JENN
Training and Consultancy
The path to enlightened education

Province of the
EASTERN CAPE
EDUCATION

PHYSICAL SCIENCES

2025 LAST PUSH

GRADE 12

GUIDE FOR TEACHERS AND LEARNERS

JENN

Training and Consultancy

The path to enlightened education

SUBJECT: PHYSICAL SCIENCES

GRADE 12

TERM 1

TEACHER AND LEARNER CONTENT MANUAL

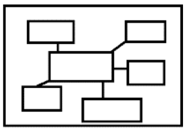
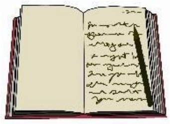
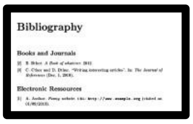
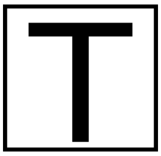
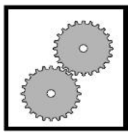
Topic(s)

1. Newton's Laws of Motion

CONTENTS **PAGE**

CONTENTS PAGE

ICON DESCRIPTION

 MIND MAP	 EXAMINATION GUIDELINE	 CONTENTS	 ACTIVITIES
 BIBLIOGRAPHY	 TERMINOLOGY	 WORKED EXAMPLES	 STEPS

DATA FOR PHYSICAL SCIENCES GRADE 12 PAPER 1 (PHYSICS)

TABLE 1: PHYSICAL CONSTANTS*:*

NAME/*NAAM*	SYMBOL/*SIMBOOL*	VALUE/*WAARDE*
Acceleration due to gravity *Swaartekrag versnelling*	g	9,8 $m \cdot s^{-2}$
Gravitational constant *Swaartekrag konstante*	G	$6,67 \times 10^{-11}$ $N \cdot m^2 \cdot kg^{-2}$
Radius of Earth *Straal van Aarde*	RE	$6,38 \times 10^6$ m
Coulomb's constant *Coulomb se konstante*	K	$9,0 \times 10^9$ $N \cdot m^2 \cdot C^{-2}$
Speed of light in a vacuum *Spoed van lig in 'n vakuum*	c	$3,0 \times 10^8$ $m \cdot s^{-1}$
Charge on electron *Lading op electron*	e	$-1,6 \times 10^{-19}$ C
Electron mass *Elektron massa*	me	$9,11 \times 10^{-31}$ kg

TABLE 2: FORMULAE/*TABEL 2:*

MOTION

$v_f = v_i + a\Delta t$	$\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2$ or/*of* $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$
$v_f^2 = v_i^2 + 2a\Delta x$ or/*of* $v_f^2 = v_i^2 + 2a\Delta y$	$\Delta x = \left(\frac{v_i + v_f}{2}\right)\Delta t$ or/*of* $\Delta y = \left(\frac{v_i + v_f}{2}\right)\Delta t$

FORCE

$F_{net} = ma$	p = mv
$F_{net}\Delta t = m\Delta v$ $\Delta p = mv_f - mv_i$	$w = mg$
$F = \frac{Gm_1m_2}{r^2}$	$g = \frac{GM}{r^2}$
$\mu_k = \frac{f_k}{N}$	$\mu_s = \frac{f_{s(maks)}}{N}$

WORK ENERGY AND POWER

$W = F\Delta x\cos\theta$	$U = mgh$ or/*of* $E_p = mgh$
$K = \frac{1}{2}mv^2$ or/*of* $E_k = \frac{1}{2}mv^2$	$W_{net} = \Delta K$ or/*of* $W_{net} = \Delta E_k$ $\Delta K = K_f - K_i$ or/*of* $\Delta E_k = E_{kf} - E_{ki}$
$W_{nc} = \Delta K + \Delta U$ or/*of* $W_{nc} = \Delta E_k + \Delta E_p$	$P = \frac{W}{\Delta t}$
$P_{ave} = Fv_{ave}$	

WAVES, SOUND AND LIGHT

$v = f\lambda$	$T = \frac{1}{f}$
$f_L = \frac{v \pm v_L}{v \pm v_s} f_s$	$E = hf$ or/*of* $E = \frac{hf}{\lambda}$
$E = W_o + K_{max}$ or/*of* $E = W_o + E_{k(max)}$ where $E = hf$ and $W_0 = hf_0$ and $K_{max} = \frac{1}{2}mv^2_{max}$ or/*of* $E_{k(max)} = \frac{1}{2}mv^2_{max}$	

ELECTROSTATICS

$F = \frac{kQ_1Q_2}{r^2}$ (k =9,0 x 10^9 N·m²·C⁻²)	$E = \frac{kQ}{r^2}$ (k =9,0 x 10^9 N·m²·C⁻²)

$E = \frac{F}{q}$	$V = \frac{W}{q}$
$n = \frac{Q}{e}$ of/*or* $n = \frac{Q}{q_e}$	

ELECTRIC CIRCUITS

$R = \frac{V}{I}$	$emk(\varepsilon) = I(R + r)$
$R = r_1 + r_2 + r_3 + \ldots$ $\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \ldots$	$q = I\Delta t$
$W = Vq$ $W = VI\Delta t$ $W = I^2R\Delta t$ $W = \frac{V^2\Delta t}{R}$	$P = \frac{W}{\Delta t}$ $P = VI$ $P = I^2R$ $P = \frac{V^2}{R}$

ALTERNATING CURRENT

$I_{rms} = \frac{I_{max}}{\sqrt{2}}$ $V_{rms} = \frac{V_{max}}{\sqrt{2}}$	$P_{ave} = V_{rms}I_{rms}$ $P_{ave} = I_{rms}^2R$ $P_{ave} = \frac{V_{rms}^2}{R}$

NEWTON'S LAWS: EXAMINATION GUIDELINES

Different kinds of forces: weight, normal force, frictional force, applied force (push or pull), tension (strings or cables)

- Define *normal force,* N, as the force or component of a force which the surface exerts on an object with which it is contact, and which is perpendicular to the surface.
- Define *frictional force, f,* as the force that opposes the motion of an object and which acts parallel to the surface.
  Define *static friction,* f_s, as the force that opposes the tendency of motion of a stationary object relative to a surface.
  Define *kinetic frictional,* f_k, as the force that opposes the motion of a moving object relative to the surface.
  Know that a frictional force:
    - Is proportional to the normal force.
    - Is independent of the area of contact.
    - Is independent of the velocity of motion.
- Solve problems using $f_s^{max} = \mu_k N$ where f_s^{max} is the maximum static frictional force and μ_s is the coefficient of static friction.
  NOTE:
    - If the force, F, applied to a body parallel to the surface does not cause the object to move, F is equal in magnitude to the static frictional force.
    - The static frictional force is a maximum (f_s^{max}) just before the object starts to move across the surface.
    - If the applied force exceed f_s^{max} , a resultant net force accelerate the object.
- Solve problems using $f_k = \mu_k N$, where f_k is the kinetic frictional force and μ_k the coefficient of kinetic friction.

Force diagrams, free-body diagrams

- Draw force diagrams.
- Draw free-body diagrams. (This is a diagram that shows the relative magnitudes and directions of the forces acting on a body/particle that has been isolated from its surroundings)
- Resolve two-dimensional forces (such as the weight on an object on an inclined plane) into its parallel (x) and perpendicular (y) components.
- Determine the resultant or net force of two or more forces.

Newton's first, second and third laws of motion.

- State 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.
- Discuss why it is important to wear a seatbelt using Newton's first law of motion.
- State Newton's second law of motion: When a net force acts on an object, the object will accelerate in the direction of the net force and acceleration is directly proportional to the force and inversely proportional to the mass of the object.

- Draw force diagrams and free-body diagram for object that are in equilibrium or accelerating.
- Apply Newton's laws to variety of equilibrium and non-equilibrium problems including:
    - A single object:
        - Moving on horizontal plane with or without friction
        - Moving on an inclined plane with and without friction
        - Moving in the vertical plane (lifts, rockets, etc)
    - Two-body systems (joined by a light inextensible string) by applying Newton's laws of motion separately to EACH of the bodies:
        - Both on the horizontal plane with and without friction
        - One on a horizontal plane with and without friction, and a second hanging vertically from a string over a frictionless pulley
        - Both on an inclined plane with or without friction
        - Both hanging vertically from a string over frictionless pulley.
- State Newton's third law of motion: When object A exert a force on object B, object B SIMULTANEOUSLY exert an oppositely directed force of equal magnitude on object A
- Identify action-reaction pairs.
- List the properties of action reaction pairs.

Newton's Law of Universal Gravitation

- State Newton's Law of Universal Gravitation: Each body in the universe attract every other body with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distances between their centres.
- Solve problems using $F = \frac{Gm1m2}{r2}$
- Describe weight as a gravitational force the earth exert on any object on or near its surface.
- Calculate weight using the expression w = mg.
- Calculate weight of an object on other planets with different values of gravitational acceleration
- Distinguish between *weight* and *mass.*
- Explain *weightlessness.*

IMPORTANT TERMS AND DEFINITIONS

T

NEWTON'S LAWS OF MOTION	
NORMAL FORCE: N	The force or the component of a force in which a surface exerts on an object with which it is in contact, and that is perpendicular to the surface.
KINETIC FRICTIONAL FORCE: fk	The force that opposes the motion of a moving object relative to a surface
STATIC FRICTIONAL FORCE: f_s^{max}	The force that opposes the tendency of a motion of a stationary object relative to a surface.
NEWTON'S FIRST LAW OF MOTION:	A body will remain in a state of rest or motion at constant velocity unless a non-zero resultant/net force acts on it.
NEWTON'S SECOND LAW OF MOTION:	When a net force acts on an object, the object will accelerate in the direction of the force and the acceleration is directly proportional to the force and inversely proportional to the mass of the object.
NEWTON'S THIRD LAW OF MOTION:	When object A exerts a force on object B, object B simultaneously exert oppositely directed force of equal magnitude on object A.
NEWTON'S LAW OF UNIVERSAL GRAVITATION:	Each body in the universe attracts every other body with the force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.
WEIGHT:	The gravitational force the Earth exerts on any object on or near its surface measured in Newton (N).
MASS:	The amount of matter in a body measured in kilogram (kg).
INERTIA:	The resistance of a body to change in its state of uniform motion or rest
WEIGHTLESSNESS:	The sensation experienced when all contact forces are removed

DATA FOR PHYSICAL SCIENCES GRADE 12
PAPER 1 (PHYSICS)

TABLE 1: PHYSICAL CONSTANTS/*TABEL 1: FISIESE KONSTANTES*

NAME/*NAAM*	SYMBOL/*SIMBOOL*	VALUE/*WAARDE*
Acceleration due to gravity *Swaartekragversnelling*	g	9,8 $m \cdot s^{-2}$
Universal gravitational constant *Universele gravitasiekonstante*	G	6,67 x 10^{-11} $N \cdot m^2 \cdot kg^{-2}$
Radius of the Earth *Radius van die Aarde*	RE	6,38 x 10^6 m
Mass of the Earth *Massa van die Aarde*	ME	5,98 x 10^{24} kg
Speed of light in a vacuum *Spoed van lig in 'n vakuum*	c	3,0 x 10^8 $m \cdot s^{-1}$

FORCE/*KRAG*

$F_{net} = ma$	$p = mv$
$f_s^{max} = \mu_s N$	$f_k = \mu_k N$
$F_{net}\Delta t = \Delta p$ $\Delta p = mv_f - mv_i$	$w = mg$
$F = G\frac{m_1 m_2}{d^2}$ or/*of* $F = G\frac{m_1 m_2}{r^2}$	$g = G\frac{M}{d^2}$ or/*of* $g = G\frac{M}{r^2}$

CONTENT

Key concepts

- Important definitions & Laws
- Free-body diagrams
- Calculations:
    - Normal force
    - Frictional force
    - Acceleration
    - Tension
    - Components of Force applied and gravitational force.
- Law of Universal Gravitation
    - Calculation of Gravitational force
    - Calculation of Gravitational acceleration

Quantity Name	Quantity Symbol	Unit Name	Unit Symbol
Normal force	N	Newtons	N
Frictional Force	f	Newtons	N
Kinetic Friction	fk	Newtons	N
Maximum Static friction	f_s^{max}	Newtons	N
Tension	T	Newtons	N
Net Force	Fnet	Newtons	N
Mass	m	Kilograms	Kg
Acceleration	a	Metres per second squared	$m.s^{-2}$
Coefficient of friction	μ	No unit	

FRICTION FORCE AND NORMAL FORCE

NORMAL FORCE (N)

The force or the component of a force in which a surface exerts on an object with which it is in contact, and that is perpendicular to the surface.

- **Normal force** is the force exerted by a flat surface on an object with which it is in contact.

- Always acts perpendicular (at right angle, 90^0) to the surface.

- **Normal force** equal to the gravitational force Fg, or the net of Fg and other forces acting perpendicular to the surface.

FRICTIONAL FORCE (f)

- **Frictional Force** is caused by one surface tending to move over another, while in contact

- Resist the movement of an object.

    - Prevents it from moving.
    - Or makes it move slower.

KINETIC FRICTIONAL FORCE

(f_k)

$$f_k = \mu_k N$$

f_k − *kinetic frictional force* (N)
μ_k − *coefficient of kinetic frictional force* (no unit)
N − *Normal force*(N)

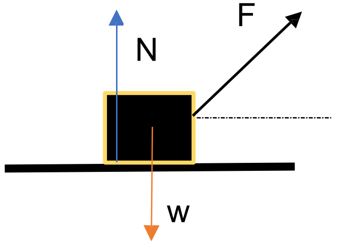
MAXIMUM STATIC FRICTIONAL FORCE (f_s^{max})

$$f_s^{max} = \mu_k N$$

f_s^{max} − *Static frictional force* (N)
μ_s − *coefficient of Static frictional force* (no unit)
N − *Normal force*(N)

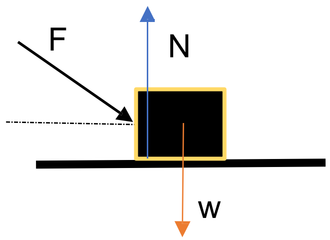
Normal force qual to gravitational force or the net of Fg and other forces acting perpendicular to the surface.

$$F_{net} = ma = 0$$
$$N + (-w) = 0$$
$$N = w$$
$$N = mg$$
$$f_k = \mu_k N$$
$$f_k = \mu_k mg$$

<table>
<tr>
<td>PULLING at an angle</td>
<td>PUSHING at an angle</td>
<td>For an object on the inclined plane Normal force will equal the magnitude of perpendicular component of weight (w⊥)</td>
</tr>
<tr>
<td>


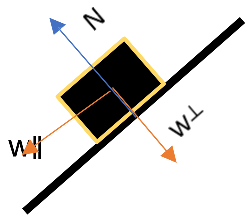
$F_{net} = ma = 0$
$N + F_y + (-w) = 0$
$N = w - F_y$
$N = mg - Fsin\theta$
$f_k = \mu_k N$
$f_k = \mu_k(mg - Fsin\theta)$

When the angle is increased, the normal will decrease, hence the frictional force will also decrease.
When the angle is decreased, the normal force will increase, hence the frictional force will also increase.

</td>
<td>


$F_{net} = ma = 0$
$N + (-F_y) + (-w) = 0$
$N = w + F_y$
$N = mg + Fsin\theta$
$f_k = \mu_k N$
$f_k = \mu_k(mg - F_a sin\theta)$

When the angle is increased, the normal will increase, hence the frictional force will also increase.
When the angle is decreased, the normal force will decrease, hence the frictional force will also decrease.

</td>
<td>


$F_{net} = ma = 0$
$N + (-w_\perp) = 0$
$N = w_\perp$
$N = wcos\theta$
$N = mgcos\theta$
$f_k = \mu_k N$
$f_k = \mu_k(mgcos\theta)$

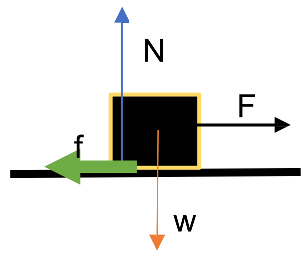
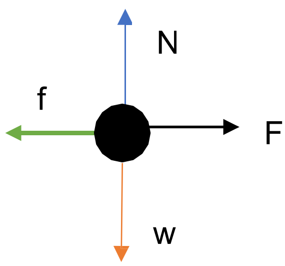
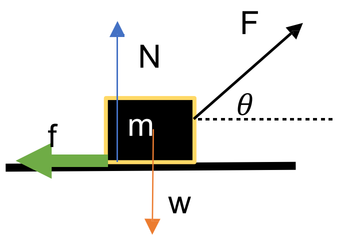
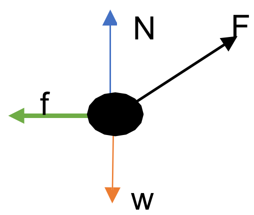
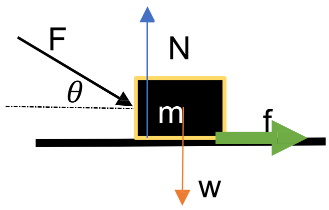
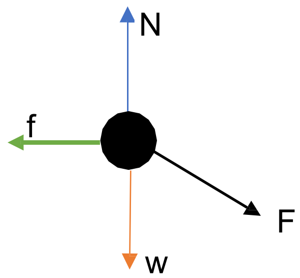
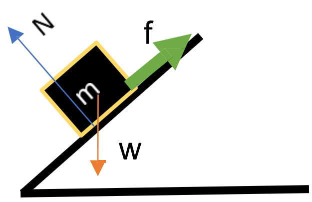
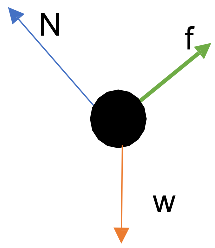
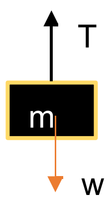
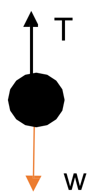
When an angle is increased, the normal force will decrease, hence the frictional force will also decrease.
When an angle is decreased, the normal force will increase, hence the frictional force will also increase.

</td>
</tr>
</table>

Any change made on an angle will affect the co-efficient of kinetic friction

FORCE DIAGRAM AND FREE BODY DIAGRAM

- **A free body diagram** is a picture of an object of interest drawn as a dot and all the forces acting on it are drawn as arrows pointing away from the dot (**in a free body diagram the object is represented by a dot**)
- **Force diagram**: force diagram is a representation of all the forces acting on the object. It is drawn as an arrow.

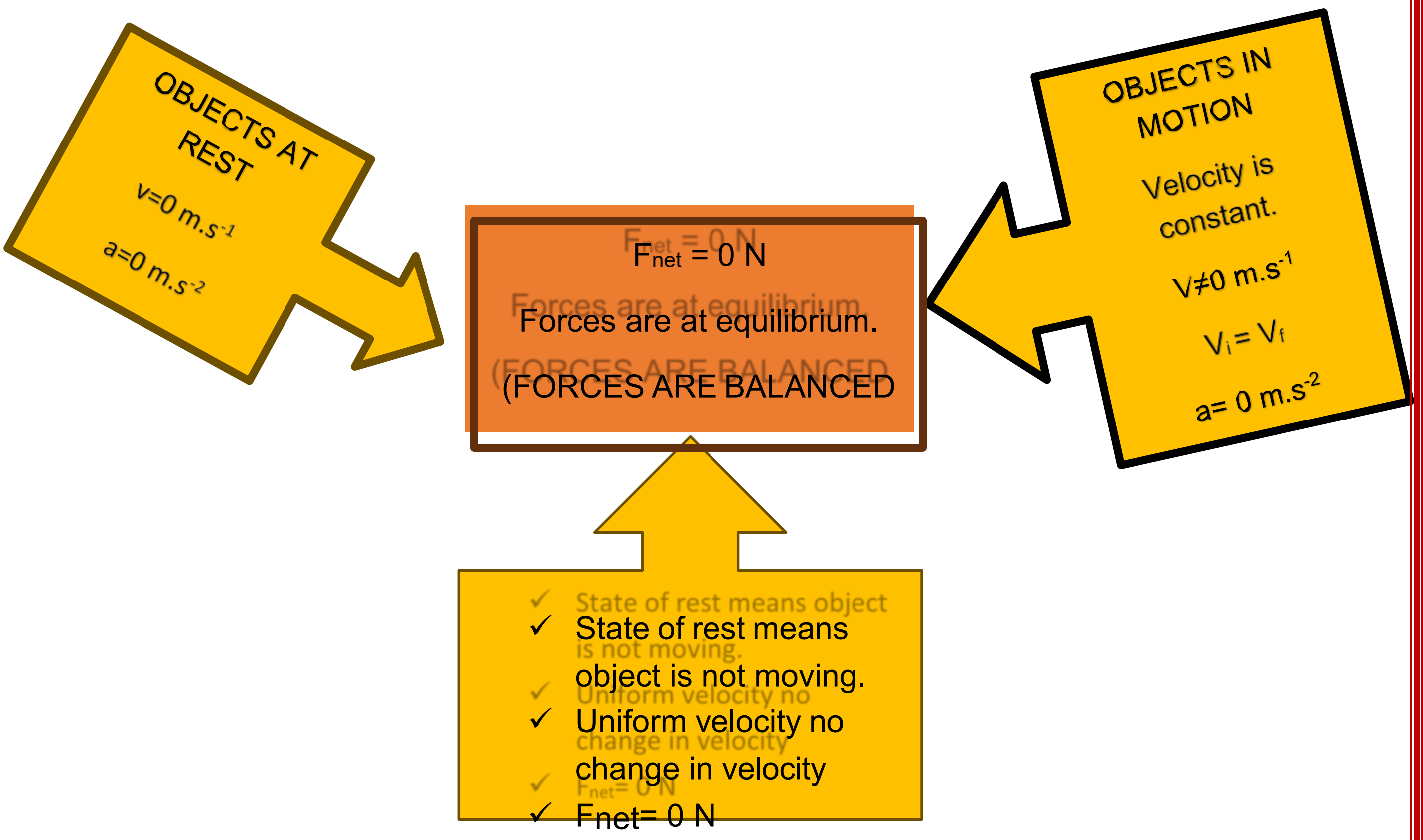
Examples	FORCE DIAGRAM	FREE BODY DIAGRAM
EXAMPLE 1 Force **A** is applied to the right, on an object resting on a rough surface.		
EXAMPLE 2 Force **A** is exerted on an object, mass **m** and pulls the object at an angle, **ɵ** to the horizontal along a rough surface.		
EXAMPLE 3 Force **A** is applied on an object, mass **m** and pushes the object at an angle, **ɵ** to the horizontal surface and experiences frictional force **f**.		
EXAMPLE 4 Object m, resting on an inclined plane and experiences a frictional force **f**		
EXAMPLE 5 Object **m** is suspended on a ceiling with a light inextensible string.		

NB: More examples must be done on an inclined plane and two-body systems (joined by a light inextensible string).

NEWTON'S LAWS OF MOTION

NEWTON'S FIRST LAW

A body will remain in its state of REST or motion at CONSTANT VELOCITY unless a non-zero resultant/net force act on it.



Newton's first law is sometimes referred as **INERTIA**.

Inertia: Is a tendency of an object to resist any change in its state of rest or uniform motion.

Application: The importance of wearing seatbelts:

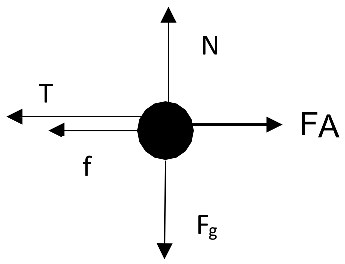
- We wear seat belts in cars. Why?
- This is to protect us when the car is involved in an accident. If a car is travelling at 120 km.h^{-1}, the passengers in the car are also travelling at 120 km.h^{-1} due to inertia.
- When the car suddenly stops a force is exerted on the car (making it slow down), but not on the passengers. The passengers will carry on moving forward at –120 km.h^{-1} according to Newton first law.
- If they are wearing seat belts, the seat belts will stop them and therefore prevent them from getting hurt.

EXAMPLE 1

Two objects are being pulled over a straight rough horizontal surface with a force of 900 N. The mass of object **A** is 130 Kg, and the mass of object **B** is 95 Kg. The two objects are connected by a light inextensible rope.

The two objects move at constant velocity.

1.1 Draw a labelled free-body diagram to show all the forces acting on object **A.** (5)



FA	✓
T	✓
N	✓
Fg	✓
f	✓

1.2 Calculate the magnitude of the kinetic frictional force between object **A** and the surface if the coefficient of kinetic friction is 0.45. (3)

$f_k = \mu_k N$✓

$f_k = \mu_k mg$

$f_k = (0.45)(130)(9.8)$✓

$f_k = 573.3\ N$✓

1.3 Name and state the Law that is relevant for the scenario above. (3)

NEWTON'S FIRST LAW

A body will remain in its state of REST or motion at CONSTANT VELOCITY unless a nonzero resultant/net force act on it.

NEWTON'S SECOND LAW OF MOTION:

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

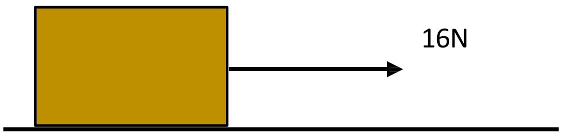
$F_{net} = ma$

- Directly proportional means as the acceleration increases also the Fnet increases or acceleration decreases also the Fnet decreases.
- a α Fnet

- Inversely proportional means that as the acceleration increases the mass decreases.
- $a \propto \frac{1}{m}$

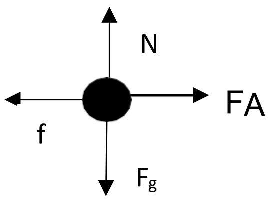
EXAMPLE 2

A 5kg block is placed on a horizontal surface. A horizontal force of 16 N is applied on the block, the block accelerates to the right as shown in the diagram below.



A frictional force between the block and the surface is 5 N

2.1 Draw a free-body diagram of all forces acting on the block as it accelerates (4)



F_A	✓
N	✓
Fg	✓
f	✓

2.2 State the law in words that can be used to explain why the block is accelerating

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

2.3 Calculate the acceleration of the block.

$F_{net} = ma$✓

$F_A - T = ma$

$16 - 5 = 5a$✓

$a = 2.2\ m.s^2$✓

2.4 The magnitu

de of the force is now increased to 25 N. Explain how the magnitude of acceleration will be affected (2)

(3)

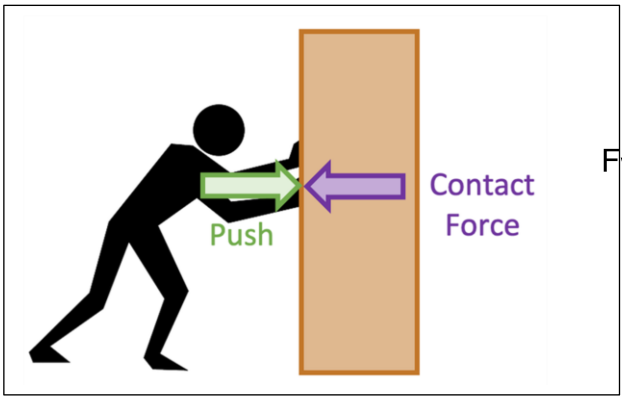
Fnet = ma
According to Newton's second law Fnet is directly proportional to acceleration. ✓

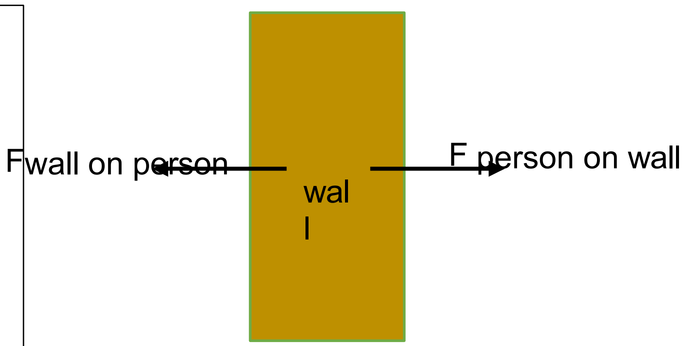
Acceleration will increase, an increase in the net force will increase acceleration since ✓

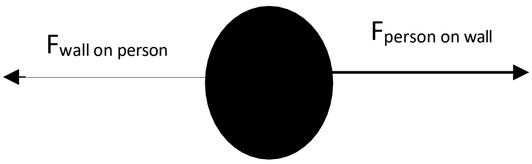
NEWTON'S THIRD LAW

When object A exert a force on object B, object B SIMULTENEOUSLY exert an oppositely directed force of equal magnitude on object A.

Person (OBJECT A) Wall (OBJECT B)







<u>**PROPERTIES OF ACTION-REACTION PAIRS**</u>
They are not balanced as the act on the different objects.

- Two forces of Action and Reaction have the same **magnitude**, but act in opposite directions.
- They act on different objects.
- They act along the same line.
- They arise from the same interaction.
- They occur simultaneously.

Newton's law of Universal Gravitation

Each body in the universe attracts every other body with the force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between their centres.

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

- The force of attraction between two objects is directly proportional to the product of their masses.

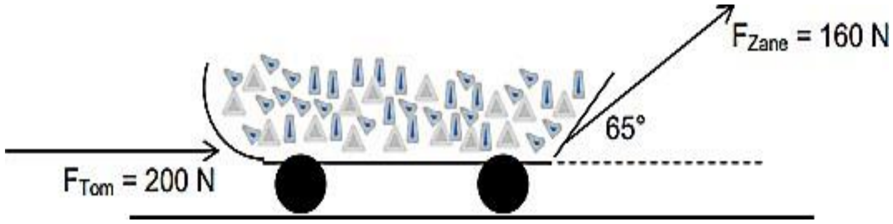
$$F \propto m_1m_2$$

- And inversely proportional to the square of the distance between their centres.

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

QUESTION 1

1.1 Tom is pushing and Zane is pulling a trolley, loaded with crushed stone, over a rough surface on a construction site. The mass of the trolley and its contents is 350 kg. Tom pushes with a force of 200 N and Zane pulls with a force of 160 N using a string, which makes an angle of 65° with the horizontal, as shown in the diagram below.



1.1.1 Define tension force and give an example of such a force in the diagram above. (3)

1.1.2 How will the frictional force on the trolley be affected by Zane's applied force? Write only INCREASES, DECREASES or REMAINS CONSTANT. (2)

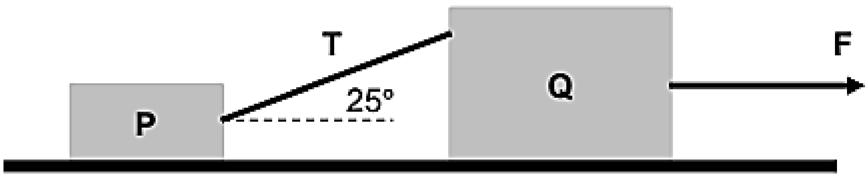
1.1.3 Draw a free-body diagram of ALL the forces acting on the trolley and its contents. (5)

1.2 If the net force acting on the trolley and its contents is 205 N, calculate the coefficient of kinetic friction (μ_k) between the surface and the trolley. (6)

[16]

QUESTION 2

Two blocks, P and Q, resting on a rough horizontal surface, are connected by a light inextensible string. The string forms an angle of 25° to the horizontal. The blocks have masses 5 kg and 8 kg respectively. A constant force F is applied to the 8 kg block, as shown below.



The two blocks now move to the RIGHT at a CONSTANT SPEED of 3 m·s-1

2.1 State Newton's first law of motion in words. (2)

2.2 Draw a labelled free-body diagram for block P. (4)

The tension in the string between the blocks is 5 N.

2.3 Calculate the horizontal component of the tension in the string (T). (2)

Block P and Q experience constant frictional forces of 2,5 N and 1 N respectively.

2.4 State the definition of a net force (resultant force) in words. (2)

2.5 Calculate the magnitude of force F. (2)

The string connecting P and Q suddenly breaks while force F is still being applied.

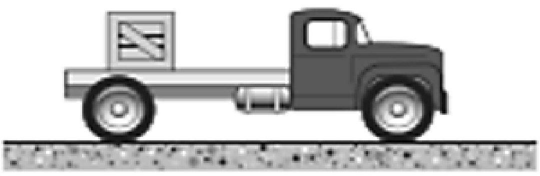
2.6 Is the direction of the acceleration of block Q now towards LEFT or RIGHT? Explain your answer. (3)

2.7 How will the net force acting on block P be affected when the string breaks? Choose from INCREASES, DECREASES or REMAINS THE SAME. (1)

[17]

QUESTION 3

3.1 A 360 kg crate rests on the back of a truck with a rough surface. The mass of the truck is 4 550 kg, and it is travelling at a speed of 105 km·h-1 to the right. The driver applies brakes, and the truck slows down to a speed of 62 $km \cdot h^{-1}$ in 7 s.



3.1.1 If the crate is not secured with ropes, explain what will happen to it when the driver applies the brakes. (2)

3.1.2 NAME and STATE in words Newton's law of motion used to answer QUESTION 3.1.1. (3)

3.1.3 Draw a labelled free-body diagram of ALL the forces acting on the crate as the driver applies the brakes. (3)

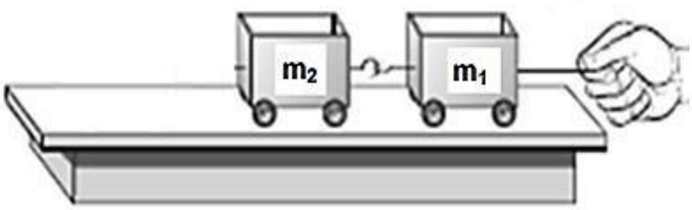
3.1.4 Calculate the acceleration of the truck as the driver applies the brakes. (4)

3.1.5 Calculate the force applied by the brakes on the truck. (4)

3.2 Two toy cars with frictionless rollers are tied together and pulled, as shown in the diagram below.

The mass of each car is as follows: m1 = 0,75 kg and m2 = 0,8 kg

The cars are pulled to the right with a horizontal force of 6,5 N.



3.2.1 State Newton's Second Law of Motion in words. (2)

3.2.2 Calculate the acceleration of the system. (4)

3.2.3 Calculate the force exerted by car m1 on car m2. (3)

[25]

Training and Consultancy

The path to enlightened education

SUBJECT: PHYSICAL SCIENCES

GRADE 12

TERM 1

TEACHER AND LEARNER CONTENT MANUAL

Topic(s)

2. Vertical Projectile Motion

A Division of Marematlou Group Holdings

ICON DESCRIPTION

MIND MAP	EXAMINATION GUIDELINE	CONTENTS	ACTIVITIES
BIBLIOGRAPHY	TERMINOLOGY	WORKED EXAMPLES	STEPS

CONTENTS PAGE

EXAMINATION GUIDLINES

- Explain what is meant by a projectile, i.e., an object which has been given an initial velocity and then it moves under the influence of the gravitational force only.
- Define free fall as motion during which the only force acting on an object is the gravitational force.
- Use equations of motion to determine the position, velocity, and displacement of a projectile at any given time.
- **Sketch position versus time (x vs. t), velocity versus time (v vs. t) and acceleration versus time (a vs. t) graphs for:**
  - A free-falling object
  - An object thrown vertically upwards
  - An object thrown vertically downwards
  - Bouncing objects (restricted to balls)
- **For a given x vs. t, v vs. t or a vs. t graph, determine:**
  - Position
  - Displacement
  - Velocity or acceleration at any time t
- **For a given x vs. t, v vs. t or a vs. t graph, describe the motion of the object:**
  - Bouncing
  - Thrown vertically upwards
  - Thrown vertically downward

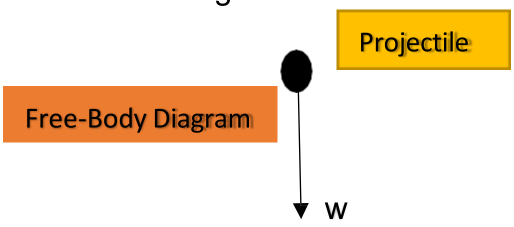
IMPORTANT TERMS AND DEFINITIONS

Projectile - an object which has been given an initial velocity and then it moves under the influence of the gravitational force only.

Free-Fall - as motion during which the only force acting on an object is the gravitational force.

Projectile

- An object that is launched into the air (**downwards or upwards**) by:
  - ✓ Kicking
  - ✓ Hitting or
  - ✓ Throwing it.
- After that, it moves under the influence of gravitational force only.



Motion of a Projectile

- The motion of an object which is thrown vertically (**downwards or upwards**). After the initial force that launches the object, it only experiences the force of gravity.
- The object is called a **projectile**

Description	Velocity	Change in Velocity	Gravitational acceleration
Object moves upwards	Upwards	Slowing down (decreases)	Downwards
Object moves downwards	Downwards	Speeding up (increases)	Downwards

Free-Fall

The motion of an object in the gravitational field of the earth under the influence of gravitational force only.

Acceleration due to gravity

- All free-falling bodies have the same **constant gravitational acceleration**.
- This acceleration is **9,8 m.s^{-2} downwards** at any point of its motion whether:
  - ✓ **moving up** or
  - ✓ **moving down** or
  - ✓ **at the maximum height (turning point)**

Equations of Motion (BIG FOUR)

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

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

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

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

Vi = initial velocity (m.s^{-2})

Vf = final velocity (m.s^{-1})

a = gravitational acceleration = 9.8 m.s^{-2}

Δt = time (s)

Δy = displacement (m)

Each of the BIG FOUR equations is missing one of the five fundamental quantities.

PROBLEM SOLVING STRATEGY

STEP 1: Read the statement carefully. Identify key words.

MOTION

$v_f = v_i + a\Delta t$	$\Delta x = v_i\Delta t + \frac{1}{2}a\Delta t^2$ or/of $\Delta y = v_i\Delta t + \frac{1}{2}a\Delta t^2$
$v_f^2 = v_i^2 + 2a\Delta x$ or/of $v_f^2 = v_i^2 + 2a\Delta y$	$\Delta x = \left(\frac{v_i + v_f}{2}\right)\Delta t$ or/of $\Delta y = \left(\frac{v_i + v_f}{2}\right)\Delta t$

STEP 2: Make sense of the statement (Draw a diagram)

STEP 3: Choose direction (upward as +; downward as – OR vice versa)

STEP 4: Tabulate/Outline the given data.

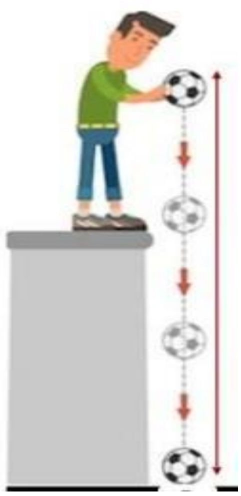
STEP 5: Identify the suitable formula from the **DATA SHEET**

STEP 6: Substitute the known values into the formula and solve for unknown variable.

N.B. It is advisable to take the direction of motion as positive.

Description of Vertical Projectile Motion

SCENARIO A1: When a projectile is DROPPED (from rest) from a certain height above the ground.



$V_i = 0$ m.s^{-1}

$V_f > 0$ m.s^{-1}

- a = 9.8 m.s^{-2} downwards
- Velocity is increasing as the ball is moving downwards
- $V_i = 0$ m.s^{-1}
- Velocity is at maximum as the ball hits the ground
- V_f (at the bottom) > V_i > 0 m.s^{-1}

positive or negative sign are used to define direction for upwards and downwards

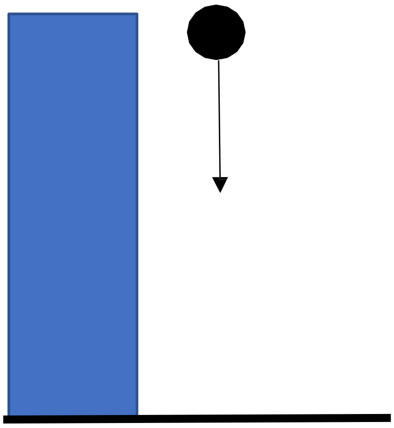
If two objects are released from different heights, they have the same acceleration, but they strike the ground at different times and have a different velocity.

Ignoring air resistance; If a **ball** and a **rock** are released from the same height at the same time, they will strike the ground at the same time, and their final velocity will be the same.

But their **momentum (mv)** and **kinetic energy (½mv2)** are not the same, due to a **difference in mass**.

WORKED EXAMPLE 1

A ball is dropped from a height of a building and reaches the ground after 2.02 s. Ignore the effects of air resistance.



1.1 Calculate the velocity at which the ball hits the ground.

1.2 Calculate the height of the building.

1.3 Draw the velocity time graph. Indicate the final velocity and the time it takes to reach the ground.

1.4 Taking the ground as reference point draw the position – time graph.

SOLUTIONS

1.1 ***STEP 1:*** Choose direction

Take downwards as **POSITIVE**

STEP 2: Identify the unknown variable first

Vf = +?

STEP 3: Collect any other given data

a	Δt	Vi	Vf	Δy
+9.8 $m.s^{-2}$	2.02 s	0 $m.s^{-1}$	?	?

STEP 4: Select an appropriate equation, substitute, calculate, get an answer with correct unit, **AND** indicate direction where necessary

$v_f = v_i + a\Delta t$

v_f = (0) + (+9.8)(2.02)

v_f = 19.8 $m.s^{-1}$ $downwards$

1.2 ***STEP 1:*** Choose direction

Take downwards as **POSITIVE**

STEP 2: Identify the unknown variable first

$\Delta y = +?$

STEP 3: Collect any other given data

a	Δt	Vi	Vf	Δy
+9.8 $m.s^{-2}$	2,02 s	0 $m.s^{-1}$	?	?

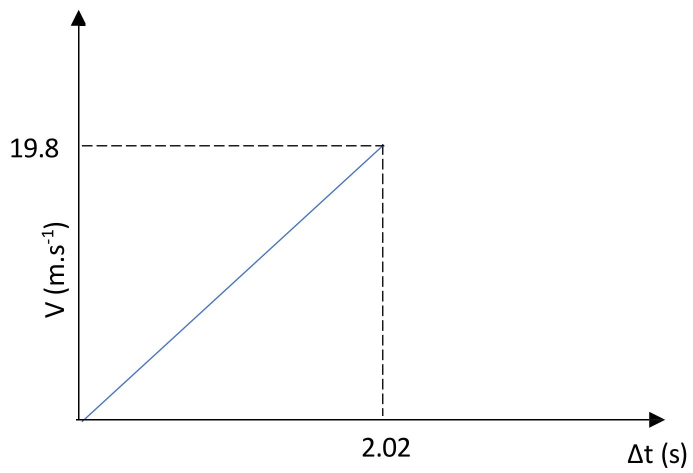
STEP 4: Select an appropriate equation, substitute, calculate, get an answer with correct unit, **AND** indicate direction where necessary

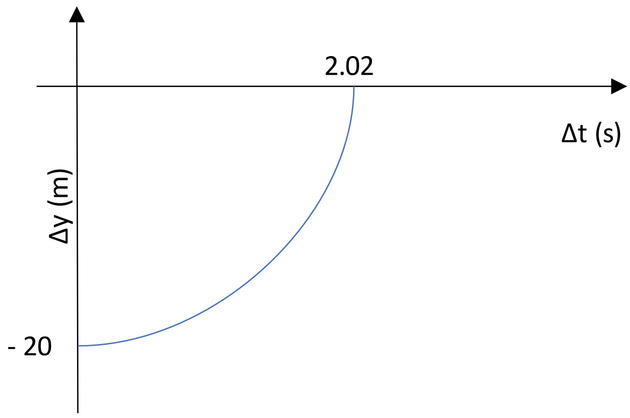
$$\Delta y = v_i \Delta t + \frac{1}{2} a \Delta t^2$$

$$\Delta y = (0)(2.02) + \frac{1}{2}(+9.8)(2.02^2)$$

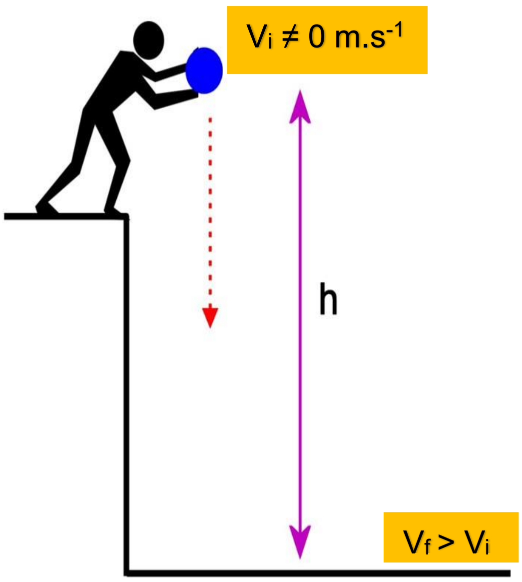
$$\Delta y = 20\ m$$

1.3





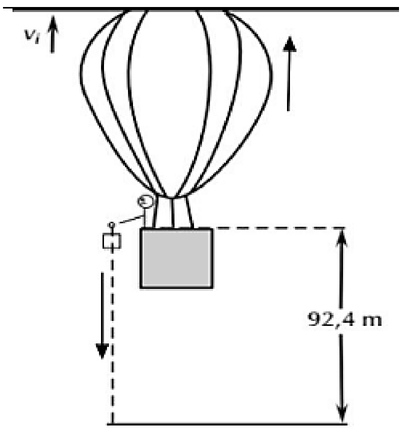
<u>SCENARIO A2</u>: When an object is THROWN (Given an initial velocity) from a certain height above the ground.



- $a = 9.8\ m.s^{-2}$ downwards
- Velocity is increasing as the ball is moving downwards
- $V_i \neq 0\ m.s^{-1}$ $V_i > 0\ m.s^{-1}$
- Velocity at maximum as the ball hits the ground
- V_f (at the bottom) > V_i

positive or negative sign are used to define direction for upwards and downwards motion

HOT AIR BALLOON



- **Vi = V of HOT AIR BALLOON**
- **Therefore Vi > 0 m.s^{-1}**

Take downwards as POSITIVE (no upwards motion)

Vi = V HOT AIR BALLOON

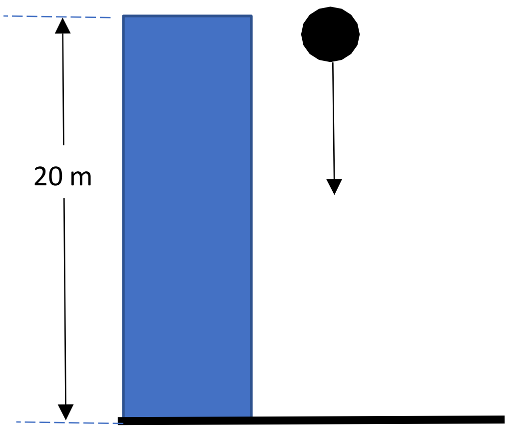
Vf = +

Δy = +

A = +9.8 m.s^{-1}

WORKED EXAMPLE 2

A ball is thrown vertically down from a height of a building with a velocity of 10 m.s^{-1}. Ignore the effects of air resistance.



2.1 Calculate the velocity at which the ball hits the ground.

2.2 Calculate the time it takes then ball to hit the ground.

2.3 Draw the velocity time graph. Indicate the final velocity and the time it takes to reach the ground.

2.4 Taking the point of projection as reference point draw the position – time graph.

SOLUTIONS

2.1 ***STEP 1:*** Choose direction

Take downwards as **POSITIVE**

STEP 2: Identify the unknown variable first

Vf = +?

STEP 3: Collect any other given data

a	Δt	Vi	Vf	Δy
+9.8 m.s^{-2}	?	+10 m.s^{-1}	?	20 m

STEP 4: Select an appropriate equation, substitute, calculate, get an answer with correct unit, **AND** indicate direction where necessary

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

$\sqrt{v_f^2} = (10)^2 + 2(9.8)(20)$

$v_f = 22.18\ m.s^{-1}\ downwards$

2.2 ***STEP 1:*** Choose direction

Take downwards as **POSITIVE**

STEP 2: Identify the unknown variable first

Δt = +?

STEP 3: Collect any other given data

a	Δt	Vi	Vf	Δy
9.8 m.s^{-2}	?	+10 m.s^{-1}	22.18 m.s^{-1}	20

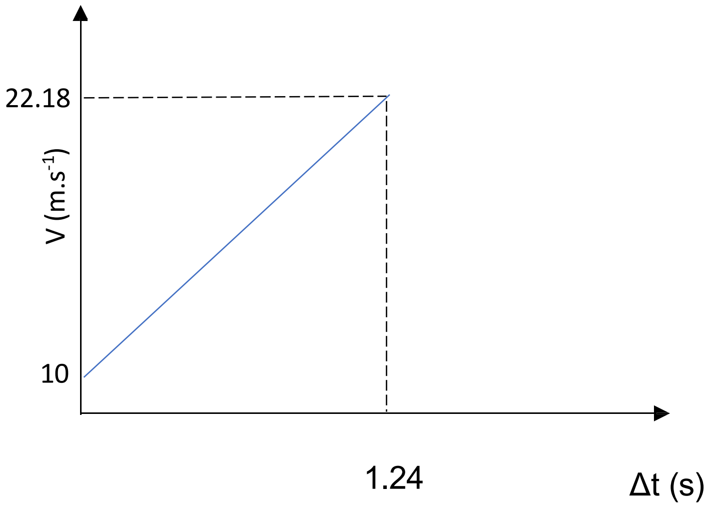
STEP 4: Select an appropriate equation, substitute, calculate, get an answer with correct unit, **AND** indicate direction where necessary

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

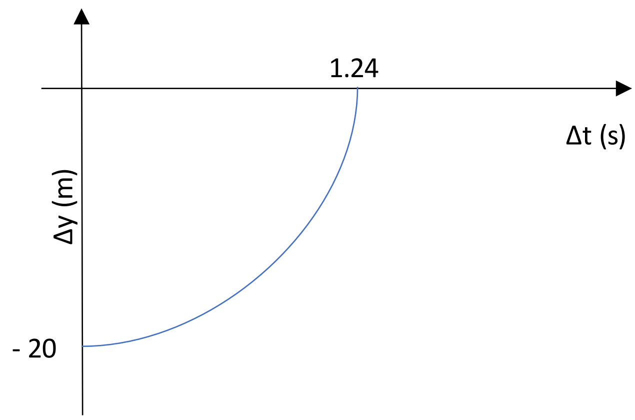
$(20) = [\frac{(10) + (22.18)}{2}]\Delta t$

$\Delta t = 1.24\ s$

2.3

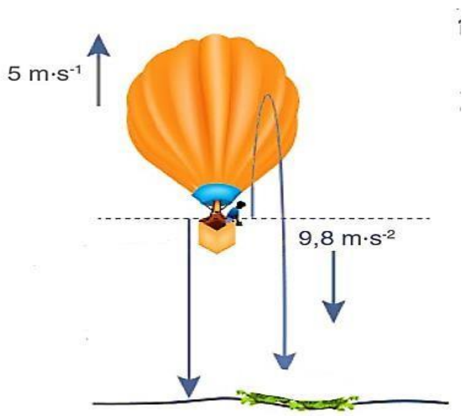


2.4



EXAMPLE 3

A hot air balloon ascends with a constant velocity of 5 $m{\cdot}s^{-1}$. A ball is dropped from the hot air balloon at a height of 50 m and falls vertically towards the ground.



3.1 Determine the distance between the hot air balloon and ball after 2 seconds

3.2 and the velocity of the ball when it reaches the ground.

50 m

SOLUTIONS

3.1 ***STEP 1:*** Choose direction

Take downwards as **POSITIVE**

STEP 2: Identify the unknown variable first

Δy = -? Distance travelled by balloon

STEP 3: Collect any other given data

a	Δt	Vi	Vf	Δy
0 $m.s^{-2}$	2 s	- 5 $m.s^{-1}$	?	-?

STEP 4: Select an appropriate equation, substitute, calculate, get an answer with correct unit, **AND** indicate direction where necessary

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

$$\Delta y = (-5)(2) + \frac{1}{2}(0)(2^2)$$

$$\Delta y = -10\ m$$

$$\Delta y = 10\ m\ upwards$$

STEP 1: Choose direction

Take downwards as **POSITIVE**

STEP 2: Identify the unknown variable first

Δy = +? Distance travelled by

STEP 3: Collect any other given data

a	Δt	Vi	Vf	Δy
9.8 $m.s^{-2}$	2 s	- 5 $m.s^{-1}$	?	?

STEP 4: Select an appropriate equation, substitute, calculate, get an answer with correct unit, **AND** indicate direction where necessary

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

$$\Delta y = (-5)(2) + \frac{1}{2}(9.8)(2^2)$$

$$\Delta y = 9.6\ m\ downwards$$

$$\therefore Total\ Distance = 10 + 9.6$$

$$= 19.6\ m\ apart$$

3.2

a	Δt	V_i	V_f	Δy
9.8 $m.s^{-2}$	?	- 5 $m.s^{-1}$	?	+50 m

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

$$v_f^2 = (-5)^2 + 2(9.8)(50)$$

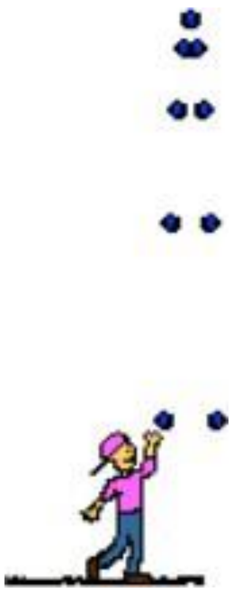
$$v_f = \sqrt{25 + 980}$$

$$v_f = 13.70\ m.s^{-1}\ downwards$$

SCENARIO B1: **The projectile is thrown vertically upwards from a starting point, turns around and returns to the starting point.**

$V_{f(up)} = V_{i(down)} = 0\ m.s^{-1}$

$V_f > V_i$

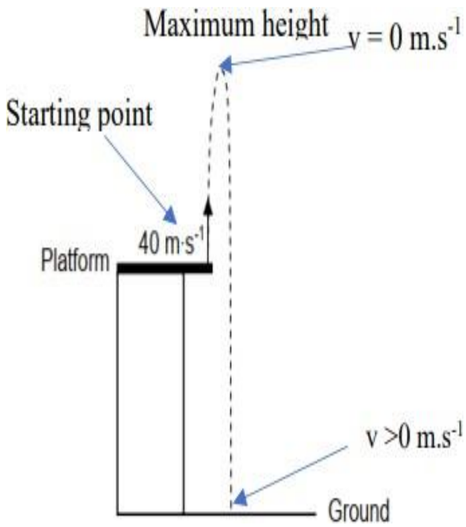


$V_{i(up)} = V_{f(down)}$

- $a = 9.8\ m.s^{-2}$ downwards
- Velocity is increasing as the ball is moving downward
- Velocity decrease as ball is moving upward
- $V_i\ (up) = V_f\ (down)$
- $V_f\ (up) = V_i\ (down) = 0\ m.s^{-1}$
- Δt (for upward motion) = Δt (down)

positive or negative sign are used to define direction for upwards and downwards

SCENARIO B2: **The projectile is thrown upwards from the starting point above the ground, turns around and moves downwards PAST THE STARTING POINT TO THE GROUND.**



- $a = 9.8\ m.s^{-2}$ downwards
- Velocity is increasing as the ball is moving downward
- Velocity decrease as ball is moving upward
- $V_i \neq 0\ m.s^{-1}$
- $V_f\ (up) = V_i\ (down) = 0\ m.s^{-1}$
- $V_f\ (down) > V_i(up)$

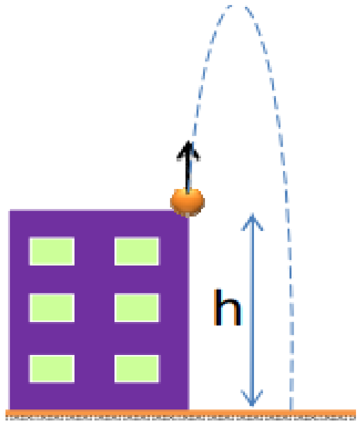
positive or negative sign are used to define direction for upwards and downwards

Starting Point as Reference Point:

- Δy below the starting point

WORKED EXAMPLE 4

A ball is projected vertically upward with a velocity of 30 $m.s^{-1}$. It strikes the ground after 8s.



4.1 Calculate the maximum height reach by the ball above the point of projection.

4.2 Determine the height of the building.

4.3 Draw the position vs. time graph for the motion take the point of projection as zero point

SOLUTIONS

4.1 ***STEP 1:*** Choose direction

Take downwards as **POSITIVE**

STEP 2: Identify the unknown variable first

Δy = -?

STEP 3: Collect any other given data

a	Δt	Vi	Vf	Δy
+9.8 $m.s^{-2}$	?	- 30 $m.s^{-1}$	0 $m.s^{-1}$	?

STEP 4: Select an appropriate equation, substitute, calculate, get an answer with correct unit, **AND** indicate direction where necessary

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

$0 = (-30)^2 + 2(9.8)\Delta y$

$\Delta y = -45.92\ m$

$\therefore\ \Delta y = 45.92\ m\ above\ point\ of\ projection$

4.2 ***STEP 1:*** Choose direction

Take downwards as **POSITIVE**

STEP 2: Identify the unknown variable first

Δy = +?

STEP 3: Collect any other given data

a	Δt	Vi	Vf	Δy
+9.8 m.s^{-2}	8 s	-30 m.s^{-1}	?	+?

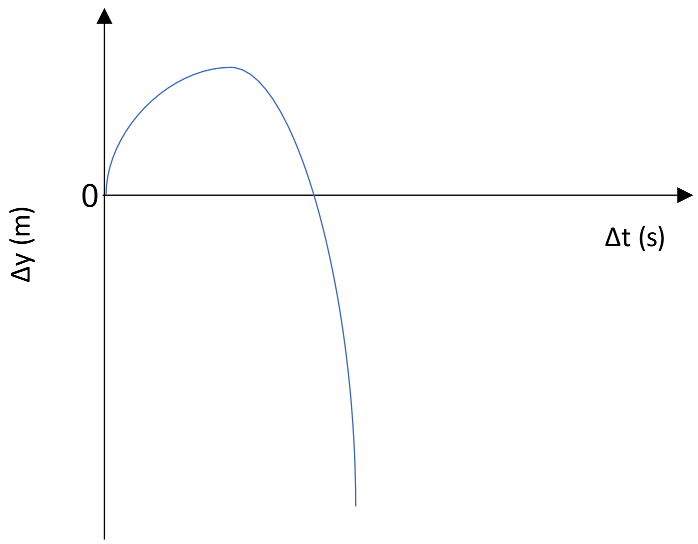
STEP 4: Select an appropriate equation, substitute, calculate, get an answer with correct unit, **AND** indicate direction where necessary

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

$$\Delta y = (-30)(8) + \frac{1}{2}(9.8)(8)^2$$

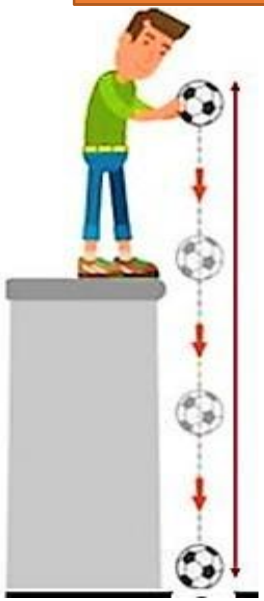
$$\Delta y = 73.6\ m\ heigh$$

4.3

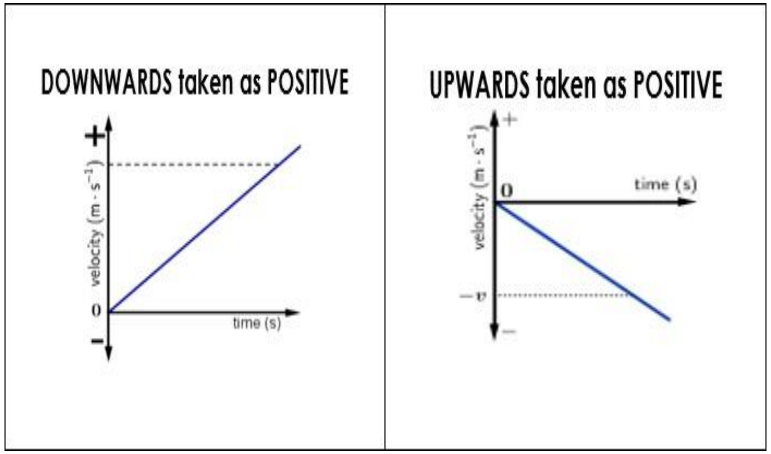


GRAPHS: The projectile is DROPPED from the starting point above the ground, turns around and moves downwards BACK TO THE STARTING POINT.

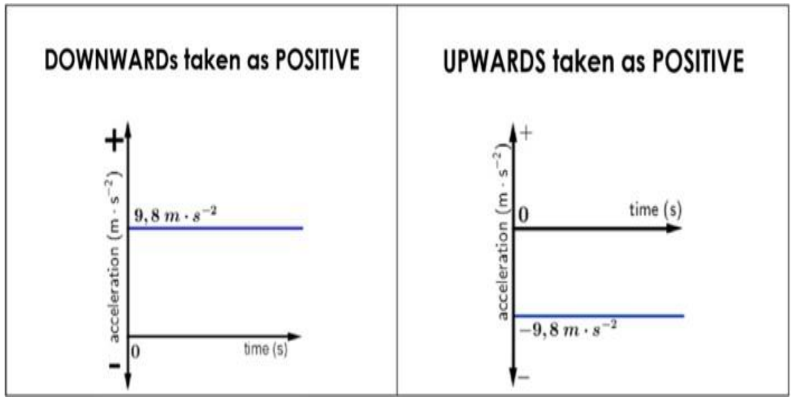
When drawing vertical projectile motion graphs, we need to use SIGN CONVENTION. Therefore, CHOOSE A DIRECTION



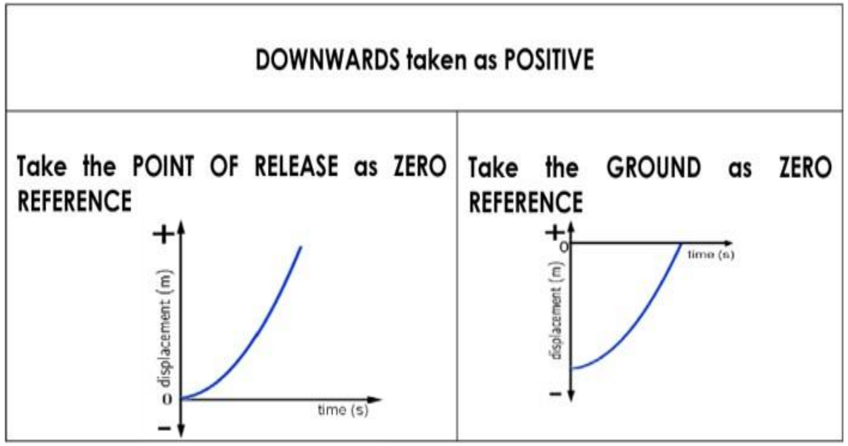
Velocity – Time Graph

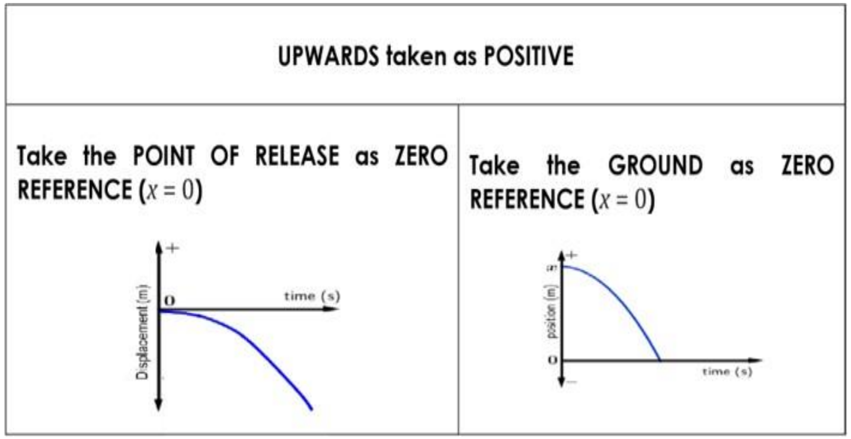


Acceleration – Time Graph

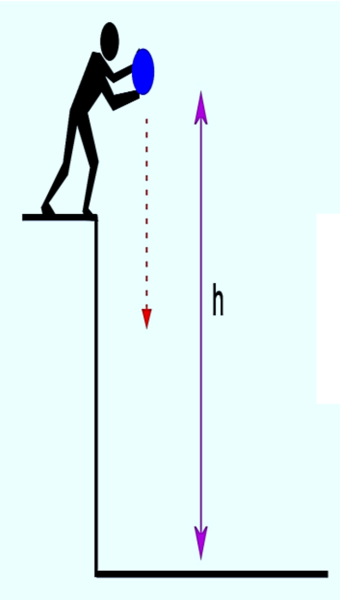


Position – Time Graph



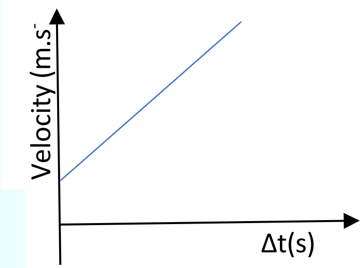


GRAPHS: The projectile is thrown upwards from the starting point above the ground, turns around and moves downwards BACK TO THE STARTING POINT.

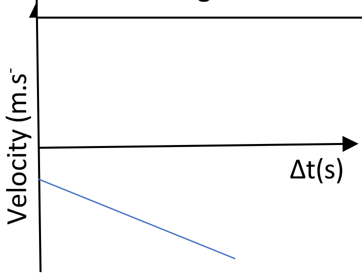


Velocity – Time Graph

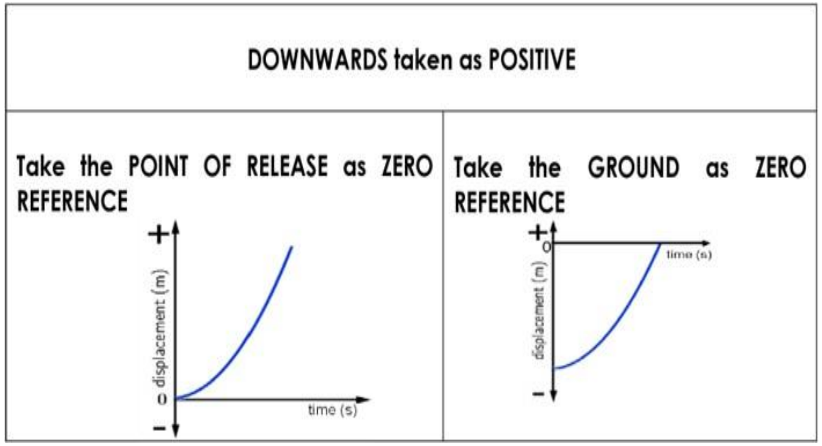
DOWNWARDS taken as Positive

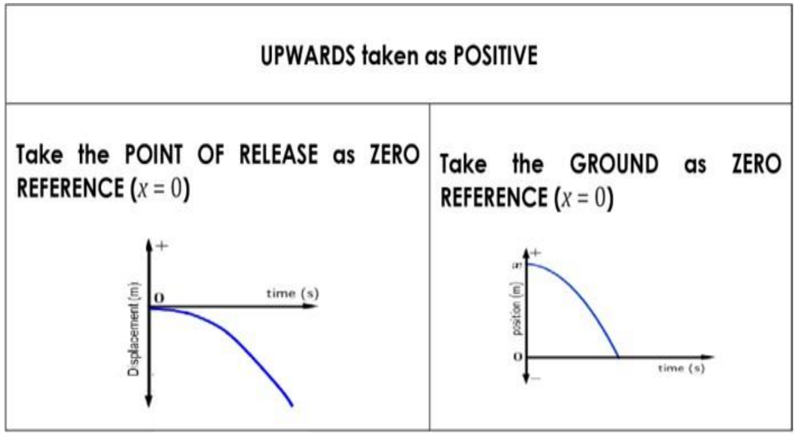


DOWNWARDS taken as Negative

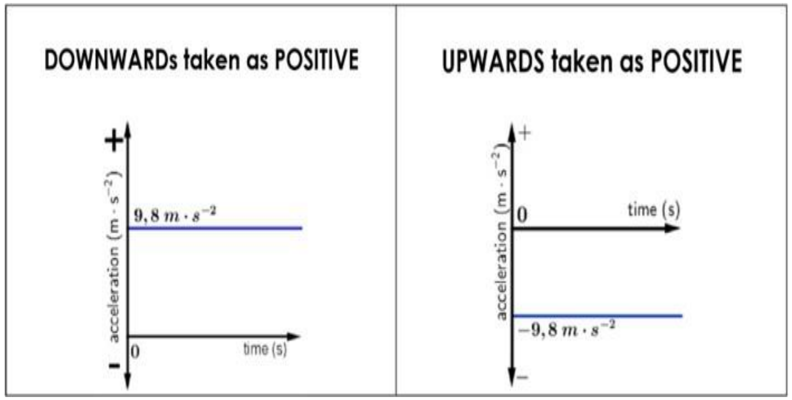


Position – Time Graph



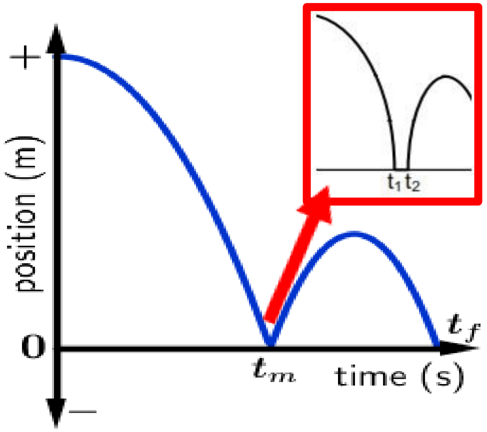


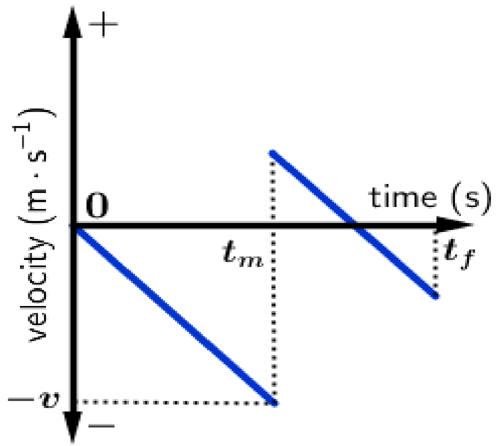
Acceleration – Time Graph

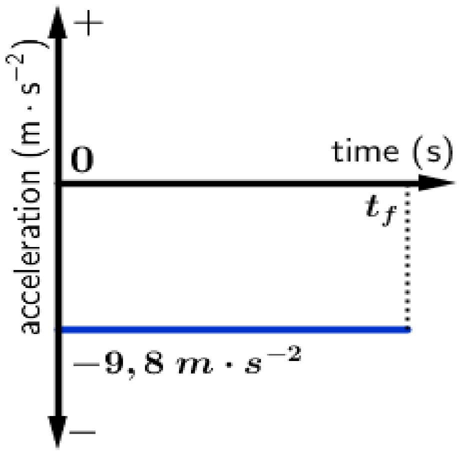


The Bouncing Ball

a ball is dropped from a height and ***bounces up off the ground***, coming to rest on the ground thereafter (up is +, ground is zero level)







In some graphs, the time interval of the bounce is indicated by a space between t1 and t2

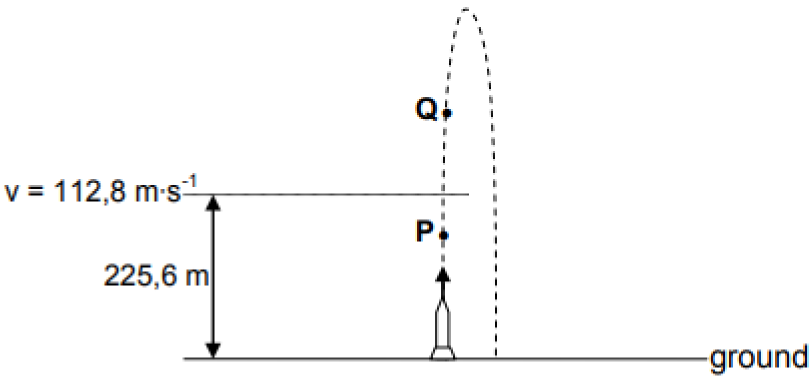
Note the transition when the ball bounces ... a **dotted line** must connect the two parts of the velocity graph …

Acceleration constant throughout, but note the discontinuity at tm

QUESTION 1

A stationary rocket on the ground is launched vertically upwards. After 4 s, the rocket's fuel is used up and it is 225,6 m above the ground. At this instant the velocity of the rocket is 112,8 $m \cdot s^{-1}$. The diagram below shows the path followed by the rocket. Ignore the effects of air friction.

Assume that g does not change during the entire motion of the rocket.



1.1 Write down the direction of the acceleration of the rocket at point:

1.1.1 **P** (1)

1.1.2 **Q** (1)

1.2 At which point (**P or Q**) is the rocket in free fall? Give a reason for the answer. (2)

1.3 TAKING UPWARD MOTION AS POSITIVE, USE EQUATIONS OF MOTION to calculate the time taken from the moment the rocket is launched until it strikes the ground. (6)

1.4 Sketch a velocity versus time graph for the motion of the rocket from the moment it runs out of fuel until it strikes the ground. Take the time when the rocket runs out of fuel as t = 0 s.

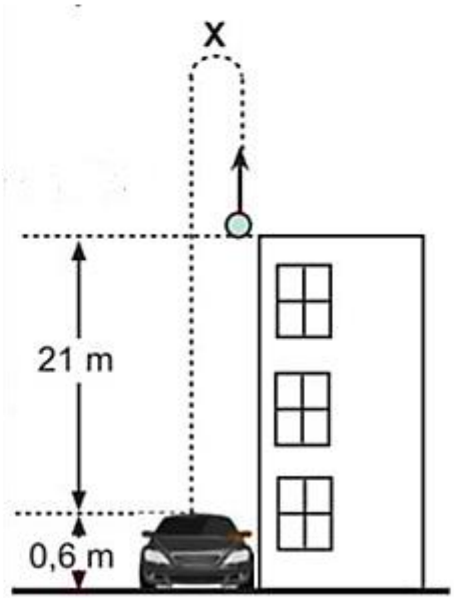
Indicate the following values on the graph:

- Velocity of the rocket when it runs out of fuel
- Time at which the rocket strikes the ground (5)

[12]

QUESTION 2

A car, 0,6 m high, is parked next to a block of flats. A learner leans over the edge. Of the roof of the building, 21 m above the roof of the car. The learner throws a ball, with a mass of 500 g, vertically upwards. The ball moves upwards to point X, falls back past the top of the building and hits the roof of the car after 2,88 s.



Ignore all effects of air resistance.

2.1 Write down the following experienced by the ball at point X:

2.1.1 Magnitude of the net force. (1)

2.1.2 Direction of the acceleration. (1)

2.2 Calculate the:

2.2.1 Magnitude of the velocity with which the ball was thrown upwards. (4)

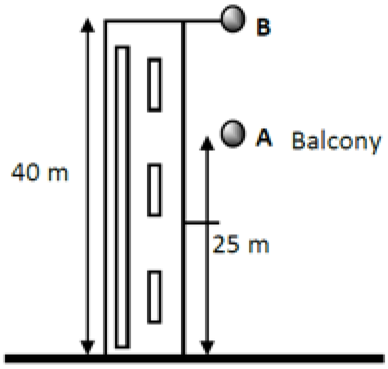
2.2.2 Maximum height that the ball will reach above the ground. (4)

2.5 The ball hits the roof of the parked car and bounces form the roof with a speed of 18 $m.s^{-1}$. The ball is in contact with the roof of the car for 0,1 s. Calculate the magnitude of the force that the roof of the car exerts on the ball. (5)

[15]

QUESTION 3

Ball **A** is dropped from a balcony 25 m from the ground. AT THE SAME TIME an identical ball **B**, is projected vertically downwards from the top of a building 40 m from the ground as shown in the diagram below.



The balls hit the ground simultaneously. Ignore the effects of air resistance.

3.1 Define the term Projectile. (2)

3.2 Calculate the magnitude of the:

3.2.1 Velocity with which of ball **A** reaches the ground (3)

3.2.2 Velocity with which **B** must be projected to reach the ground at the same time as **A**. (4)

3.3 On the same set of axes, sketch a velocity versus time graph for each ball (**A and B**), for the entire motion. Take down as positive.

Show the following on your graph:

- Initial velocity of both balls **A** and **B**
- Time taken to hit the ground (4)

[13]

QUESTION 4

A man throws ball **A** downwards with a speed of 2 m·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.

4.1 Calculate the:

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

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

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

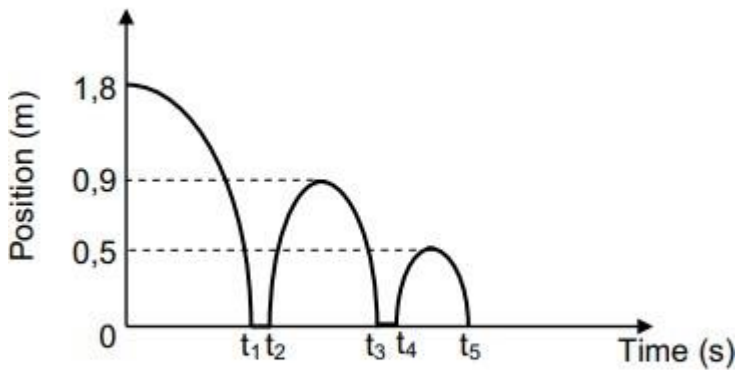
4.3 On the same set of axes, sketch a velocity versus time graph for the motion of balls **A** and **B**. Clearly indicate the following on your graph:

- 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 5

A ball of mass 0,5 kg is projected vertically downwards towards the ground from a height of 1.8 m at a velocity of 2 m.s^{-1} . The position-time graph for the motion of the ball is shown below.



5.1 What is the maximum vertical height reached by the ball after the second bounce? (1)

Calculate the:

5.2 Magnitude of the time t1 indicated on the graph (5)

5.3 Velocity with which the ball rebounds from the ground during the first bounce (4)

The ball is in contact with the ground for 0,2 s during the first bounce.

5.4 Calculate the magnitude of the force exerted by the ground on the ball during the first bounce if the ball strikes the ground at 6.27 m.s^{-1}. (4)

5.5 Draw a velocity-time graph for the motion of the ball from the time that it is projected to the time when it rebounds to a height of 0,9 m.

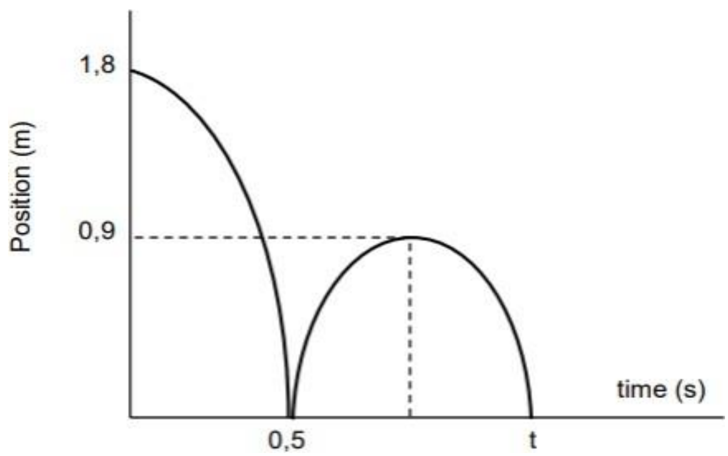
Clearly show the following on your graph:

- The time when the ball hits the ground
- The velocity of the ball when it hits the ground
- The velocity of the ball when it rebounds from the ground (3)

[15]

QUESTION 6

The position-time graph is given for a ball which is thrown down from a vertical height of 1,8 m and bounces once on reaching the ground. The contact time between the ball and the floor can be ignored.



6.1 Calculate the initial velocity with which the ball was thrown. (3)

6.2 At what speed does the ball strike the ground? (3)

6.3 At what speed did the ball leave the ground after bouncing? (3)

6.4 Calculate the value of time t. (4)

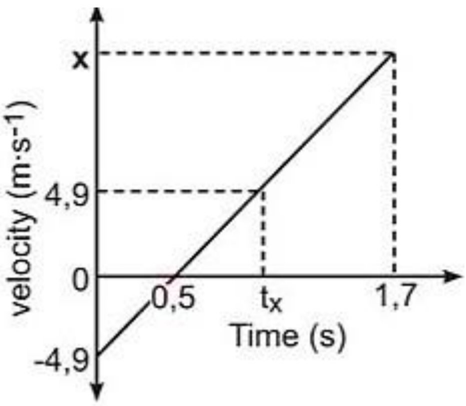
6.5 Sketch a velocity-time graph to represent the motion of the ball. Indicate the following values on the graph:

- The initial velocity at which the object was thrown.
- The velocity at which the ball strikes the ground.
- The velocity at which the ball bounces off the ground.
- The time at which the ball strikes the ground for the first time.
- The time, t, when the ball strikes the ground after the first bounce. (6)

[19]

QUESTION 7

The velocity-time graph below indicates the motion of the ball that is thrown upwards from a balcony of a building. It takes 0,5 s for the ball to reach its highest point above the balcony, after which it falls past the balcony and hits the ground. Ignore the effects of friction.



7.1 State the numerical value of:

7.1.1 The gradient of the velocity-time graph. Give a reason for your answer. (2)

7.1.2 Time, t_x, as shown on the graph. (1)

7.2 Use ONLY the graph (NO equations of motion) to determine, the maximum height the ball reaches at the top of the balcony. (3)

7.3 By using equations of motion and data from the graph, calculate the:

7.3.1 Velocity, x, with which the ball hits the ground. (3)

7.3.2 Height of the balcony above the ground (3)

7.4 Sketch an acceleration versus time graph for the motion of the ball. (2)

[14]

JENN

Training and Consultancy

The path to enlightened education

SUBJECT: PHYSICAL SCIENCES

GRADE 12

TERM 1

TEACHER AND LEARNER CONTENT MANUAL

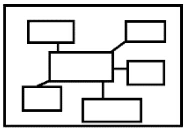
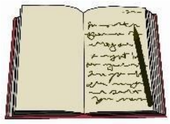
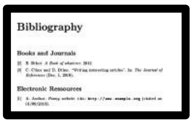
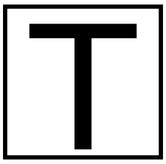
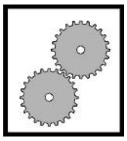
Topic(s)

MOMENTUM AND IMPULSE

JENN MAREMATLOU TRAINING INSTITUTE

A Division of Marematlou Group Holdings

ICON DESCRIPTION

 MIND MAP	 EXAMINATION GUIDELINE	 CONTENTS	 ACTIVITIES
 BIBLIOGRAPHY	 TERMINOLOGY	 WORKED EXAMPLES	 STEPS

CONTENTS **PAGE**

EXAMINATION GUIDELINE

Momentum and Impulse

(This section must be read in conjunction with the CAPS, p. 99–101.)

Momentum

- Define *momentum* as the product of an object's mass and its velocity.
- Describe *linear momentum* as a vector quantity with the same direction as the velocity of the object.
- Calculate the momentum of a moving object using p = mv.
- Describe the vector nature of momentum and illustrate it with some simple examples.
- Draw vector diagrams to illustrate the relationship between the initial momentum, the final momentum and the change in momentum for each of the cases above.

Newton's second law in terms of momentum

- State 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.
- Express Newton's second law of motion in symbols: $F_{net} = \frac{\Delta p}{\Delta t}$
- Explain the relationship between net force and change in momentum for a variety of motions.
- Calculate the change in momentum when a resultant/net force acts on an object and its velocity:
  - Increases in the direction of motion, e.g. 2nd stage rocket engine fires
  - Decreases, e.g. brakes are applied
  - Reverses its direction of motion, e.g. a soccer ball kicked back in the direction it came from

Impulse

- Define *impulse* as the product of the resultant/net force acting on an object and the time the net force acts on the object.
- Use the impulse-momentum theorem, $F_{net}\Delta t = m\Delta v$, to calculate the resultant/net force exerted, the time for which the force is applied and the change in momentum for a variety of situations involving the motion of an object in one dimension.
- Explain how the concept of impulse applies to safety considerations in everyday life, e.g. airbags, seatbelts and arrestor beds.

Conservation of momentum and elastic and inelastic collisions

- Explain what is meant by a *system* (in Physics).
- Explain (when working with systems) what is meant by *internal* and *external forces*.
- ...in what is meant by *an isolated system* (in Physics), i.e. a system on which ...t external force is zero.
  ...olated system excludes external forces that originate outside the colliding bodies, e.g. friction. Only internal forces, e.g. contact forces between the colliding objects, are considered.)

- State the principle of conservation of linear momentum: The total linear momentum of an isolated system remains constant (is conserved).
- Apply the conservation of momentum to the collision of two objects moving in one dimension (along a straight line) with the aid of an appropriate sign convention.
- Distinguish between *elastic collisions* and *inelastic collisions* by calculation.

IMPORTANT TERMS AND DEFINITIONS

TERMS AND DEFINITIONS	
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: N·s or $kg{\cdot}m{\cdot}s^{-1}$
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: $F_{net} = \frac{\Delta p}{\Delta t}$
Principle of conservation of linear momentum	The total linear momentum in an isolated system remains constant (is conserved). In symbols: $\sum p_{before} = \sum p_{after}$
Isolated system	A system on which the net external force 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: Impulse = $F_{net}\Delta t$ Unit: N·s or $kg{\cdot}m{\cdot}s^{-1}$
Impulse-momentum theorem	In symbols: $F_{net}\Delta t = m\Delta v = m(v_f – v_i)$ Unit: N·s or $kg{\cdot}m{\cdot}s^{-1}$
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.

MOMENTUM AND IMPULSE

Momentum

facts:
- $p = mv$ (p: momentum, m: mass, v: velocity)
- Unit: $kg \cdot m \cdot s^{-1}$
- Vector quantity: magnitude and direction

Change in momentum

$\Delta p = p_f - p_i = mv_f - mv_i$

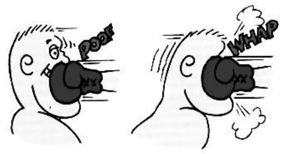
Impulse-momentum theorem

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

Impulse ($F_{net} \Delta t$) — change in momentum ($m\Delta v$)

The theorem shows an INVERSE relationship between FORCE and TIME.

$$F_{net} = \frac{m\Delta v}{\Delta t}$$

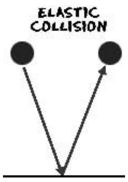


F t = change in momentum   F t = change in momentum

Conservation of momentum

$\Sigma p_{initial} = \Sigma p_{final}$ (in an isolated system)

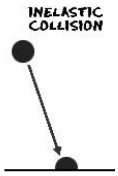
Collisions



Elastic

$\Sigma p_{initial} = \Sigma p_{final}$

$E_k(initial) = E_k(final)$



Inelastic

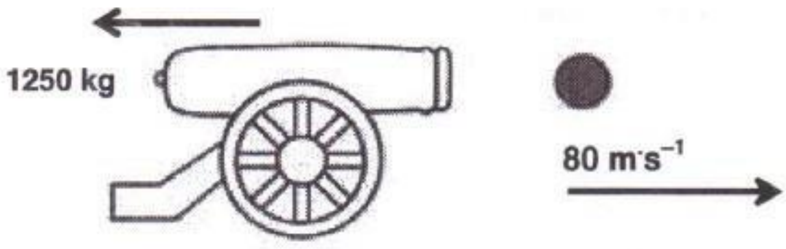
$\Sigma p_{initial} = \Sigma p_{final}$

$E_k(initial) \neq E_k(final)$

WORKED EXAMPLES

QUESTION 1

A cannon has a mass of 1 250 kg and is a 1 000 times heavier than the cannon ball that it fires during a routine training exercise. The cannon ball leaves the barrel at a horizontal velocity of 80m·s^{-1}



The cannon comes to rest 1 second after being fired.

1.1 Define, in words, the term *impulse*. (2)

1.2 Calculate the:

1.2.1 Maximum velocity with which the cannon moves backwards (5)

1.2.2 Magnitude of the average net force that causes the cannon to come to rest. (4)

[11]

1.1 Impulse is the product of the resultant/ net force acting on an object and the time the resultant / net force acts on the object. □□ (2)

1. 2.1

OPTION 1	OPTION 2
Take direction towards left as positive $\sum p_i = \sum p_f$□ } Any one $0 = Mv_{cannon}$ □ mv_{ball} 0 □= (1250)□v + 1, 25 (-80)□ v = 100/1250 = 0, 08 $m.s^{-1}$ left	**Take direction towards right as positive** $\sum p_i = \sum p_f$□ } Any one $0 = Mv_{cannon}$ □ mv_{ball} 0 □= (1250)□ v + 1, 25 (80)□ v = 100/1250 = -0, 08 $m.s^{-1}$ v = 0, 08 $m.s^{-1}$ left□ (5)

1.2.2

OPTION 1	OPTION 2
Take direction towards left as positive $F_{net}\Delta t$□= $m\Delta v$ = mv_f – mv_i□ F(1, 0)□ = (1250)[(0)- (0, 08)] F = -100 N F_{net}= 100 N□ **OR** $V_f = v_i + a\Delta t$ 0=0, 08 + a(1,0)□ a = -0, 08 F_{net} = m x a = 1250 x (-0, 08) □= -100 N = 100 N□	**Take direction towards right as positive** $F_{net}\Delta t$□= $m\Delta v$ = mv_f – mv_i□ F(1, 0) □= (1250)[(0)-(-0, 08)] F_{net} = 100 N□

(4)

[11]

Question 2

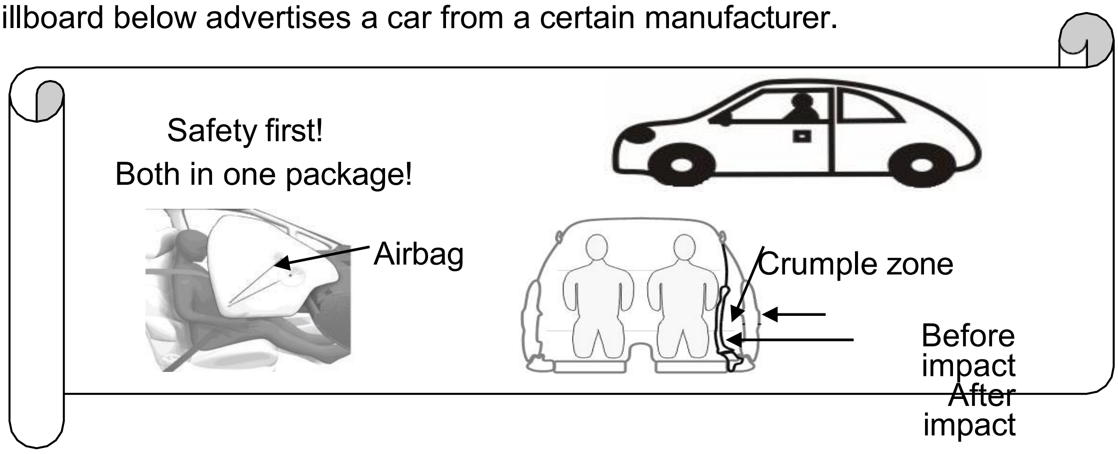
Collisions happen on the roads in our country daily. In one of these collisions, a delivery vehicle of mass 5 000 kg, moving at a velocity of 10 m·s^{-1} to the right collides head on with a car of mass 2 000 kg moving at 15 m·s^{-1} in the opposite direction. Immediately after the collision, the car moves at a velocity of 5 m·s^{-1} to the right.

2.1 Write down the *principle of conservation of linear momentum* in words. (2)

2.2 Calculate the magnitude of the velocity of the delivery vehicle immediately after the collision. (4)

2.3 If the collision lasts 0,4 seconds, calculate the force the delivery vehicle exerts on the car during the collision. (4)

The billboard below advertises a car from a certain manufacturer.



2.4 Use your knowledge of momentum and impulse to justify how the safety features mentioned in the advertisement contribute to the safety of passengers. (3)

2.5 Mention one disadvantage of passenger car airbags? (1)

[14]

Question 2 [Solution]

2.1 The total linear momentum in a closed/isolated system remains constant / is conserved.□□

(2)

2.2 **Right as positive**

$\Sigma p_i = \Sigma p_f$

$(mv_i)_1 + (mv_i)_2 = (mv_f)_1 + (mv_f)_2$□

(5000)(10) + (2000)(-15) □ = (5000)v_f + (2000)(5) □

v_i = 2 m·s^{-1}□

Left as

positive Σp_i =

Σp_f

$(mv_i)_1 + (mv_i)_2 = (mv_f)_1 + (mv_f)_2$□

(5000)(-10) + (2000)(15) □ = (5000)v_f + (2000)(-5) □ (4)

v_i = -2 m·s^{-1}

Magnitude of velocity = 2 m·s^{-1}□

2.3 $F_{net}\Delta t = mv_f - mv_i$□

Fnet (0,4) □= (5000)(2) – (5000)(10) □

Fnet = -100 000 N

Fnet = 100 000 N to the right□

OR

$F_{net}\Delta t = mv_f - mv_i$□

Fnet (0,4) □ = (2000)(-5) – (2000)(15) □

Fnet = -100 000 N

Fnet = 100 000 N to the right□ (4)

2.1 During a collision, the crumple zone/ airbag **increases the time** during which momentum changes □ and according to the equation

$F_{net} = \frac{\Delta p}{\Delta t}$ the **force during impact will decrease**. □

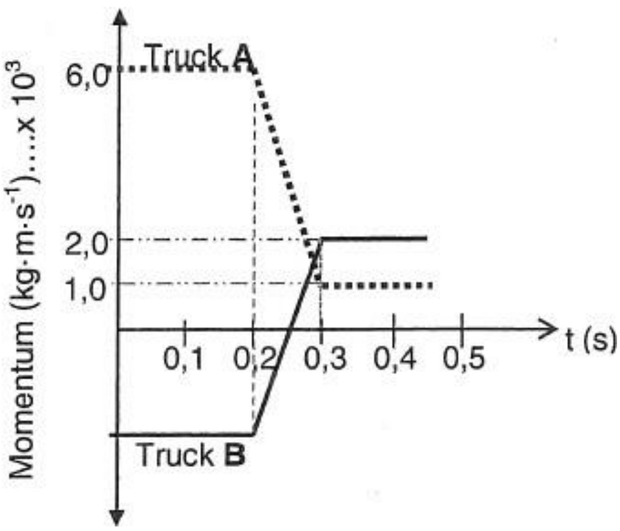
The crumple zone also crumples away from the passengers, causing less injury to the passengers. □ (3)

2.5

- When airbags deploy unexpectedly, they can result in trauma and sometimes injuries such as contusion of the face, chest or internal organs.□
- Because air bags deploy very rapidly, serious or sometimes fatal injuries can occur if the occupant is too close to- or is in direct contact with air bag when it first begins to deploy.
- The impact of an airbag can also hurt a passenger who is improperly positioned. (1)

Acitivity 1

Truck A of mass 2 000 kg moving eastwards collides with **truck B** of mass 1 500 kg. The graph (Not drawn to scale) shows how the momentum of each of the trucks varies with time.



1.1 Write down the initial momentum of **truck A** (2)

1.2 Determine the magnitude and direction of the velocity of **truck B** before the collision (4)

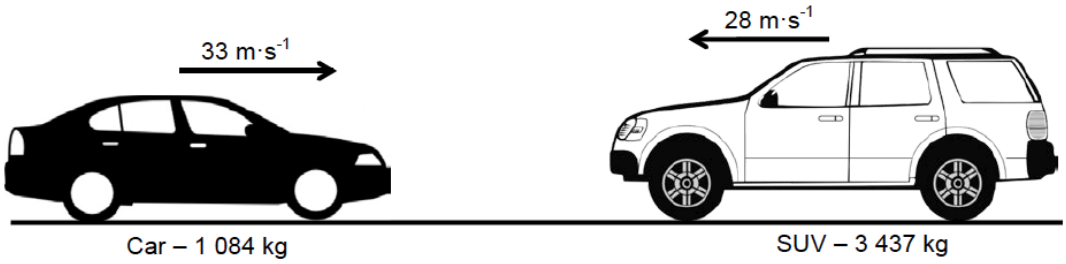
1.3 Is the collision between the trucks ELASTIC or INELASTIC? Show how you arrived at the answer by means of calculations (6)

[12]

Activity 2

Momentum and Impulse.

2.1 A small car of mass 1 084 kg was travelling east at a speed of 33 $m \cdot s^{-1}$. A large SUV of mass 3437 kg was travelling west at a speed of 28 $m \cdot s^{-1}$. The two vehicles collided head-on with each other.



Immediately after the collision the smaller car was moving west at 5 $m \cdot s^{-1}$.

2.1.1 Name the principle that you can use to determine the velocity of the SUV after collision (1)

2.1.2 Determine the velocity of the SUV immediately after collision. (4)

2.1.3 Use a relevant Calculation to determine whether the collision is ELASTIC or INELASTIC. (5)

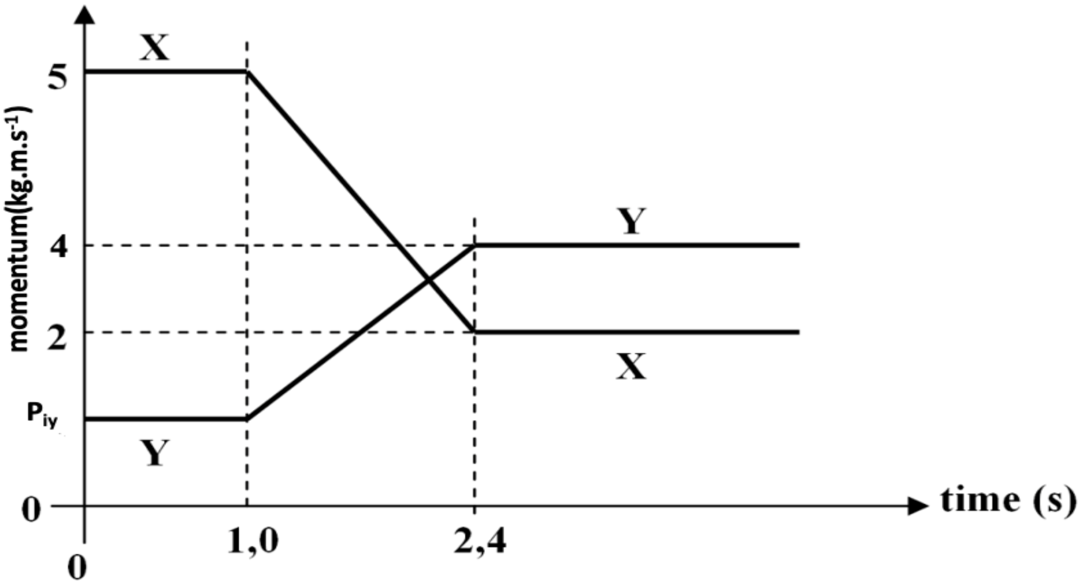
2.2 In another crash car of mass 1 200 kg crashes into a lamp post while moving at 20 $m \cdot s^{-1}$ and it rebounds(moves backwards) from the lamp post at 8 $m \cdot s^{-1}$.

The net force exerted by the lamp post on the car is $2{,}1 \times 10^5$ N backwards.

2.2.1 Define impulse in words. (2)

2.2.2 Calculate the contact time. (4)

2.3 The graph below shows the how the momentum of an objects **X** and Y changes with time before ,during and after collision The mass of object **X** is 500g and that of object **Y** is 1kg. East was taken as the positive direction.



2.3.1 Calculate the initial velocity of Object X. (3)

2.3.2 Calculate the initial momentum of object Y. (4)

2.3.3 Write down the physical quantity represented by the gradient of the graph (1)

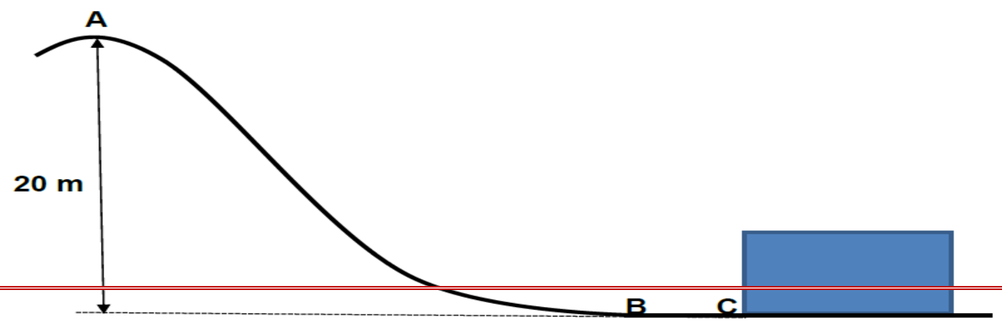
2.3.4 Calculate the magnitude of the net force experienced by Object X during the collision. (3)

2.3.5 Write down the magnitude of the net force experienced by Object X between 0 and 1,0s. (1)

[28]

Activity 3

3.1 A child of mass 40 kg slides down a water slide from point **A** through point **B** and collides with a soft foam cushion at point C. The segment **B** through to **C** is horizontal and at the lowest point of the water slide. The height of the slide is 20 m.



The magnitude of the velocity of the child at **A** is 0,5 $m \cdot s^{-1}$.

3.1.1 Define *kinetic energy*. (2)

3.1.2 Calculate the kinetic energy of the child at **A**. (3)

3.1.3 Assume that the child experiences friction while sliding between **A** and **B**, and that the child's velocity at **B** is 19,24 $m \cdot s^{-1}$. Calculate the work done by friction as the child slides from A to B. (5)

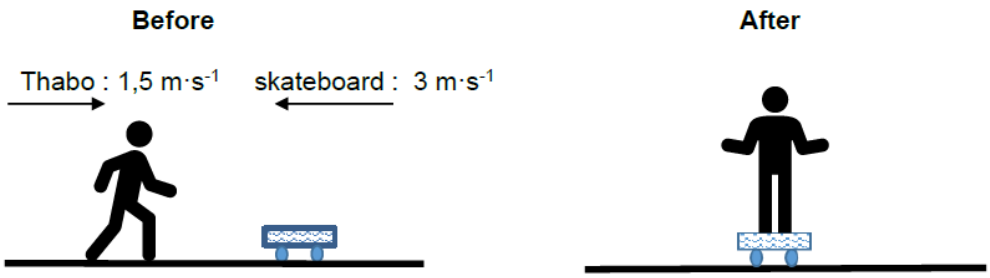
Assume that friction can be ignored in the portion of the slide from **B** to **C**.

The time taken for the child to come to rest, after hitting the surface of the foam, is 1,4 s.

3.1.4 Define the term *impulse*. (2)

3.1.5 Calculate the force exerted by the foam in bringing the child to rest. (5)

3.2 A skateboard of mass 5 kg is pushed to the left at 3 m·s-1 on a smooth flat surface. Thabo, mass 45 kg, runs to the right at 1,5 m·s-1 and jumps onto the skateboard.



3.2.1 State the law of *conservation of linear momentum*. (2)

3.2.2 Calculate the velocity of Thabo and the skateboard immediately after he lands on the skateboard. (5)

[24]

SUBJECT: PHYSICAL SCIENCES

GRADE 12

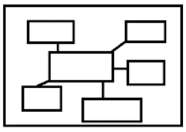
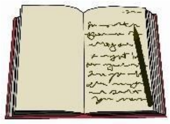
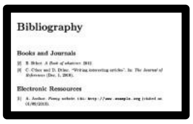
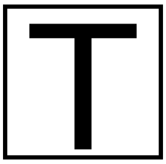
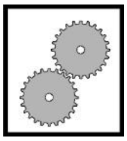
TERM 2

TEACHER AND LEARNER CONTENT MANUAL

Topic(s)

WORK ENERGY AND POWER

ICON DESCRIPTION

 MIND MAP	 EXAMINATION GUIDELINE	 CONTENTS	 ACTIVITIES
 BIBLIOGRAPHY	 TERMINOLOGY	 WORKED EXAMPLES	 STEPS

CONTENTS **PAGE**

Work, Energy and Power

(This section must be read in conjunction with the CAPS, p. 117–120.)

Work

- Define the work done on an object by a constant force F as $F\Delta x cos\theta$, where F is the magnitude of the force, Δx the magnitude of the displacement and θ the angle between the force and the displacement. (Work is done by a force – the use of the term 'work is done against a force', e.g. work done against friction, must be avoided.)
- Draw a force diagram and free-body diagrams.
- Calculate the net work done on an object.
- Distinguish between positive net work done and negative net work done on the system.

Work-energy theorem

- State the work-energy theorem: The work done on an object by a net force is equal to the change in the object's kinetic energy OR the work done on an object by a net force is equal to the change in the object's kinetic energy. In symbols: Wnet = ΔK = Kf - Ki
- Apply the work-energy theorem to objects on horizontal, vertical, and inclined planes (for both frictionless and rough surfaces).

Conservation of energy with non-conservative forces present.

- Define a conservative force as 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 (coulombic forces).
- Define a non-conservative force as 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.
- State the principle of conservation of mechanical energy: The total mechanical energy (sum of gravitational potential energy and kinetic energy) in an isolated system remains constant. NOTE: A system is isolated when the net external force (excluding the gravitational force) acting on the system is zero.
- Solve conservation of energy problems using the equation: $W_{nc} = \Delta E_k + \Delta E_p$
- Use the relationship above to show that in the absence of non-conservative forces, mechanical energy is conserved.

Power

- Define power as the rate at which work is done or energy is expended. In symbols: $P = \frac{W}{\Delta t}$
- Calculate the power involved when work is done.
- Perform calculations using $P_{ave} = Fv_{ave}$ when an object moves at a constant speed along a rough horizontal surface or a rough inclined plane.
- Calculate the power output for a pump lifting a mass (e.g. lifting water through a height at constant speed).

IMPORTANT TERMS AND DEFINITIONS	
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: $W_{net} = \Delta K = K_f - K_i$.
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: $E_{M(intial)} = E_{M(final)}$ OR $(E_p + E_k)_{initial} = (E_p + E_k)_{final}$
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)

TABLE 1: WORK, ENERGY AND POWER

$W = F\Delta x \cos\theta$	$U = mgh$ or/*of* $E_P = mgh$
$K = \frac{1}{2}mv^2$ or/*of* $E_k = \frac{1}{2}mv^2$	$W_{net} = \Delta K$ or/*of* $W_{net} = \Delta E_k$ $\Delta K = K_f - K_i$ or/*of* $\Delta E_k = E_{kf} - E_{ki}$
$W_{nc} = \Delta K + \Delta U$ or/*of* $W_{nc} = \Delta E_k + \Delta E_p$	$P = \frac{W}{\Delta t}$
$P_{ave} = Fv_{ave}$ / $P_{gemid} = Fv_{gemid}$	

MIND MAP

WORK DONE

- **Work** is the transfer of energy.
- **Work done (W)** on an object by a constant force is the product of the displacement and the component of the force parallel to the displacement.

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

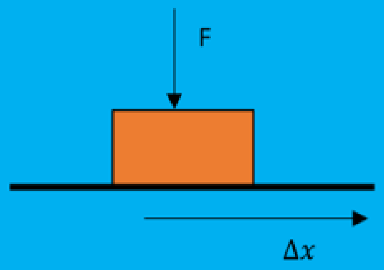
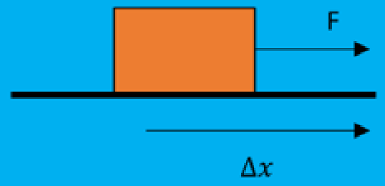
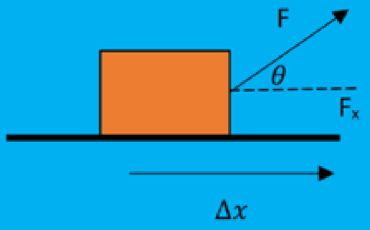
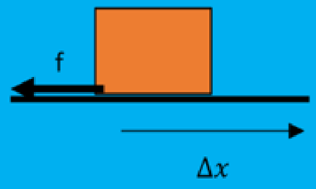
WHERE:

$\boldsymbol{W \rightarrow Work\ done\ in\ Joules(J)}$
$\boldsymbol{F \rightarrow magnitude\ of\ force\ in\ Newtons(N)}$
$\boldsymbol{\Delta x/\Delta y \rightarrow magnitude\ of\ displacement\ in\ metres(m)}$
$\boldsymbol{\theta \rightarrow magnitude\ of\ the\ angle\ between\ force\ and\ displacement}$

- Work is a scalar quantity, i.e. no direction.
- The joule is the amount of work done when a force of one newton moves its point of application one metre in the direction of the force.

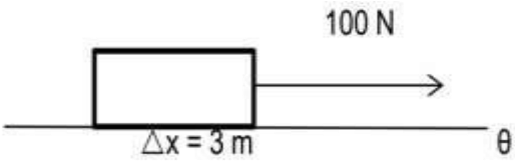
Work always involves two things:

- A constant force which acts on a certain object.
- The displacement of that object.

Zero Work done	Positive Work done		Negative Work done
			
$W = F\Delta x\cos\theta$ F *and* Δx ***perpendicular to each other*** $\theta = 90^\circ$ **$\cos\theta = \cos 90^\circ = 0$**	$W = F\Delta x\cos\theta$ F *and* Δx *parallel to each other* ***same diraction*** $\theta = 0^\circ$ **$\cos\theta = \cos 0^\circ = 1$**	$W = F_x\Delta x\cos\theta$ F *and* Δx ***angle θ to each other*** $F_x = F\cos\theta$ $W = F\cos\theta\Delta x\cos\theta$ $\theta = 0^\circ$ **$\cos\theta = \cos 0^\circ = 1$**	$W = f\Delta x\cos\theta$ F *and* Δx *parallel to each other* ***opposite diraction*** $\theta = 180^\circ$ **$\cos\theta = \cos 180^\circ = -1$**
• No Work done on an object if the force and displacement are perpendicular to each other.	• A force in the direction of the displacement does positive work on the object. The force increases the energy of the object.	• A force component in the direction of the displacement does positive work on the object. The force increases the energy of the object.	• A frictional force in the opposite direction of the displacement does negative work on the object. The force decreases the energy of the object.
	• Positive work means that energy is added to the system.		Negative work means that energy is removed to the system.

EXAMPLE 1

A box lying on a horizontal frictionless surface is pulled by a horizontal force of 100 N. The box is displaced 3m to the right, as shown in the sketch below. Calculate the work done by the force on the box.



There is one force acting on the object. .

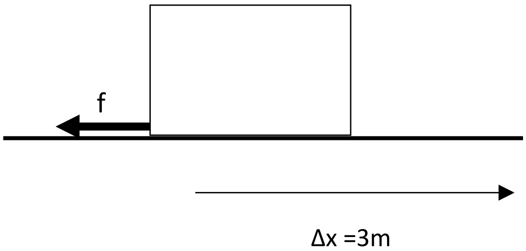
$W = F\Delta x cos\theta$

$W = (100)(3)cos0^{\circ}$

$W = 300\ J$

EXAMPLE 2

A box on a horizontal rough surface slide to the right and experiences a frictional force of 100 N. The box is displaced 3 m to as shown in the sketch below. Calculate the work done by the frictional force on the box.



. **There is one force acting on the object.**

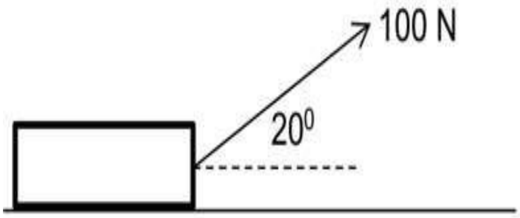
$W = f\Delta x cos\theta$

$W = (100)(3)cos180^{\circ}$

$W = -300\ J$

EXAMPLE 3

Calculate the work done on a box lying on a horizontal frictionless surface, by a 100 N force, which acts at an angle of 20º to the horizontal. The force displaces the box 3 m, as shown in the diagram below.



Again, there is one force (100 N) acting on the object.

$F_x = Fcos\theta$

$F_x = 100cos20^{\circ}$

$F_x = 93.9692620786N$

$W = F_x\Delta x cos\theta$

$W = (93.9692620786)(3)cos0^{\circ}$

$W = 281.91\ J$

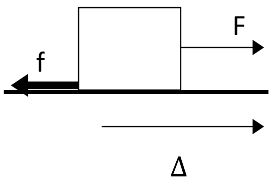
NET WORK ON AN OBJECT

- Several forces can act on an object at the same
- Each force can do work on the object to change the energy of object.
- The net work done on the object is the sum of the work done by force acting on the object.

  If W_{net} is **positive** **energy is** to the system.

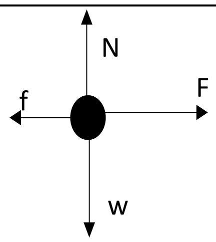
  If W_{net} is **negative** **energy is** from the system.

EXAMPLE 4



Calculate the net work done on a crate if a force of 60 N is applied on a crate. The crate moves 6 m to the right and experiences a frictional force of 10 N to the left.

N.B Draw a free-body diagram showing all the forces acting on the crate and label the forces.



Work done by weight and Normal force equal 0J BOTH are perpendicular to the displacement $(\theta = 90^\circ)$

OPTION 1

$W_{net} = W_F + W_f$

$W_{net} = F\Delta x\cos\theta + f\Delta x\cos\theta$

$W_{net} = (60)(6)\cos 0^\circ + (10)(6)\cos 180^\circ$

$W_{net} = 300J$

$F_{net} = F - f$

$F_{net} = 60 - 10$

$F_{net} = 50N$

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

$W_{net} = (50)(6)\cos 0^\circ$

$W_{net} = 300\ J$

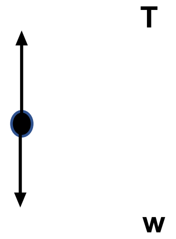
OPTION 3

OPTION

EXAMPLE 5

An electric motor is used to lift a load of bricks through a vertical height of 20m. The tension in the cable attached to the lift is 2000 N. Calculate the work done by the electric motor on the bricks.

- Draw a free-body diagram showing all the forces acting on the bricks and label the forces. There is one acting on the bricks, which is the tension (T) in the cable. Note that there is no normal force in this example



The angle between w and Δx is 180°.

There are two forces, and we use W_{net} and $F_{net.}$ $W_{net} = F_{net}\Delta x\cos\theta$

$$W_T = T\Delta x\cos\theta \qquad W_w = w\Delta x\cos\theta$$

$$W_T = 2000(20)\cos 0^{\circ} \qquad W_w = (50\,x\,9,8)\,(20)\cos 180$$

$$= 40000\,J \qquad = -\,9800\,J$$

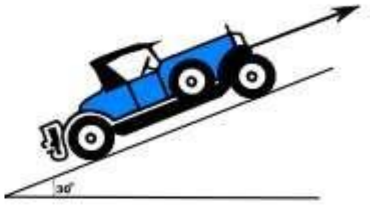
$$W_{net} = W_T + W_w$$

$$= 40000 + (-9800)$$

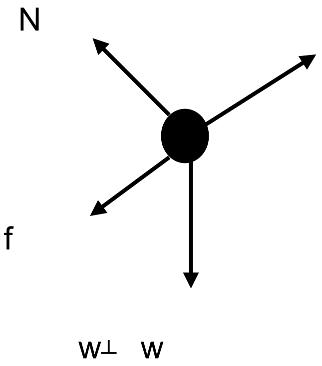
$$= 30200\,J$$

EXAMPLE 4

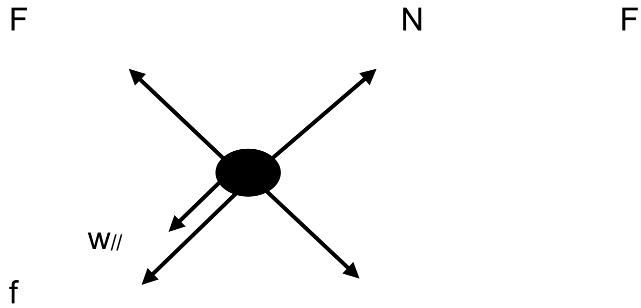
A 1200kg car is pulled 3m up an incline (30^0 with the ground) by a rope exerting a force of 8000N on the car. The car experiences a 20N frictional force.



4.1. Draw a labelled free body diagram of all the forces acting on the car.



or



4.2. Calculate the net work done on the car.

Work done by force applied (F)	**Work done by friction (f)**	**Work done by weight.**
$W_F = F\Delta x cos\theta$ $W_F = 8000(3)cos0°$ $W_F = 24000J$	$W_f = f\Delta x cos\theta$ $W_f = 20(3)cos180°$ $W_f = -60J$	$W_{w//} = w_{//}\ \Delta x cos\theta$ $W_{w//} = [mgsin\theta]\ \Delta x cos\theta$ $W_{w//} = [(1200)(9,8)sin30°](3)cos\ 180°$ $W_{w//} = -17640J$

Work Net

$Wnet = WF + Wf + Ww//$

$W_{net} = 24000 - 60 - 17640$

$W_{net} = 6300\ J$

WORK - ENERGY THEOREM:

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

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

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

- The work - energy theorem can be applied to the objects on horizontal, vertical, and inclined planes for both frictionless and rough surfaces.

CONSERVATIVE AND NON-CONSERVATIVE FORCES CONSERVATIVE FORCE

- Conservative force is a force for which the work done in moving an object between two points is independent of the path taken. *A force is a conservative force if:*
  The work done by the force in moving an object from point A to point B is independent of the path taken.
  The net work done in moving an object in a closed path which starts and ends at the same point is zero.

NON-CONSERVATIVE FORCE

- Non-conservative force is a force for which the work done in moving an object between two points depends on the path taken. *A force is a non-conservative force if:*

  The work done by the force in moving an object from point A to point B depends on the path taken.
  The net work done in moving an object in a closed path which starts and ends at the same point is not zero.

CONSEVATIVE FORCES	NON-CONSEVATIVE FORCES
Gravitational force	Frictional force
Electrostatic force	Tension
Elastic force	Applied force
	Air resistance

ENERGY

PRINCIPLE OF CONSERVATION OF MECHANICAL ENERGY

The total mechanical energy in an isolated system remains constant.

- Mechanical energy is **sum of gravitational potential energy** and **kinetic energy**.
- A system is isolated when the resultant/net external force acting on the system is zero.
- Be in the position to use the principles of energy to show that in the absence of nonconservative forces, mechanical energy is conserved.
- The **mechanical energy of a system is conserved** when **only conservative forces are present** in the system.
- The **mechanical energy of a system is not conserved when non-conservative forces are present** in the system (e.g. friction, air resistance, applied forces and tension).
- The **work done by these non-conservative forces** is **equal to the change in the total mechanical energy** of the system.

POWER

the rate at which work is done or energy is expended.

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

P → Power in Watts(W)

W → work done in Joules (J).

Δt → change in time in seconds (s).

- Be in the position to calculate the power involved when work is done.
- Perform calculations using when an object moves at a constant speed along a rough horizontal surface or a rough inclined plane.

AVERAGE POWER (CONSTANT VELOCITY)

- We can calculate the average power needed to keep an object moving at constant speed.
- If the car is driven at a constant speed, the magnitude of the forward force is equal to the magnitude of the frictional force.
- If the car is driven at constant speed, then the force of the engine up the slope must be equal in magnitude to the force down the slope.
- Be able to calculate the power output for a pump lifting a mass (e.g. lifting water through a height at constant speed).

Velocity is given by displacement over time:

$$v_{ave} = \frac{\Delta x}{\Delta t}$$

$$P_{ave} = F v_{ave}$$

NOTE:
P → Average Power
F → Force
V → Constant Velocity

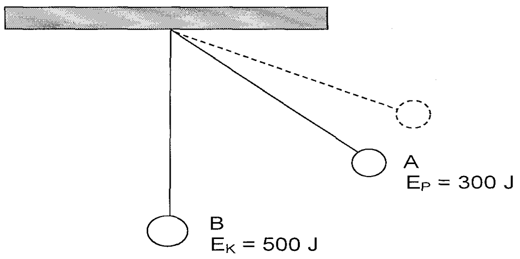
ACTIVITY 1 [MULTIPLE CHOICE QUESTIONS] **10 MARKS 10 MINUTES**

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Write only the letter (A–D) next to the question number (1.1–1.10) in the ANSWER BOOK

1.1 A 20,4 kg box remains at rest on a horizontal surface while the box is pushed horizontally with a force of 60 N. The coefficient of static friction between the box and the surface is 0,60.
What is the force of friction acting on the box during the push? (Rounded off to the closest whole number)

A 200 N
B 140 N
C 120 N
D 60 N (2)

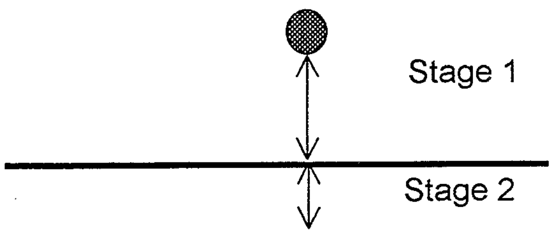
1.2 Consider the pendulum in the sketch. At a certain point A of its swing the ball has a gravitational potential energy of 300 J with respect to its **lowest point at B**. At point B the ball has a kinetic energy of 500 J.



The total mechanical energy of the system is ...

A. 800 J
B. 500 J
C. 300 J
D. 200 J (2)

1.3 A solid rubber ball dropped from a certain height above a swimming pool, takes 0,3 seconds to reach the surface of the water (**stage 1**). The ball enters the water and reaches its maximum depth after 0,2 seconds (**stage 2**). (Air resistance is negligible.



Which one of the following statements is **TRUE**?

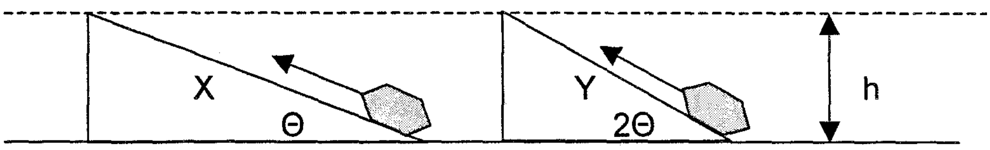
A. Both the mechanical energy and momentum of the ball are constant during **both stages** (0,5 seconds).

B. Both the mechanical energy and momentum of the ball are constant during **stage 1** (first 0,3 seconds).

C. Only the mechanical energy of the ball remains constant during **both stages** (0,5 seconds).

D. Only the mechanical energy of the ball remains constant during **stage 1** (0,3 seconds), but changes during **stage 2** (0,2 seconds) (2)

1.4 Two boys are pulling two identical objects at the same uniform speed up two different inclines, X and Y, of different gradients, but equal height. Friction can be ignored.

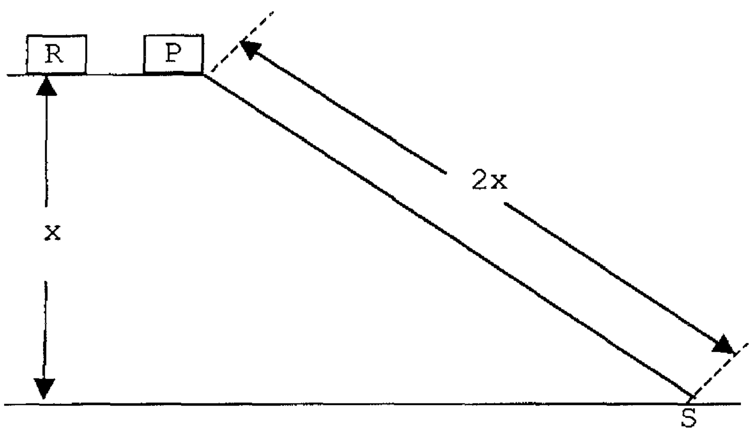


The **magnitude of the force** exerted by each of the boys and the **work done** can be compared as follows:

	Magnitude of the force	Work done
A	$F_X < F_Y$	$W_X > W_Y$
B	$F_X > F_Y$	$W_X > W_Y$
C	$F_X < F_Y$	$W_X = W_Y$
D	$F_X > F_Y$	$W_X = W_Y$

(2)

1.5 Two objects, **R** and **P**, of equal mass are at rest on top of a wall that has a vertical height **x**. **R** falls straight down and hits the ground with a speed ***v***. **P** slides down the frictionless incline, length **2x**, as shown in the sketch:



The speed of **P** at the bottom of the incline (point **S**) is …

A. ½ $\boldsymbol{v}$

B. $\boldsymbol{v}$

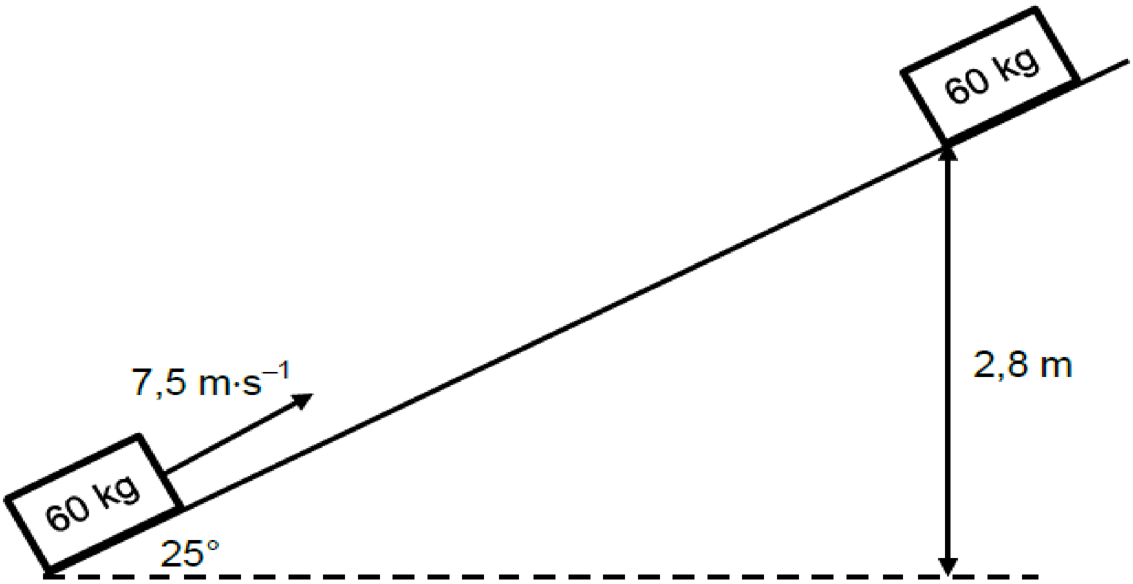
C. $\sqrt{2}\,\boldsymbol{v}$

D. 2 $\boldsymbol{v}$ (2)

[10]

ACTIVITY 2 **14 marks 14 minutes**

A cart with a mass of 60 kg is travelling at a speed of 7,5 m·s^{-1} at the bottom of a rough slope inclined at 25° to the horizontal. The cart comes to rest after travelling up the slope to a vertical height of 2,8m.



2.1 Define *kinetic energy* (2)

2.2 Calculate the kinetic energy of the cart at the bottom of the slope. (3)

2.3 Calculate the gain in gravitational potential energy of the cart at the highest point. (3)

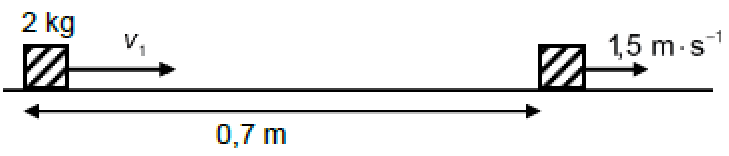
2.4 Calculate the work done against the frictional force as the cartmoves up the slope. (2)

2.5 Hence, calculate the magnitude of the frictional force acting onthe cart as it moves up the slope. (4)

[14]

ACTIVITY 3 **23 MARKS 23 MINUTES**

3.1 A box of mass 2 kg has an initial speed of v_i. The box travels across a rough surface and has a speed of 1,5 m·s^{-1}after it has travelled 0,7 m. The frictional force acting on the box is 26 N.



3.1.1 Define *frictional force*. (2)

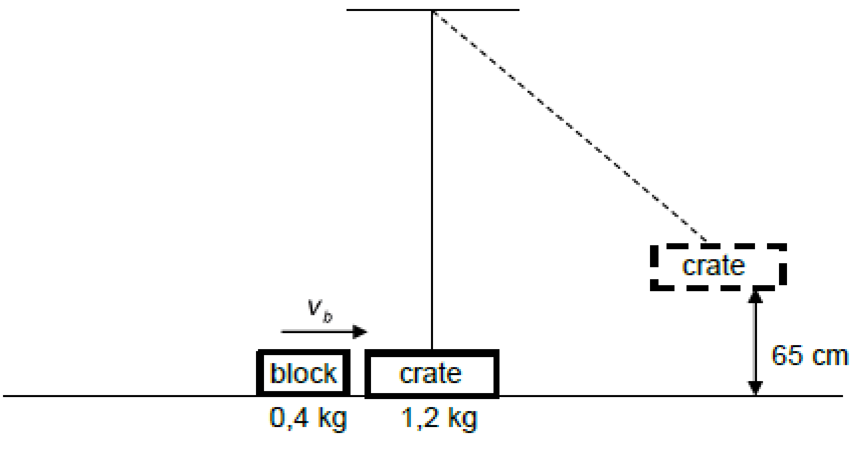
3.1.2 Calculate the kinetic energy of the box while it is travelling at 1,5 m·s^{-1} . (3)

3.1.3 Calculate the work done on the box by the frictional force. (3)

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

3.1.5 Calculate the initial speed v_i of the box. (3)

3.2 A 1,2 kg crate is attached to a long string as shown in the diagram. A block of mass 0,4 kg collides with the stationary crate with a velocity $v_b$and rebounds with a velocityof 0,36m·s^{-1}causing the crate to swing up through a vertical height of 65 cm. (Frictional forces are negligible)



3.2.1 State *the principle of conservation of mechanical energy.* (2)

3.2.2 Calculate the magnitude of the velocity of the crate immediately after the block collided with the crate. (3)

3.2.3 State *the law of conservation of linear momentum*. (2)

3.2.4 Calculate the magnitude of the velocity of the block, just before it collides with the crate. (3)

[23]

ACTIVITY 4 **13 MARKS 13 MINUTES**

A rescue helicopter is stationary (hovering) above the water to rescue a man in difficulties off the Clifton beachfront (**FIGURE 1**). It lowers a a lifebuoy with a mass 2 kg onto the water for the man to cling to it while the crew prepare to bring him aboard the helicopter (**FIGURE 2**). When the buoy is at a height of 10 m above the ground it has a velocity of 1,5 $m.s^{-1}$. A buoy is then lowered at a constant acceleration onto the water with a cable, where it eventually comes to rest. Assume there is no sideways motion during the descent. *Air friction is NOT to be ignored*.

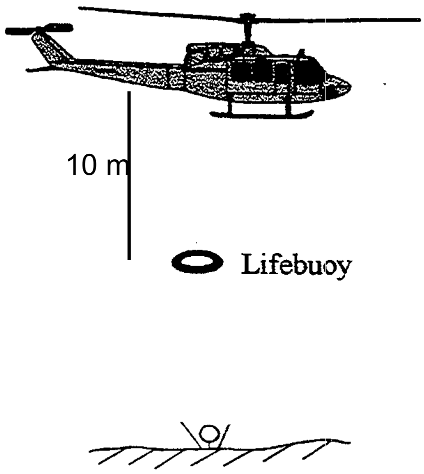


FIGURE 1

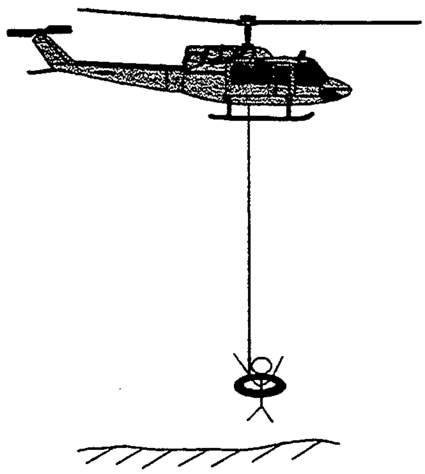


FIGURE 2

4.1 Define a *non-conservative force*. (2)

4.2 Identify TWO *non-conservative forces* acting on the buoy during its downward descent (motion). (2)

4.3 Write down the name of a *non-contact force* that acts on the man while he is out of the water and being hoisted upwards. (1)

4.4 Draw a free-body diagram showing ALL the forces acting on the buoy while it is being lowered to the water. (3)

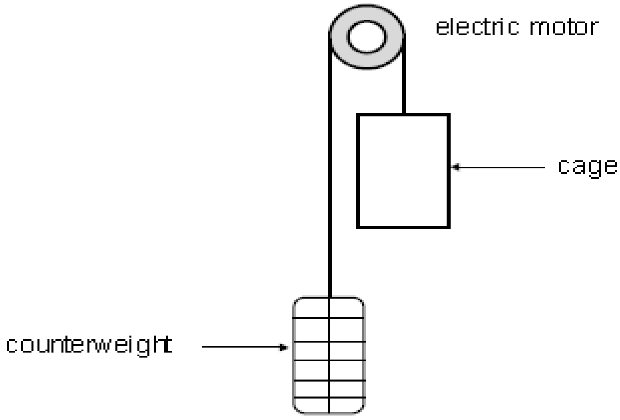
4.5 Write down the equation/formula of the WORK-ENERGY THEOREM (1)

4.6 Use the work-energy theorem to calculate the acceleration of the buoy as it is lowered to the water. (4)

[13]

QUESTION 5 **10 MARKS 10 MINUTES**

A lift arrangement comprises an electric motor, a cage, and its counterweight. The counterweight moves vertically downwards as the cage moves upwards. The cage and counterweight move at the same constant speed. Refer to the diagram below.



The cage, carrying passengers, moves vertically upwards at a constant speed, covering 60 m in 3 minutes. The counterweight has a mass of 870 kg. The total mass of the cage and passengers is 1 100 kg. The electric motor provides the power needed to operate the lift system. Ignore the effects of friction.

5.1 Calculate the work done by the:

5.1.1 Gravitational force on the cage (3)

5.1.2 Counterweight on the cage (2)

5.2 Calculate the average power required by the motor to operate the lift arrangement in 3 minutes. Assume that there are no energy losses due to heat and sound. (5)

[10]

JENN

Training and Consultancy

The path to enlightened education

SUBJECT: PHYSICAL SCIENCES

GRADE 12

TERM 2

TEACHER AND LEARNER CONTENT MANUAL

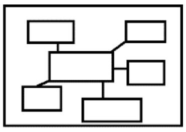
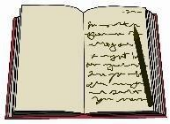
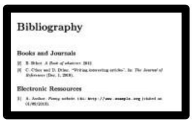
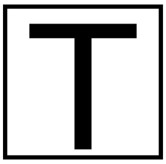
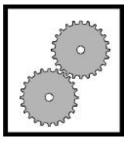
Topic(s)

ELECTROSTATICS

JENN MAREMATLOU TRAINING INSTITUTE

A Division of Marematlou Group Holdings

ICON DESCRIPTION

 MIND MAP	 EXAMINATION GUIDELINE	 CONTENTS	 ACTIVITIES
 BIBLIOGRAPHY	 TERMINOLOGY	 WORKED EXAMPLES	 STEPS

CONTENTS **PAGE**

EXAMINATION GUIDELINES

Electrostatics
(This section must be read in conjunction with the CAPS, p. 84–85.)

Coulomb's law

- State Coulomb's law: 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:
- Solve problems using the equation F = $\frac{kQ_1Q_2}{r^2}$ for charges in one dimension (1D)

  (restrict to three charges).
- Solve problems using the equation F = $\frac{kQ_1Q_2}{r^2}$ for charges in two dimensions (2D) – for r

  three charges in a right-angled formation (limit to charges at the 'vertices of a right-angled triangle').

Electric field

- Describe an *electric field* as a region of space in which an electric charge experiences a force. The direction of the electric field at a point is the direction that a positive test charge would move if placed at that point.
- Draw electric field lines for the following configurations:
  - A single point charge
  - Two point charges (one negative, one positive OR both positive OR both negative)
  - A charged sphere

NOTE: Restrict to situations in which the charges are identical in magnitude.

- Define *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 =$\frac{F}{Q}$
- Solve problems using the equation E = $\frac{F}{Q}$
- Calculate the electric field at a point due to a number of point charges, using the kQ equation E = $\frac{kQ}{r^2}$ to determine the contribution to the field due to each charge. Restrict

  to three charges in a straight line.

IMPORTANT DEFINITIONS

TERMS AND DEFINITIONS	
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 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.

CONTENT

ELECTROSTATICS

ELECTROSTATICS — Study of charges at rest

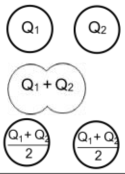
Two kinds of charge
Positive: electron deficient
Negative: excess of electrons

Neutral (uncharged):
Number of protons = number of electrons

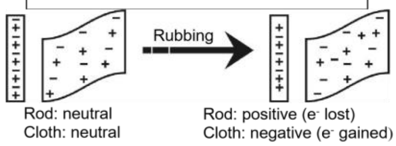
Quantisation of charge
All charges are multiples of the smallest charge i.e. the charge on one electron:
$q_e = 1,6 \times 10^{-19}$ C ($Q = nq_e$)

Conservation of charge
Charge cannot be created or destroyed. It can only be transferred from one object to another.

Charge on each of two identical conductors
Two identical conductors, each carrying a charge, will during contact share the charges equally and after separation they will have the same charge.



Charging of objects
By contact: Electrons transferred from one object to another.

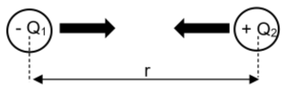


Unit of charge: coulomb (C)
1 C is a huge charge. Charges we encounter are much smaller. Therefore, smaller units of charge are used as given below:

1 C	1 coulomb	
1 mC	1 millicoulomb	1×10^{-3} C
1 μC	1 microcoulomb	1×10^{-6} C
1 nC	1 nanocoulomb	1×10^{-9} C
1 pC	1 picocoulomb	1×10^{-12} C

Electrostatic force
Like charges repel; Unlike charges attract

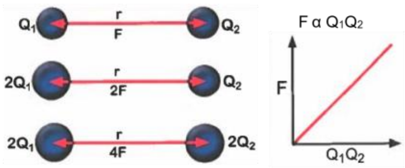
Coulomb's law

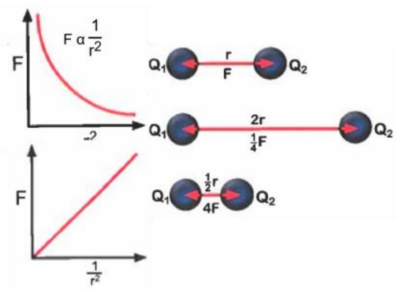


$F \propto Q_1Q_2$ and $F \propto \frac{1}{r^2}$

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

F: electrostatic force in newton (N)
k: Coulomb's constant (9×10^9 N·m²·C⁻²)
Q_1: point charge 1 in coulomb (C)
Q_1: point charge 2 in coulomb (C)
r: distance between two charges in meter (m)





Electric field — Region in space where an electric charge will experience a force.

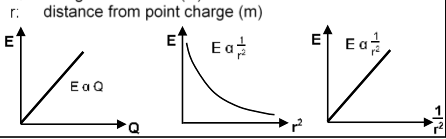
Electric field
- **Definition:** The electric field at a point is the electrostatic **force experienced per unit positive charge** placed at that point.
- **In symbols**: $E = \frac{F}{q}$
- **Unit:** N·C⁻¹
- **Vector quantity** with magnitude and direction
- Direction **away from positive towards negative charge**

Represented by field lines.

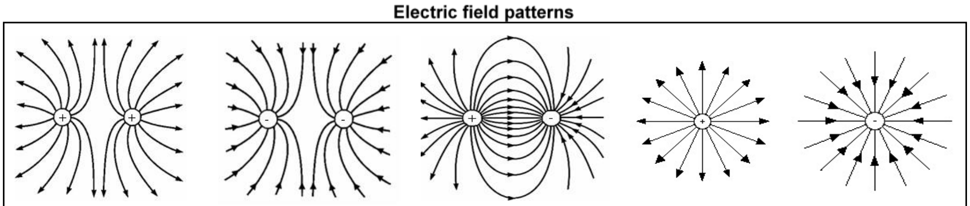
Electric field
At a certain distance from a point charge:

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

E: electric field
k: Coulomb's constant (9×10^9 N·m²·C⁻²)
Q: charge in coulomb (C)
r: distance from point charge (m)



Electric field patterns

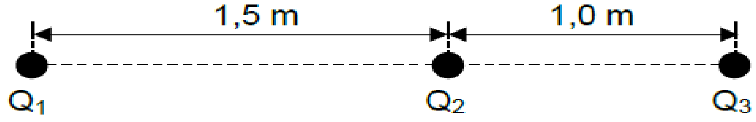


WORKED EXAMPLES

QUESTION 1

In the diagram below, **Q1, Q2** and **Q3** are three-point charges placed along a straight line.

All three charges are fixed in position. The distance between **Q1** and **Q2** is 1,5 m and the distance between **Q2** and **Q3** is 1,0 m as shown in the diagram below.



1.1 State *Coulomb's law*. (2)

The magnitude of charges **Q1** and **Q2** are unknown. The charge on **Q1** is positive. The charge on **Q3** is + 2 μC and **Q3** experiences a net electrostatic force of 0,3 N to the left (towards **Q1**)

1.2 Is the sign of charge **Q2** positive or negative? (2)

Charge Q2 is now removed. The magnitude of the electrostatic force experienced by **Q3** due to **Q1** is now 0,012 N.

1.3 Calculate the magnitude of the unknown charge **Q1**

(5)
[9

QUESTION 1 [Solution]

1.1 Coulomb's law states that two point charges in free space or air exert forces on each other. The force is directly proportional to the product of the charges ✓ and inversely proportional to the square of the distance between the charges. ✓ (2)

1.2 negative✓✓ (2)

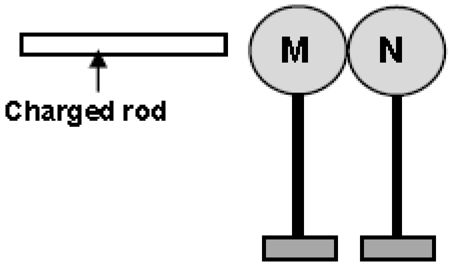
1.3 $F = \frac{kQ_1Q_3}{r^2}$ √

0.012 √= $(9 \times 10^9)Q_1 (2 \times 10^{-6}) / (2,5)^2$ √√

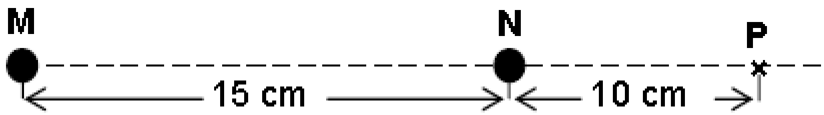
$Q_1 = 4,17 \times 10^{-6}$ C√
(5)

ACTIVITY 1

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**.



1.1 What is the net charge on sphere **N** after separation? (2)

1.2 Write down the net charge on sphere **M** after separation. (1)

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.

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

1.4 Calculate the net electric field at point **P** due to **M** and **N**. (4)

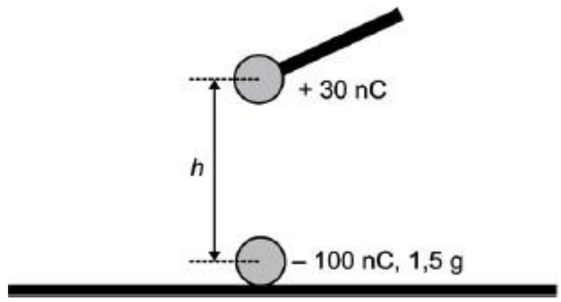
[9]

ACTIVITY 2

2.1 In a demonstration on electrostatics, a small metal ball on an insulating rod is given a charge of + 30 nC.

2.1.1 Draw a diagram showing the electric field around a + 30 nC charge. (2)

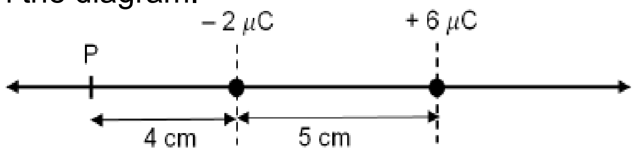
The + 30 nC charge is now held directly above a similar ball having a charge of – 100 nC and a mass of 1,5 g, which lies on an insulating table. The upper ball is brought closer to the lower ball in order to pick it up.



2.1.2 State *Coulomb's Law*, in words (2)

2.1.3 Calculate the distance h at which the 1,5 g ball will just be lifted off the table by the electrostatic force. (5)

2.2 Charged particles of – 2 μ C and + 6 μ C are placed 5 cm apart as shown in the diagram.



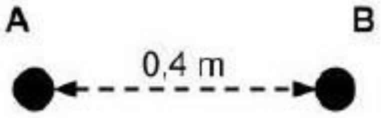
2.2.1 Calculate the magnitude of the electric field due to the + 6 μ C charge at point **P**. (4)

2.2.2 Hence, calculate the net electric field at point **P**. (5)

[18]

ACTIVITY 3

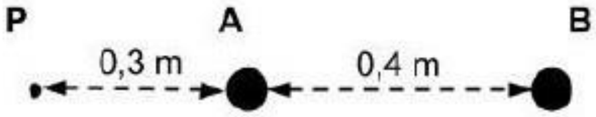
Two identical spheres, **A** and **B,** both negatively charged, are placed 0,4 m apart in a vacuum. The charge on sphere B is -16 nC. The magnitude of the electrostatic force that one sphere exerts on the other is 7,2 x 10^{-6} N.



3.1 State *Coulomb's Law* in words. (2)

3.2 Calculate the charge on sphere A. (3)

Point P is a point 0, 3 m to the left of A as shown below:



3.3 Calculate the net electric field at the location of **P** due to **A** and **B**. (Treat the spheres as if they were point charges.) (6)

The spheres are brought together, allowed to touch, and then moved back to their original positions, 0,4 m apart.

3.4 When the spheres touch, are electrons transferred from **A** to **B** or from **B** to **A**? (1)

3.5 Calculate the number of electrons transferred from one sphere to the other. (4)

[16]

JENN

Training and Consultancy

The path to enlightened education

SUBJECT: PHYSICAL SCIENCES

GRADE 12

TERM 2

TEACHER AND LEARNER CONTENT MANUAL

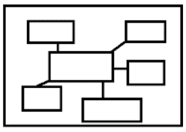
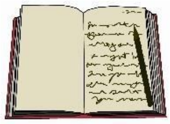
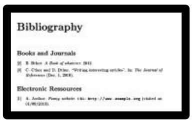
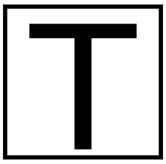
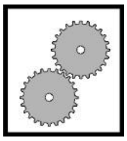
Topic(s)

ELECTRIC CIRCUITS

JENN MAREMATLOU TRAINING INSTITUTE

A Division of Marematlou Group Holdings

ICON DESCRIPTION

 MIND MAP	 EXAMINATION GUIDELINE	 CONTENTS	 ACTIVITIES
 BIBLIOGRAPHY	 TERMINOLOGY	 WORKED EXAMPLES	 STEPS

CONTENTS PAGE

Examination guideline

Electric Circuits (This section must be read in conjunction with the CAPS, p. 88–89 & 121.)

Ohm's law

- State Ohm's law in words: The potential difference across a conductor is directly proportional to the current in the conductor at constant temperature.
- Determine the relationship between current, potential difference and resistance at constant temperature using a simple circuit.
- State the difference between ohmic conductors and non-ohmic conductors and give an example of each.
- Solve problems using R= $\frac{V}{I}$ for series and parallel circuits (maximum four resistors).

Power, energy

- Define *power* as the rate at which work is done.
- Solve problems using P = $\frac{W}{\Delta t}$
- Solve problems using P = VI , P = I^2R or P = $\frac{V^2}{R}$
- Solve circuit problems involving the concepts of power and electrical energy.
- Deduce that the kilowatt hour (kWh) refers to the use of 1 kilowatt of electricity for
 1 hour.
- Calculate the cost of electricity usage given the power specifications of the appliances used, the duration and the cost of 1 kWh.

Internal resistance, series and parallel networks

- Solve problems involving current, voltage and resistance for circuits containing arrangements of resistors in series and in parallel (maximum four resistors excluding internal resistance).
- Define the term *emf* as the maximum energy provided by a battery per unit

charge passing through it.

- Solve circuit problems using $\varepsilon = V_{load} + V_{internal\ resistance}$ or $\varepsilon = IR_{ext} + Ir$.
- Solve circuit problems, with internal resistance, involving series-parallel networks of resistors (maximum four resistors).

IMPORTANT TERMS AND DEFINITIONS

TERMS AND DEFINITIONS	
Ohm's law	The potentiaL difference across a conductor is directly proportional to the current in the conductor at constant temperature. In symbols: $R = \frac{V}{I}$ The units: $\Omega = V \cdot A^{-1}$
Emf	Maximum energy provided / amount of 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 terminals of a battery when there IS a current in the circuit.)
Ohmic	A conductor that obeys Ohm's law, i.e., the ratio of potential

conductors	difference to current remains constant. (Resistance of the conductor remains constant.)
Non-ohmic conductors	A conductor that does NOT obey Ohm's law, i.e., the ratio of potential difference to current does NOT remain constant. (Resistance of the conductor increases as the current increases, e.g. a bulb.)
Potential difference	Potential difference is the amount of work done (or energy transferred) per coulomb of charge. It is measured in volt (V). In symbols: V = $\frac{W}{Q}$ The units: $V = J \cdot C^{-1}$
Current	Current is the rate of flow of charge. It is measured in ampere (A). In symbols: I =$\frac{Q}{\Delta t}$ The units: $A = C \cdot s^{-1}$
Resistance	Resistance is the opposition to the flow of charge (electric current). It is measured in ohm (Ω) and can be calculated by using the ratio of potential difference (V) to current (I). In symbols: R = $\frac{V}{I}$ The units: $\Omega = V \cdot A^{-1}$
Resistors in series	The total resistance of resistors in series is given by: $R_T = R_1 + R_2 + \cdots$ OR $R_S = R_1 + R_2 + \cdots$
Resistors in parallel	The effective resistance (do NOT use the word "total") of resistors in parallel is given by: $\frac{1}{RP} = \frac{1}{R1} + \frac{1}{R2} + \cdots$
Internal resistance	The resistance within a battery that causes a drop in the potential difference across the battery when there is a current in the circuit.
Power	Power is the rate at which work is done or rate at which energy is transferred. It is measured in watt (W). In symbols: P = $\frac{W}{\Delta t}$The units: $W = J \cdot s^{-1}$
	Other formulae for power: $P = VI$ $P = I^2R$ P = $\frac{V^2}{R}$
kilowatt hour (kWh) (This is an energy unit related to the formula $W = P\Delta t$.)	It is the use of 1 kilowatt of electricity for 1 hour.
Other energy formulae (electric circuits)	$W=VQ$ $W=VI\Delta t$ $W = I^2R\Delta t$ $W = \frac{V^2}{R}\Delta t$

CONTENT

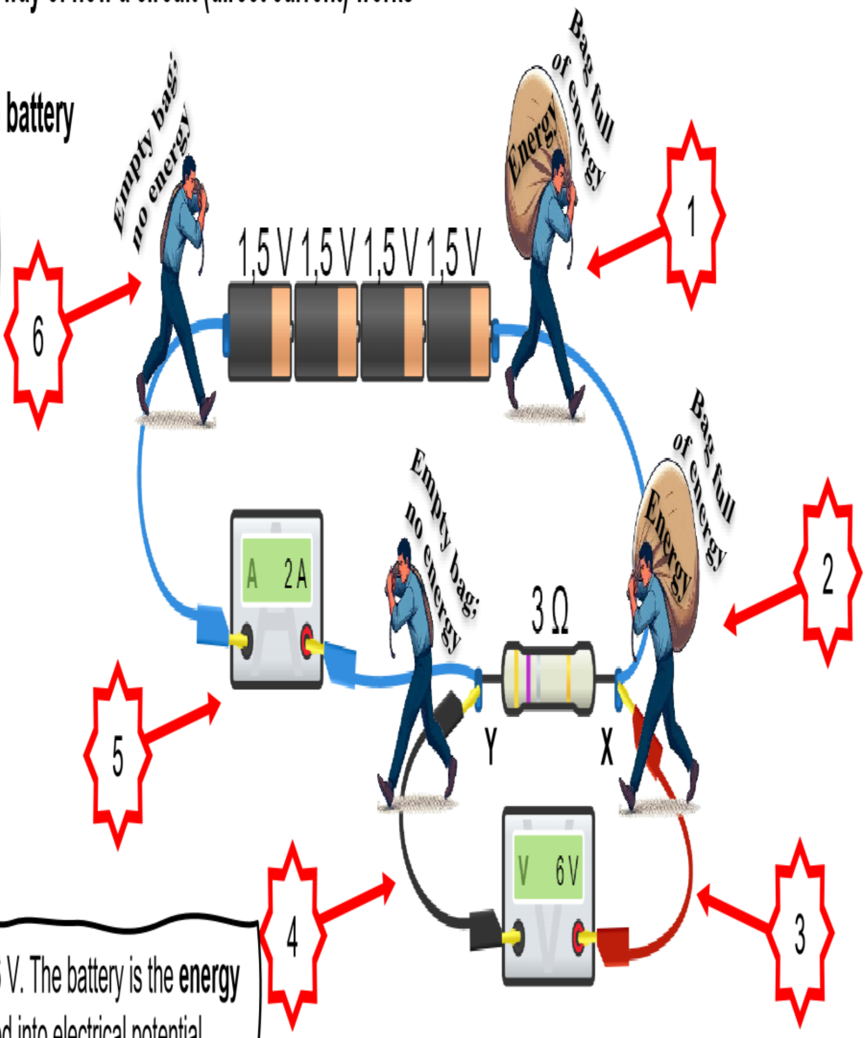
A simple way of how a circuit (direct current) works

Example 1: One resistor is connected in series with the battery

Read this first to understand the idea of the picture.

In this example, **one coulomb of charge** is represented by the **picture of the man**. He carries a bag initially filled with **energy**. The **same man** is represented at **different positions** in the circuit. Only ONE coulomb is represented here, but there are millions of charges behind and in front of this one doing the same things described in this example.

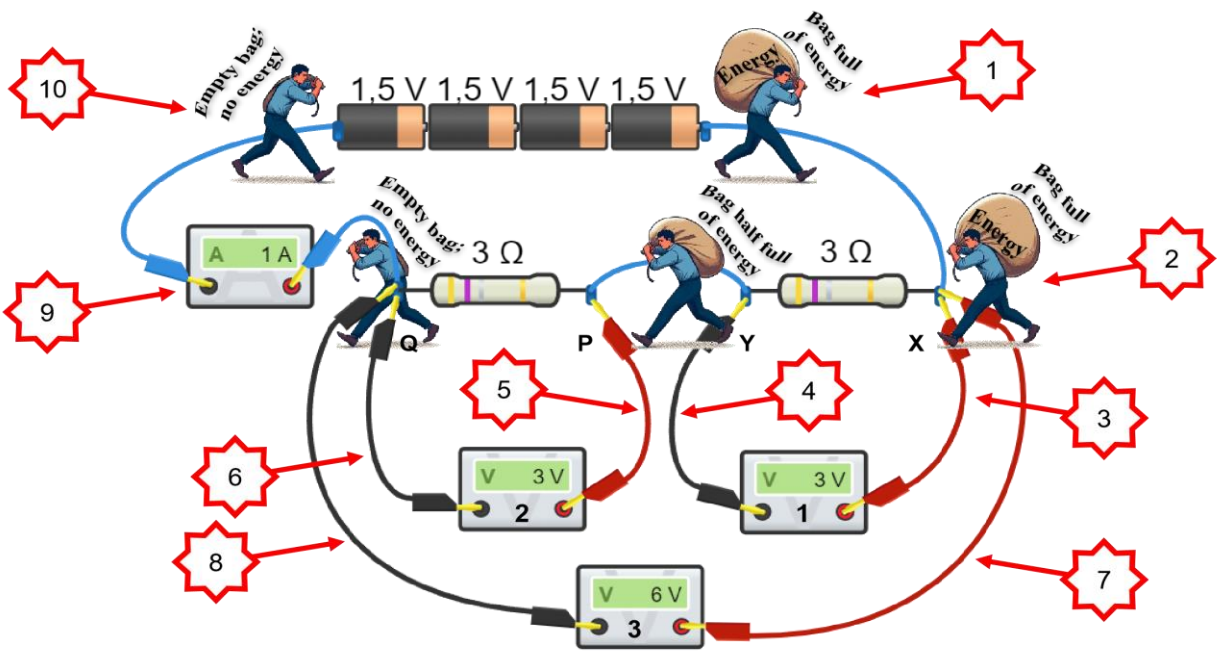
Follow the numbers below and study what happens in the circuit.



Each cell's emf is 1,5 V. For four cells (the battery), the emf is 6 V. The battery is the **energy factory**. Chemical potential energy of the chemicals is converted into electrical potential energy and the **charges are transporting the energy** to the resistor in the circuit.

CONTENT

Example 2: Two resistors are connected in series with the battery



1

1.One coulomb of charge leaves the battery with the **maximum amount of energy**. In this case it is 6 J·C^{-1} because the emf of the battery is 6 V.

2. This coulomb of charge arrives at the first resistor with 6 J of energy. If there are **more than one resistor in series**, the charges must **transfer energy to EACH of the resistors**. The amount of energy transferred depends on each resistor's resistance. In this example, the resistances are the same; hence, each one gets half of the energy.

3.Voltmeter 1 measures 6 J·C^{-1} at **X before** the energy is transferred to the resistor. Half of this energy is transferred to the first resistor. Hence, there is 3 J·C^{-1} of energy left.

4.Voltmeter 1 measures 3 J·C^{-1} at **Y after** the energy was transferred.
The reading on voltmeter 1 = reading at **X** - reading at **Y** = 6 J·C^{-1} - 3 J·C^{-1} = 3 J·C^{-1} = 3 V

5.The coulomb of charge flows further and reaches the second resistor where the remaining energy is transferred to the resistor. Voltmeter 2 measure 3 J·C^{-1} at **P before** the energy is transferred to the resistor. It is the same reading as at **Y** because no energy is transferred to the conductors.

6.Voltmeter 2 measures 0 J·C^{-1} at **Q after** the energy was transferred.
The reading on voltmeter 2 = reading at **P** - reading at **Q** = 3 J·C^{-1} - 0 J·C^{-1} = 3 J·C^{-1} = 3 V

7.Voltmeter 3 is connected **across BOTH resistors**. It therefore measures the amount of energy at **X** and **Q**. At **X** it measures 6 J·C^{-1}. All the energy is transferred to both resistors.

8.Voltmeter 3 measures 0 J·C^{-1} at **Q after** the energy was transferred.
The reading on voltmeter 3 = reading at **X** - reading at **Q** = 6 J·C^{-1} - 0 J·C^{-1} = 6 J·C^{-1} = 6 V

Note that the reading on voltmeter 3 is equal to the sum of the readings on voltmeters 1 and 2.

9.The charges flow **through** the ammeter. If one coulomb of charge flows through the ammeter in one second, the current is:

$I = \frac{Q}{\Delta t} = \frac{1}{1} = 1\, C \cdot s^{-1} = 1\, A.$

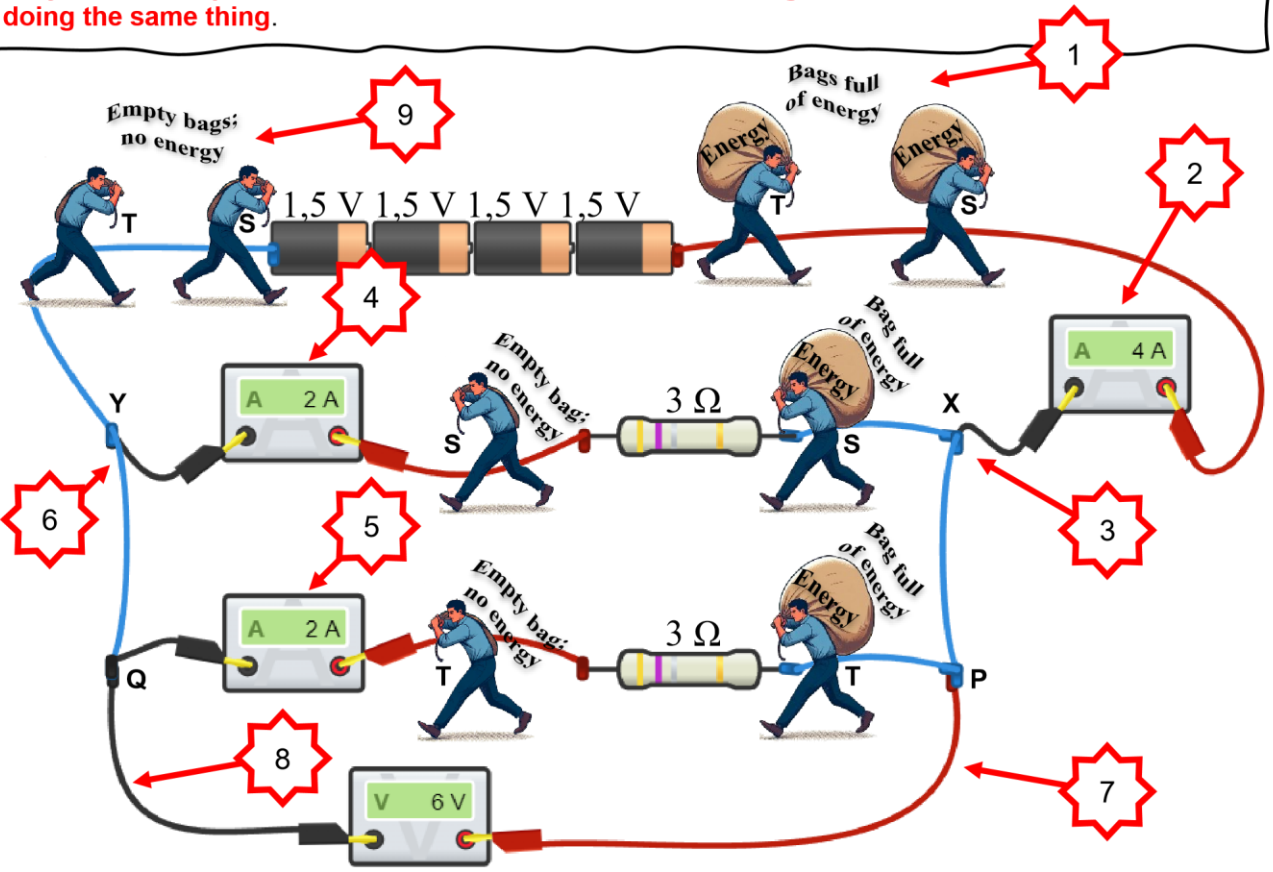
10.The coulomb of charge returns to the battery where the bag is again filled with energy and the process is then repeated for this coulomb of charge until the battery is flat.

Note once again that:

- Each voltmeter measures the **potential difference at TWO points**.
- The voltmeter reading represents the energy per coulomb of charge transferred to the resistor that is **connected between its wires**. This is important. **The reading on any voltmeter is only applicable to the resistor(s) connected between its wires while charges are flowing**.
- All three **voltmeters** are connected in **parallel** with the resistors.
- **There is no change in the charges** itself. It is **only the energy that is transferred** to the resistor.
- The charges flow **through** the ammeter and the latter measures the current **at the point where it is connected**.

Example 3: Two resistors are connected in parallel with the battery

In this example, we look at **two coulomb of charge**, **each one** represented by the **picture of the man**. **Only TWO are represented here, but there are millions of charges behind and in front of those doing the same thing**.



1 **Each coulomb** of charge, labelled **S** and **T**, leaves the battery with the **maximum amount of energy**. In

a. each case it is 6 J·C^{-1} because the emf of the battery is 6 V.

2. Both coulombs of charge flow **through** this ammeter because it is the **only path** for them to follow. This is what is called the **main current** of the circuit. If, for example, four coulomb of charge flows through this ammeter in one second, the **main current** I = $\frac{Q}{\Delta t}$ = $\frac{4C}{1S} = 4A$
3. At point **X**, the main current splits into **two branch currents**. One branch is represented by **XY** and the other branch by **XPQY**. Some of the coulombs of charge (labelled **S**) flow through branch **XY** and the others (labelled **T**) flow through branch **XPQY**. **The ratio in which the main current splits into two branch currents depend on the ratio of the resistors in the branches.** In **this example** the **resistances** are **equal**; hence the main current splits into **two equal branch currents**.
4. This ammeter measures the current in branch **XY** only. Hence, it measures 2 A if the main current is 4 A with equal branch resistances.
5. This ammeter measures 2 A, which is the current in branch **XPQY**.
6. 2,4&5 **Very important: The sum of the two branch currents is equal to the main current**.
7. At point **Y**, the two branch currents combine again to form the main current.

Note that the voltmeter is connected across both resistors because they are connected in parallel.

1. The wire of the voltmeter is connected at **P**, but the reading on the voltmeter is also valid for **X** because there is just another wire between **P** and **X**. The coulomb of charge labelled **S** arrives at the resistor in branch **XY** with 6 J of energy. Hence, the voltmeter measures 6 $J \cdot C^{-1}$ at **X before** the energy is transferred to the resistor.
2. The voltmeter measures 0 $J \cdot C^{-1}$ at **Y after** the energy was transferred to the single resistor in branch **XY**.
3. The coulomb of charge labelled **T** arrives at the resistor in branch **XPQY** with 6 J of energy. Hence, the voltmeter also measures 6 $J \cdot C^{-1}$ at **P before** the energy is transferred to the resistor.
4. For branch **XPQY**, the voltmeter measures 0 $J \cdot C^{-1}$ at **Q after** the energy was transferred to the single resistor in branch **XPQY**.
   a. The reading on the voltmeter = reading at **P** (or **X**) - reading at **Q** (or **Y**)
5. = 6 $J \cdot C^{-1}$ - 0 $J \cdot C^{-1}$ = 6 $J \cdot C^{-1}$ = 6 V
6. **Very important: The reading on the voltmeter is the same for both resistors.**
7. The two coulombs of charge return to the battery where new energy is obtained from the battery and the process is then repeated until the battery is flat.
8. Let's confirm the readings on the ammeters and voltmeters in the three examples and make some important conclusions about the use of formulae.

<u>**Example 1**</u>

Known data is: emf = 6 V; external resistor = 3 Ω; internal resistance = 0 Ω

To calculate the reading on the ammeter, which is the total (main) current in the circuit:

$$R_{total} = \frac{V_{emf}}{I_{total}}$$
$$3 = \frac{6}{I_{total}}$$
$$I_{total} = 2\,A$$

The three variables deal with the **same situation**. The **total** resistance, the **total** current and the **emf**, which is the "maximum" potential difference.

To calculate the reading on the voltmeter, which is the potential difference across the specific resistor:

$$R = \frac{V}{I_{total}}$$
$$3 = \frac{V}{2}$$
$$V = 6\,V$$

Once again, the three variables deal with the **same situation**. The **specific** resistance, the current in **that** resistor and the potential difference across the **specific** resistor.

Example 2

Known data is: emf = 6 V; each external resistor = 3 Ω and they are connected in series; internal resistance = 0 Ω

To calculate the reading on the ammeter, which is the total (main) current in the circuit:

$$R_T = R_1 + R_2 = 3 + 3 = 6\,\Omega$$
$$R_T = \frac{V_{emf}}{I_{total}}$$
$$6 = \frac{6}{I_{total}}$$
$$I_{total} = 1\,A$$

The three variables in $R = \frac{V}{I}$ deal with the **same situation**. The **total** resistance, the **total** current and the **emf**.

To calculate the reading on voltmeter 1, which is the potential difference across **one** of the resistors:

$$R = \frac{V_1}{I_{total}}$$
$$3 = \frac{V_1}{1}$$
$$V_1 = 3\,V$$

The three variables deal with the **same situation**. The **specific** resistance, the current in **that** resistor and the potential difference across the **specific** resistor.

To calculate the reading on voltmeter 2, which is the potential difference across **one** of the resistors:

$$R = \frac{V_2}{I_{total}}$$
$$3 = \frac{V_2}{1}$$
$$V_2 = 3\,V$$

The three variables deal with the **same situation**. The **specific** resistance, the current in **that** resistor and the potential difference across the **specific** resistor.

To calculate the reading on voltmeter 3, which is the potential difference across **both** resistors:

$$R_T = \frac{V_3}{I_{total}}$$
$$6 = \frac{V_3}{1}$$
$$V_3 = 6\,V$$

The three variables deal with the **same situation**. The **total** resistance is used, the current in **both** resistors and the potential difference across **both** resistors.

Example 3

Known data is: emf = 6 V; each external resistor = 3 Ω and they are connected in parallel; internal resistance = 0 Ω

To calculate the reading on the ammeter that measures the **main** current in the circuit:

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$$
$$= \frac{1}{3} + \frac{1}{3}$$
$$R_P = 1{,}5\ \Omega$$

$$R_P = \frac{V_{emf}}{I_{total}}$$
$$1{,}5 = \frac{6}{I_{total}}$$
$$I_{total} = 4\ A$$

The three variables in $R = \frac{V}{I}$ deal with the **same situation**. The **effective** resistance, the **total** current and the **emf**.

To calculate the reading on the voltmeter, which is the potential difference across each resistor: (*)

$$R_P = \frac{V}{I_{total}}$$
$$1{,}5 = \frac{V}{4}$$
$$V = 6\ V$$

The three variables deal with the **same situation**. The **effective** resistance, the **total** current in both resistors and the potential difference across **one or both** resistors.

To calculate the reading on the ammeter in branch **XY**, which is **one** of the branch currents:

$$R = \frac{V}{I_{XY}}$$
$$3 = \frac{6}{I_{XY}}$$
$$I_{XY} = 2\ A$$

The three variables deal with the **same situation**. The **specific** resistance, the current in **that** resistor and the potential difference across the **specific** resistor.

To calculate the reading on the ammeter in branch **XPQY**, which is the **other** branch current:

$$R = \frac{V}{I_{XPQY}}$$
$$3 = \frac{6}{I_{XPQY}}$$
$$I_{XPQY} = 2\ A$$

The three variables deal with the **same situation**. The **specific** resistance, the current in **that** resistor and the potential difference across the **specific** resistor.

(*) In this solution, the voltmeter reading was calculated by using the main current, followed by the calculation of the two branch currents by using the voltmeter reading. If a branch current is available, it can also be used to calculate the voltmeter reading.

The most important conclusion to make from these examples is that you must always ensure that **variables** in an equation **address the same situation!**

That is true for any equation!

A few notes about internal resistance

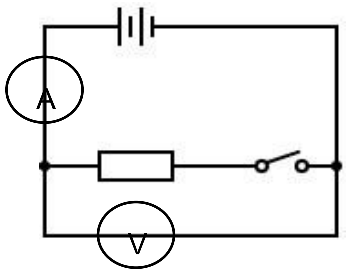
Questions usually indicate whether the cell or battery has internal resistance and therefore it is important to know how to deal with internal resistance if it must be taken into consideration.

The following are important aspects of internal resistance:

- Cells consists of chemicals and other materials and in real life it resists the flow of charge (the current) like an ordinary resistor. This resistance of a cell (or battery) is called "internal resistance".
- **Cells are connected in series with the external resistors**. Hence, the internal resistance must be seen as **connected in series** with the external resistors, irrespective if the external resistors are connected in series or parallel.

Voltmeter readings with or without internal resistance

Consider the following circuit and study the summary below to see how a voltmeter reading differs when internal resistance is present or not.



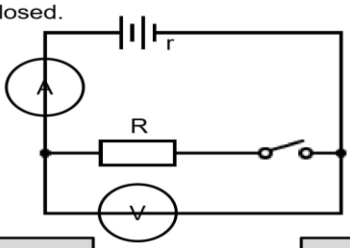
No internal resistance

Switch open	Switch closed
Ammeter reading is zero.	Ammeter measures the current. In this case the main current.
Voltmeter measures the emf.	The voltmeter measures the potential difference across the resistor, and it is **the SAME as** the emf.

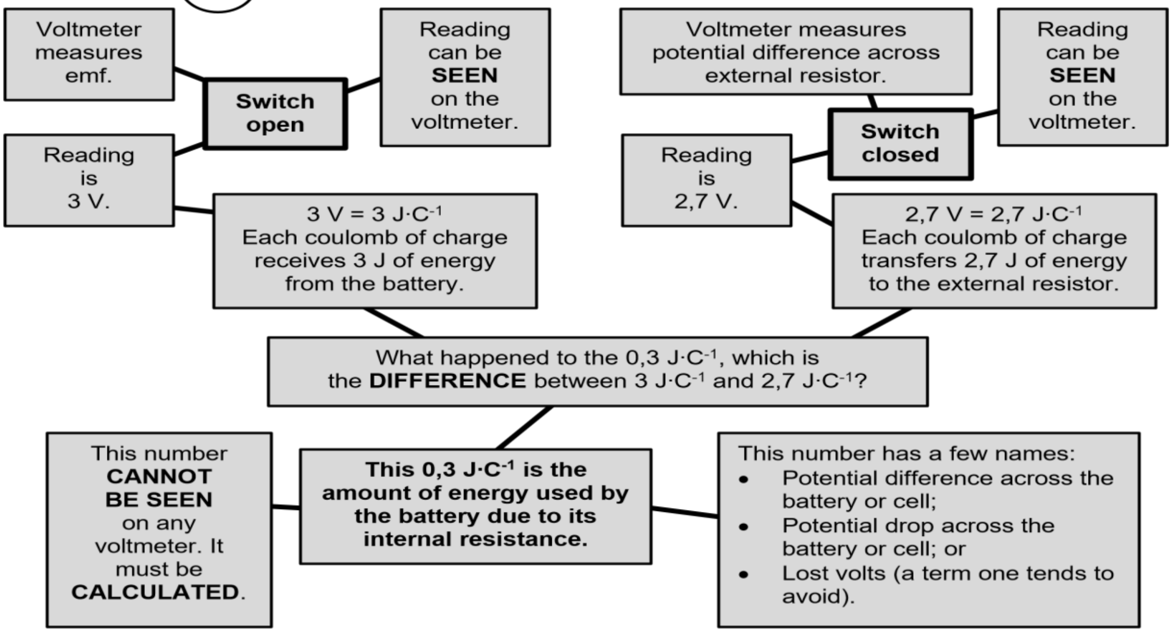
With internal resistance

Switch open	Switch closed
Ammeter reading is zero.	Ammeter measures the current. In this case the main current.
Voltmeter measures the emf.	The voltmeter measures the potential difference across the resistor and it is **LESS THAN** the emf.

A mind experiment may further clarify the situation of internal resistance. Consider the circuit below. The battery has an internal resistance represented by *r*. Ammeter and voltmeter readings are taken; first with the switch open and then closed.



	Switch open	Switch closed
Ammeter reading (A)	0	0,3
Voltmeter reading (V)	3	2,7



Look at the following applications of the formula R = $\frac{V}{I}$ to see how it should be used correctly.

To calculate the external resistance *R*:

$$R = \frac{V}{I_{total}}$$
$$R = \frac{2,7}{0,3}$$
$$= 9\,\Omega$$

The three variables deal with the **same situation**. The **external** resistor, the current in **that** resistor and the potential difference across **that** resistor.

To calculate the total resistance R_T:

$$R_T = \frac{V_{emf}}{I_{total}}$$
$$= \frac{3}{0,3}$$
$$= 10\,\Omega$$

The three variables deal with the **same situation**. The **total** resistance (*R*+*r*), the current in **those** resistors and the **emf**.

To calculate the internal resistance *r*: (**)

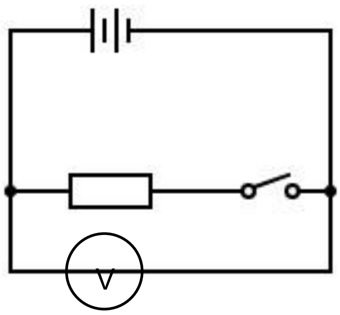
$$r = \frac{V_{cell}}{I_{total}}$$
$$= \frac{3 - 2,7}{0,3}$$
$$= 1\,\Omega$$

The three variables deal with the **same situation**. The **internal** resistance, the current **in the battery** and the potential drop across **the battery**.

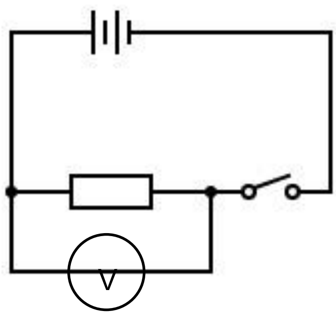
(**) The internal resistance is also the total resistance minus the external resistance, because $R_T = R + r$.

General useful hints about electric circuits

1. Check the connections of the voltmeters when emf is considered.



This voltmeter measures the emf. The switch is open and both wires are in contact with the battery.

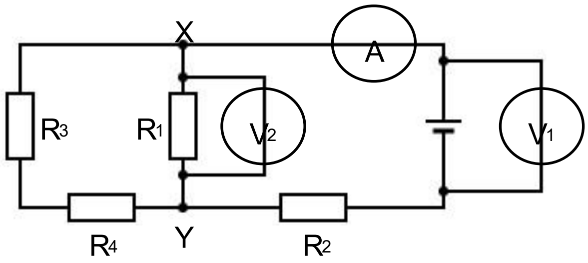


This voltmeter **does not** measure the emf although the switch is open. One of the wires is not in contact with the battery.

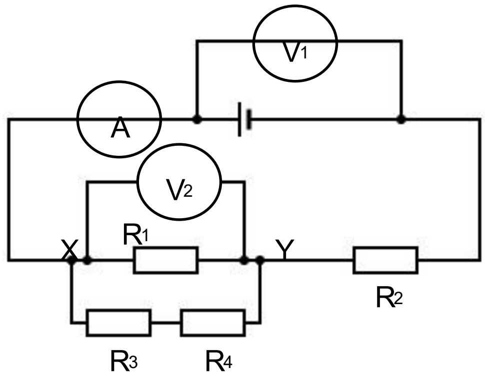
2.From examples 1 to 3 above you must remember that a voltmeter measures potential difference across the resistor(s) between its wires when there is a current in that resistor / those resistors.

3.

Simplify a circuit diagram if it is complicated.



Circuit1



Circuit2

Circuit 1 can be simplified to look like circuit 2 where all the resistors are put on one side of the circuit diagram. One way of doing it is as follows:

- Do the voltmeters after the battery, wires, resistors, ammeters and switches have been connected.
- Follow the direction of the conventional current from the positive terminal of the cell.
- The ammeter is reached first, and it measures the main current.
- The main current splits into two branch currents at **X** and combine again at **Y**.
- In one of the branches resistors $\mathbf{R_3}$ and $\mathbf{R_4}$ are connected in series.
- Resistor $\mathbf{R_1}$ is in the other branch, and $\mathbf{R_1}$ is connected in parallel with $\mathbf{R_3}$ and $\mathbf{R_4}$.
- From **Y** back to the negative terminal of the cell one has the main current again.
- Resistor $\mathbf{R_2}$ is between **Y** and the cell. In circuit 2 it is easy to see that $\mathbf{R_2}$ is connected in series with the parallel combination of resistors.

- Finally, consider the position of the voltmeters:
  - One of the wires of **V_1** is connected between the positive terminal of the cell and the ammeter. The other wire is connected between the negative terminal and **R_2**. Looking at circuit 2 it is easy to see that **V_1** is actually connected across all four resistors. When no current exists, it measures the emf, and with current in the circuit, it measures the potential difference across all four external resistors (terminal potential difference).
  - One of the wires of **V_2** is connected between **X** and **R_1**. The other wire is connected between **R_1** and **Y**. Looking at circuit 2 it is easy to see that **V_2** is connected across the parallel set of resistors. It therefore measures the potential difference across **R_1**, but also the potential difference across **R_3** and **R_4**. It has nothing to do with **R_2**.

Activity 1

1.1 A pump is connected to a water tank to pump rainwater into a house. The pump is rated 750W and it is connected to the 240 V main supply.

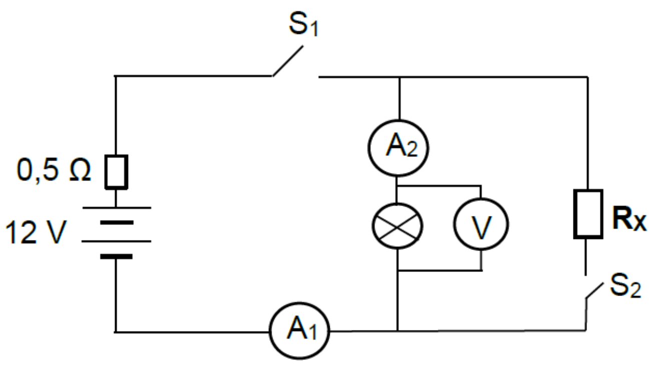
1.1.1 What current will the pump draw when operating on the 240 V supply? (3)

1.1.2 The cost of electricity is R1,20 per kilowatt hour. Calculate the cost of

using the pump continuously for 20 minutes. (3)

1.2 In the circuit represented below, the battery has an emf of 12 V and an

internal resistance of 0,5 Ω. The battery is connected as shown to a light bulb and resistor RX, both of unknown resistance. Ammeters have zero resistance, and the voltmeter has infinite resistance.



Switch S1 and switch S2 are initially both open.

1.2.1 Define emf. (2)

1.2.2 What will be the reading on the voltmeter, V, when both switches are open? (2)

Switch S1 is now closed, while S2 remains open. Ammeter A1 reads 1,6 A.

1.2.3 Determine the resistance of the bulb. (4)

1.2.4 Calculate the reading on the voltmeter, V. (3)

1.2.5 Calculate the rate of energy dissipation in the battery. (3)

1.2.6 Switch S2 is now closed so that both switches are closed. When switch S2 is closed, state whether the following will DECREASE, INCREASE or STAY THE SAME:

(a) the reading on ammeter A1. Explain your answer. (2)

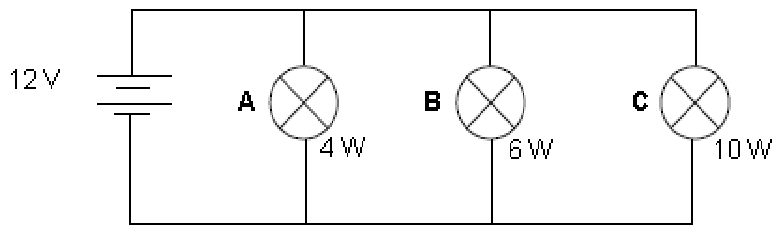
(b) the rate of energy dissipation in the battery. (2)

(c) the reading on voltmeter V. Explain your answer. (2)

[26]

ACTIVITY 2

2.1 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.



2.1.1 Calculate the resistance of the 4 W bulb. (3)

2.1.2 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)

2.1.3 How will the power dissipated by the 10 W bulb change if the 6 W bulb burns out? Write down only INCREASES, DECREASES or NON CHANGE. Give a reason for the answer. (2)

2.2 A learner connects a high-resistance voltmeter across a battery. The

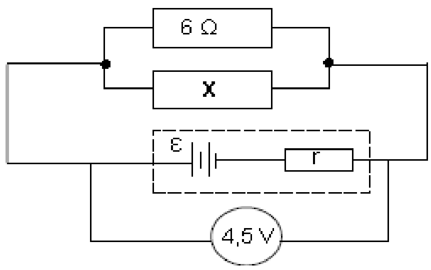
voltmeter reads 6 V. She then connects a 6 Ω resistor across the battery. The voltmeter now reads 5 V.

2.2.1 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.

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



2.2.3 Calculate the resistance of **X** when the voltmeter reads 4,5 V. (5)

[17]

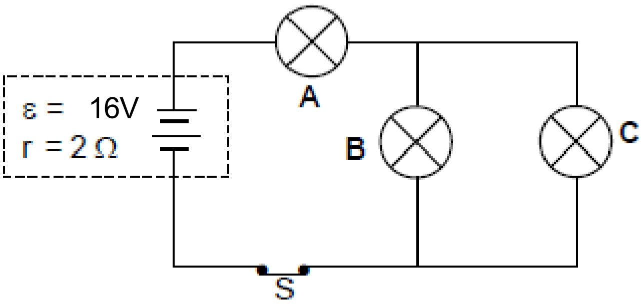
ACTIVITY 3

3.1 Three identical light bulbs, **A, B** and **C**, are each rated at 8 W, 16 V.

3.1.1 Define the term *power*. (2)

3.1.2 Calculate the resistance of EACH bulb when used as rated. (3)

The light bulbs are connected in a circuit with a battery having an emf (□) of 16 V and internal resistance (r) of 2 □. Refer to the diagram below. Assume that the resistance of each light bulb is the same as that calculated in QUESTION 10.1.2. Switch **S** is closed.

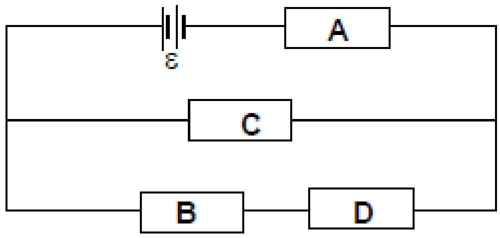


3.1.3 Calculate the total current in the circuit. (5)

3.1.4 Calculate the potential difference across light bulb **C**. (3)

3.1.5 Explain why light bulb **C** in the circuit will NOT burn at its maximum brightness (3)

3.2 Resistors **A, B, C** and **D** are connected to a battery having emf (□) and negligible internal resistance, as shown in the diagram below.



3.2.1 Give a reason why the current in resistor **A** is greater than That in resistor **C**. (2)

3.2.2 Resistor **C** is removed. How will the current in resistor **B** compare to the current in **A**? Give a reason for the answer. (2)

[20]

JENN

Training and Consultancy

The path to enlightened education

SUBJECT: SUBJECT NAME

GRADE 12

2025 SPRING CLASSES

TEACHER AND LEARNER CONTENT MANUAL

Topic(s)

Electrodynamics

EXAMINATION GUIDELINES

Electrical machines (generators, motors):

- State the energy conversion in generators.
- Use the principle of electromagnetic induction to explain how a generator works.
- Explain the functions of the components of an AC and a DC generator.
- State examples of the uses of AC and DC generators.
- State the energy conversion in motors.
- Use the motor effect to explain how a motor works.
- Explain the functions of the components of a motor.
- State examples of the use of motors.

Alternating current

- State the advantages of alternating current over direct current.
- Sketch graphs of voltage versus time and current versus time for an AC circuit.
- Define the term rms for an alternating voltage/current. The rms potential difference is the AC potential difference which dissipates/produces the same amount of energy as an equivalent DC potential difference. The rms current is the alternating current which dissipates/produces the same amount of energy as an equivalent direct current (DC).
- Solve problems using

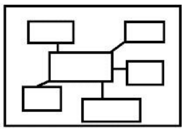
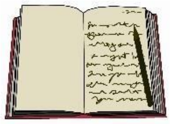
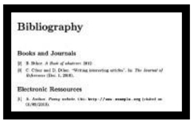
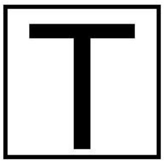
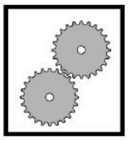
$I_{rms} = \frac{I_{max}}{\sqrt{2}}$, $V_{rms} = \frac{V_{max}}{\sqrt{2}}$.

- Solve problems using

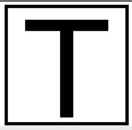
$P_{ave} = I_{rms}V_{rms} = \frac{1}{2} I_{max}V_{max}$ (for a purely resistive circuit),

$P_{ave} = I^2_{rms}R$ and $P_{ave} = \frac{V^2_{rms}}{R}$.

ICON PRESCRIPTION

 MIND MAP	 EXAMINATION GUIDELINE	 CONTENTS	 ACTIVITIES
 BIBLIOGRAPHY	 TERMINOLOGY	 WORKED EXAMPLES	 STEPS

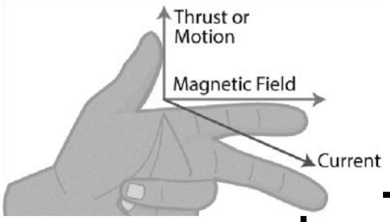
IMPORTANT TERMS AND DEFINITIONS



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).
Coventional 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 (Vrms)	The root-mean-square potential difference is the AC potential difference that produces the same amount of electrical energy (power) 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 produces the same amount of energy (power) as and 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.

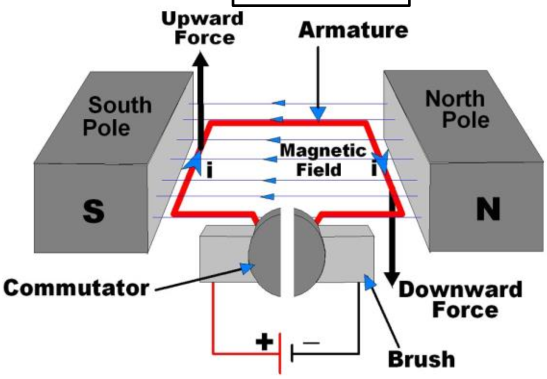
CONTENT



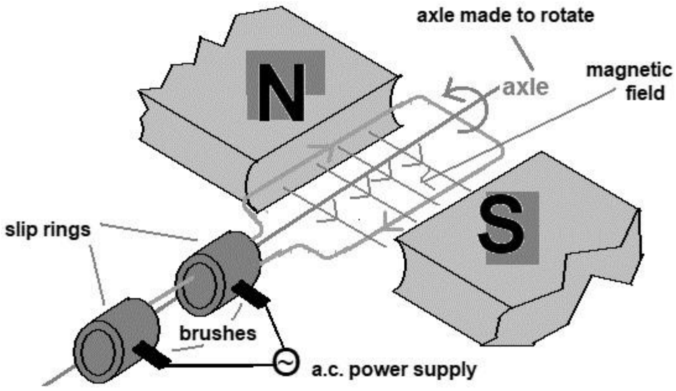
MOTORS

Converts electrical energy to mechanical energy

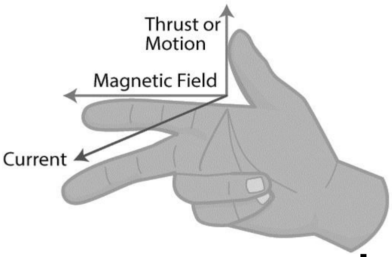
DC Motor



AC Motor



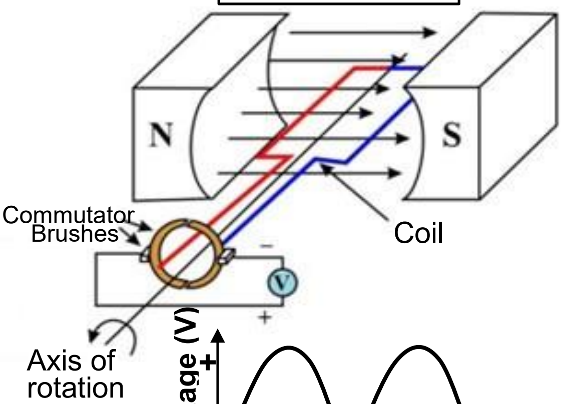
Fleming's Right Hand Dynamo Rule



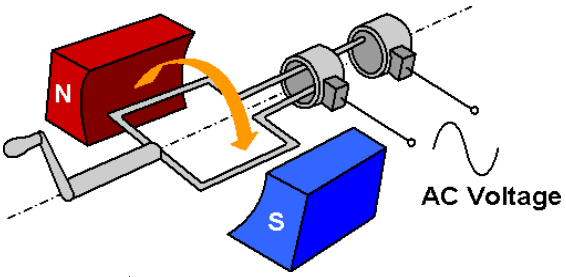
GENERATORS

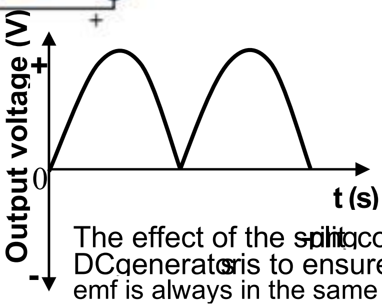
Converts mechanical energy to electrical energy

DC Generator

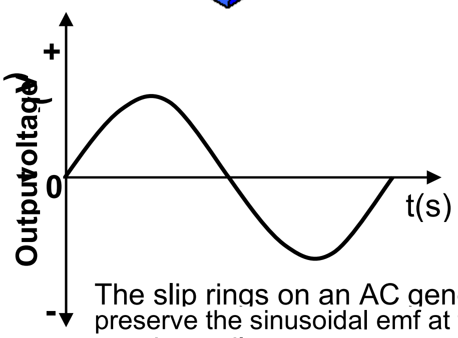


AC Generator

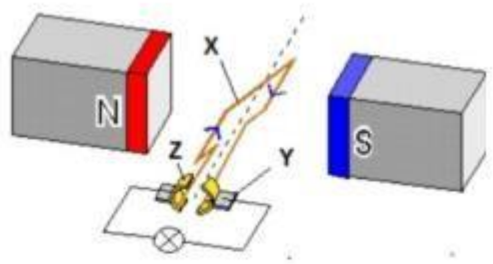
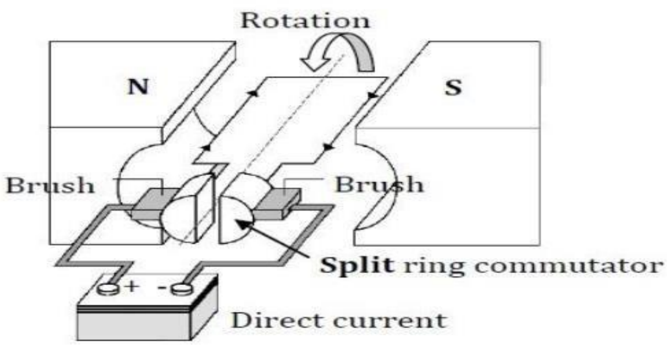




The effect of the split ring commutator in DC generators is to ensure the induced emf is always in the same direction.



The slip rings on an AC generator preserve the sinusoidal emf at the rotating coils

Generator	Motor
	
<u>Energy conversion</u>: Mechanical energy into electrical energy	Energy **<u>conversion:</u>** Electrical energy into mechanical energy
<u>External circuit:</u> load e.g. Bulb or resistor	**<u>External circuit:</u>** consist of power source (cell or battery)
<u>Principle:</u> Electromagnetic induction: states that when a conductor is rotated in a magnetic field, there is a change in the magnetic flux which induces an emf that causes an induced current to flow in the conductor.	**<u>Principle:</u>** Motor effect: states that when a conductor carrying current is placed in a magnetic field, the conductor experiences a force.
<u>Rule:</u> *Fleming's right-hand rule* Says that when the thumb, the first finger and the second finger are placed at right angles to each other, the First finger pointing in the direction of the magnetic Field (North to South), the thumb in the direction of Motion of the coil, then the second finger will point in the direction of flow of the induced current.	**<u>Rule</u>**: *Fleming's left-hand rule* Says that when the thumb, the first finger and the second finger are placed at right angles to each other, with the first finger pointing in the direction of the magnetic Field (North to South), the second finger in the direction of the Current, then the thumb will point in the direction of Motion of the coil.
<u>Carbon brushes</u>: conduct the induced current from the armature(coil) to the commutator and the external circuit.	**<u>Carbon brushes;</u>** conduct current from the external circuit to the commutator and the armature (coil).

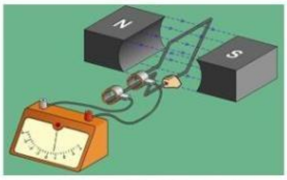
Generators (AC or DC)

Generators

Load Resistor

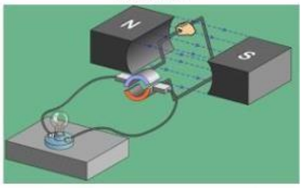
AC GENERATOR
Slip rings

An AC Generator with slip rings



DC GENERATOR
Split ring

A DC Generator with a split ring and brushes

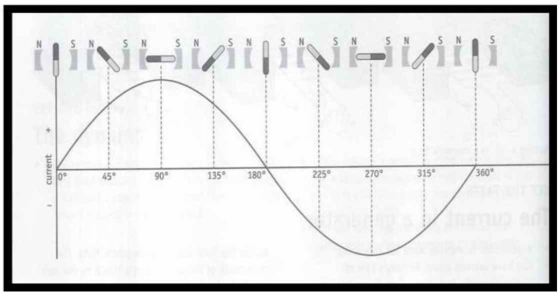


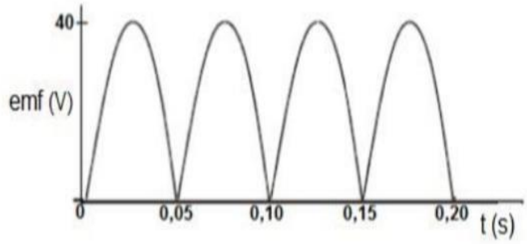
AC GENERATOR

- Structural component: **Slip rings**
- • Slip-rings ensures that the current that passes into the carbon brushes and the external circuit is always in the same direction
- An AC generator produces alternating current. Our power stations produce alternating current and the current that we get from the plug points in our homes is AC.
- The current changes direction every half revolution and is changing strength continually.
- This has the advantage of changing the magnetic field in transformers on the national power grid.
- The graphs of alternating current and alternating voltage are shaped like sine and cosine graphs

DC GENERATOR

- Structural component; **Split rings**
- Allows induced current to flow in one direction.
- The split ring commutator serves as a change switch that reverses the current after every half revolution. (ensures continuous rotation of the coil)
- DC generator produces direct current
- Current flows from positive to negative terminal (use conventional current
- The emf and current induced in a DC generator has the same polarity through the rotation of the armature. This is due to split rings

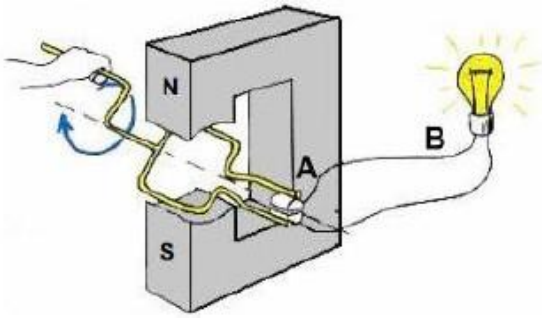




Examples

QUESTION 1

1.1 A learner is turning a lever connected to a metal coil with a commutator that rotates inside a magnetic field as shown in the diagram below.



1.1.1 Write down the name of the TYPE of electrical machine represented by the diagram. (1)

1.1.2 Write down the energy conversion that occurs in the diagram. (1)

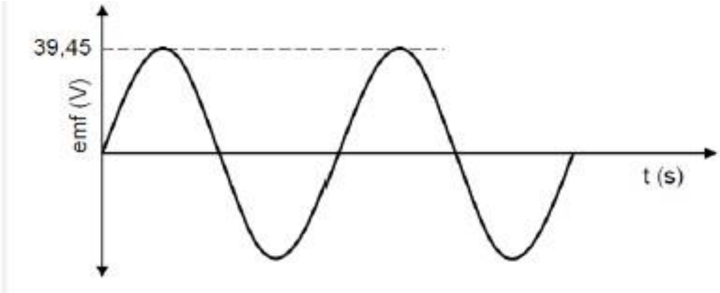
1.1.3 In which direction will the current flow in the wire that is connected to the light bulb? Only write A to B OR B to A. (1)

1.1.4 What type of current will be generated in the diagram above? Only write DIRECT CURRENT or ALTERNATING CURRENT. (1)

1.1.5 Explain the answer to QUESTION 9.1.4 (2)

1.1.6 Except for increasing the speed with which the handle is turned, write down two changes that could be made to this setup to increase its output. (2)

1.2 The graph of the output emf versus time of a AC generator is shown below:



1.2.1 Define the term **root mean square value** (rms) of an AC voltage. (2)

1.2.2 Calculate the *rms* voltage for the generator. (3)

1.3 Give ONE reason why AC voltage is preferred to DC voltage for everyday use. (1)

[14]

QUESTION 1 [ANSWERS]

1.1 1.1.1 Generator ✓ (1)

1.1.2 Kinetic/mechanical energy→electrical energy✓ (1)

1.1.3 B to A ✓ (1)

1.1.4 Direct Current (DC)✓ (1)

1.1.5 The split ring commutator ensures✓that the current that passes through to the external circuit is always in the same direction.✓ (2)

1.1.6 Use a coil that consist of more windings ✓

Increase the strengths of the magnets.✓ (2)

1.2.1 The rms value of AC is the DC potential difference which dissipates the same amount of energy as AC.✓✓ (2)

1.2.2 $V_{rms} = $ ✓ $\frac{V_{max}}{\sqrt{2}}$

$= \frac{39,45}{\sqrt{2}}$ ✓

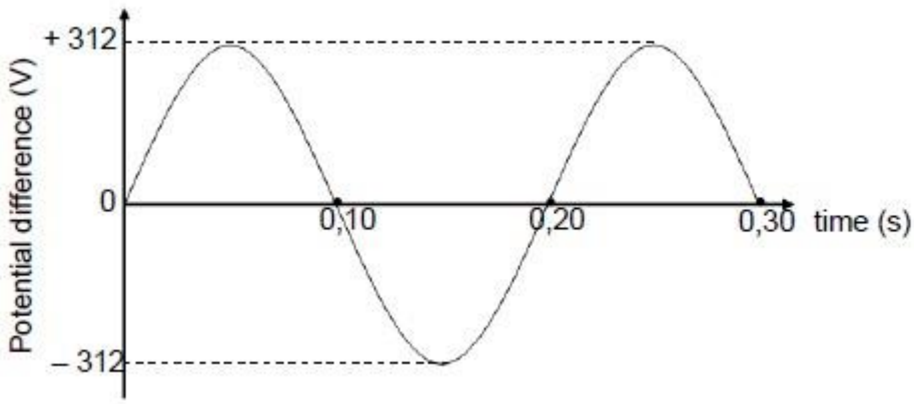
= 27,9 V ✓ (3)

1.3 It can be stepped up or stepped down / is easier to transmit ✓ (1)

[14]

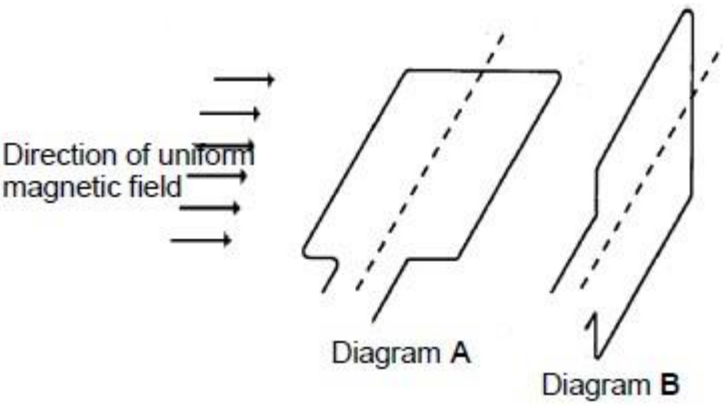
QUESTION 2

The diagram below shows the voltage output of a generator.



2.1 Does this generator have split rings or slip rings? (1)

2.2 Which ONE of the diagrams below, A or B, shows the position of the generator's coil at time = 0,10 s? (1)



2.3 Calculate the root mean square (rms) voltage for this generator (3)

2.4 A device with a resistance of 60 ohms is connected to this generator.

Calculate the:

2.4.1 Average power delivered by the generator to the device (3)

2.4.2 Maximum current delivered by the generator to the device (4)

[12]

QUESTION 2 [ANSWERS]

2.1 Slip rings√ (1)

2.2 B √ (1)

2.3 $V_{rms} = \frac{V_{max}}{\sqrt{2}}$ √

$= \frac{+312}{\sqrt{2}}$ √

= 220, 62V √ (3)

2.4.1

OPTION 1

$P_{aver} = \frac{{V_{rms}}^2}{R}$ □ (3)

$= \frac{(220.62)^2}{60}$ □

= 811, 22 W□

10.4.2 $I_{max} = \frac{V_{max}}{R}$ √

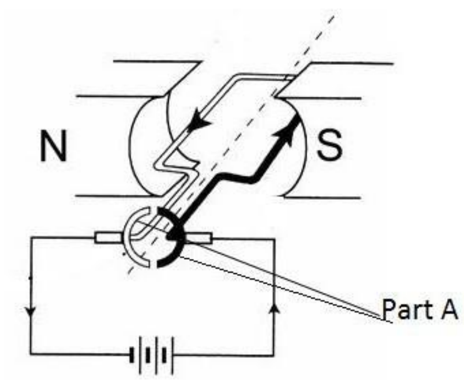
$= \frac{312}{60}$ √√

= 5.2 A√

(4)

ACTIVITY 1

The sketch below shows a simple dc motor.



1.1.1 Describe the energy conversion that takes place in the dc motor. (2)

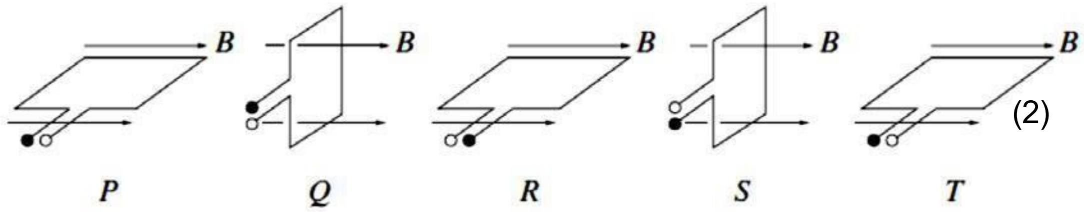
1.1.2 Name the law used to predict the direction of rotation of the coil. (1)

1.1.3 Predict whether the coil will rotate clockwise or anti-clockwise. (1)

1.1.4 Name and state the function of **part A**, and describe briefly how it
achieves this function.

(3)

1.2The coil of an AC generator rotates at a constant



(2)

1.2.1 Explain briefly why an *emf* is induced in the coil.

1.2.2 Draw a sketch graph showing emf against position for the , coil
marking **P, Q, R, S** and **T** on the x-axis. (3)
rate in a magnetic field as shown below.

This generator with a maximum voltage of 24 V and frequency 50 Hz is connected to a resistor with a resistance of 265 Ω.

Calculate:

1.2.3 The rms current. (5)

1.2.4 The average power dissipated in the resistor. (3)

[20]

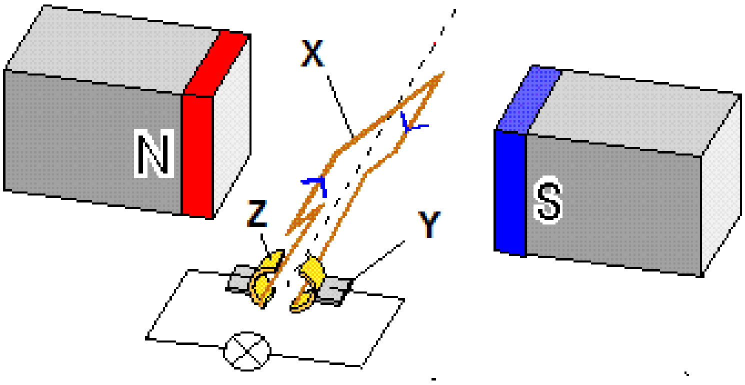
ACTIVITY 2

2.1 The table below compares a motor and a generator in terms of the type of energy conversion and the underlying principle on which each operates. Complete the table by writing down only the question number (9.1.1–9.1.4) in the ANSWER BOOK and next to each number the answer.

	TYPE OF ENERGY CONVERSION	**PRINCIPLE OF OPERATION**
Motor	2.1.1	2.1.3
Generator	2.1.2	2.1.4

(4)

The diagram below shows a simplified version of a generator. A light bulb of 25 Ω is connected to it with wires of negligible resistance.



2.2 What type of generator (AC or DC) is represented in the diagram? (1)

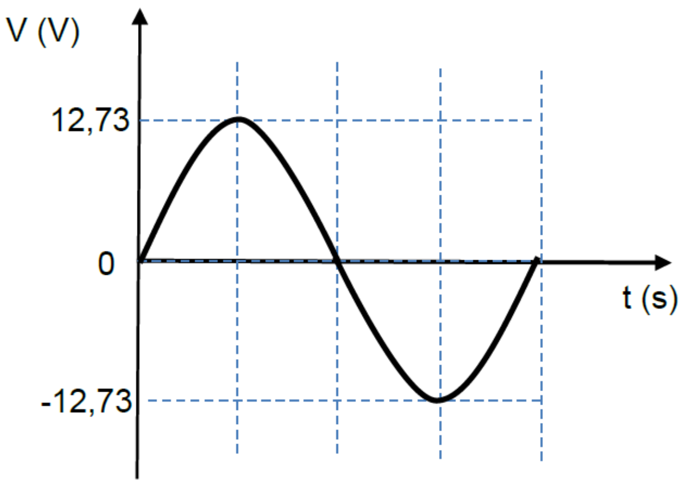
2.3 Write down the name of component **X**. (1)

2.4 Explain the function of:

2.4.1 Component **Y** (2)

2.4.2 Component **Z** (2)

Component **Z** in the above generator is replaced by slip rings. The graph below shows how the potential difference across the light bulb, resistance 25 Ω, changes with time for one complete cycle when this generator is functioning.



2.5 Calculate the:

2.5.1 rms voltage across the light bulb. (3)

2.5.2 Average power dissipated in the bulb (3)

[16]

JENN

Training and Consultancy

The path to enlightened education

SUBJECT: SUBJECT NAME

GRADE 12

2025 SPRING CLASSES

TEACHER AND LEARNER CONTENT MANUAL

Topic(s)

DOPPLER EFFECT

EXAMINATION GUIDELINE

Doppler Effect (relative motion between source and observer)
(This section must be read in conjunction with the CAPS, p. 121–122.)

With sound and ultrasound

- State the Doppler effect as 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.
- Explain (using appropriate illustrations) the change in pitch observed when a source moves toward or away from a listener.
- Solve problems using the equation $f_L = \frac{v \pm v_L}{v \pm v_s} f_s$ when EITHER the source OR the listener is moving.
- State applications of the Doppler effect.

With light – red shifts in the universe (evidence for the expanding universe) Explain red shifts.

- Use the Doppler effect to explain why we conclude that the universe is expanding.

IMPORTANT TERMS AND DEFINITIONS

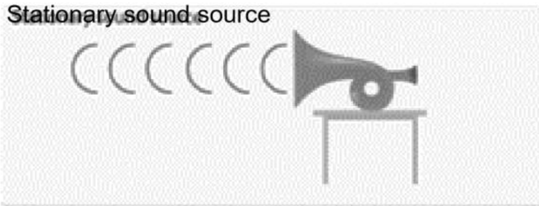
TERMS AND DEFINITIONS

Doppler Effect	The apparent change in frequency/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:** The change in frequency/pitch of the sound detected by a listener due to relative motion between the sound source and the listener.
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

CONTENT

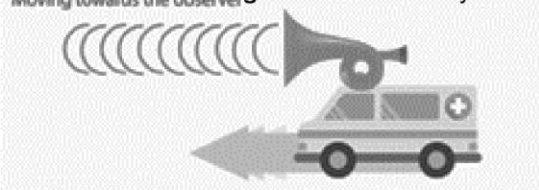
Observer/Listener

Stationary sound source



No relative motion between listener and sound source – no change in observed frequency.

Sound source moving towards stationary observer.



The waves to the front of the source are compressed resulting in a shorter observed wavelength and thus a **higher observed frequency**.

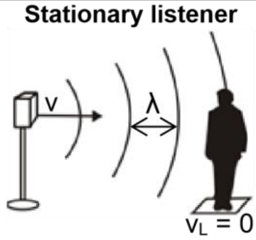
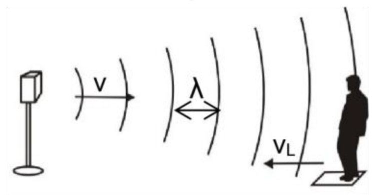
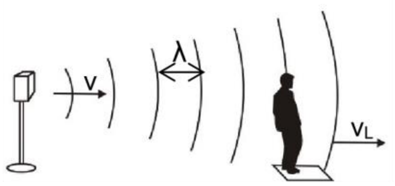
$$f_L = \frac{v}{v - v_s}$$

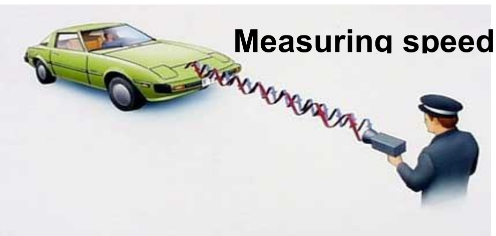
Sound source moving away from stationary observer.

The waves behind the source are further part due to the motion of the source resulting in a longer observed wavelength and thus a **lower observed frequency**.

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

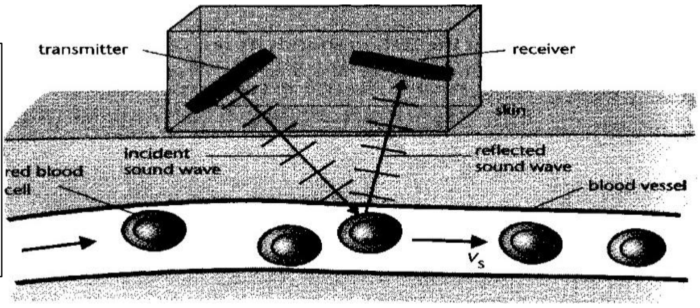
Stationary Source, Moving Listener

Stationary listener	Listener moving towards source	Listener moving away from source
		
No relative motion between sound source and listener. $f_L = f_S$	A listener moving at speed v_L towards a stationary source **intercepts more** wave compressions per unit time, than a stationary listener does, and **hears a higher frequency**. $f_L = \frac{v + v_L}{v}$	A listener moving at speed v_L away from a stationary source **intercepts fewer** wave compressions per unit time, than a stationary listener does, and **hears a lower frequency**. $f_L = \frac{v - v_L}{v}$



Measuring foetal heartbeat

Doppler flow meter
Ultrasound waves, which are sound waves with frequency greater than 20 kHz, are used by medical scientists in **Doppler flow meters to measure the speed of blood flow**. A device consisting of a transmitter and a receiver is placed directly on the skin.



WORKED EXAMPLES

QUESTION 1

The driver of a car pulls over to the side of a straight road and stops when he hears the siren of an approaching fire truck. As the fire truck approaches, the person hears a frequency of 460 Hz; as the fire truck moves away, the person hears a frequency of 410 Hz. Consider the speed of sound in air as 340 $m \cdot s^{-1}$.

1.1 State the Doppler effect in words. (2)

1.2 Does the stationary person detect a LONGER or SHORTER wavelength as the fire truck moves away? Explain your answer. (3)

1.3 Calculate the frequency of the sound of the siren. (6)

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

The two diagrams below represents 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

Diagram 1

Diagram 2

can be made about the Universe? (1)

[15]

QUESTION 1

1.1 Doppler effect is 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. ✓✓

OR

The change in the observed frequency ✓when there is relative motion between the source and the observer.✓ (2)

1.2 Longer✓

For the same (constant) speed of sound✓ the frequency of sound is inversely proportional to the wave length and as the fire truck moves away from the listener the listener hears a lower frequency.✓

OR

Speed of sound is constant✓, frequency detected (by the observer) is lower wevelenghts is inversely proportional to frequncy. ✓ (3)

1.3 $f_L = \left(\frac{v \pm v_L}{v \pm v_s}\right) f_s$ OR $f_L = \left(\frac{v}{v \pm v_s}\right) f_s$✓

Approaching

460 = $\left(\frac{340}{340 - v_s}\right) f_s$✓

Moving away

$$460 = \left(\frac{340}{340 - v_s}\right)\left(\frac{410}{\frac{340}{340 + v_s}}\right)✓$$

v_s=19,54 m·s^{-1}

460 ✓= $\left(\frac{340}{340-19,54}\right) f_s$✓ **OR/*OF*** 410 ✓= $\left(\frac{340}{340+19,54}\right) f_s$✓

$f_s = 433,56\ Hz$ ✓ (6)

1.4 The star is moving away from the Erath ✓ because the spectrum shows a shift towards the red end ✓which is a lower frequency✓ (3)

1.5 The universe is expanding ✓ (1)

[15]

<u>QUESTION 1</u>

The siren of a police car produces a sound of frequency 420 Hz. A girl sitting next to the road notices that the pitch of the sound changes as the car moves towardsand then away from her.

1.1 Name and state in words the phenomenon described above. (3)

1.2 Calculate the frequency of the sound of the siren observed by the girl, when the car is moving towards her at a constant speed of 16 m·s^{-1}.

Assume that the speed of sound in air is 340 m·s^{-1}. (5)

1.3 The police car moves away from the girl at a constant velocity, then slows down and finally comes to rest.

1.3.1 How will the observed frequency COMPARE with the original

frequency
of the siren when the police car moves away from the girl at constant velocity? Write only GREATER THAN, SMALLER THAN or EQUAL TO (1)

1.3.2 How will the observed frequency CHANGE if the car moves away from the observer at a lower speed?

Write only INCREASES, DECREASES or REMAINS THE SAME. (1)

1.4 Draw a graph of the observed frequency versus time as the sound source moves towards the listener, passing her and then moves away from the listener. Clearly indicate the frequency of the sound source (420 Hz) and the frequency observed by the listener in **1.2** on the graph. (4)

[14]

QUESTION 2

A sound source, moving at a constant speed of 240 $m \cdot s^{-1}$ towards a detector, emits sound at a constant frequency. The detector records a

frequency of 3 650 Hz. Take the speed of sound in air as 340

$m \cdot s^{-1}$.

1.1 State the *Doppler Effect*. (2)

1.2 Calculate the wavelength of the sound emitted by the source. (7)

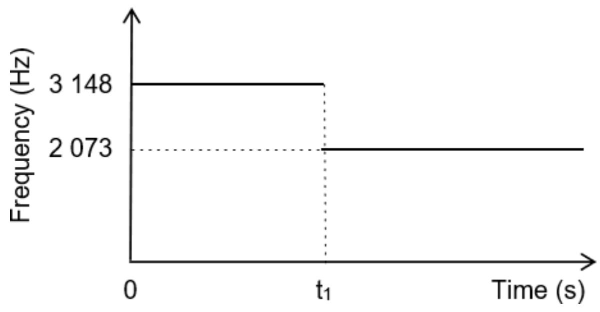
Some of the sound waves are reflected from the detector towards the approaching source.

1.3 Will the frequency of the reflected sound wave detected by the sound Source be EQUAL TO, GREATER THAN or SMALLER THAN 3 650 Hz? (1)

[10

Question 3

The siren of a train, moving at a constant speed along a straight horizontal track, emits sound with a constant frequency. A detector, placed next to the track, records the frequency of the sound waves. The results obtained are as shown in the graph.



3.1 State the Doppler effect in words. (2)

3.2 Does the detector record the frequency of 3 148 Hz when the train moves TOWARDS the detector or AWAY from the detector? (1)

3.3 Calculate the speed of the train. Take the speed of sound in air as 340 $m \cdot s^{-1}$. (6)

3.4 The detector started recording the frequency of the moving train's siren when the train was 350 m away. Calculate time t_1 indicated on the graph above. (2)

[11]

SUBJECT: SUBJECT NAME

GRADE 12

2025 SPRING CLASSES

TEACHER AND LEARNER CONTENT MANUAL

Topic(s)

Optical Phenomenon

Exa

Opt
(Thi

Photo-electric effect

- Describe the *photoelectric effect* as the process whereby electrons are ejected from a metal surface when light of suitable frequency is incident on that surface.
- State the significance of the photoelectric effect.
- Define *threshold frequency*, f_o, as the minimum frequency of light needed to emit electrons from a certain metal surface.
- Define *work function*, W_o, as the minimum energy that an electron in the metal needs to be emitted from the metal surface.
- Perform calculations using the photoelectric equation:

  $E = W_o + E_{k(max)}$, where $E = hf$ and $W_o = hf_o$ and $E_{k(max)} = ½ mv_{max}^2$

- Explain the effect of intensity and frequency on the photoelectric effect.
- State that the photoelectric effect demonstrates the particle nature of light.

Emission and absorption spectra

- Explain the *formation of atomic spectra* by referring to energy transition.
- Explain the difference between *atomic absorption* and *emission spectra*.

  An atomic absorption spectrum is formed when certain frequencies of electromagnetic radiation passing through a substance is absorbed.

  For example, when light passes through a cold gas, atoms in the gas absorb characteristic frequencies of the light and the spectrum observed is a continuous spectrum with dark lines where characteristic frequencies of light were removed. The frequencies of the absorption lines are unique to the type of atoms in the gas.

  An atomic emission spectrum is formed when certain frequencies of electromagnetic radiation are emitted due to an atom making a transition from a higher energy state to a lower energy state.

  For example, atoms in a hot gas emit light at characteristic frequencies. The spectrum observed is a line spectrum with only a few coloured lines of frequencies unique to the type of atom that is producing the emission lines.

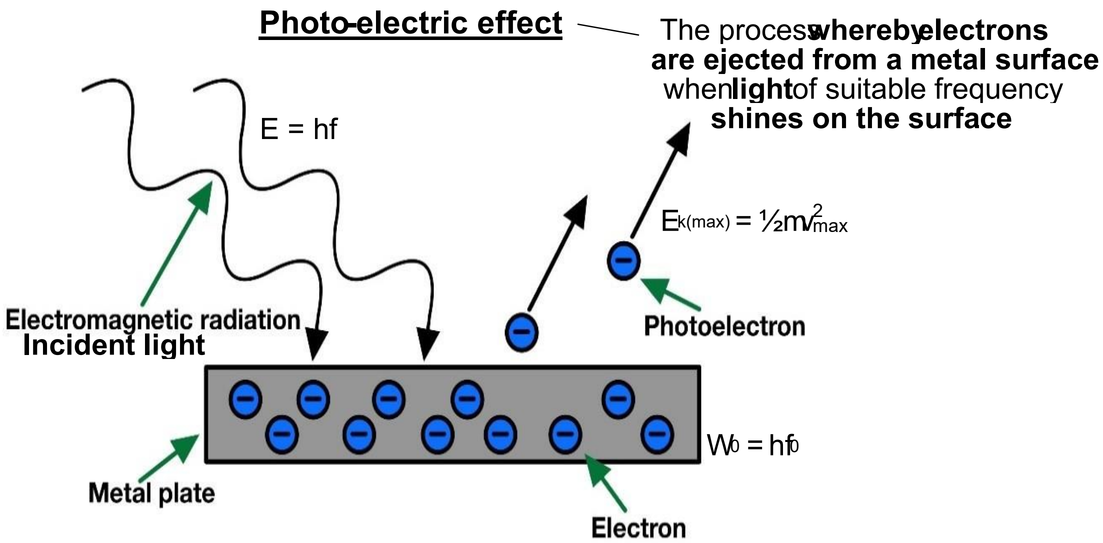
IMPORTANT TERMS AND DEFINITIONS

TERMS AND DEFINITIONS	
Dual nature	Double nature – light behaves like waves when in propagation and like particles when interacting with matter.
Photo-electric effect	The process whereby electrons are ejected from a metal surface when light of suitable frequency is incident on /shines on the surface.
Threshold frequency (f_o)	The minimum frequency of light needed to emit electrons from a certain metal surface.
Work function (W_o)	The minimum energy that an electron in the metal needs to be emitted from the metal surface.
Photo-electric equation	$E = W_o + K_{max}$, where $E = hf$ and $W_o = hf_o$ and $K_{max} = ½mv^2_{max}$
Spectrum	A band of colours with different wavelengths observed when light is dispersed by a prism. The rainbow is an example of a

	continuous spectrum.
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.

CONTENT

OPTICAL PHENOMENA AND PROPERTIES OF MATERIALS



Each incident light photon has energy **$E = hf$**

The metal needs energy (work function) to release an electron: **$W_0 = hf_0$**

A photoelectron moves away at kinetic energy: **$E_{k(max)} = ½mv^2_{max}$**

$$E_{k(max)} = hf - W_0 \quad \text{OR} \quad hf = W_0 + E_{k(max)}$$

h: Planck's constant 6,63 x 10^{-34} J·s

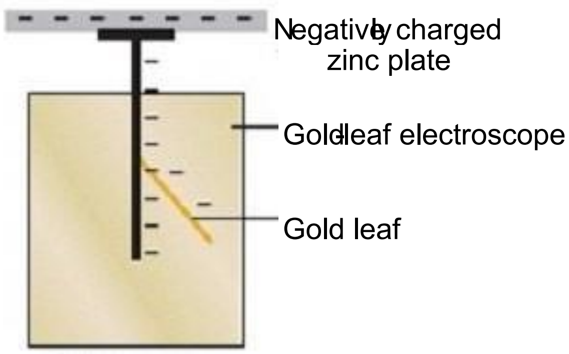
f: Frequency of incident light in hertz (Hz)

W_0: Work function of the metal in joule (J)

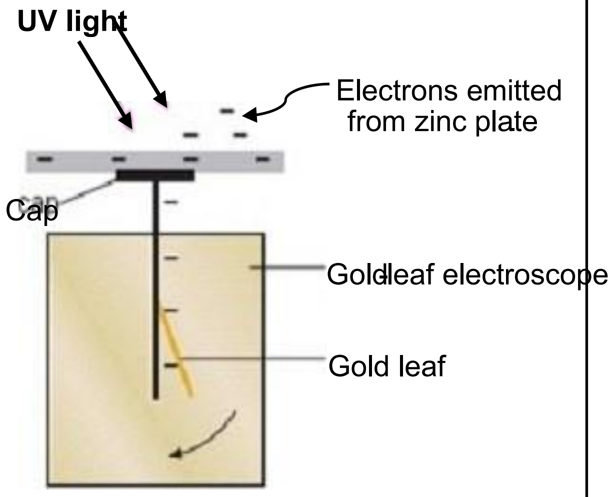
$E_{k(max)}$: Maximum kinetic energy of photoelectrons in joule (J)

Demonstration of the photo-electric effect

- A zinc plate is placed on the cap of an electroscope.
- The electroscope and zinc plate are negatively charged.
- UV light is shone on the zinc plate.



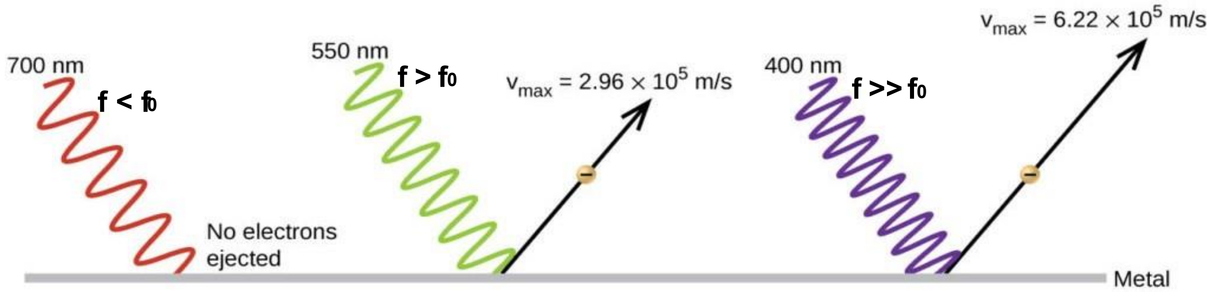
Initial position of gold leaf



Leaf falls when UV light is incident

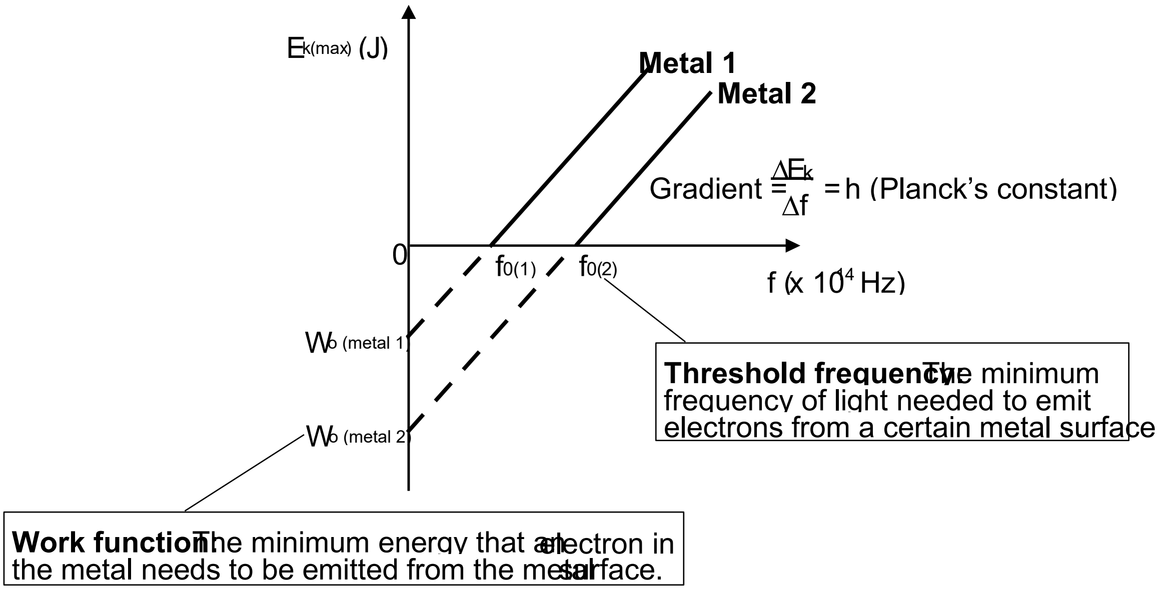
FACTORS INFLUENCING THE PHOTO-ELECTRIC EFFECT

Effect of FREQUENCY OF LIGHT on the photo-electric effect

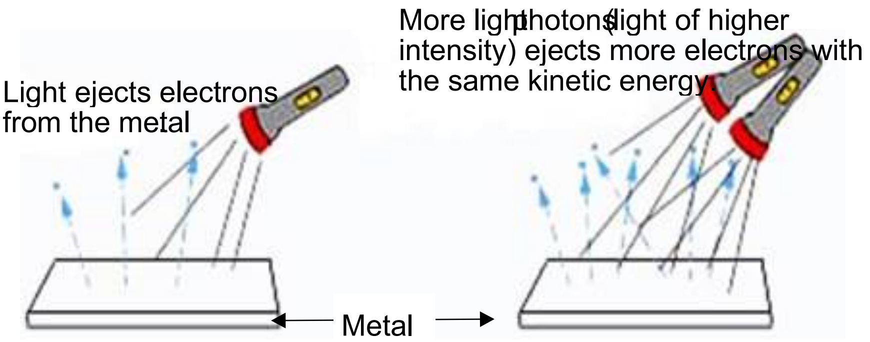


- The frequency of incident light determines whether electrons will be emitted or not.
- A metal has a minimum frequency needed to release electrons from the surface of the metal. It is called the **threshold frequency** f_0.
- If the frequency of the incident light is smaller than the threshold frequency for the metal, no electrons will be emitted.
- If the frequency of the incident light is equal to the threshold frequency for the metal, electrons will be emitted with zero kinetic energy.
- If the frequency of the incident light is greater than the threshold frequency for the metal, electrons will be emitted with a certain kinetic energy i.e. $E_{k(max)} = \frac{1}{2}mv^2_{max} = hf - hf_0$.
- **Work function** of a metal $W_0 = hf_0$, is the minimum energy that an electron in the metal needs to be emitted from the metal surface

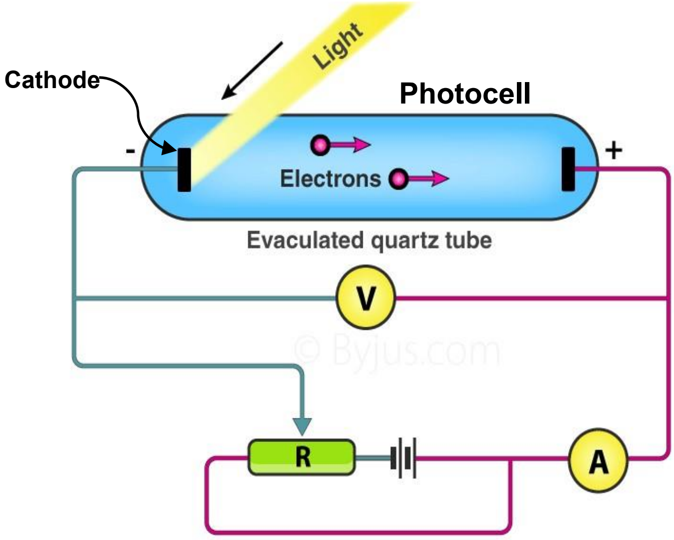
Graph of E_{kmax} versus frequency



Effect of INTENSITY OF LIGHT on the photoelectric effect

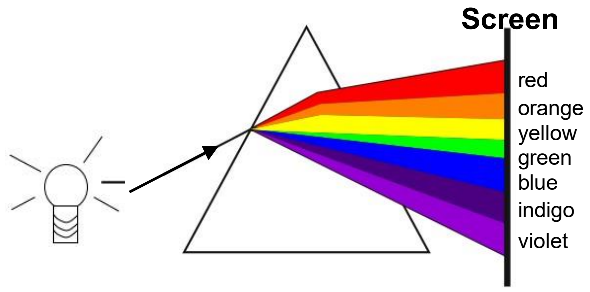


If the frequency of incident light is high enough to emit electrons from a metal surface, a **higher intensity** of this light will **emit more electrons per unit time with the same kinetic energy**.



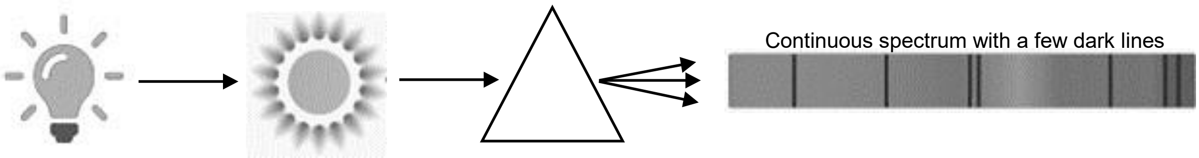
- Incident light emits electrons from the cathode
- The photoelectrons are then attracted by the positive anode and a current flows in the circuit.
- The ammeter registers a reading.
- If light of higher intensity is used, the ammeter will register a higher reading because more photons strike the metal cathode per unt time and therefore more electrons are emitted from the cathode per unit time.

Absorption and Emission Spectra



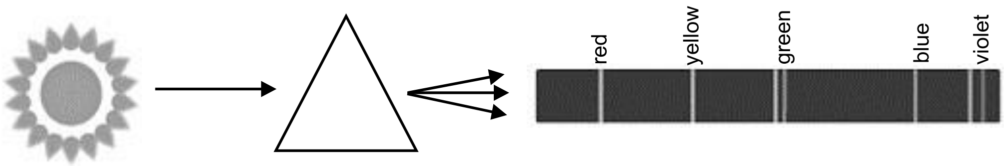
White light **Prism** **Continuous Spectrum**

A **Continuous Spectrum** contains all the wavelengths of visible light. Many electron transitions between energy levels are possible and all wavelengths of light are radiated.



Hot matter **Cold gas** **Prism** **Line Absorption Spectrum on screen**

An **Absorption Spectrum** shows the spectrum of electromagnetic waves that passed through a substance with a few dark lines due to the absorption of specific wavelengths when electrons in atoms of the substance make transitions from lower to higher energy levels.



Hot gas **Prism** **Line Emission Spectrum on screen**

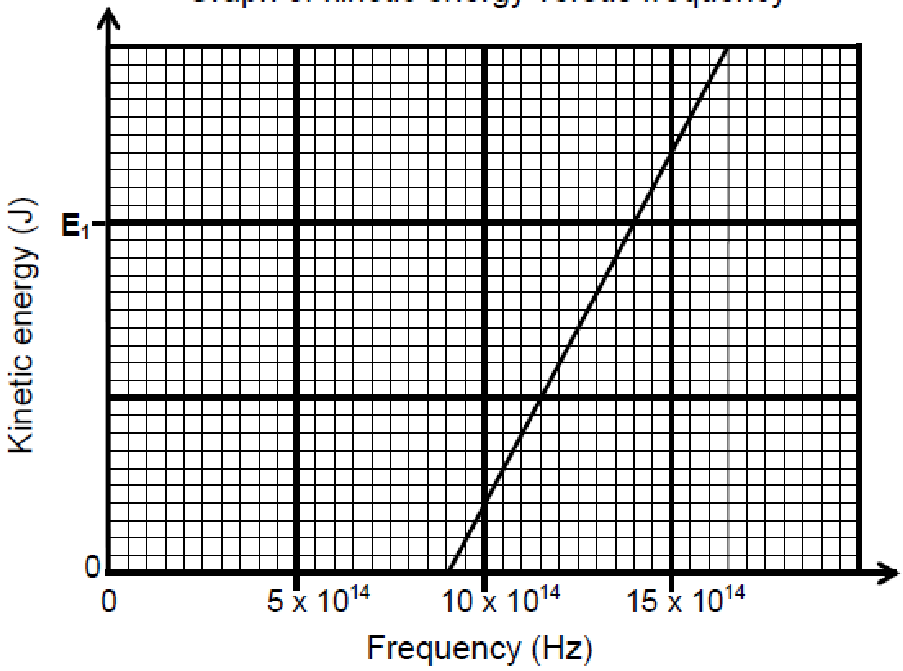
An **Emission Spectrum** shows the spectrum of electromagnetic waves emitted by a hot substance with only a few bright lines due to the emission of specific wavelengths when electrons in atoms of the substance make transitions from higher to lower energy levels.

WORKED EXAMPLES

QUESTION 1

During an investigation, light of different frequencies is shone onto the metal cathode of a photocell. The kinetic energy of the emitted photoelectrons is measured. The graph below shows the results obtained.

Graph of kinetic energy versus frequency



1.1 For this investigation, write down the following:

10.1.1 Dependent variable (1)

10.1.2 Independent variable (1)

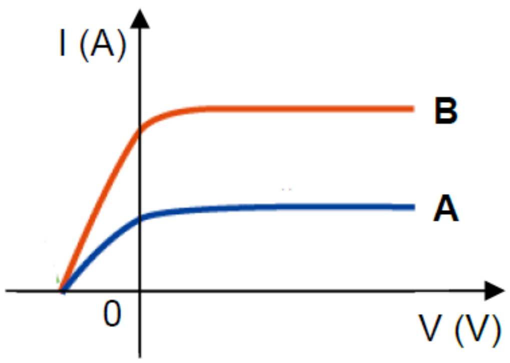
10.1.3 Controlled variable (1)

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

1.3 Use the graph to obtain the threshold frequency of the metal used as cathode in the photocell. (1)

1.4 Calculate the kinetic energy at E_1 shown on the graph. (4)

To determine the e ... hoto-electric current,
radiations of the sa ... ncident on the sodium
plate. The followin ... erence (V) were obtained.



1.5 Which ONE of the curves corresponds to a radiation of greater intensity? Explain the answer. (3)

1.6 How does the maximum kinetic energy of the ejected electrons by radiation **A** compare to the maximum kinetic energy of the ejected electrons by radiation **B**.

Choose from GREATER THAN, SMALLER THAN or EQUAL TO. (1)
[14]

QUESTION 1 [SOLUTIONS]

1.1 1.1.1 Kinetic energy□ (1)

1.1.2 Frequency □ (1)

1.1.3 (Type of) metal□□ (1)

1.2 The minimum frequency needed to emit electrons ✓from (the surface of) a metal. □ (2)

1.3 9×10^{14} Hz ✓ (1)

1.4 $E = W_0 + E_k$ ✓

$hf = hf_0 + E_k$

$(6,63 \times 10^{-34})(14 \times 10^{14})$ ✓ $= (6,63 \times 10^{-34})(9 \times 10^{14})$ ✓ $+ E_k$

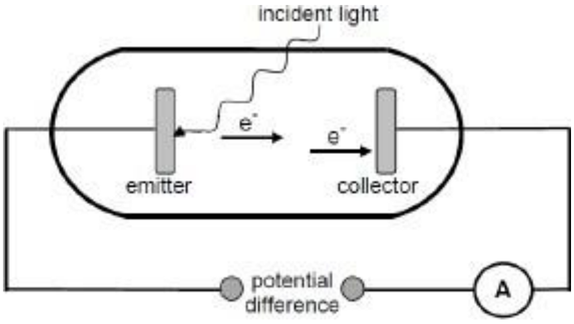
$\therefore E_k = 3,32 \times 10^{-19}$ J ✓ $(3,31 \times 10^{-19}$ J$)$ (4)

1.5 **B**. ✓
As the intensity of light increases the number of photons per second increase. ✓ Since each photon releases one electron, the number of ejected electrons per second increases. ✓This causes the current /ammeter reading to increase. (3)

1.6 Equal to✓ **[14]**

QUESTION 2

2. The apparatus below is used to demonstrate the photoelectric effect using sodium metal.



The longest wavelength that will cause electrons to be ejected from a sodium metal surface when light is shone on the metal is 583 nm.

2.1.1 Define *threshold frequency*. (2)

2.1.2 Calculate the threshold frequency for sodium metal. (3)

2.1.3 Hence, calculate the work function of sodium metal. (3)

A low intensity light of wavelength of 450 nm is incident on the sodium.

2.1.4 Calculate the kinetic energy of the ejected electrons. (4)

A higher intensity light, also of wavelength 450 nm, replaces the low intensity light.

2.1.5 What will the effect be of the higher intensity light on

2.5.2.1 The kinetic energy of the ejected electrons? (1)

2.5.2 The number of ejected electrons? (1)

Diagram 1 below shows some of the possible energy emissions as excited electrons in a hot gas fall to lower energy levels. (Level n = 4 has the highest energy.)

Diagram 2 below shows the line emission spectrum produced. The white lines indicate the wavelengths at which light was observed

Diagram 1

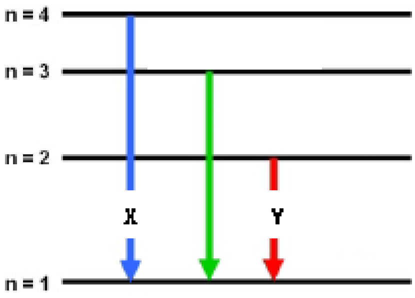


Diagram 2

2.2.1 Which of the emissions, **X** or **Y** (diagram 1) is most likely to Correspond to spectral line **A** in diagram 2?

Explain your answer. (3)

2.2.2 Write down ONE important use of line emission spectra (1)

[18]

Question 2 [Answers]

2.1.1 **Threshold frequency** is the minimum frequency of light needed to eject electrons from a metal (surface) **OR Threshold frequency** is the minimum frequency of incident radiation at which electrons will be emitted from a particular metal(surface). (2)

2.1.2 $c = f\lambda$ √

$3 \times 10^8 = f_0 \ (583 \times 10^{-9})$√

$\mathbf{f_0 = (5,15 \times 10^{14}\ Hz}$ √ (3)

2.1.3 $W_0 = hf_0$ √

$W_0 = (6,6 \times 10^{-34})\ (5,15 \times 10^{14})$ √

$\mathbf{W_0 = 3,\ 40 \times 10^{-19}\ J}$ √ (3)

2.1.4 $E = \frac{hc}{\lambda} = W_0 + E_{kmax}$ √

$= \frac{(6,6 \times 10^{-34})(3 \times 10^8)}{450 \times 10^{-9}}$ ✓ $= 3,40 \times 10^{-19}$ √ $+ E_{kmax}$

Ekmax **= 1 x 10^{-19} J** √ (4)

2.1.5.1Higher intensity has no effect □ (1)

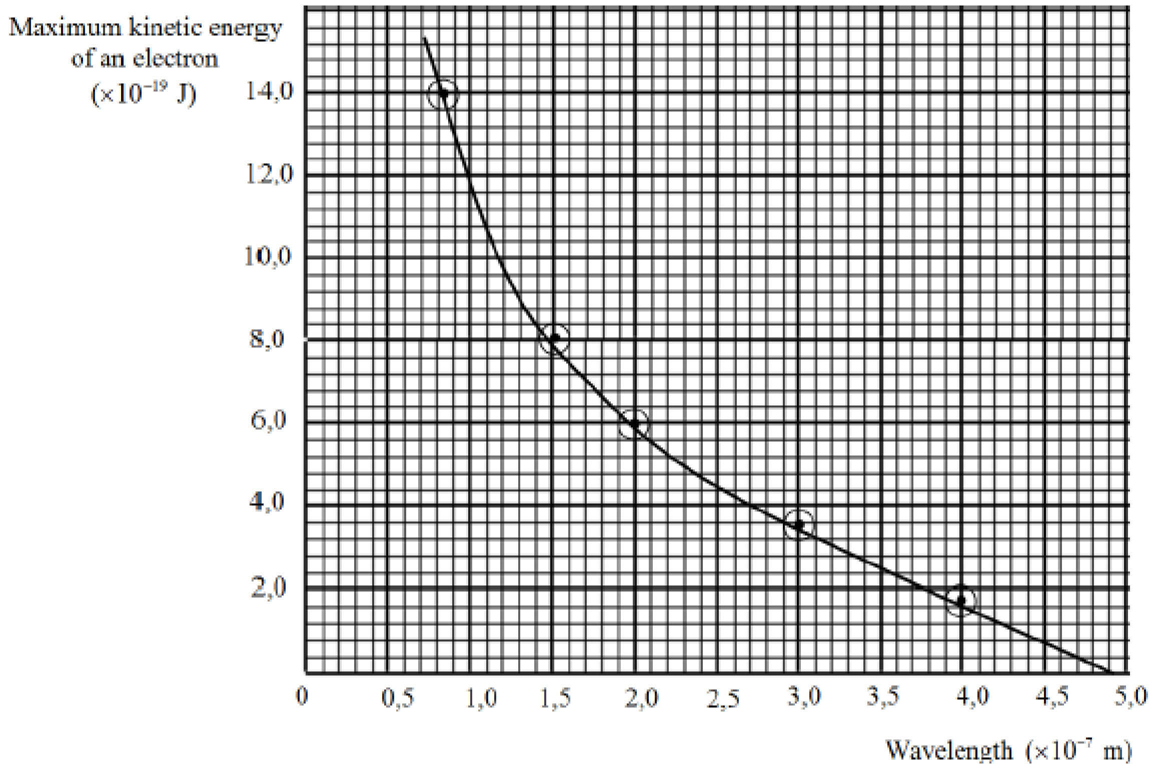
2.1.5.2 Higher intensity increases the number of ejected electrons□ (1)

2.2.1 **Emission X**✓ corresponds to spectral line A. The **energy** of the Photon emitted is **greatest** in emission X✓∴ wavelength is shortest,□
(3)

2.2.2 To identify unknown elements□ (Each element has its own characteristic line spectrum).
(1)

ACTIVITY 1

The graph below shows how the maximum kinetic energy of an electron emitted from the metal cathode of a photoelectric cell varies with the wavelength of the incident radiation.



1.1 Use the graph to determine the maximum kinetic energy of the electron Emitted when the wavelength of the incident radiation is 1,0x10^{-7} m. (1)

1.2 Describe the relationship shown in the graph. (2)

1.3 Use your knowledge of the photoelectric effect to EXPLAIN the relationship

Shown in the graph. Support your answer with reference to relevant formulae. (2)

1.4 Use the graph to calculate the threshold frequency of the light needed to emit electrons from the metal cathode of the photovoltaic cell. (3)

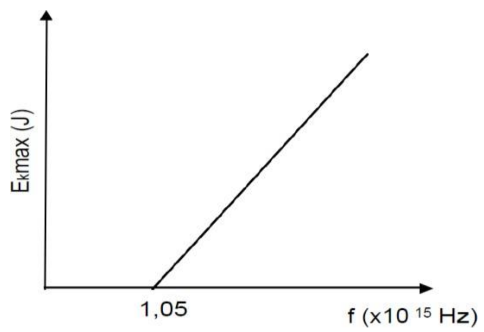
1.5 Calculate the work function of the metal used for the cathode of the photovoltaic cell. (3

[11]

ACTIVITY 2

A Physics student measures the maximum kinetic energy of photoelectrons emitted from the surface of metal **X**, using different frequencies of the incident radiation. The student uses his data to plot the graph shown below.

Graph showing the relationship between the maximum kinetic energy of photoelectrons and the frequency of incident radiation for metal X.



The following table shows the work function of a variety of metals:

Metal	Work Function (J)
Sodium	$3,82 \times 10^{-19}$
Zinc	$6,97 \times 10^{-19}$
Copper	$7,52 \times 10^{-19}$
Platinum	$1,02 \times 10^{-18}$
Calcium	$4,78 \times 10^{-19}$

2.1 Define *work function*. (2)

2.2 State the independent variable in this experiment. (1)

2.3 Show that the gradient of the graph has units N·m·s. (2)

2.4 Use information from the graph and the table above to determine the identity of metal **X**. (5)

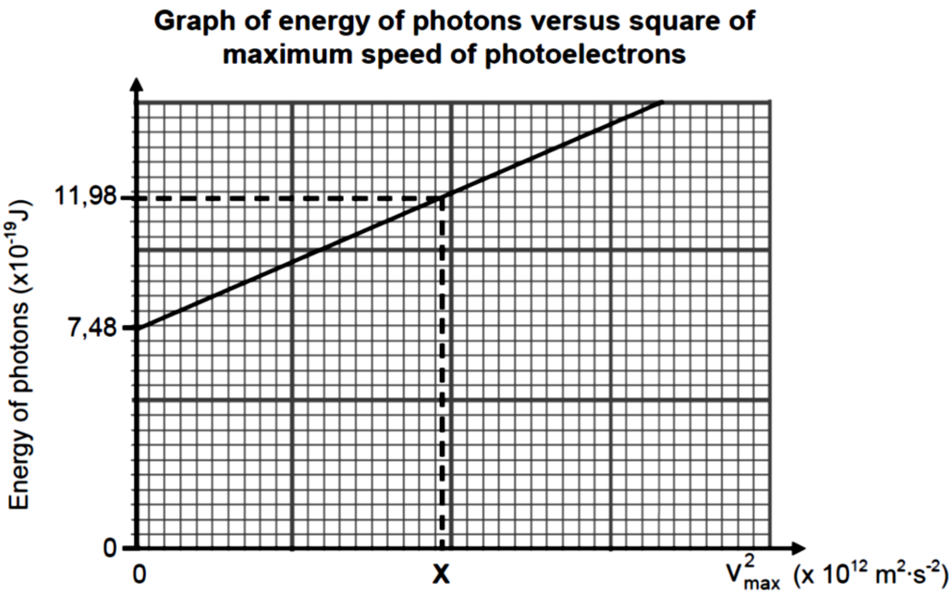
2.5 The wavelength of blue light is given as 475 nm. When this blue light is shone onto a certain metal surface, the maximum velocity of emitted electrons is $2{,}77 \times 10^5$ m·s^{-1}. Determine which metal from the table above is being used. (6)

[16]

Activity 3

During an experiment, light of different frequencies is radiated onto a silver cathode of a photocell and the corresponding maximum speed of the ejected photoelectrons are measured.

A graph of the energy of the incident photons versus the square of the maximum



speed of the ejected photoelectrons is shown below.

3.1 Define the term *photoelectric effect*. (2)

Use the graph to answer the following questions.

3.2 Write down the value of the work function of silver. Use a relevant equation to justify the answer. (3)

3.3 Which physical quantity can be determined from the gradient of the graph? (1)

3.4 Calculate the value of **X** as shown on the graph. (5)

The experiment above is now repeated using light of higher intensity.

3.5 How will EACH of the following be affected? Choose from INCREASES, DECREASES or REMAINS THE SAME.

3.5.1 The gradient of the graph (1)

3.5.2 The number of photoelectrons emitted per unit time (1)

BIBLIOGRAPHY

1	Department of Basic Education 2013-2024. The Curriculum Assessment and Policy Statement National and Provincial question papers.
2	Department of Basic Education 2021. The Curriculum Assessment and Policy Statement examination guideline. Pretoria: Government Printing Works.
3	Learner Guide Physical Sciences Chemistry Paper 2 2024 by Free State Department of Education
4	Kutlwanong Maths and Science Project Last push Material 2024