) \frac{(1 \times 10^{-6})(2 \times 10^{-6})}{(0,2)^2 \checkmark} = 0,45 \text{ N} / 4,5 \times 10^{-1} \text{ N left}$$

$$\text{OR } F_{TS} = \frac{1}{4} F_{RT} = \frac{1}{4} (1,8) = 0,45 \text{ N}$$

Step 2:

$$F_{RT} = 9 \times 10^9 \times \frac{(2 \times 10^{-6})(1 \times 10^{-6})}{(0,1)^2 \checkmark} = 1,8 \text{ N right}$$

$$\text{OR } F_{RT} = 4F_{ST} = 4(0,45) = 1,8 \text{ N right regs}$$

Step 3:

$$F_{\text{net}} = F_{ST} + F_{RT} = 1,8 + (-0,45) \checkmark$$

$$= 1,35 \text{ N or towards sphere S or right S} \checkmark$$

(6)

1.6 Force experienced ✓ per unit positive charge ✓ placed at that point. (2)

1.7 **POSITIVE MARKING FROM QUESTION 1.5.**

OPTION 1

$$E = \frac{F}{q} \checkmark = \frac{1,35}{1 \times 10^{-6}} \checkmark = 1,35 \times 10^6 \text{ N} \cdot \text{C}^{-1} \checkmark$$

OPTION 2

$$E_R = \frac{kQ}{r^2} \checkmark = \frac{(9 \times 10^9)(2 \times 10^{-6})}{(0,1)^2} \checkmark = 1,8 \times 10^6 \text{ N} \cdot \text{C}^{-1} \text{ right}$$

$$E_S = \frac{kQ}{r^2} = \frac{(9 \times 10^9)(2 \times 10^{-6})}{(0,2)^2} = 4,5 \times 10^5 \text{ N} \cdot \text{C}^{-1} \text{ left}$$

$$E_{\text{net}} = 1,8 \times 10^6 - 4,5 \times 10^5 = 1,35 \times 10^6 \text{ N} \cdot \text{C}^{-1} \checkmark$$

(3)

[19]



QUESTION 2

- 2.1 The force of attraction or repulsion between two point charges is directly proportional to the product of the charges ✓ and inversely proportional to the square of the distance between them. ✓ (2)

2.2

2.2.1
$$F = \frac{kQ_1Q_2}{r^2}$$

$$1,44 \times 10^{-1} = \frac{(9 \times 10^9)Q^2}{(0,5)^2}$$
 ✓
 $Q = 2 \times 10^{-6} \text{ C}$ ✓ (4)

2.2.1 **POSITIVE MARKING FROM Q2.2.1.**

$Q = ne$ ✓
 $2 \times 10^{-6} = n(1,6 \times 10^{-19})$ ✓
 $n = 1,25 \times 10^{13} \text{ electrons/elektrone}$ ✓ (3)

2.3

2.3.1 Left / West ✓ (1)

2.3.2 Take right as positive/Neem regs as positief

$E_{\text{net}} = E_A + E_B$ ✓
 $(3 \times 10^4) = -\frac{(9 \times 10^9)(2 \times 10^{-6})}{(1,5)^2} + \frac{(9 \times 10^9)Q_{\text{final}}}{(1)^2}$ ✓
 $Q_{\text{final}} = 4,22 \times 10^{-6} \text{ C}$ ✓
 $Q = ne$ ✓
 $4,22 \times 10^{-6} = n(1,6 \times 10^{-19})$ ✓
 $n_f = 2,64 \times 10^{13} \text{ electrons/elektrone}$ ✓
 electrons removed/elektrone verwyder
 $= (2,64 \times 10^{13} + 1,25 \times 10^{13})$ ✓
 $= 3,89 \times 10^{13} \text{ electrons/elektrone}$ ✓ (8)

[18]

QUESTION 3

- 3.1 The (magnitude) of the electrostatic force exerted by one charge on another is directly proportional to the product of the charges ✓ and inversely proportional to the square of the distance between their centres. ✓ (2)

3.2

$F = k \frac{Q_1Q_2}{r^2}$ ✓
 $F_{31} = \frac{(9 \times 10^9)(5 \times 10^{-6})(6 \times 10^{-6})}{(0,3)^2}$ ✓ = 3 N to the left
 $F_{32} = \frac{(9 \times 10^9)(5 \times 10^{-6})(3 \times 10^{-6})}{(0,1)^2}$ ✓ = 13,5 N downwards

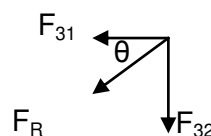
$F_R = F_{31} + F_{32}$
 $F_R = \sqrt{(3)^2 + (13,5)^2}$ ✓ = 13,83 N

$\theta = \tan^{-1} \frac{13,5}{3}$ ✓ = 77,47°

OR

$\theta = \tan^{-1} \frac{3}{13,5}$ ✓
 = 12,53°

∴ Net force = 13,83 N in direction 192,53° / 77,47° ✓



Can use any trigonometric ratio

(7)

[9]



QUESTION 4

4.1 For object N:

$$n = \frac{Q}{q_e} \checkmark$$

$$Q = (5 \times 10^6)(-1,6 \times 10^{-19}) \checkmark$$

$$= -8 \times 10^{-13} \text{ C} \checkmark$$

(3)

4.2 **POSITIVE MARKING FROM 4.1**

Charge on / *Lading op* M (Q_M) is $+8 \times 10^{-13} \text{ C}$ ✓✓

(2)

4.3 The electric field at a point is the (electrostatic) force experienced per unit positive charge placed at that point. ✓

(2)

4.4 **POSITIVE MARKING FROM 4.1 AND 4.2.**

$$E = \frac{kQ}{r^2} \checkmark$$

$$E_{PM} = \frac{(9 \times 10^9)(8 \times 10^{-13})}{(0,25)^2} \checkmark$$

$$= 0,12 \text{ N} \cdot \text{C}^{-1} \text{ to the right}$$

Q from 4.2

$$E_{PN} = \frac{(9 \times 10^9)(8 \times 10^{-13})}{(0,1)^2} \checkmark$$

$$= 0,72 \text{ N} \cdot \text{C}^{-1} \text{ to the left}$$

Q from 4.1

$$E_{\text{net}} = E_{PM} - E_{PN} \checkmark = 0,12 - 0,72 = -0,60 \text{ N} \cdot \text{C}^{-1}$$

$$= \underline{0,60 \text{ N} \cdot \text{C}^{-1} \text{ to the left}}$$

(6)
[13]

QUESTION 5

5.1

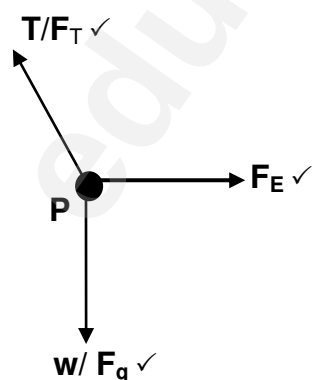
$$n = \frac{Q}{e} \checkmark$$

$$n = \frac{0,5 \times 10^{-6}}{1,6 \times 10^{-19}} \checkmark$$

$$n = 3,13 \times 10^{12} \text{ electrons} \checkmark$$

(3)

5.2



Accepted labels	
w	F_g / F_w / weight / mg / gravitational force
T	F_T / tension
F_E	Electrostatic force/ F_C / Coulombic force/ F_Q / $F_{RP/PR}$

(3)

5.3 The magnitude of the electrostatic force exerted by one point charge (Q_1) on another point charge (Q_2) is directly proportional to the product of the (magnitudes of the) charges ✓ and inversely proportional to the square of the distance (r) between them. ✓

(2)



5.4

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

$$\frac{T \sin \theta}{T \cos \theta} = F_E$$

$$\therefore \frac{T \sin 7^\circ}{T \cos 83^\circ} \checkmark = \frac{(9 \times 10^9)(0,5 \times 10^{-6})(0,9 \times 10^{-6})}{(0,2)^2} \checkmark$$

$$\therefore T = 0,83 \text{ N} \checkmark$$

(5)
[13]

QUESTION 6

6.1

$$E_X = E_2 + E_{(-8)} \checkmark$$

$$= \frac{kQ_2}{r^2} + \frac{kQ_{-8}}{r^2} \quad \checkmark \text{ correct equation}$$

$$= \frac{(9 \times 10^9)(2 \times 10^{-5})}{(0,25)^2} \checkmark + \frac{(9 \times 10^9)(8 \times 10^{-6})}{(0,15)^2} \checkmark$$

$$= 2,88 \times 10^6 + 3,2 \times 10^6$$

$$= 6,08 \times 10^6 \text{ N} \cdot \text{C}^{-1} \checkmark \text{ to the east/right} \checkmark$$

OR

$$E = k \frac{Q}{r^2} \checkmark$$

$$E_2 = \frac{(9 \times 10^9)(2 \times 10^{-5})}{(0,25)^2} \checkmark$$

$$= 2,88 \times 10^6 \text{ N} \cdot \text{C}^{-1} \text{ to the east/right}$$

$$E_{-8} = \frac{(9 \times 10^9)(8 \times 10^{-6})}{(0,15)^2} \checkmark$$

$$= 3,2 \times 10^6 \text{ N} \cdot \text{C}^{-1} \text{ to the east/right}$$

$$E_X = E_2 + E_{(-8)}$$

$$= (2,88 \times 10^6 + 3,2 \times 10^6) \checkmark$$

$$= 6,08 \times 10^6 \text{ N} \cdot \text{C}^{-1} \checkmark \text{ to the east/right} \checkmark$$

(6)

6.2

POSITIVE MARKING FROM 6.2.

OPTION 1	OPTION 2
$F_E = QE \checkmark$ $= (-2 \times 10^{-9})(6,08 \times 10^6) \checkmark$ $= -12,16 \times 10^{-3} \text{ N}$ $F_E = 1,22 \times 10^{-2} \text{ N} \checkmark \text{ to the west/left} \checkmark$	$F_{(-2)Q1} = qE_{(2)} \checkmark$ $= (2 \times 10^{-9})(2,88 \times 10^6)$ $= 5,76 \times 10^{-3} \text{ N to the west/left}$ $F_{(-2)Q2} = qE_{(8)}$ $= (2 \times 10^{-9})(3,2 \times 10^6)$ $= 6,4 \times 10^{-3} \text{ N to the west/left}$ $F_{\text{net}} = \frac{5,76 \times 10^{-3} + 6,4 \times 10^{-3}}{1} \checkmark$ $= 1,22 \times 10^{-2} \text{ N} \checkmark \text{ to the west/left}$

(4)

6.3

POSITIVE MARKING FROM Q6.2.

$$2,44 \times 10^{-2} \text{ N} \checkmark / \text{ twice} / \text{ double}$$

(1)
[11]

QUESTION 7

7.1 The magnitude of the charges is equal. ✓

OR

The balls repel each other with the same/identical force or force of equal magnitude.

(1)

7.2 The magnitude of the electrostatic force exerted by one point charge (Q_1) on another point charge (Q_2) is directly proportional to the product of the (magnitudes of the) charges ✓ and inversely proportional to the square of the distance (r) between them. ✓

(2)

7.3

$$\begin{aligned} 7.3.1 \quad T \cos 20^\circ &= w \checkmark \\ &= mg \\ &= (0,1)(9,8) \checkmark = 0,98 \text{ N} \\ \therefore T &= 1,04 \text{ N} \checkmark \end{aligned}$$

(3)

7.3.2 **POSITIVE MARKING FROM Q7.3.1.**

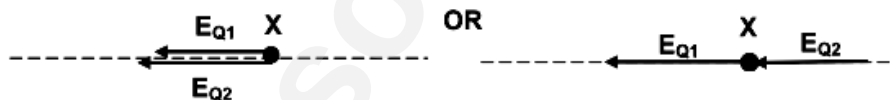
$$\begin{aligned} F_{\text{electrostatic/electrostatics}} &= T \sin 20^\circ \checkmark \\ \frac{kQ_1Q_2}{r^2} \checkmark &= (1,04) \sin 20^\circ \\ \frac{kQ_1Q_2}{r^2} &= 0,356 \\ \frac{(9 \times 10^9)(250 \times 10^{-9})(250 \times 10^{-9})}{r^2} \checkmark &= 0,356 \checkmark \\ \therefore r &= 0,0397 \text{ m} \checkmark \end{aligned}$$

(5)

[11]

QUESTION 8

8.1



Vectors E_{Q1} and E_{Q2} in the same direction. ✓✓

Correct drawing of vectors E_{Q1} and E_{Q2} . ✓✓

The fields due to the two charges add up because they come from the same direction. Hence the field cannot be zero.

(4)

8.2

$$\begin{aligned} E &= k \frac{Q}{r^2} \checkmark \\ E_{-2,5\mu\text{C}} &= k \frac{Q}{r^2} = \frac{(9 \times 10^9)(2,5 \times 10^{-6})}{(0,3)^2} \checkmark = 250\,000 \text{ N.C}^{-1} \text{ to the left/na links} \\ E_{6\mu\text{C}} &= k \frac{Q}{r^2} = \frac{(9 \times 10^9)(6 \times 10^{-6})}{(1,3)^2} \checkmark = 31\,952,66 \text{ N.C}^{-1} \text{ to the left/na links} \\ E_P &= E_{6\mu\text{C}} + E_{-2,5\mu\text{C}} \checkmark \\ &= 31\,952,66 + 250\,000 \\ &= 281\,952,66 \text{ N.C}^{-1} \checkmark \text{ to the left/na links} \checkmark \end{aligned}$$

(6)

[10]

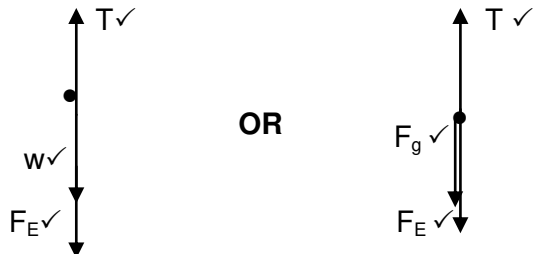
QUESTION 9

9.1

$n = \frac{Q}{e} \checkmark$ $= \frac{-32 \times 10^{-9}}{-1,6 \times 10^{-19}} \checkmark$ $= 2 \times 10^{11} \checkmark \text{ electrons}$	$n = \frac{Q}{e} \checkmark$ $= \frac{32 \times 10^{-9}}{1,6 \times 10^{-19}} \checkmark$ $= 2 \times 10^{11} \checkmark \text{ electrons}$
---	---

(3)

9.2



Accepted labels	
w	$F_g/F_w/\text{weight}/mg/\text{gravitational force}$
T	$F_T/\text{tension}$
F_E	$F_{\text{electrostatic}}/F_{Q1Q2}/\text{Coulomb force}/F$

(3)

9.3

$$F_{\text{net}} = 0$$

$$mg + F_E = T$$

$$mg + k \frac{Q_1 Q_2}{r^2} - T = 0 \checkmark$$

$$(0,007)(9,8) \checkmark + (9 \times 10^9) \frac{(32 \times 10^{-9})(55 \times 10^{-9})}{(0,025)^2} \checkmark = T \quad \therefore T = 9,39(4) \times 10^{-2} \text{ N} \checkmark$$

(5)

[11]

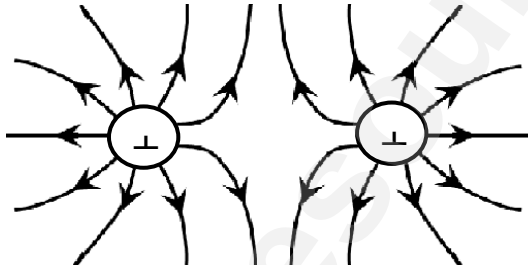
QUESTION 10

10.1

The (electrostatic) force experienced by a unit positive charge (placed at that point). $\checkmark \checkmark$

(2)

10.2



Guideline for allocating marks	
Lines must not cross / Lines must touch the spheres but not enter spheres	$\checkmark$
Arrows point outwards	$\checkmark$
Correct shape	$\checkmark$

(3)

10.3

$$E = \frac{kQ}{r^2} \checkmark$$

$$E_{Q1X} = \frac{(9 \times 10^9)(30 \times 10^{-6})}{(x)^2} \checkmark$$

$$E_{Q2X} = \frac{(9 \times 10^9)(45 \times 10^{-6})}{(0,15 + x)^2} \checkmark$$

$$E_{\text{net}} = 0$$

$$E_{Q1X} = E_{Q2X}$$

$$\left. \frac{(9 \times 10^9)(30 \times 10^{-6})}{(x)^2} = \frac{(9 \times 10^9)(45 \times 10^{-6})}{(0,15 + x)^2} \right\} \text{ For equating equations}$$

$$\frac{5,477}{x} = \frac{6,708}{0,15 + x} \quad \therefore x = 0,67 \text{ m } (0,667 \text{ m}) \checkmark$$

(5)

[10]

QUESTION 11

11.1.1 The (magnitude of the) electrostatic force exerted by one (point) charge on another is directly proportional to the product of the charges ✓ and inversely proportional to the square of the distance between their (centres) them. ✓ (2)

11.1.2 F_E /Electrostatic force ✓ (1)

11.1.3 The electrostatic force is inversely proportional to the square of the distance between the charges ✓

OR The electrostatic force is directly proportional to the inverse of the square of the distance between the charged spheres (charges).

OR $F \propto \frac{1}{r^2}$

OR They are inversely proportional to each other. (1)

11.1.4

$$\text{Slope} = \frac{\Delta F_E}{\Delta \frac{1}{r^2}} = \frac{(0,027 - 0)}{(5,6 - 0)} = 4,82 \times 10^{-3} \text{ N} \cdot \text{m}^2$$

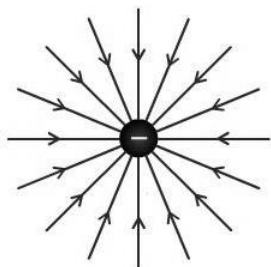
$$\text{Slope} = F_E r^2 = kQ_1 Q_2 = kQ^2 \quad \checkmark$$

$$4,82 \times 10^{-3} \checkmark = \frac{9 \times 10^9 Q^2}{\checkmark}$$

$$\therefore Q = 7,32 \times 10^{-7} \text{ C} \quad \checkmark$$

(6)

11.2.1



Criteria for drawing electric field:	
Direction	✓
Field lines radially inward	✓

(2)

11.2.2

$$E = \frac{kQ}{r^2} \quad \checkmark$$

Take right as positive

$$E_{PA} = \frac{(9 \times 10^9)(0,75 \times 10^{-6})}{(0,09)^2} \checkmark = 8,33 \times 10^5 \text{ N} \cdot \text{C}^{-1} \text{ to the left}$$

$$E_{PB} = \frac{(9 \times 10^9)(0,8 \times 10^{-6})}{(0,03)^2} \checkmark = 8 \times 10^6 \text{ N} \cdot \text{C}^{-1} \text{ to the left}$$

$$E_{\text{net}} = E_{PA} + E_{PB}$$

$$= [-8,33 \times 10^5 + (-8 \times 10^6)] \quad \checkmark \checkmark$$

$$= -8,83 \times 10^6 = 8,83 \times 10^6 \text{ N} \cdot \text{C}^{-1} \quad \checkmark$$

Take left as positive

$$E_{PA} = \frac{(9 \times 10^9)(0,75 \times 10^{-6})}{(0,09)^2} \checkmark$$

$$= 8,33 \times 10^5 \text{ N} \cdot \text{C}^{-1} \text{ to the left}$$

$$E_{PB} = \frac{(9 \times 10^9)(0,8 \times 10^{-6})}{(0,03)^2} \checkmark = 8 \times 10^6 \text{ N} \cdot \text{C}^{-1} \text{ to the left}$$

$$E_{\text{net}} = E_{PA} + E_{PB} = (8,33 \times 10^5 + 8 \times 10^6) \quad \checkmark \checkmark = 8,83 \times 10^6 \text{ N} \cdot \text{C}^{-1} \quad \checkmark$$

(5)
[17]

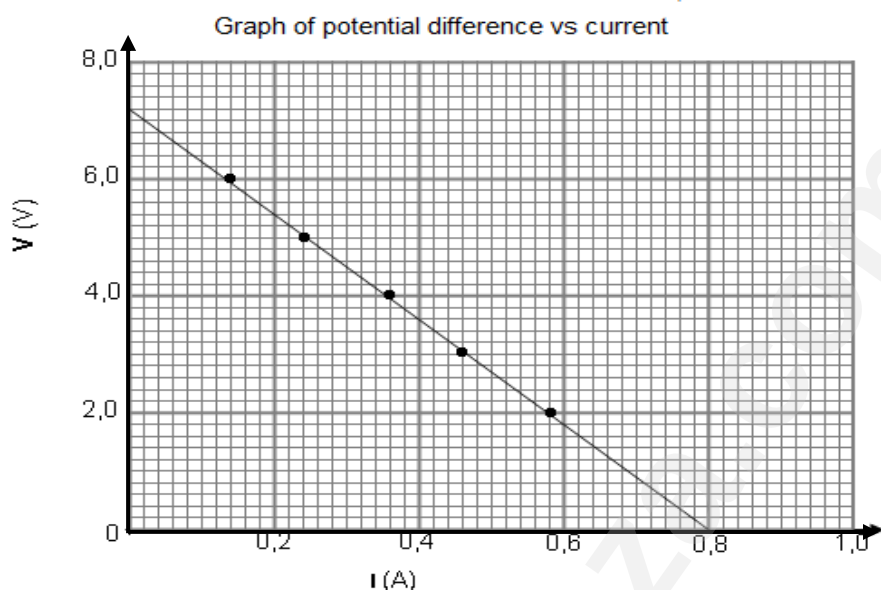


ELECTRIC CIRCUITS

QUESTION 1

1.1.1 Keep the temperature (of battery) constant. ✓ (1)

1.1.2



Criteria for drawing line of best fit:	
ALL points correctly plotted (at least 4 points)	✓✓
Correct line of best fit if all plotted points are used (at least 3 point)	✓

(3)

1.1.3 7,2 V ✓
(Accept any readings between 7,0 V and 7,4 V or the value of the y-intercept.) (1)

1.1.4 **POSITIVE MARKING FROM QUESTION 8.1.3**

$$\text{Slope} = \frac{\Delta V}{\Delta I} = \frac{0 - 7,2}{0,8 - 0} = -9 \therefore r = 9 \Omega \quad \checkmark$$

(3)

1.2.1 $P = VI \checkmark \therefore 100 = 20(I) \checkmark \therefore I = 5 \text{ A} \checkmark$ (3)

1.2.2 $P = \frac{V^2}{R} \checkmark \therefore R = \frac{(20)^2}{150} \checkmark = 2,67 \Omega \checkmark$ (3)

1.2.3 **POSITIVE MARKING FROM QUESTION 1.2.2.**

$$P = VI \quad \text{OR} \quad P = I^2 R$$

$$\therefore I_{150W} = \frac{150}{20} \checkmark = 7,5 \text{ A} \quad \therefore I_{150W} = \sqrt{\frac{150}{2,67}} \checkmark = 7,5 \text{ A}$$

$$I_{\text{tot}} = (5 + 7,5) \checkmark$$

$$\varepsilon = I(R + r) \checkmark$$

$$24 = 12,5(R + r)$$

$$24 = V_{\text{ext}} + V_{\text{ir}}$$

$$24 = 20 + 12,5(r) \checkmark$$

$$r = 0,32 \Omega \checkmark$$

(5)

1.2.4 Device Z is a voltmeter. ✓ (1)

8.2.5 Device **Z** should be a voltmeter (or a device with very high resistance) because it has a very high resistance ✓ and will draw very little current. ✓
The current through **X** and **Y** will remain the same hence the device can operate as rated. (2)

[22]



QUESTION 2

2.1

2.1.1 Ensure wires have:

Same length ✓

Same thickness/cross-sectional area. ✓

(2)

2.1.2 Wire A (Resistor A)/Draad A ✓

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

$$R_A = \frac{4,4}{0,4} \checkmark = 11 \Omega \checkmark$$

$$R_B = \frac{2,2}{0,4} \checkmark = 5,5 \Omega \checkmark$$

$$E = I^2 R \Delta t \checkmark$$

I

Accept any correct coordinates chosen from the graph
Aanvaar enige korrekte koördinate van die grafiek gekies.

For the same time and current, the heating in A will be higher because its resistance is higher than that of B. ✓

(8)

2.2

2.2.1

OPTION 1/OPSIE 1

$$I_{5,5\Omega} : I_{11\Omega}$$

$$2 : 1$$

$$I_{5,5\Omega} = (0,2)(2) \checkmark \checkmark$$

$$= 0,4 \text{ A} \checkmark$$

OPTION 2/OPSIE 2

$$V = IR$$

$$V_{11\Omega} = 0,2 \times 11$$

$$= 2,2 \text{ V} \checkmark$$

$$V_{5,5} = V_{11} = 2,2 \text{ V} \checkmark$$

$$I_{5,5} = \frac{2,2}{5,5}$$

$$= 0,4 \text{ A} \checkmark$$

(3)

2.2.2

OPTION 1/OPSIE 1

$$V = IR$$

$$I_{\text{tot}} = (0,4 + 0,2) \checkmark$$

$$= 0,6 \text{ A}$$

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \dots \checkmark$$

$$\frac{1}{R_p} = \frac{1}{11} + \frac{1}{5,5} \checkmark$$

$$R_p = 3,67 \Omega$$

$$R_T = R_p + R_A$$

$$= 3,67 + 11 \checkmark$$

$$= 14,67 \Omega$$

$$\varepsilon = I(R + r) \checkmark$$

$$9 = 0,6(14,67 + r) \checkmark$$

$$r = 0,33 \Omega \checkmark$$

OPTION 2/OPSIE 2

$$I_{\text{tot}} = (0,4 + 0,2) \checkmark$$

$$= 0,6 \text{ A}$$

$$V_{\text{ext}} = V_{11\Omega} + V_{//} \checkmark$$

$$= [I_{\text{tot}}(R_{11}) + 2,2]$$

$$= 0,6(11) \checkmark + 2,2$$

$$= 8,8 \text{ V} \checkmark$$

$$\varepsilon = V_{\text{ext}} + I_{\text{tot}}(r) \checkmark$$

$$9 = 8,8 + 0,6r \checkmark$$

$$r = 0,33 \Omega \checkmark$$

(7)

2.1.1

Decrease ✓

The total resistance increase. ✓

(2)

[22]

QUESTION 3

3.1

NEGATIVE ✓

(1)

3.2

$$I_{2\Omega} = \frac{V}{R} \checkmark$$

$$= \frac{1,36}{(4 + 2)} \checkmark$$

$$= 0,23 \text{ A} \checkmark$$

(3)



3.3

POSITIVE MARKING FROM QUESTION 3.2

OPTION 1 $I_{3\Omega} = \frac{V}{R}$ $= \frac{1,36}{3} \checkmark$ $= 0,45 \text{ A}$ $I_T = I_2 + I_3$ $= 0,23 + 0,45 \checkmark$ $= 0,68 \text{ A}$ $V_{\text{int/lost}} = \varepsilon - V_{\text{ext}} \checkmark$ $= 1,5 - 1,36 \checkmark$ $= 0,14 \text{ V}$ $V_{\text{int/lost}} = Ir \checkmark$ $0,14 = (0,68)r \checkmark$ $r = 0,21 \Omega \checkmark$	OPTION 2 $I_3 = \frac{V}{R}$ $= \frac{1,36}{3} \checkmark$ $= 0,45 \text{ A}$ $I_T = I_2 + I_3$ $= 0,23 + 0,45 \checkmark$ $= 0,68 \text{ A}$ $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} \checkmark$ $\frac{1}{R_p} = \frac{1}{6} + \frac{1}{3} \checkmark$ $R_p = 2 \Omega$ $\varepsilon = I(R + r) \checkmark$ $1,5 = 0,68(2 + r) \checkmark$ $r = 0,21 \Omega \checkmark$
OPTION 3 $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} \checkmark$ $\frac{1}{R_p} = \frac{1}{6} + \frac{1}{3} \checkmark$ $R_p = 2 \Omega$ $V = IR$ $1,36 \checkmark = I(2) \checkmark$ $I = 0,68 \text{ A}$ $\varepsilon = I(R+r) \checkmark$ $1,5 = 0,68(2 + r) \checkmark$ $r = 0,21 \Omega \checkmark$	OPTION 4 $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} \checkmark$ $\frac{1}{R_p} = \frac{1}{6} + \frac{1}{3} \checkmark$ $R_p = 2 \Omega$ $V = IR \checkmark$ $1,36 = I(2) \checkmark$ $I = 0,68 \text{ A}$ $V_{\text{int}} = 1,5 - 1,36 \checkmark$ $= 0,14 \text{ V}$ $Ir = 0,14$ $(0,68)r = 0,14 \checkmark$ $R = 0,21 \Omega \checkmark$

(7)

3.4

Decrease ✓

The effective resistance across the parallel circuit decreases ✓

The terminal potential difference decreases

The resistance in the ammeter branch remains constant ✓ **hence the ammeter reading decreases**

(4)
[15]



QUESTION 4

- 4.1 The potential difference across a conductor is directly proportional to the current ✓ in the conductor at constant temperature. ✓
(Provided temperature and all other physical conditions are constant.) (2)

4.2

OPTION 1 $V = IR$ ✓ $V_8 = (0,5)(8) = 4 \text{ V}$ $V_8 = V_{16}$ $\therefore V_{16} = 4 \text{ V}$ $I_{16} = \frac{V}{R} = \frac{4}{16} = 0,25 \text{ A}$ $I_{\text{tot}} = A_1 = (0,5 + 0,25) \checkmark = 0,75 \text{ A} \checkmark$	OPTION 2 $V = IR$ ✓ $V_8 = (0,5)(8) \checkmark = 4 \text{ V}$ $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$ $= \frac{1}{8} + \frac{1}{16} \checkmark$ $R = 5,33 \Omega$ $I_{\text{tot}} = \frac{4}{5,33}$ $A_1 = 0,75 \text{ A} \checkmark$
OPTION 3 $I_1 R_1 = I_2 R_2 \checkmark$ $(0,5)(8) = I_{16}(16) \checkmark$ $I_{16} = \frac{(8)(0,5)}{16} = 0,25 \text{ A}$ $I_{\text{tot}} = A_1 = (0,5 + 0,25) \checkmark = 0,75 \text{ A} \checkmark$	OPTION 4 $2R_{8\Omega} = R_{16\Omega} \checkmark$ $\therefore I_{R16} = \frac{1}{2} I_{R8} \checkmark$ $\therefore I_{R16} = \frac{1}{2} (0,5) = 0,25 \text{ A}$ $A_1 = (0,5 + 0,25) \checkmark = 0,75 \text{ A} \checkmark$

(4)

4.3

POSITIVE MARKING FROM 4.2.

OPTION 1 $V = IR$ $V_{20\Omega} = (0,75)(20) \checkmark = 15 \text{ V}$ $V_{//\text{tot}} = (15 + 4) \checkmark = 19 \text{ V}$ $V_R = 19 \text{ V}$ $P = VI \checkmark$ $12 = (19)I \checkmark$ $I_R = A_2 = 0,63 \text{ A} \checkmark$	OPTION 2 $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{8} + \frac{1}{16} \checkmark$ $R_{//} = 5,33 \Omega$ $R_{//} + R_{20} = (5,33 + 20) \checkmark = 25,33 \Omega$ $V_{//\text{tot}} = I(R_{//} + R_{20})$ $= (0,75)(25,33)$ $= 19 \text{ V}$ $P = VI$ $12 \checkmark = I(19) \checkmark$ $I_R = A_2 = 0,63 \text{ A} \checkmark$
OPTION 3 $V = IR$ $V_{20\Omega} = (0,75)(20) \checkmark = 15 \text{ V}$ $V_{//\text{tot}} = (15 + 4) \checkmark = 19 \text{ V}$ $V_R = 19 \text{ V}$ $P = \frac{V^2}{R}$ $12 = \frac{(19)^2}{R}$ $R = 30,08 \Omega$ $P = I^2 R \checkmark$ $12 = I^2(30,08) \checkmark$ $I = 0,63 \text{ A} \checkmark$	

(5)



4.4

POSITIVE MARKING FROM 4.2 AND 4.3.

OPTION 1 $(\varepsilon) = I(R + r) \checkmark$ $= V_{//tot} + V_{int}$ $= 19 + (0,75 + 0,63)(1) \checkmark$ $= 20,38 \text{ V} \checkmark$	OPTION 2 $V_{int} = Ir$ $= (0,75 + 0,63)(1) \checkmark$ $= 1,38 \text{ V}$ $\varepsilon = V_{//tot} + V_{int} \checkmark$ $= 19 + 1,38$ $= 20,38 \text{ V} \checkmark$
OPTION 3 $R = \frac{V}{I} = \frac{19}{0,63} = 30,16 \Omega$ $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{30,16} + \frac{1}{25,33} \therefore R_p = 13,77 \Omega$ $I_{tot} = 0,63 + 0,75 = 1,38 \text{ A}$ $\varepsilon = I(R + r) \checkmark$ $= (1,38)(13,77 + 1) \checkmark$ $= 20,38 \text{ V} \checkmark$	

(3)
[14]

QUESTION 5

5.1

5.1.1

$$V = IR \checkmark$$

$$= (0,2)(4+8) \checkmark$$

$$= 2,4 \text{ V} \checkmark$$

(3)

5.1.2

V = IR $2,4 = I_2(2) \checkmark$ $I_{2\Omega} = 1,2 \text{ A} \checkmark$ $I_T = I_2 + 0,2 \text{ A} \checkmark$ $= 1,4 \text{ A} \checkmark$	OR $I_2 = 6 \times 0,2 \checkmark$ $I_2 = 1,2 \text{ A} \checkmark$ $I_T = I_2 + 0,2 \checkmark$ $= 1,4 \text{ A} \checkmark$
--	--

(4)

5.1.3

OPTION 1 $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} \checkmark$ $\frac{1}{R_p} = \frac{1}{12} + \frac{1}{2} \checkmark$ $R_p = 1,72 \Omega \checkmark$ $\varepsilon = I(R+r) \checkmark$ $= 1,4(1,72 + 0,5) \checkmark$ $= 3,11 \text{ V} \checkmark$	OPTION 2 $V_{int} = Ir \checkmark$ $= (1,4)(0,5) \checkmark$ $= 0,7 \text{ V} \checkmark$ $\varepsilon = V_{ext/eks} + V_{int} \checkmark$ $= 2,4 + 0,7 \checkmark$ $= 3,1 \text{ V} \checkmark$
--	---

(5)

5.2

Removing the 2Ω resistor increases the total resistance of the circuit. $\checkmark$ Thus the total current decreases, decreasing the V_{int} (V_{lost}). $\checkmark$ Therefore the voltmeter reading V increases. $\checkmark$

(3)
[15]

QUESTION 6

6.1

6.1.1

OPTION 1	OPTION 2	OPTION 3
$P = \frac{V^2}{R} \checkmark$	$P = VI$	$P = VI$
$4 = \frac{V^2}{R} \checkmark$	$4 = I(12)$	$4 = I(12)$
$4 = \frac{V^2}{R} = \frac{(12)^2}{R} \checkmark$	$I = 0,33...A$	$I = 0,33...A$
$R = 36 \Omega \checkmark$	$V = IR \checkmark$	$P = I^2 R \checkmark$
	$12 = 0,33R \checkmark$	$4 = (0,33^2)R \checkmark$
	$R = 36,36 \Omega \checkmark$	$R = 36,73 \Omega \checkmark$

(3)

6.1.2 Increase $\checkmark$

(1)

6.1.3 No change $\checkmark$

Same potential difference $\checkmark$ (and resistance)

(2)

6.2.1

$V = IR \checkmark$		
$5 = I(6) \checkmark$		
$\therefore I = 0,83 A$		
$V_{\text{lost}} = Ir$	OR/OF	$\mathcal{E} = I(R + r)$
$1 = (0,83)r \checkmark$		$6 = (0,83)(6 + r) \checkmark$
$r = 1,20 \Omega \checkmark$		$r = 1,23 \Omega \checkmark$

(4)

6.2.2 Work done $\checkmark$ in moving a unit charge $\checkmark$ through a cell.

(2)

6.2.3

POSITIVE MARKING FROM 6.2.1.

OPTION 1	OPTION 2/OPSIE 2
$V_{\text{lost}} = Ir$	$V_{\text{lost}} = Ir$
$1,5 \checkmark = I(1,2)$	$1,5 \checkmark = I(1,2)$
$I = 1,25 A$	$I = 1,25 A$
$V_{\parallel} = I_6 R_6$	$V_{\parallel} = I_p R_p$
$4,5 = I_6(6)$	$4,5 = (1,25)R_p \checkmark$
$I_6 = 0,75 A$	$R_p = 3,6 \Omega$
$V_x = IR_x \checkmark$	$\frac{1}{R_{\parallel}} = \frac{1}{R_x} + \frac{1}{R_6} \checkmark$
$4,5 = (1,25 - 0,75)R_x \checkmark$	$\frac{1}{R_{\parallel}} = \frac{1}{R_x} + \frac{1}{6} \checkmark$
$R_x = 9 \Omega \checkmark$	$\therefore R_{\parallel} = \frac{6R_x}{R_x + 6} = 3,6$
	$R_x = 9 \Omega \checkmark$

(5)

[17]



QUESTION 7

7.1.1 (Maximum) energy provided (work done) by a battery per coulomb/unit charge passing through it. ✓✓ (2)

7.1.2 12 V ✓ (1)

7.1.3 0 V / Zero ✓ (1)

7.1.4 $\left. \begin{aligned} \varepsilon &= I(R + r) \\ \varepsilon &= V_{\text{ext}} + V_{\text{int}} \end{aligned} \right\} \checkmark$
 $12 = 11,7 + Ir$
 $0,3 = I_{\text{tot}}(0,2) \checkmark$
 $I_{\text{tot}} = 1,5 \text{ A} \checkmark$

OR

$V = IR \checkmark$

$0,3 = I_{\text{tot}}(0,2) \checkmark$

$I_{\text{tot}} = 1,5 \text{ A} \checkmark$

(3)

7.1.5 $\left. \begin{aligned} \frac{1}{R_{//}} &= \frac{1}{R_1} + \frac{1}{R_2} \\ \frac{1}{R} &= \frac{1}{10} + \frac{1}{15} \end{aligned} \right\} \checkmark \text{Any one}$
 $R = 6 \Omega \checkmark$

(2)

7.1.6 **POSITIVE MARKING FROM QUESTIONS 7.1.4 AND 7.1.5.**

OPTION 1

$V = IR \checkmark$

$11,7 \checkmark = 1,5(6 + R) \checkmark$

$R = 1,8 \Omega \checkmark$

OR

$V = IR \checkmark$

$11,7 = 1,5R \checkmark$

$R = 7,8 \Omega$

$\downarrow$
 $R_R = 7,8 - 6 \checkmark \checkmark \text{ (for subtraction)}$
 $= 1,8 \Omega \checkmark$

OPTION 2

$\varepsilon = I(R + r) \checkmark$

$12 = 1,5(R + 0,2) \checkmark$

$R = 7,8 \Omega$

$\downarrow$
 $R_R = 7,8 - 6 \checkmark \checkmark \text{ (for subtraction)}$
 $= 1,8 \Omega \checkmark$

OPTION 3/OPSIE 3

$V_{//} = IR_{//} \checkmark$

$= (6)(1,5) \checkmark$

$= 9 \text{ V}$

$V_R = IR \checkmark$

$(11,7 - 9) = (1,5)R \checkmark$

$R = 1,8 \Omega \checkmark$

(4)

7.2

7.2.1 $P_{\text{ave}} = Fv_{\text{ave}} \checkmark = mg(v_{\text{ave}})$
 $= (0,35)(9,8)(0,4) \checkmark$
 $= 1,37 \text{ W} \checkmark$

OR

$P = \frac{W_{\text{nc}}}{\Delta t} \checkmark = \frac{\Delta E_k + \Delta E_p}{\Delta t} = \frac{0 + (0,35)(9,8)(0,4 - 0)}{1} \checkmark = 1,37 \text{ W} \checkmark$

OR

$P = \frac{W}{\Delta t} \checkmark = \frac{E_p}{\Delta t} = \frac{(0,35)(9,8)(0,4)}{1} \checkmark = 1,37 \text{ W} \checkmark$

(3)



7.2.2 POSITIVE MARKING FROM QUESTION 7.2.1.

OPTION 1 $P = VI$ $1,37 = (3)I$ ✓ $I = 0,46 \text{ A}$ $\varepsilon = V_{\text{ext}} + V_{\text{int}}$ $= V_T + V_X + V_{\text{int}}$ $12 = V_T + 3 + (0,2)(0,46)$ ✓ $V_T = 8,91 \text{ V}$ $V_T = IR_T$ $8,91 = (0,46)R_T$ ✓ $R_T = 19,37 \Omega$ ✓	OPTION 2 $P = \frac{V^2}{R}$ $1,37 = \frac{3^2}{R}$ ✓ $R = 6,57 \Omega$ $P = VI$ $1,37 = (3)I$ ✓ $I = 0,46 \text{ A}$ $\varepsilon = I(R + r)$ $12 = 0,46(6,57 + R_T + 0,2)$ ✓ $R_T = 19,38 \Omega$ ✓	
OPTION 3 $P = VI$ ✓ $1,37 = (3)I$ ✓ $I = 0,46 \text{ A}$ $P_{\text{tot}} = P_r + P_{\text{motor}} + P_T$ $(12)(0,46)$ ✓ $= (0,46)^2(0,2) + 1,37 + (0,46)^2 R_T$ ✓ $R_T = 19,41 \Omega$ ✓ OR $P = VI$ ✓ $1,37 = (3)I$ ✓ $I = 0,46 \text{ A}$ $P_{\text{tot}} = P_r + P_{\text{motor}} + P_T$ $(12)(0,46) = (0,46)^2(0,2) + 1,37 + P_T$ ✓ $P_T = 4,07 \text{ W}$ $P = I^2 R$ $4,07 = (0,46)^2 R_T$ ✓ $R_T = 19,49 \Omega$ ✓ (19,33 Ω - 19,49 Ω)		
OPTION 4 $P = VI$ $1,37 = (3)I$ ✓ $I = 0,46 \text{ A}$ $\varepsilon = I(R + r)$ $12 = (0,46)(R + 0,2)$ ✓ $R = 25,87 \Omega$		
$V = IR$ $3 = (0,46)R$ ✓ $R = 6,52 \Omega$ $R_T = 25,87 - 6,52$ $= 19,35 \Omega$ ✓	$P = I^2 R$ $1,37 = (0,46)^2 R$ ✓ $R = 6,47 \Omega$ $R_T = 25,87 - 6,47$ $= 19,4 \Omega$ ✓	$P_{\text{motor}} = \frac{V^2}{R}$ $1,37 = \frac{3^2}{R}$ ✓ $R = 6,56 \Omega$ $R_T = 25,87 - 6,56$ $= 19,31 \Omega$ ✓

(5)
[21]



ELECTRICAL MACHINES

QUESTION 1

- 1.1 Electromagnetic induction ✓ (1)
- 1.2 Rotate the coil faster/Increase the number of coils/ Increase the strength of the magnetic field. ✓ (1)
- 1.3 Slip rings ✓ (1)
- 1.4 It is the value of the voltage in a DC circuit ✓ that will have the same heating effect as an AC circuit. ✓ (2)
- 1.4.2 $V_{rms} = \frac{V_{max}}{\sqrt{2}}$ ✓
 $= \frac{339,45}{\sqrt{2}}$ ✓
 $V_{rms} = 240,03 \text{ V}$ ✓ (3)
- [8]**

QUESTION 2

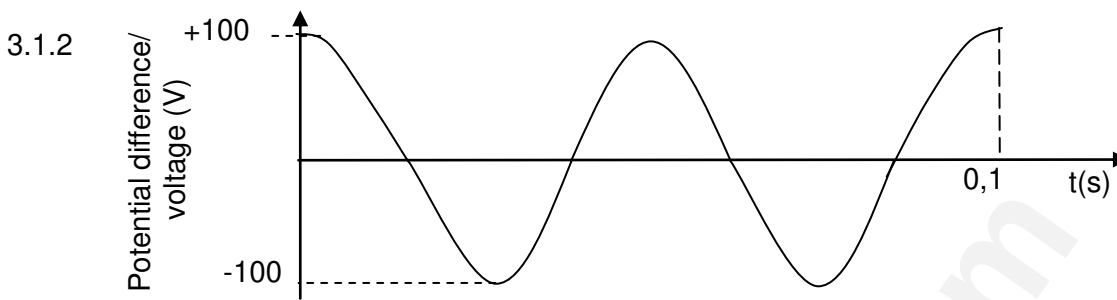
- 2.1
- 2.1.1
- | OPTION 1/OPSIE 1 | OPTION 2/OPSIE 2 |
|---|--|
| $P_{av} = \frac{V_{rms}^2}{R}$ ✓
$100 \checkmark = \frac{\left(\frac{340}{\sqrt{2}}\right)^2}{R}$ ✓
$R = 578 \Omega \checkmark$ | $V_{rms} = \frac{V_{max}}{\sqrt{2}} = \frac{340}{\sqrt{2}} \checkmark = 240,04$
$P_{ave} = \frac{V_{rms}^2}{R}$ ✓
$100 \checkmark = \frac{240,04^2}{R}$ ✓
$R = 578 \Omega \checkmark$ |
- (5)
- 2.1.2
- | OPTION 1/OPSIE 1 | OPTION 2/OPSIE 2 |
|--|--|
| $P_{av} = I_{rms} V_{rms}$ ✓
$100 = I_{rms} \frac{340}{\sqrt{2}}$ ✓
$I_{rms} = \frac{100}{\frac{340}{\sqrt{2}}}$
$= 0,417 \text{ A} \checkmark$ | $V_{rms} = I_{rms} R$ ✓
$\frac{340}{\sqrt{2}} = I_{rms} (578) \checkmark$
$I_{rms} = 0,417 \text{ A} \checkmark$ |
- (3)
- 2.3 Can be stepped up or down/ can be transmitted with less power loss. ✓ (1)
- [9]**



QUESTION 3

3.1.1 Anticlockwise ✓

(1)



Criteria for graph:	
Two full cycles with correct shape.	✓
Showing the maximum voltage.	✓
Showing the time 0,1s for two cycles.	✓

(3)

3.1.3 Decrease the frequency/ speed of rotation ✓

(1)

3.2

$$P_{ave} = V_{rms} I_{rms} \checkmark$$

$$1\,500 = (220)(I_{rms}) \checkmark$$

$$I_{rms} = 6,82\text{ A}$$

$$I_{rms} = \frac{I_{max}}{\sqrt{2}} \checkmark$$

$$I_{max} = (\sqrt{2})(6,82) \checkmark$$

$$= 9,65\text{ A} \checkmark$$

(5)

[10]

QUESTION 4

4.1.1 Move the bar magnet very quickly ✓✓ **OR** up and down inside the coil.

(2)

4.1.2 Electromagnetic induction ✓

(1)

4.1.3 Commutator ✓

(1)

4.2.1

OPTION 1 $P_{average} = \frac{V_{rms}^2}{R} \checkmark$ $= \frac{220^2}{40,33} \checkmark$ $= 1\,200,10\text{ W (J}\cdot\text{s}^{-1}) \checkmark$	$W = \frac{V_{rms}^2}{R} \Delta t \checkmark$ $= \frac{220^2}{40,33} (1) \checkmark$ $= 1\,200,10\text{ J} \checkmark$
OPTION 2 $I_{rms} = \frac{V_{rms}}{R} \checkmark = \frac{220}{40,33} \checkmark = 5,45\text{ A}$ $P_{average} = I_{rms}^2 R$ $= (5,45^2)(40,33) \checkmark$ $= 1\,197,9\text{ W} \checkmark \text{ OR } 1\,200,10\text{ W}$	$I_{rms} = \frac{V_{rms}}{R} \checkmark = \frac{220}{40,33} \checkmark = 5,45\text{ A}$ $W = I_{rms}^2 R \Delta t$ $= (5,45^2)(40,33)(1) \checkmark$ $= 1\,197,9\text{ J} \checkmark \text{ OR } 1\,200,10\text{ J}$
OPTION 3 $I_{rms} = \frac{V_{rms}}{R} \checkmark = \frac{220}{40,33} \checkmark = 5,45\text{ A}$ $P_{average} = V_{rms} I_{rms}$ $= (220)(5,45) \checkmark$ $= 1\,199\text{ W or } 1\,200,10\text{ W} \checkmark$	$I_{rms} = \frac{V_{rms}}{R} \checkmark = \frac{220}{40,33} \checkmark = 5,45\text{ A}$ $W = V_{rms} I_{rms} \Delta t$ $= (220)(5,45)(1) \checkmark$ $= 1\,199\text{ J or } 1\,200,10\text{ J} \checkmark$

(4)

4.2.2 **POSITIVE MARKING FROM 4.2.1.**

OPTION 1 $V_{rms} = \frac{V_{max}}{\sqrt{2}}$ $220 = \frac{V_{max}}{\sqrt{2}}$ $V_{max} = 311,13 \text{ V}$ $I_{max} = \frac{V_{max}}{R} = \frac{311,13}{40,33} \checkmark$ $= 7,71 \text{ A} \checkmark$ OR $P_{ave} = \frac{V_{max} I_{max}}{2}$ $1200,1 = \frac{311,13 I_{max}}{2}$ $I_{max} = 7,71 \text{ A}$	OPTION 2 $P_{average} = V_{rms} I_{rms} \checkmark$ $1200,1 = (220) I_{rms} \checkmark$ $I_{rms} = 5,455 \text{ A}$ $I_{max} = \sqrt{2} (5,455)$ $= 7,71 \text{ A} \checkmark \quad (7,715 \text{ A})$
OPTION 3 $P_{average} = I_{rms}^2 R \checkmark$ $1200,1 = I_{rms}^2 (40,33) \checkmark$ $I_{rms} = 5,455 \text{ A}$ $I_{max} = \sqrt{2} I_{rms}$ $= \sqrt{2} (5,455)$ $= 7,71 \text{ A} \checkmark$	OPTION 4 $V_{rms} = I_{rms} R \checkmark$ $220 = I_{rms} (40,33) \checkmark$ $I_{rms} = 5,455 \text{ A}$ $I_{max} = \sqrt{2} I_{rms}$ $= \sqrt{2} (5,455)$ $= 7,71 \text{ A} \checkmark$

(3)
[11]

QUESTION 5

5.1

5.1.1 North pole ✓

(1)

5.1.2 Q to P ✓

(1)

5.2

5.2.1

OPTION 1/OPSIE 1 $I_{rms} = \frac{I_{max}}{\sqrt{2}} \checkmark$ $I_{rms} = \frac{8}{\sqrt{2}} \checkmark$ $= 5,66 \text{ A}$ $V_{rms} = I_{rms} R \checkmark$ $220 = (5,66) R \checkmark$ $R = 38,87 \Omega \checkmark$	OPTION 2/OPSIE 2 $V_{rms} = \frac{V_{max}}{\sqrt{2}} \checkmark$ $220 = \frac{V_{max}}{\sqrt{2}} \checkmark$ $V_{max} = 311,12 \text{ V}$ $V_{max} = I_{max} R \checkmark$ $311,12 = (8) R \checkmark$ $R = 38,89 \Omega \checkmark$
--	--

(1)



5.2.2

OPTION 1/OPSIE 1	OPTION 2/OPSIE 2	OPTION 3/OPSIE 3
$P_{\text{average}} = V_{\text{rms}} I_{\text{rms}} \checkmark$ $= (220)(5,66) \checkmark$ $= 1\,245,2 \text{ W}$ $P = \frac{W}{\Delta t} \checkmark$ $1245,2 = \frac{W}{7200} \checkmark$ $W = 8\,965\,440 \text{ J} \checkmark$	$P_{\text{average}} = I_{\text{rms}}^2 R \checkmark$ $= (5,66)^2 (38,87) \checkmark$ $= 1\,245,22 \text{ W} \checkmark$ $1245,22 = \frac{W}{7200} \checkmark$ $W = 8\,965\,584 \text{ J} \checkmark$	$P_{\text{average}} = \frac{V_{\text{rms}}^2}{R} \checkmark$ $= \frac{220^2}{38,87} \checkmark$ $= 1245,18 \text{ W}$ $P = \frac{W}{\Delta t} \checkmark$ $1245,18 = \frac{W}{7200} \checkmark$ $W = 8\,965\,296 \text{ J} \checkmark$

(5)
[12]

QUESTION 6

- 6.1.1 a to b ✓ (1)
- 6.1.2 Fleming's left hand rule /Left hand motor rule ✓ (1)
- 6.1.3 Split rings /commutator ✓ (1)
- 6.2.1 Mechanical/Kinetic energy to electrical energy. ✓✓ (2)

6.2.2

OPTION 1	OPTION 2
$V_{\text{rms}} = \frac{V_{\text{max}}}{\sqrt{2}} \checkmark$ $= \frac{430}{\sqrt{2}} \checkmark$ $= 304,06 \text{ V}$ $I = \frac{V}{R} \checkmark$ $= \frac{304,06}{400} \checkmark$ $= 0,76 \text{ A} \checkmark$	$V_{\text{max}} = I_{\text{max}} R \checkmark$ $430 = I_{\text{max}} (400) \checkmark$ $I_{\text{max}} = 1,075$ $I_{\text{rms}} = \frac{I_{\text{max}}}{\sqrt{2}} = \frac{1,075}{\sqrt{2}} \checkmark$ $= 0,76 \text{ A} \checkmark$
OPTION 3	OPTION 4
$V_{\text{rms}} = \frac{V_{\text{max}}}{\sqrt{2}} \checkmark$ $= \frac{430}{\sqrt{2}} \checkmark = 304,06 \text{ V}$ $P_{\text{average}} = \frac{V_{\text{rms}}^2}{R} = \frac{(304,06)^2}{400}$ $= 231,13 \text{ W}$ $P_{\text{ave}} = I_{\text{rms}} V_{\text{rms}} \checkmark$ $231,13 = I_{\text{rms}} (304,06) \checkmark$ $I_{\text{rms}} = 0,76 \text{ A} \checkmark$	$V_{\text{rms}} = \frac{V_{\text{max}}}{\sqrt{2}} \checkmark$ $= \frac{430}{\sqrt{2}} \checkmark = 304,06 \text{ V}$ $P_{\text{average}} = \frac{V_{\text{rms}}^2}{R} = \frac{(304,06)^2}{400}$ $= 231,13 \text{ W}$ $P_{\text{ave}} = I_{\text{rms}}^2 R \checkmark$ $231,13 = I_{\text{rms}}^2 (400) \checkmark$ $I_{\text{rms}} = 0,76 \text{ A} \checkmark$

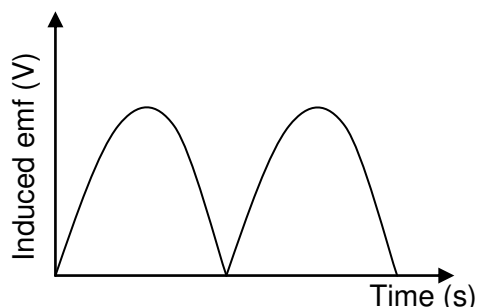
(5)
[10]

QUESTION 7

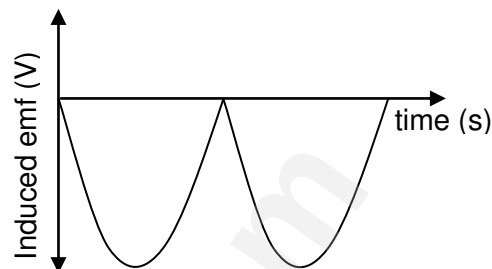
- 7.1.1 DC-generator ✓
Uses split ring/commutator ✓

(2)

7.1.2



OR



Curve starts at zero to first peak. ✓
Shape and one complete DC cycle. ✓

(2)

9.2.1

OPTION 1

$$V_{rms} = \frac{V_{max}}{\sqrt{2}}$$

$$P_{ave} = V_{rms} I_{rms} \checkmark$$

$$800 = \frac{340}{\sqrt{2}} I_{rms} \checkmark$$

$$I_{rms} = 3,33 \text{ A} \checkmark$$

OR

$$V_{rms} = \frac{V_{max}}{\sqrt{2}} = \frac{340}{\sqrt{2}} = 240,416 \text{ V}$$

$$P_{ave} = V_{rms} I_{rms} \checkmark$$

$$800 = I_{rms} (240,416) \checkmark$$

$$I_{rms} = 3,33 \text{ A} \checkmark$$

OPTION 2

$$P_{ave} = \frac{V_{rms}^2}{R} = \frac{V_{max}^2}{2R} \checkmark$$

$$800 = \frac{(340)^2}{(\sqrt{2})^2 R} \checkmark$$

$$R = 72,25 \Omega$$

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

$$I_{rms} = \frac{240,416}{72,25} \checkmark$$

$$= 3,33 \text{ A} \checkmark$$

OR

$$P_{ave} = I_{rms}^2 R$$

$$800 = I_{rms}^2 (72,25) \checkmark$$

$$I_{rms} = 3,33 \text{ A} \checkmark$$

(3)

7.2.2

POSITIVE MARKING FROM QUESTION 7.2.1.

OPTION 1

$$P_{ave} = V_{rms} I_{rms} \checkmark$$

For the kettle:

$$2000 = \frac{340}{\sqrt{2}} I_{rms} \checkmark$$

$$I_{rms} = 8,32 \text{ A}$$

$$I_{tot} = (8,32 + 3,33) \checkmark$$

$$= 11,65 \text{ A} \checkmark$$

OPTION 2

$$P_{ave} = V_{rms} I_{rms} \checkmark$$

$$= \frac{V_{max} I_{max}}{2}$$

$$2\ 800 \checkmark = \frac{340 I_{max}}{2} \checkmark$$

$$I_{max} = 16,47 \text{ A}$$

$$I_{rms} = \frac{I_{max}}{\sqrt{2}} = \frac{16,47}{\sqrt{2}}$$

$$I_{rms} = 11,65 \text{ A} \checkmark$$



7.2.2

OPTION 3 $P_{\text{ave}} = \frac{V_{\text{rms}}^2}{R} \checkmark$ $= \frac{V_{\text{max}}^2}{2R}$ $800 = \frac{(340)^2}{(\sqrt{2})^2 R} \checkmark$ $R = 72,25 \, \Omega$ $2\,000 = \frac{(340)^2}{(\sqrt{2})^2 (R_{2000})}$ $R = 28,9 \, \Omega$ $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$ $V_{\text{rms}} = I_{\text{rms}} R$ $240,42 = I_{\text{rms}} (20,64) \checkmark$ $I_{\text{rms}} = 11,65 \, \text{A} \checkmark$	OPTION 4 $P_{\text{ave}} = V_{\text{rms}} I_{\text{rms}} \checkmark$ $2\,800 \checkmark = \frac{340}{\sqrt{2}} I_{\text{rms}} \checkmark$ $I_{\text{rms}} = 11,65 \, \text{A} \checkmark$ OPTION 5 $P_T : P_K$ $800 : 2\,000 \checkmark$ $1 : 2,5$ $I_T : I_K$ $3,33 : 8,325 \checkmark$ $I_{\text{rms}} = 3,33 + 8,325 \checkmark$ $= 11,66 \, \text{A} \checkmark$
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(4)
[11]



OPTICAL PHENOMENA AND PROPERTIES OF MATERIALS

QUESTION 1

- 1.1 The minimum frequency of light needed to emit electrons ✓ from (the surface of) a metal. ✓ (2)

- 1.2 **OPTION 1**
- $$\left. \begin{aligned} E &= W_0 + E_{k(\max)} \\ E &= W_0 + \frac{1}{2}mv_{\max}^2 \\ h\frac{c}{\lambda} &= hf_0 + \frac{1}{2}mv_{\max}^2 \end{aligned} \right\} \checkmark \text{Any one}$$
- $$\frac{(6,63 \times 10^{-34})(3 \times 10^8)}{\lambda} \checkmark = (6,63 \times 10^{-34})(5,548 \times 10^{14}) \checkmark + \frac{1}{2}(9,11 \times 10^{-31})(5,33 \times 10^5)^2 \checkmark$$
- $$\lambda = 4 \times 10^{-7} \text{ m} \checkmark \quad (5)$$

- 1.3 Smaller (less) than ✓ (1)

- 1.4 The wavelength/frequency/energy of the incident light (photon/hf) is constant. ✓
Since the speed is higher, the kinetic energy is higher ✓ and the work function / W_0 / threshold frequency smaller. ✓ (3)
[11]

QUESTION 2

- 2.1 The minimum energy needed to emit an electron ✓ from (the surface of) a metal. ✓ (2)

- 2.2
- $$\left. \begin{aligned} E &= W_0 + \frac{1}{2}mv_{\max}^2 \\ h\frac{c}{\lambda} &= W_0 + \frac{1}{2}mv_{\max}^2 \end{aligned} \right\} \text{Any ONE OF/ENIGE EEN van} \checkmark$$
- $$\frac{(6,63 \times 10^{-34})(3 \times 10^8)}{(\lambda)} \checkmark = (3,36 \times 10^{-19}) + 2,32 \times 10^{-19} \checkmark$$
- $$\lambda = 3,50 \times 10^{-7} \text{ m} \checkmark \quad (4)$$

- 2.3
- $$\left. \begin{aligned} E &= W_0 + \frac{1}{2}mv_{\max}^2 \\ \text{OR/OF} \\ h\frac{c}{\lambda} &= W_0 + \frac{1}{2}mv_{\max}^2 \end{aligned} \right\} \checkmark$$
- $$\frac{(6,63 \times 10^{-34})(3 \times 10^8)}{(3,50 \times 10^{-7})} \checkmark = (3,65 \times 10^{-19}) + E_k$$
- $$E = 2,03 \times 10^{-19} \text{ J} \checkmark \quad (4)$$

- 2.4
- 2.4.1 Increasing the intensity does not change the energy / frequency / wavelength of the incident photons. ✓
OR The energy of a photon remains unchanged (for the same frequency). (1)

- 2.4.2 Increases ✓ (1)

- 2.4.3 More photons (packets of energy) strike the surface of the metal per unit time. ✓ Hence more (photo) electrons ejected per unit time ✓ (leading to increased current). (2)

[14]



QUESTION 3

3.1.1 The particle nature of light. ✓ (1)

3.1.2 Shorter wavelength means higher photon energy. ✓

Photon energy is inversely proportional to wavelength ✓ ($E = \frac{hc}{\lambda}$).

For the same metal, kinetic energy is proportional to photon energy.

OR

Shorter wavelength means higher frequency. ✓

Higher frequency means higher photon energy ✓ ($E = hf$).

For the same metal, kinetic energy is proportional to photon energy. (2)

3.2.1

OPTION 1

$$W_0 = h \frac{c}{\lambda_0} \checkmark$$

$$= \frac{(6,63 \times 10^{-34})(3 \times 10^8)}{330 \times 10^{-9}} \checkmark$$

$$W_0 = 6,03 \times 10^{-19} \text{ J } \checkmark$$

OPTION 2

$$c = f\lambda$$

$$3 \times 10^8 = f_0(330 \times 10^{-9}) \checkmark$$

$$f_0 = 9,09 \times 10^{14} \text{ Hz} \quad \checkmark \text{ for both equations}$$

$$W_0 = hf_0$$

$$= (6,63 \times 10^{-34})(9,09 \times 10^{14}) \checkmark$$

$$= 6,03 \times 10^{-19} \text{ J } \checkmark$$

(4)

3.2.2

POSITIVE MARKING FROM QUESTION 3.2.1.

OPTION 1

$$\left. \begin{aligned} E &= W_0 + E_k \\ hf &= hf_0 + E_k \\ hf &= hf_0 + \frac{1}{2}mv^2 \\ E &= W_0 + \frac{1}{2}mv^2 \end{aligned} \right\} \checkmark \text{ Any one}$$

$$(6,63 \times 10^{-34})(1,2 \times 10^{15}) \checkmark = (6,03 \times 10^{-19}) \checkmark + \frac{1}{2}(9,11 \times 10^{-31})v^2 \checkmark$$

$$\therefore v = 6,5 \times 10^5 \text{ m} \cdot \text{s}^{-1} \checkmark$$

OPTION 2

$$\left. \begin{aligned} E_k &= E_{\text{light/lig}} - W_0 \\ &= hf_{\text{light/lig}} - hf_0 \end{aligned} \right\} \checkmark \text{ Any one}$$

$$= (6,63 \times 10^{-34})(1,2 \times 10^{15}) \checkmark - 6,03 \times 10^{-19} \checkmark$$

$$= 1,926 \times 10^{-19} \text{ J}$$

$$E_k = \frac{1}{2}mv^2$$

$$1,926 \times 10^{-19} = \frac{1}{2}(9,11 \times 10^{-31})v^2 \checkmark$$

$$\therefore v = 6,5 \times 10^5 \text{ m} \cdot \text{s}^{-1} \checkmark$$

(5)
[12]

QUESTION 4

4.1 It is the process whereby electrons are ejected from a metal surface when light (of suitable frequency) is incident on it. ✓✓

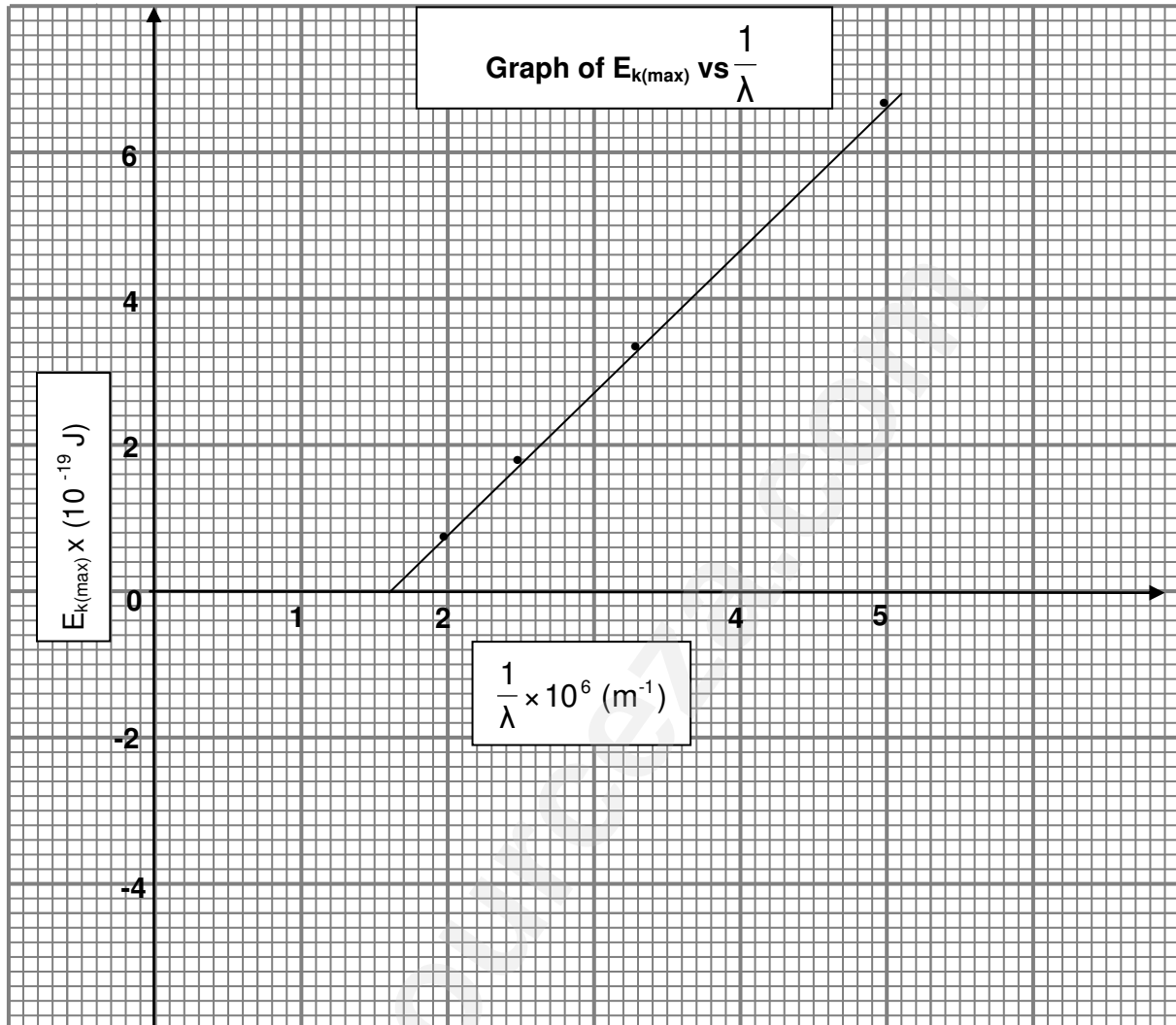
OR

It is the phenomenon that occurs when light of (suitable frequency), incident on a metal surface, ejects electrons ✓✓ (from the metal surface).

(2)



4.2



Criteria for drawing line of best fit:	
ALL points correctly plotted (at least 3 points)	✓✓
Correct line of best fit if all plotted points are used.	✓

(3)

4.3.1 **POSITIVE MARKING FROM 4.2.**

OPTION 1

$$\frac{1}{\lambda} = 1,6 \times 10^6 \text{ m}^{-1} \quad (\text{Accept } 1,6 \times 10^6 \text{ m}^{-1} \text{ to/tot } 1,7 \times 10^6 \text{ m}^{-1})$$

$$f_o = c \frac{1}{\lambda} \checkmark$$

$$= (3 \times 10^8)(1,6 \times 10^6) \checkmark$$

$$= 4,8 \times 10^{14} \text{ Hz} \checkmark \quad (\text{Accept } 4,8 \times 10^{14} \text{ Hz to/tot } 5,1 \times 10^{14} \text{ Hz})$$

OPTION 2

By extrapolation: y-intercept = $-W_o$

$$W_o = hf_o \checkmark$$

$$3,2 \times 10^{-19} \checkmark = (6,63 \times 10^{-34})f_o \checkmark$$

$$f_o = 4,8 \times 10^{14} \text{ Hz} \checkmark \quad (\text{Accept } 4,8 \times 10^{14} \text{ Hz to/tot } 4,83 \times 10^{14} \text{ Hz})$$

(4)



4.3.1

OPTION 3 (Points from the graph)

$$E = W_0 + E_{k(max)}$$

$$\frac{hc}{\lambda_0} = hf_0 + E_{k(max)} \checkmark$$

$$(6,63 \times 10^{-34})(3 \times 10^8)(1,6 \times 10^6) = (6,63 \times 10^{-34})f_0 + 0 \quad \checkmark$$

$$f_0 = 4,8 \times 10^{14} \text{ Hz} \quad \checkmark$$

OR

$$(6,63 \times 10^{-34})(3 \times 10^8)(5 \times 10^6) = (6,63 \times 10^{-34})f_0 + 6,6 \times 10^{-19}$$

$$f_0 = 4,92 \times 10^{14} \text{ Hz}$$

OR

$$(6,63 \times 10^{-34})(3 \times 10^8)(3,3 \times 10^6) = (6,63 \times 10^{-34})f_0 + 3,3 \times 10^{-19}$$

$$f_0 = 4,8 \times 10^{14} \text{ Hz}$$

OR

$$(6,63 \times 10^{-34})(3 \times 10^8)(2,5 \times 10^6) = (6,63 \times 10^{-34})f_0 + 1,7 \times 10^{-19}$$

$$f_0 = 4,94 \times 10^{14} \text{ Hz}$$

OR

$$(6,63 \times 10^{-34})(3 \times 10^8)(2,2 \times 10^6) = (6,63 \times 10^{-34})f_0 + 0,7 \times 10^{-19}$$

$$f_0 = 5,54 \times 10^{14} \text{ Hz}$$

(4)

4.3.2

POSITIVE MARKING FROM 4.2.

OPTION 1

$$hc = \text{gradient} \checkmark = \frac{\Delta y}{\Delta x}$$

$$= \frac{6,6 \times 10^{-19}}{(5 - 1,6) \times 10^6} \checkmark$$

$$= 1,941 \times 10^{-25} \text{ (J.m)}$$

$$h = \frac{\text{gradient}}{c}$$

$$h = \frac{1,941 \times 10^{-25}}{3 \times 10^8} \checkmark$$

$$= 6,47 \times 10^{-34} \text{ J.s} \quad \checkmark$$

OPTION 2

$$W_0 = y \text{ intercept} \quad \checkmark$$

$$= 3,2 \times 10^{-19} \text{ J}$$

Accept

$$3,2 \times 10^{-19} \text{ J to } 3,4 \times 10^{-19} \text{ J}$$

$$W_0 = hf_0$$

$$3,2 \times 10^{-19} \checkmark = h(4,8 \times 10^{14}) \quad \checkmark$$

$$h = 6,66 \times 10^{-34} \text{ J.s} \quad \checkmark$$

Accept

$$6,66 \times 10^{-34} \text{ J.s to } 7,08 \times 10^{-34} \text{ J.s}$$

OPTION 3 (Points from the graph)

$$\frac{hc}{\lambda} = W_0 + K_{max} = 3,2 \times 10^{-19} \checkmark + 6,6 \times 10^{-19} \quad \checkmark$$

$$h = \frac{9,8 \times 10^{-19}}{(3 \times 10^8)(5 \times 10^6)} \checkmark = 6,53 \times 10^{-34} \text{ J.s} \quad \checkmark$$

OR

$$\frac{hc}{\lambda} = W_0 + K_{max} = 3,2 \times 10^{-19} \checkmark + 3,3 \times 10^{-19} \quad \checkmark$$

$$h = \frac{6,5 \times 10^{-19}}{(3 \times 10^8)(3,3 \times 10^6)} \checkmark = 6,57 \times 10^{-34} \text{ J.s} \quad \checkmark$$

OR

$$\frac{hc}{\lambda} = W_0 + K_{max} = 3,2 \times 10^{-19} \checkmark + 1,7 \times 10^{-19} \quad \checkmark$$

$$h = \frac{4,7 \times 10^{-19}}{(3 \times 10^8)(2,5 \times 10^6)} \checkmark = 6,27 \times 10^{-34} \text{ J.s} \quad \checkmark$$

OPTION 4

$$W_0 = \frac{hc}{\lambda} \quad \checkmark$$

$$3,2 \times 10^{-19} \checkmark = h(3 \times 10^8)(1,6 \times 10^6) \checkmark$$

$$h = 6,66 \times 10^{-34} \text{ J.s} \quad \checkmark$$

(4)

[13]

QUESTION 5

5.1 The minimum energy needed to emit an electron ✓ from (the surface of) a metal. ✓ (2)

5.2 Frequency / Intensity ✓ (1)

5.3 The minimum frequency (of a photon/light) needed to emit electrons ✓ from (the surface of) a metal. (substance). ✓ (2)

5.4
$$\left. \begin{aligned} E &= W_0 + E_k \\ hf &= hf_0 + E_k \end{aligned} \right\} \checkmark \text{ Any one/Enige een}$$

$$(6,63 \times 10^{-34})(6,50 \times 10^{14}) \checkmark = (6,63 \times 10^{-34})(5,001 \times 10^{14}) \checkmark + \frac{1}{2}(9,11 \times 10^{-31})v^2 \checkmark$$

$$\therefore v = 4,67 \times 10^5 \text{ m} \cdot \text{s}^{-1} \checkmark$$

OR/OF

$$\left. \begin{aligned} E_k &= E_{\text{light}} - W_0 \\ &= hf_{\text{light}} - hf_0 \end{aligned} \right\} \checkmark \text{ Any one/Enige een}$$

$$= (6,63 \times 10^{-34})(6,50 \times 10^{14} - 5,001 \times 10^{14}) \checkmark$$

$$= 9,94 \times 10^{-20} \text{ J}$$

$$E_k = \frac{1}{2}mv^2 \checkmark$$

$$v = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{(2)(9,94 \times 10^{-20})}{9,11 \times 10^{-31}}} \checkmark$$

$$v = 4,67 \times 10^5 \text{ m} \cdot \text{s}^{-1} \checkmark$$

(5)

5.5 The photocurrent is directly proportional to the intensity of the incident light. ✓✓ (2)

[12]

QUESTION 6

6.1.1 Light has a particle nature. ✓ (1)

6.1.2 Remain the same. ✓

For the same colour/ frequency/wavelength the energy of the photons will be the same. ✓ (The brightness causes more electrons to be released, but they will have the same maximum kinetic energy.)

OR

Intensity only affects the number of ejected photo-electrons and not the maximum kinetic energy or maximum speed of the ejected photo-electrons

OR

Maximum kinetic energy of ejected photo-electrons is independent of intensity of radiation. (2)

6.1.3
$$\left. \begin{aligned} E &= W_0 + E_k \\ hf &= hf_0 + E_k \\ hf &= hf_0 + \frac{1}{2}mv^2 \\ E &= W_0 + \frac{1}{2}mv^2 \end{aligned} \right\} \checkmark \text{ Any one}$$

$$\frac{(6,63 \times 10^{-34})(3 \times 10^8)}{420 \times 10^{-9}} \checkmark = \frac{(6,63 \times 10^{-34})(3 \times 10^8)}{\lambda_0} \checkmark + \frac{1}{2}(9,11 \times 10^{-31})(4,76 \times 10^5)^2 \checkmark$$

$$\lambda_0 = 5,37 \times 10^{-7} \text{ m}$$

$$\therefore \text{the metal is sodium} \checkmark$$
 (5)

- 6.2 **Q**✓ and **S** ✓
Emission spectra occur when excited atoms /electrons drop from higher energy levels to lower energy levels. ✓✓
(Characteristic frequencies are emitted.)

(4)
[12]

QUESTION 7

- 7.1.1 The minimum frequency (of a photon/light) needed✓ to emit electrons from (the surface of) a metal. (substance). ✓

(2)

- 7.1.2 Silver ✓
Threshold frequency / cutoff frequency (of Ag) is higher. ✓
 $W_o \propto f_o / W_o = hf_o$ ✓

(3)

- 7.1.3 Planck's constant ✓

(1)

- 7.1.4 Sodium ✓

(1)

- 7.2.1 Energy radiated per second by the blue light = $(\frac{5}{100})(60 \times 10^{-3})$ ✓ = $3 \times 10^{-3} \text{ J} \cdot \text{s}^{-1}$

$$E_{\text{photon}} = \frac{hc}{\lambda} \checkmark$$

$$= \frac{(6,63 \times 10^{-34})(3 \times 10^8)}{470 \times 10^{-9}} \checkmark = 4,232 \times 10^{-19} \text{ J}$$

$$\text{Total number of photons incident per second} = \frac{3 \times 10^{-3}}{4,232 \times 10^{-19}} \checkmark = 7,09 \times 10^{15} \checkmark$$

(5)

- 7.2.2 **POSITIVE MARKING FROM QUESTION 7.2.1.**

$7,09 \times 10^{15}$ (electrons per second) ✓

OR

Same number as that calculated in Question 7.2.1 above.

(1)
[13]

BIBLIOGRAPHY

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