KWAZULU-NATAL PROVINCE
EDUCATION
REPUBLIC OF SOUTH AFRICA

CURRICULUM GRADE 10 -12 DIRECTORATE

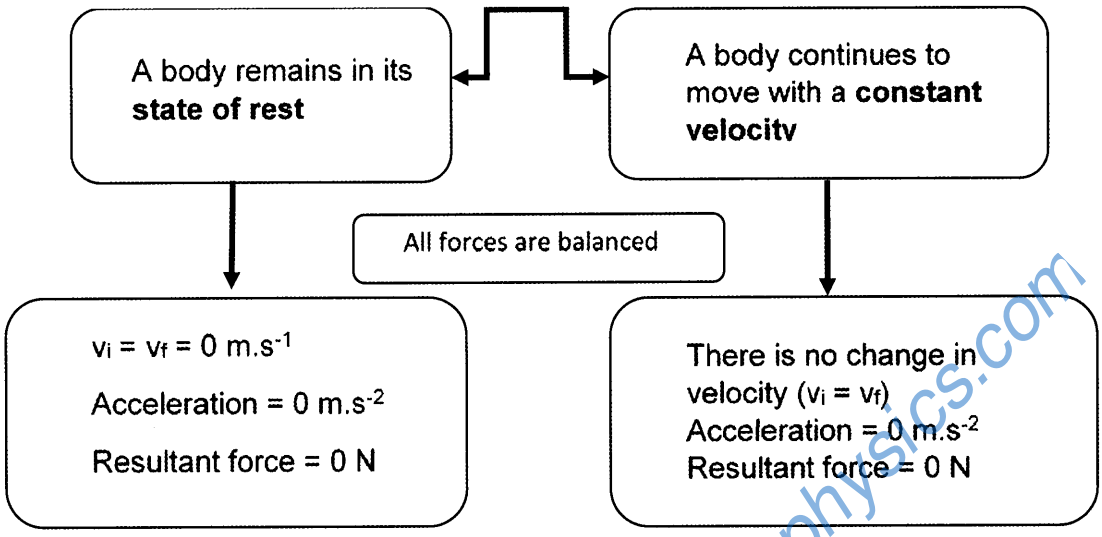
NCS (CAPS) SUPPORT

JUST IN TIME LEARNER REVISION DOCUMENT

PHYSICAL SCIENCES

TABLE OF CONTENT

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.



Newton's Second Law of Motion

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

Mathematically expressed as: $F_{net} = ma$

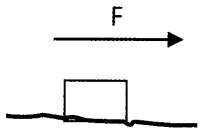
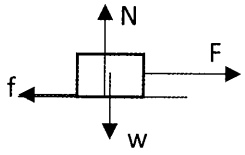
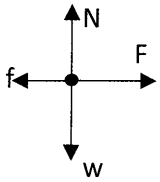
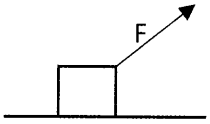
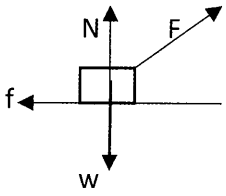
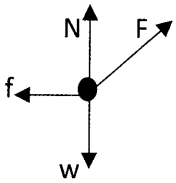
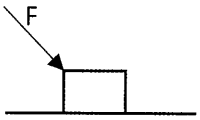
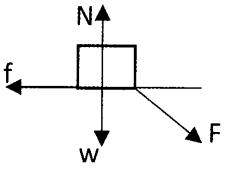
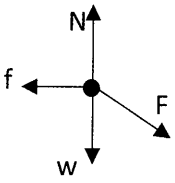
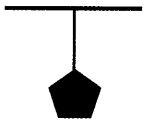
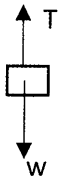
Where: F_{net} - net force, measured in Newton's(N)
a- acceleration, measured in metres per second squared (m.s^{-2})
m-mass of the object, measured in kilograms (kg)

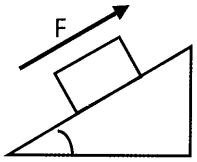
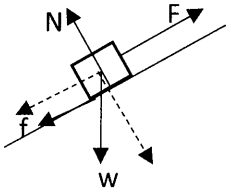
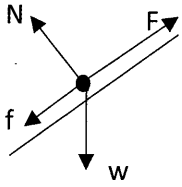
A net force acts on an object. $F_{net} \neq 0$ N Forces acting on the object are not balanced Net force cause the object to accelerate in the direction of the force. Acceleration and net force go in the same direction. There is a change in velocity ($v_i \neq v_f$). $a \neq 0$ m.s^{-2}

$\boldsymbol{a \propto F_{net}}$ When the net force increases, the acceleration also increases. vice versa

$\boldsymbol{a \propto \frac{1}{m}}$ When the mass increases, the acceleration decreases.

FREE BODY DIAGRAMS, FORCE DIAGRAMS VS THE NET FORCE

Plane	Diagram	Force diagram	Free-body diagram	$F_{net}=ma$
Horizontal				$F_{net}=ma$ $F+(-f)=ma$ **$(N=w=mg)$**
Horizontal at an angle				$F_{net}=ma$ $F_{//}-f=ma$ **$(N=w-F_{\perp})$**
				$F_{net}=ma$ $F_{//}-f=ma$ **$(N=w+F_{\perp})$**
Vertical				$F_{net}=ma$ $w-T=ma$

Inclined				$F_{net}=ma$
				$F-f-w_{//}=ma$
				$w_{//}=mgSin\theta$
				$w_{\perp}=mgCos\theta$
				$(N=w_{\perp}=mgCos\theta)$

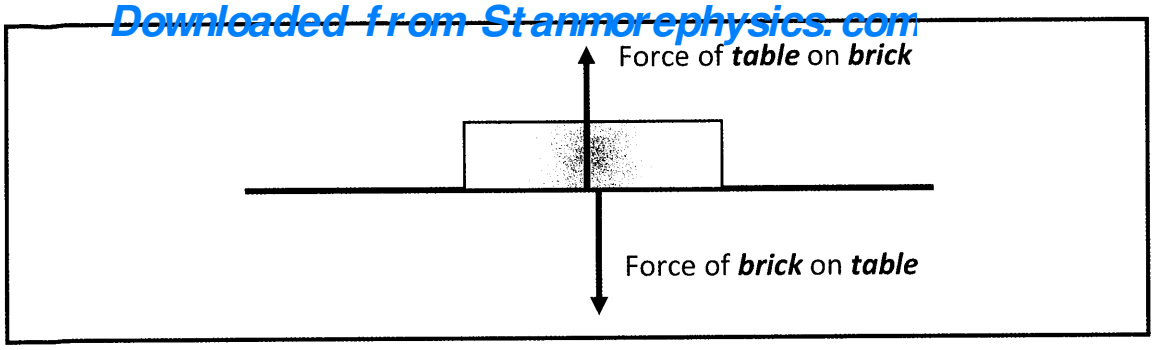
Newton's Third Law of Motion

When object A exerts a force on object B, object B **Simultaneously** exerts an oppositely directed force of equal magnitude on object A.

- The forces are **equal in magnitude**
- The forces act in the same straight line but in the **opposite directions** on different objects
- The forces do not cancel each other, as they act on **different objects**

For any two objects **A** and **B**: $F_{AonB} = -F_{BonA}$

Example



Newton's Law of Universal Gravitation

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

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

Where:

F-force between objects, measured in newtons (N)

G-Universal Gravitational constant ($G= 6.67\times10^{-11}N\cdot m^2\cdot kg^{-2}$)

m_1m_2-masses of objects in kilograms(kg)

r-distance between the objects in metres(m)

MULTIPLE CHOICE QUESTIONS

1.1. A constant net force, F, is applied to a crate which moves along a frictionless horizontal surface. Which ONE the following quantities remains constant while force F acts on the crate?

A The rate of change of velocity
B The change in momentum
C The work done on the crate
D The change in kinetic energy

(2)

1.2. A spaceship experiences a weight of X on earth. It is sent into space and lands on a planet which has a mass twice that of the earth and a radius ½ that of the earth. The weight of the spaceship will be...

A 8X
B $\frac{1}{2}$ X
C X
D 2X

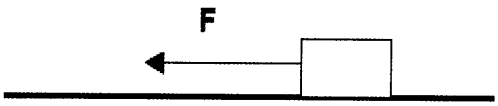
(2)

1.3. A car is moving at a constant speed. Which ONE of the following statements about the forces acting on the car is CORRECT?

A The net force acting on the car is zero.
B There are no forces acting on the car
C The weight of the car is equal to the normal force acting on the car.
D There is a non-zero net force acting on the car.

(2)

1.4. A block, being pulled by a force F, and moving to the left on a rough horizontal surface, is slowing down.



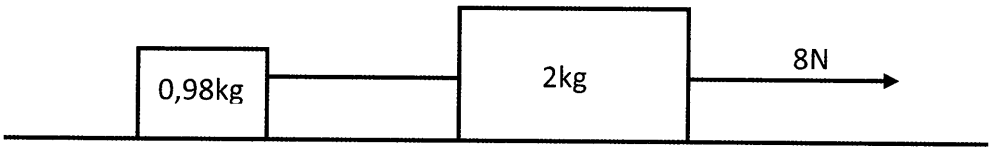
	DIRECTION OF RESULTANT FORCE	DIRECTION OF ACCELERATION
A	to the right	to the left
B	to the right	to the right
C	to the left	to the left
D	to the left	to the right

(2)

WORKED EXAMPLES

EXAMPLE 1

A 8 N force pulls horizontally on a block of mass 2 kg. The block slides on a smooth horizontal surface. The first block is connected by a horizontal weightless inelastic string to a second block of mass 0,98 kg on the same surface.



1.1 Draw a free-body diagram for each block. (7)

1.2 Determine the acceleration of the blocks (7)

1.3 Determine the tension in the string. (3)

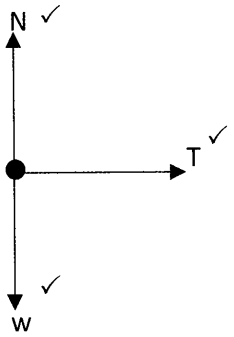
1.4 The mass of the first block is increased. State whether the tension in the string will INCREASE, DECREASE OR STAY THE SAME. (1)

[18]

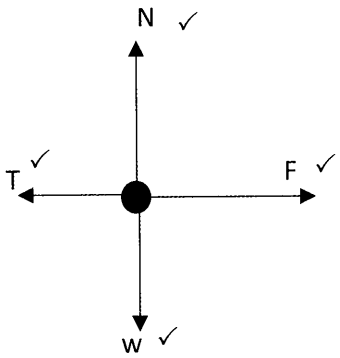
SOLUTIONS:

1.1.

m=0.98kg



m=2kg



(7)

1.2. $F_{net}=ma$✓

For 0.98kg block

T=ma

T=(0.98)a---------(1) ✓

For 2kg block

F-T=ma

8-T=(2)a----------(2) ✓

(1) To (2)

8-0,98a ✓ = 2a ✓

a = 2.68 m.s^{-2} ✓✓

$F_{net}=ma$

$F_{net}=(m_1+m_2)\ a$

8 = (0.98+2) a

8 = 2.98a

a = 2.68 m.s^{-2}

(7)

1.3. m=0,98kg block

T = ma ✓

T = (0,98)(2,68) ✓

T = 2,63N ✓

m = 2kg block

F_{net} = ma

F-T = ma

8-T = (2) (2,68)

-T = -2,63N

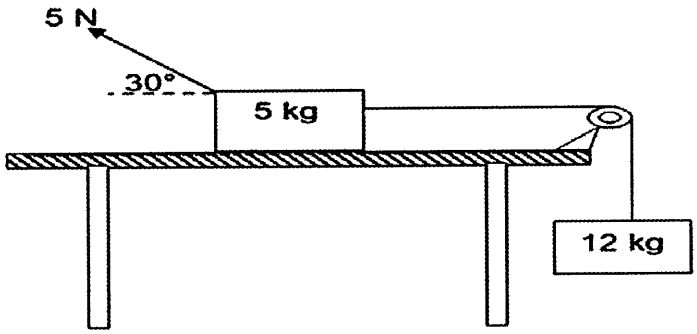
T = 2,63N

(3)

1.4. Stays the same. ✓ (1)

EXAMPLE 2

A 5 kg block, resting on a rough horizontal table, is connected to a 12 kg block by a light inextensible string that passes over a light frictionless pulley. A 5 N force is applied to the 5 kg block at 30° to the horizontal as shown in the diagram below.



2.1. Draw a labelled free-body diagram showing ALL the forces acting on the 5kg. The coefficient of kinetic friction (μk) between the 5 kg block and the surface is 0,2. Use Newton's Laws to calculate the magnitude of the: (5)

2.2. Normal force acting on the 5 kg block. (3)

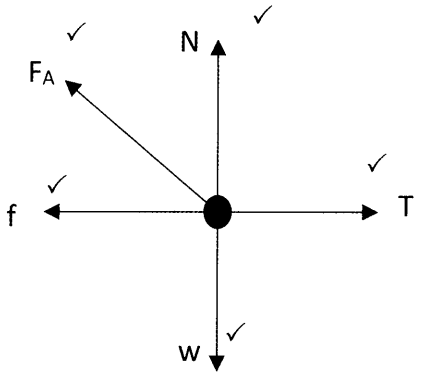
2.3. Kinetic frictional force acting on the 5 kg block. (3)

2.4. Acceleration of the 5 kg block. (4)

[15]

SOLUTIONS

2.1.



(5)

2.2. $F_N + F_{AY} = w$

$F_N + (5 \times \sin 30^0)$ ✓ $= (5)(9,8)$ ✓

$F_N = 46,5$ N ✓ (3)

2.3. $f_k = \mu N$ ✓

$f_k = 0,2 \times 46,5$ ✓

$f_k = 9,3$ N ✓ (3)

2.4. At 5 kg block B:

Fnet = ma

T + (-f) + ($-F_{AX}$) = ma

T = 5 × a ✓

T = 5a + 9,3 + 5 cos30°✓..(1)

At 12 kg block A

W + (-T) = ma

mg – T = 12 × a

12 × 9,8 – T = 12 × a

T = 117,6 – 12a✓.. (2)

(1) = (2):

117,6 –12a = 5a + 4,9 + 5cos30°

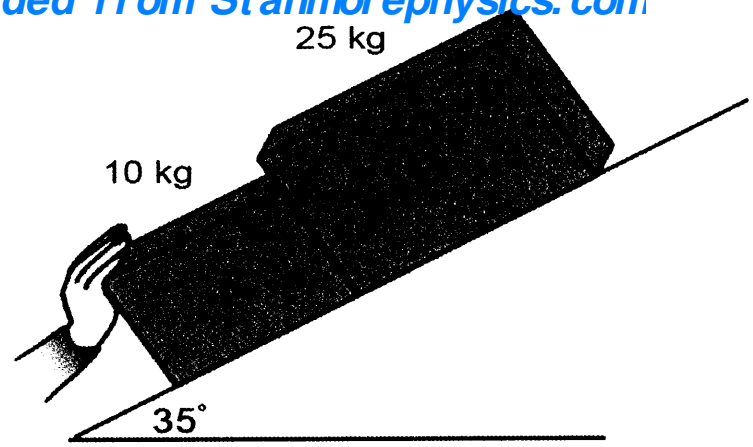
117,6 – (9,3+ 5cos30°)=5a + 12a

103,96987 = 17a

a = 6,12 m•s^{-2} ✓ (4)

EXAMPLE 3

Two blocks, **A** and **B**, are placed on an inclined rough surface that makes an angle of 35° with the horizontal. Nceba is applying a force **F** on block **A** to push the system up the incline. Block **B** experiences a frictional force of 15 N.



3.1. State Newton's Third law of motion in words. (2)

3.2. If the system accelerates at 1.5 $m.s^{-2}$ up the force exerted by block B on block A. (6)

3.3. Draw a labelled free-body diagram of all the forces acting on block B. (4)

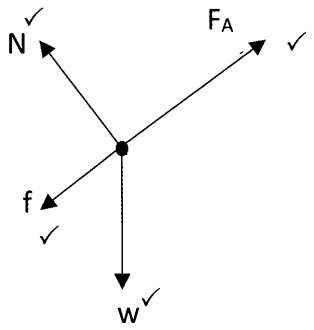
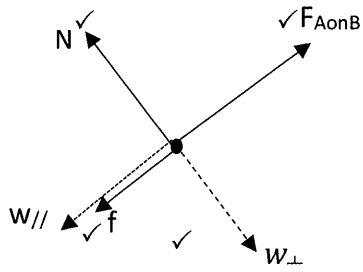
3.4. If block A experiences a frictional force of 4,5 N when the system was accelerating at 1,5$m.s^{-2}$, calculate magnitude of the force applied by Ncenda. (4)

[16]

SOLUTIONS

3.1. When object A exerts a force on object B, object B **Simultaneously** exerts an oppositely directed force of equal magnitude on object A.✓✓ (2)

3.2.

OPTION 1	OPTION 2
	

(4)

3.3. $F_{net} = ma$ ✓

$F_{AonB} + f_B + w_{//} = ma$

$F_{AonB} + (-15) + (-25 \times 9.8 \times 0{,}574)$✓ $= 25 \times 1{,}5$ ✓

$F_{AonB} - 155{,}63 = 37{,}50$

$F_{AonB} = 193{,}13$ N✓

$F_{AonB} = -F_{BonA}$

$F_{BonA} = -193{,}13$ N

$F_{BonA} = 193{,}13$ N✓ down the slope ✓ (6)

3.4. $F_{net} = ma$

$F_{Nceba} + F_{BonA} + f_A + w_{//} = ma$ ✓

$F_{Nceba} + (-193,13) + (-4,5) + (-10 \times 9,8 \times 0,574)$✓ $= 10 \times 1,5$ ✓

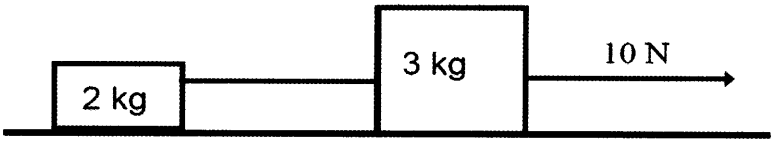
$F_{Nceba} - 253,88 = 15$

$F = 268,88$ N ✓ (4)

ACTIVITIES

QUESTION 1

Two wooden blocks of masses 2kg and 3kg respectively are placed on a rough horizontal surface. They are connected by a string. A constant horizontal force of 10N is applied to the second string attached to 3kg mass as shown in the diagram below. Assume that both strings are inextensible.



The system moves towards the right with a CONSTANT VELOCITY.

1.1. Define the term kinetic frictional force. (2)

1.2. What is the magnitude of the net force acting on the system? (1)

1.3. Draw a labelled free-body diagram showing ALL the forces acting on the 3kg block as it moves towards the right. (5)

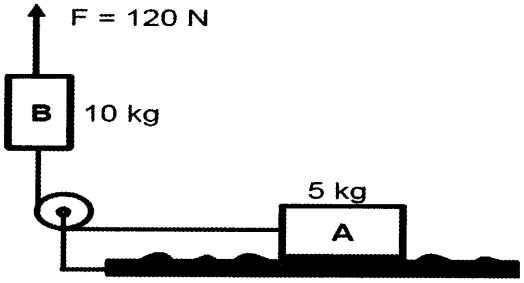
1.4. Calculate the coefficient of kinetic friction between the surface and the two wooden blocks. (4)

1.5. The 10N force is increased to 30N so that the system now accelerates. Calculate the acceleration of the system. (5)

[17]

QUESTION 2

A block **A** of mass 5 kg, at rest on a rough horizontal table, is connected to another block **B** of mass 10 kg by means of a light inextensible string which passes over a light frictionless pulley. A force of 120 N is applied vertically upwards on block **B** as shown in the diagram below.



The coefficient of kinetic friction between the surface and block **A** is 0,3. Ignore the effects of air friction.

2.1. State Newton's Second Law in words. (2)

2.2. Draw a labelled free-body diagram of ALL forces acting on block **B**. (3)

Calculate the magnitude of the:

2.3. Friction force acting on block **A** (3)

2.4. Tension force acting on block **B** (6)

2.5 A man on the surface of planet **Y** weighs HALF his weight compared to his weight on the surface of the Earth. The mass of planet **Y** is TWICE that of the Earth.

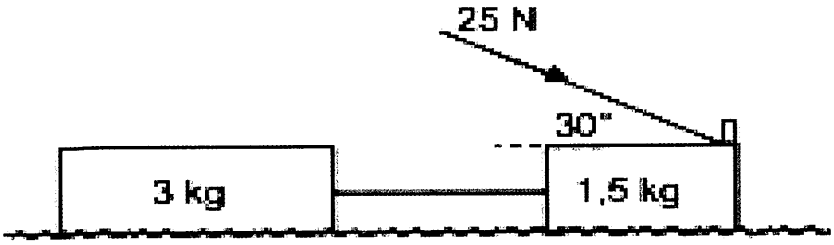
2.5.1. State Newton's Law of Universal Gravitation in words. (2)

2.5.2. Calculate the radius of planet **Y** in terms of the radius of the Earth. (4)

[20]

QUESTION 3

A learner constructs a push toy using two blocks with masses 1,5 kg and 3 kg respectively. The blocks are connected by a massless, inextensible cord. The learner then applies a force of 25 N at an angle of 30° to the 1,5 kg block by means of a light rigid rod, causing the toy to move across a flat, rough, horizontal surface, as shown in the diagram. The coefficient of kinetic friction (μk) between the surface and each block is 0,15.



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

3.2. Calculate the magnitude of the kinetic frictional force acting on the 3 kg block. (3)

3.3. Draw a labelled free-body diagram showing ALL the forces acting on the 1,5 kg block. (5)

3.4 Calculate the magnitude of the:

3.4.1 Kinetic frictional force acting on the 1,5 kg block (3)

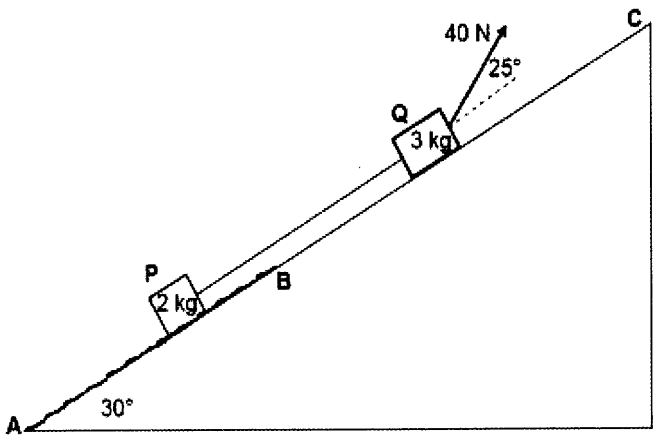
3.4.2 Tension in the cord connecting the two blocks (5)

[18]

QUESTION 4

Block **P**, of mass 2 kg, is connected to block **Q**, of mass 3 kg, by a light inextensible string. Both blocks are on a plane inclined at an angle of 30° to the horizontal. Block **Q** is pulled by a constant force of 40 N at an angle of 25° to the incline. Block **P** moves on a rough section, **AB**, of the incline, while block **Q** moves on a frictionless section, **BC**, of the incline. See diagram.

An average constant frictional force of 2,5 N acts on block **P** as it moves from **A** to **B** up the incline.



4.1. State Newton's Second Law in words. (2)

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

4.3. Calculate the magnitude of the acceleration of block **P** while block **P** is moving on section **AB**. (8)

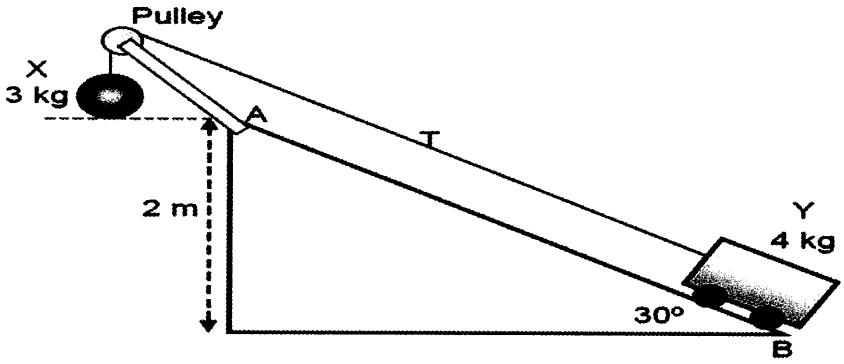
4.4. If block **P** has now passed point **B**, how will its acceleration compare to that calculated in QUESTION 4.3? Choose from GREATER THAN, SMALLER THAN or EQUAL TO. Give a reason for the answer. (2)

[16]

QUESTION 5

Ball X of mass 3 kg is attached to trolley Y of mass 4 kg by a light string which passes over a frictionless pulley as shown in the diagram. Initially the trolley is at rest on a slope AB, which makes an angle of 30° with the horizontal. When the ball is released it falls to the ground and the trolley moves 2 m up the slope accelerating at 0,43 $m.s^{-2}$.

The coefficient of kinetic friction along the slope AB is μ_k =0,2. (Ignore the rotation effect of the wheels and air friction)



5.1. Draw a labelled free body diagram to show ALL the forces acting on the trolley as it moves up the slope. (4)

5.2. Show that a friction force of 6,79 N acts on the trolley as it moves up the slope. (3)

5.3. State Newton's Second Law of motion in words. (2)

5.4. Calculate the tension T in the string. (5)

5.5. Calculate the speed with which the 3 kg ball strikes the ground. (4)

[18]

TIPS ON SOLVING MOMENTUM PROBLEMS

NB: educator to ensure that learners follow these tips during activities.

1. Write down given information and quantity (unknown data) to be calculated.
2. Where necessary, convert mass, ***m***, of an object to kilograms (kg).
3. Where necessary convert the velocity of an object to meters per second ($m \cdot s^{-1}$).
4. Choose and correctly copy an appropriate formula as given in the data sheet.
5. Substitute all the variables correctly (before manipulating the formula).
6. Write the answer with the correct unit.
7. Always include direction in all momentum calculations / answers.

MOMENTUM ACTIVITIES

QUESTION 1: Multiple Choice Questions

Various options are provided as possible answers to the following questions. Choose the answer and write only the letter (A-D) next to the question number (1.1- 1.20) in the ANSWER BOOK, e.g., 1.21 B.

1.1 In the equation $F_{net}\Delta t = \Delta p$, the product $F_{net}\Delta t$ represents …

A change in momentum
B impulse.
C force per unit time.
D rate of change of momentum (2)

1.2 A ball with a mass m, travelling West, hits a wall with a velocity of v. It bounces back with the same velocity.

	Contact time (Δt)	**Δp**	**F_{net}**
A	Decrease	Increase	Decrease
B	Increase	Remains constant	Decrease
C	Decrease	Remains constant	Remains constant
D	Remains constant	Decrease	Decrease

(2)

1.3 Two trolleys approach each other in a straight line at the SAME speed and collide. After the collision, they remain in contact and come to REST. Which one of the following statements is FALSE?

A The two trolleys have the same mass
B The total linear momentum remains constant
C The linear momenta of the two trolleys are different before collision
D The total linear momentum before the collision is greater than the total linear momentum after the collision. (2)

1.4 A moving body with mass **m** and velocity v has a linear momentum **p**. What is the linear momentum, in terms of **p**, of another moving body with a mass of **4 m** and velocity of $\frac{1}{2}v$?

A 8p
B 2p

C p
D $\frac{1}{2}p$

(2)

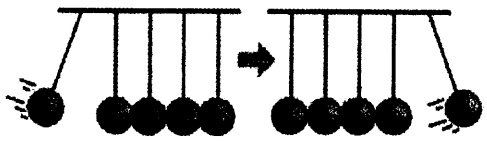
1.5 The front end of a modern car is designed to crumple in the case of a head-on collision. The chance of serious injuries to a passenger is reduced because the net force on the passenger is smaller since the …

A contact time between the passenger and inside of the car is decreased
B rate of the change in momentum is decreased.
C change in momentum is decreased.
D change in momentum is increased. (2)

1.6 Impulse is…

A is the same as momentum
B the same as force
C Determined by the change in momentum
D Independent from force (2)

1.7 The photograph below demonstrates an elastic collision.



One ball One ball in One ball Out

Assuming that the system is ISOLATED, the conclusion is only CORRECT if the kinetic energy is …

A Conserved and the total energy of the system is conserved
B not conserved and the total energy of the system is conserved.
C conserved.
D not conserved and the total energy of the system is not conserved. (2)

1.8 A car experiences a constant net force of 500 N as it moves towards the west. The rate at which the momentum of the car changes during its motion is ...

A Equal to an impulse
B Equal to 500 N
C Greater than the net force
D Less than 500 N (2)

1.9 A ball with mass m strikes a wall with speed v. Assume that the collision is elastic. If the ball bounces back with the same speed v the magnitude of the change in momentum will be...

A 2 mv in the opposite direction
B mv in the opposite direction
C 2 mv in the original direction
D mv in the original direction (2)

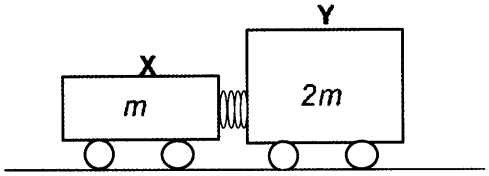
1.10 Which one of the following best describes an inelastic collision?

A Both momentum and kinetic energy are conserved.
B Total kinetic energy is not conserved but total linear momentum is conserved.
C Neither kinetic energy nor momentum are conserved
D Kinetic energy is conserved but the total momentum is not conserved. (2)

1.11 The impulse acting on an object is equal to the … of the object.

A product of the mass and speed
B rate of change in momentum
C change in momentum
D Acceleration (2)

1.12 Two trolleys, X and Y with masses m and 2m respectively, are held together with a compressed spring between them. Initially they are stationery on a horizontal floor as shown. Ignore the effects of friction.



The spring is now released and falls to the floor while the trolleys move apart. The magnitude of the MOMENTUM of trolley **X** is …

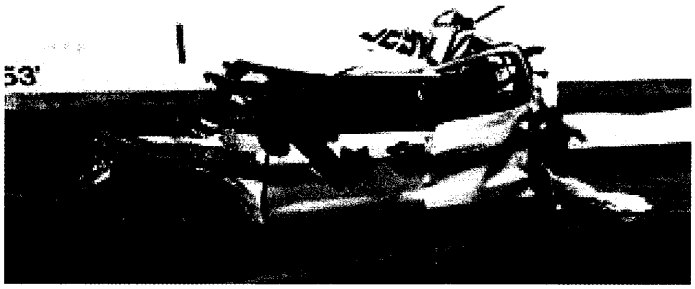
A the same as the magnitude of the momentum of trolley **Y.**
B twice the magnitude of the momentum of trolley **Y**
C half the magnitude of the momentum of trolley **Y**.
D zero. (2)

1.13 The impulse on an object is equal to the objects change in...

A Momentum
B Force
C Kinetic energy
D Velocity (2)

1.14 The police patrol vehicle in the photograph below collided with a big truck. Forensic tests showed that the collision was inelastic.

Assuming that the system is ISOLATED, the collision is only CORRECT if the kinetic energy is…

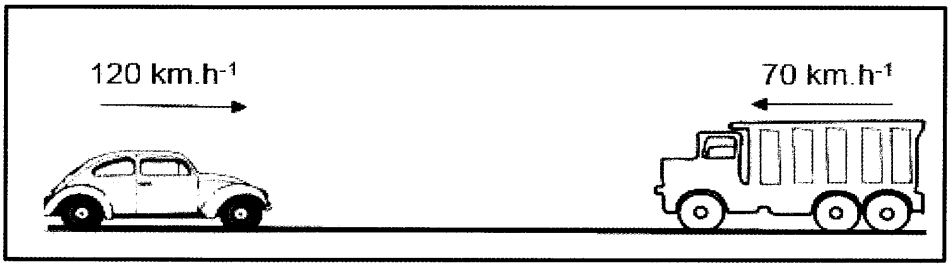


A Conserved and the total energy of the system is conserved.
B Not conserved and the total energy of the system is not conserved.
C Not conserved and the total energy of the system is conserved.
D Conserved. (2)

LONG QUESTIONS

QUESTION 2

A car of mass 800 kg travels due east with a velocity of 120 km.h^{-1} and collides head on with a construction truck of mass 2500 kg that travels with a velocity of 70 km.h^{-1} due west. After the collision, the car and the truck move together



2.1 Define ***momentum.*** (2)
2.2 State the ***Principle of Conservation of Momentum***. (2)
2.3 Calculate the velocity of the car and truck combination after the collision. (5)
2.4 The car is fitted with an airbag. Explain how the airbag reduces the fatal injuries on a driver. (3)
[12]

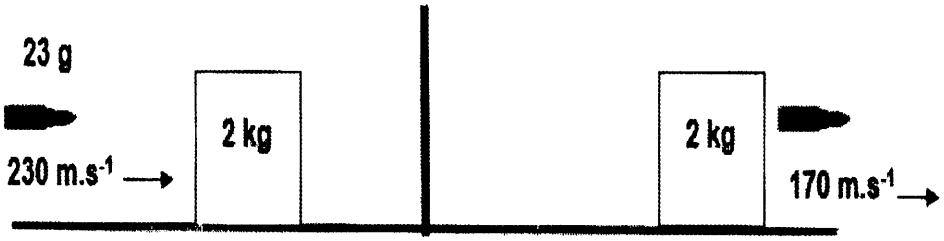
QUESTION 3

A nail of mass 5 g is held horizontally and is hit with a hammer. The hammer exerts 7 N force on the nail and was in contact with the nail for 0,005 s

3.1 Define impulse. (2)
3.2 Calculate the impulse on the nail. (3)
3.3 Calculate the velocity of the nail after the blow. (4)
[9]

QUESTION 4

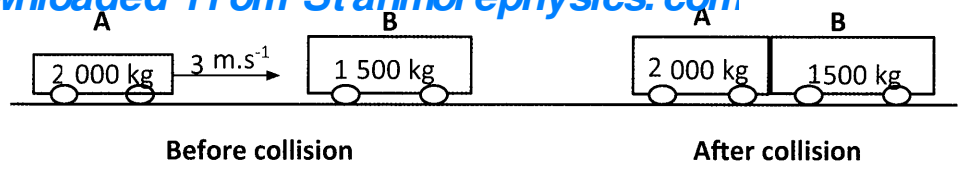
A 23 g bullet travelling at 230 $m \cdot s^{-1}$ penetrates a 2 kg block of wood which is at rest on a frictionless surface. The bullet emerges cleanly at 170 $m \cdot s^{-1}$. The collision is *inelastic*



4.1 State the Principle of Conservation of Linear Momentum in words (2)
4.2 Calculate the velocity of the block of the block immediately after the bullet emerges from it (4)
4.3 Explain whether the kinetic energy is *CONSERVED or NOT CONSERVED* (2)
[8]

QUESTION 5

A railway truck **A**, mass 2 000 kg, moves eastwards at a velocity of 3 $m \cdot s^{-1}$. It collides with a stationary truck **B**, mass 1 500 kg. The two trucks combine after the collision. Ignore the effects of friction.



5.1 Define the term *momentum* in words (2)

5.2 State the *Principle of Conservation of Linear Momentum* in words (2)

5.3 Calculate the VELOCITY of truck **B** after the collision (4)

5.4 Calculate the magnitude of the force that truck **A** exerts on truck **B** if the collision lasts for 0,5 s. (4)

5.5 The front and rear ends of railway trucks are fitted with thick rubber to reduce the damage during collisions. Explain how this is possible by referring to relevant scientific principles. (2)

[14]

QUESTION 6

A truck **T**, mass 3 600 kg, is travelling due EAST at 25 m·s^{-1} when it collides head on with a car **C**, overtaking a vehicle on a blind rise. The mass of the car is 800 kg. It was travelling at 35 m·s^{-1} due WEST at the moment of impact. After the collision, the two vehicles are so intertwined that the wreck moves together as one piece

6.1 Which conservation principle can we use to calculate the velocity of the wreck after the collision? (1)

6.2 Write down this principle in words. (2)

6.3 Calculate the velocity of the wreck immediately after the collision. (5)

6.4 Suppose that the 65 kg truck driver is NOT wearing his seat belt and the truck does not have a crumple zone. When the driver makes contact with the windscreen, it brings him to the same speed as the wreck in 0,005 s. Ignore any frictional forces on the driver.

6.4.1 Calculate the force exerted on the truck driver by the windscreen (4)

6.4.2 Without any further calculation, write down the magnitude of the force that the truck driver exerts on the windscreen. (1)

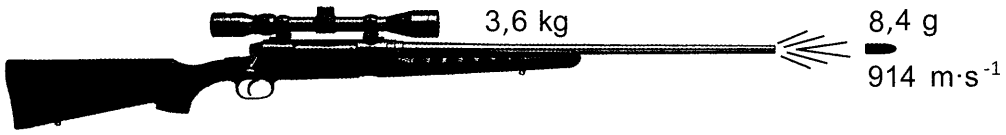
6.5 Distinguish between elastic and inelastic collisions. Refer to momentum and energy (4)

6.6 Head-on collisions are fatal most of the time. What may be the scientific reason for that? Briefly explain it in terms of force and velocity (2)

[19]

QUESTION 7

7.1 A hunting rifle of 3,6 kg fires a bullet with a mass of 8,4 g. The bullet leaves the barrel of the rifle at a speed of 914 $m \cdot s^{-1}$.



7.1.1 When we deal with the principle of the conservation of momentum, we refer to an isolated system. What does *isolate system* mean? (2)

An explosion like this one that takes place inside the chamber of the rifle, can be considered a special kind of 'collision' in physics.

7.1.2 Calculate the *VELOCITY* of the rifle at the instant the shot is fired. (4)

7.1.3 Will the MAGNITUDE of the velocity of the rifle be GREATER THAN, THE SAME AS or LESS, if a *HEAVIER* bullet is fired at the same velocity with the same rifle? (1)

7.1.4 Is this 'collision' elastic or inelastic? (1)

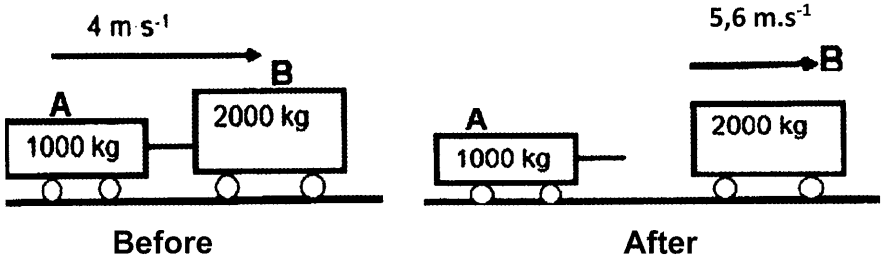
7.1.5 Give a reason for your answer to QUESTION 3.1.4 and support your reason with the necessary calculation(s). (4)

7.2 A soccer ball, with a mass of 400 g, moves across a horizontal floor in a straight line at a speed of 4 $m \cdot s^{-1}$. It hits a wall and then it moves in the opposite direction at 3 $m \cdot s^{-1}$ directly after the collision. The ball is in contact with the wall for 0,14 s. Calculate the magnitude of the force that the wall exerts on the ball. (4)

[16]

QUESTION 8

Two train coaches, A and B, with masses of 1000 kg and 2 000 kg respectively are attached to each other with a compressed spring. They move to the right at 4 $m \cdot s^{-1}$ along a frictionless, horizontal railway track. When the spring is released, and it has expanded completely, the 2000 kg coach moves to the right at a velocity of 5,6 $m \cdot s^{-1}$ as shown in the diagram below.



Before **After**

8.1 State the Principle of Conservation of Linear Momentum in words (2)

8.2 Calculate the magnitude and direction of the velocity of the 1 000 kg coach immediately after the spring has expanded completely. (4)

8.3 If it takes 2 s for the spring to expand completely

8.3.1 Calculate the impulse of *Coach A on Coach B*. (3)

8.3.2 Calculate the average force exerted by Coach A on Coach B. (4)

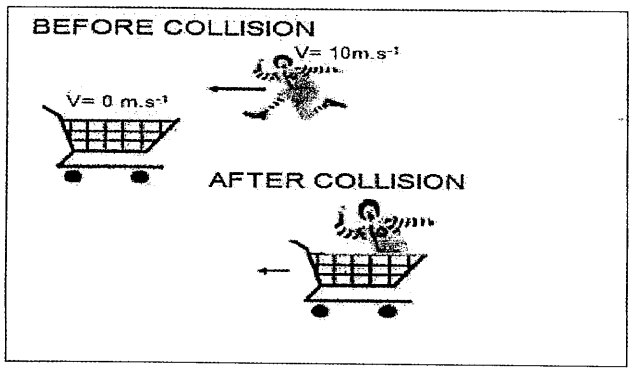
8.3.3 How will the average force exerted by Coach A on Coash B be affected if the time taken for the spring to expand is increased to seconds. Write down only INCREASE, DECREASE or REMAIN THE SAME (1)

8.3.4 Explain your answer to *Question 8.3.3* (2)

[16]

QUESTION 9

A clown with a mass of 80 kg is running at a constant velocity towards the left. While still running he observes a stationery cart of mass 30 kg ahead of him and when he is closer to the cart, he immediately jumps HORIZONTALLY into the cart at a velocity of 10 $m \cdot s^{-1}$. The clown and the cart move together as a unit in a straight line towards the left after the collision



9.1 State the *Principle of Conservation of Linear Momentum* in words. (2)

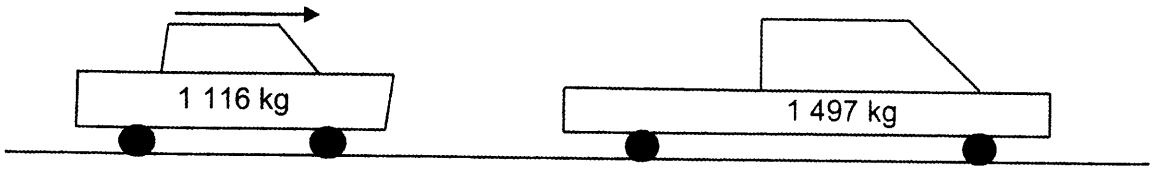
9.2 Calculate the combined velocity of the clown and the cart after collision (5)

9.3 Do necessary calculations to show that the collision was inelastic (6)

[13]

QUESTION 10

A car of mass 1116 kg was travelling at 30 $m \cdot s^{-1}$ towards the east when it collided with a stationary bakkie of mass 1497 kg. After the collision, the bakkie moved at 8 $m \cdot s^{-1}$ to the east.



Assume that the system is isolated

10.1 Define the term *Isolated System* (2)

10.2 Calculate the momentum of the car just before the collision (3)

10.3 Determine the magnitude of the car's velocity after the collision (4)

10.4 Name and state the principle used to answer *Question 10.3* (3)

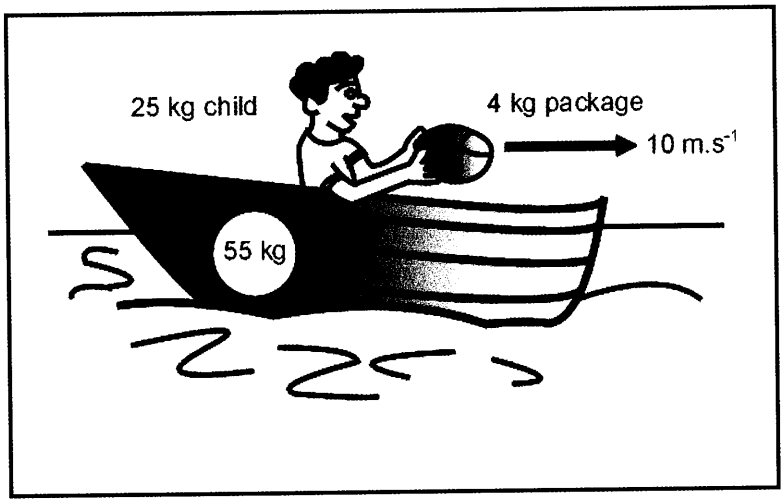
10.5 Without calculation, determine how the final momentum of the car compares with the initial momentum. Write only GREATER THAN, SMALLER THAN or EQUAL TO. (1)

10.6 Explain your answer to *QUESTION 10.5* (2)

[15]

QUESTION 11

A child, mass 25 kg, at rest in a boat throws a package out horizontally at a speed of 10 $m.s^{-1}$. The mass of the boat is 55 kg.



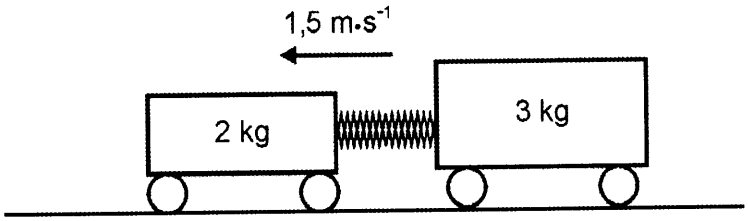
11.1 What is the total momentum of the system before the parcel is thrown? (2)

11.2 Calculate the velocity (magnitude and direction) of the boat immediately after the parcel was thrown. (6)

11.3 Name the law used in *QUESTION 11.2* (2)

QUESTION 12

A compressed spring joins two trolleys with masses of 2 kg and 3 kg. The trolleys move at a velocity of 1,5 m⊠s^{-1} to the left under frictionless conditions on a horizontal surface.



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

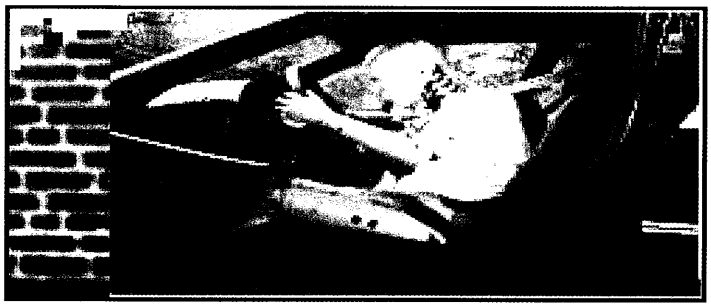
12.2 Say whether the total momentum of the system changes. (1)

12.3 Calculate the velocity of the 2 kg trolley after the spring expands. (4)

QUESTION 13

13.1 On a railway shunting line a locomotive is coupling with a stationary carriage of a mass of 2 500 kg. The locomotive has a mass of 5 800 kg and it is moving due west at a velocity of 1,5 $m \cdot s^{-1}$. After coupling the locomotive carriage combination moves due west.

13.1.1 Define the term *momentum*. (2)
13.1.2 Calculate the momentum of the locomotive before the collision. (3)
13.1.3 Calculate the velocity of the locomotive-carriage combination after (5)
13.1.4 Differentiate between *elastic* and *inelastic* collisions. (4)
13.2 The effective use of seat belts was demonstrated during a crash test at a motor manufacturing plant. The car hit the wall with a momentum of 24 300 kg.m.s^{-1} and took 1,2 s to come to rest.



13.2.1 Use physics principles to explain how seatbelts can save lives during (2)

QUESTION 14

A car of mass 1 120 kg, moving to the right at a velocity of 25 m.s^{-1}, collides with the back of a construction vehicle loaded with cement bags and moving in the same direction at a velocity of 6,25 m.s^{-1}. After the collision, the car moves at a velocity of 7,45 m.s^{-1} and the construction vehicle moves at a velocity of 8,45 m.s^{-1}. Both move towards their original directions. Assume that the system is isolated.

14.1 Define the term *momentum*. (2)
14.2 State the principle of conservation of linear momentum in words. (2)
14.3 What is the magnitude of the net external force acting on the system above? (2)
14.4 Calculate the mass of the construction vehicle if the cement bags have a mass (5)
14.5 Use calculations to determine whether the collision is elastic or inelastic. (5)

QUESTION 15

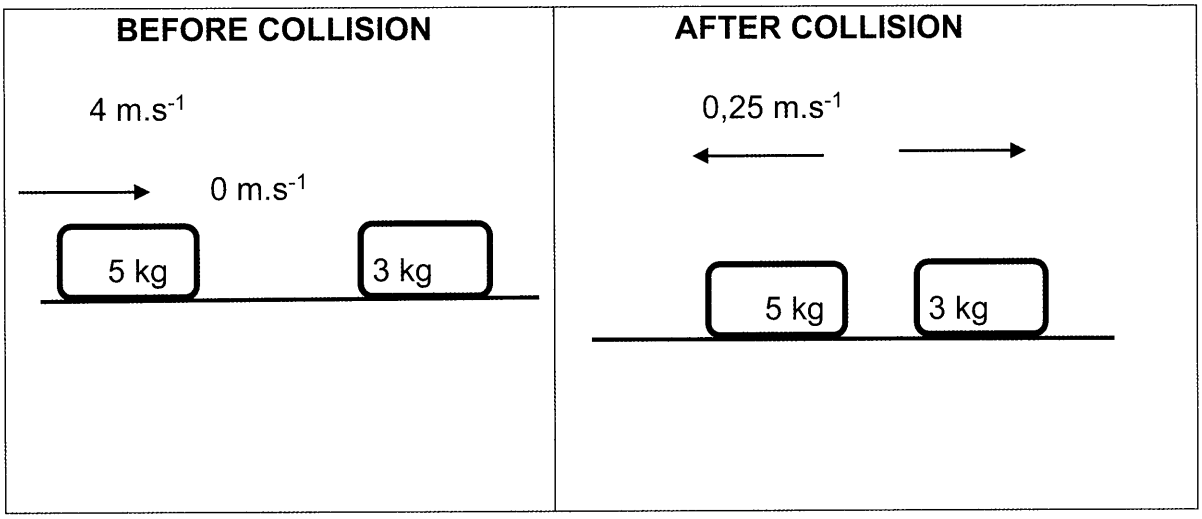
A small car of mass 950 kg, travelling to the left at a velocity of 6 m.s^{-1}, collided with a stationary truck. The car was in contact with the truck for 1,28 s during the collision, after which it moved backwards at 1,24 m.s^{-1}.

15.1 Define the term *impulse*. (2)
15.2 Calculate the net force exerted by the truck on the car. (4)

QUESTION 16

A 5 kg block moving due east with a velocity of 4 m·s^{-1} collides with a stationary 3 kg block.

Immediately after the collision, the 5 kg block moves due west with a velocity of 0,25 m.s^{-1} and the 3 kg block moves with a constant velocity due east as shown in the diagram below. The collision is inelastic.



16.1 Define the term *momentum*. (2)

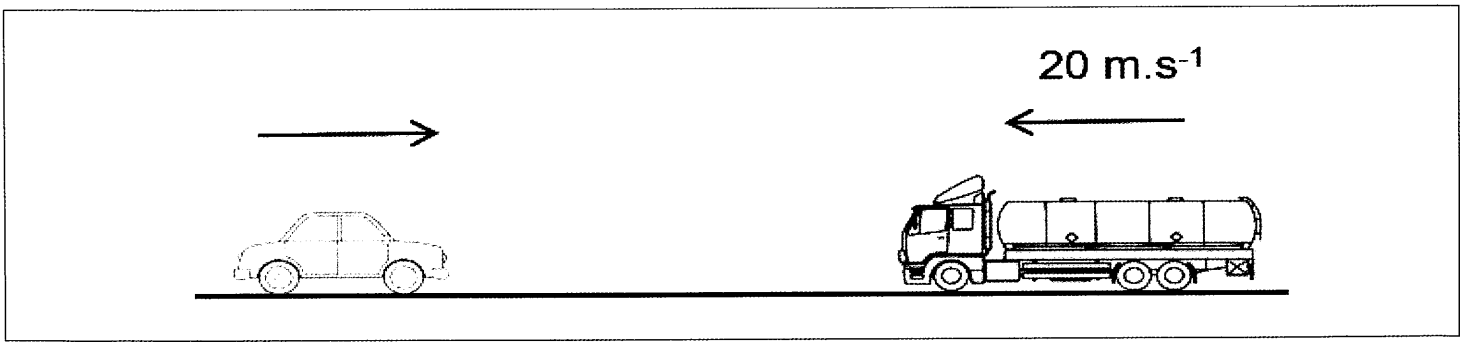
16.2 Which quantity (MOMENTUM or KINETIC ENERGY) is conserved during this collision? (1)

16.3 Calculate the velocity of the 3 kg block after collision. (4)

16.4 Name and state the law used in the calculation in QUESTION 4.3 above. (3)

QUESTION 17

A car with a mass of 1 000 kg travelling due east, collides head-on with a truck with a mass of 5 000 kg moving at 20 m·s^{-1} due west. The force exerted by the truck on the car during the collision is 100 000 N and the collision lasts for 0,4 s.



After the collision, the car and the truck move together.
Ignore the effects of friction.

17.1 What is the magnitude and direction of the force exerted by the car on the truck during the collision? (2)

17.2 Name and state the law used to answer QUESTION 17.1 above. (3)

17.3 Define the term *impulse*. (2)

17.4 Calculate the velocity of the car after the collision. (4)

VERTICAL PROJECTILE MOTION

Definitions and Key Concepts

- A **projectile** is an object which has been given an initial velocity and then it moves under the influence of the gravitational force only.
- **Free fall** is motion in which an object is moving under the influence of gravitational force only where there is no air resistance.

EQUATIONS OF MOTIONS

$v_f = v_i + a\Delta t$

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

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

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

Where:

Δy= displacement in meters (m)

Δt = time in seconds (s)

v_i = initial velocity in meters per seconds ($m \cdot s^{-1}$)

v_f = final velocity in meters per seconds ($m \cdot s^{-1}$)

a = acceleration in meters per seconds squared ($m \cdot s^{-2}$)

(**NB:** $a = 9{,}8\ m \cdot s^{-2}$ downwards)

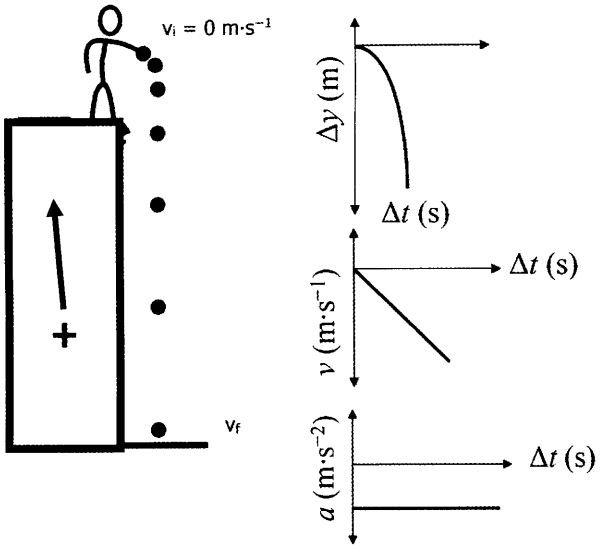
REMEMBER:
1. Draw a sketch diagram
2. Write down given variables
3. Choose one direction of motion as positive
4. Choose an equation that satisfies at least three known variables.
5. Solve taking into considerations the **signs** of each variable

HOW TO CONSIDER SIGNS?

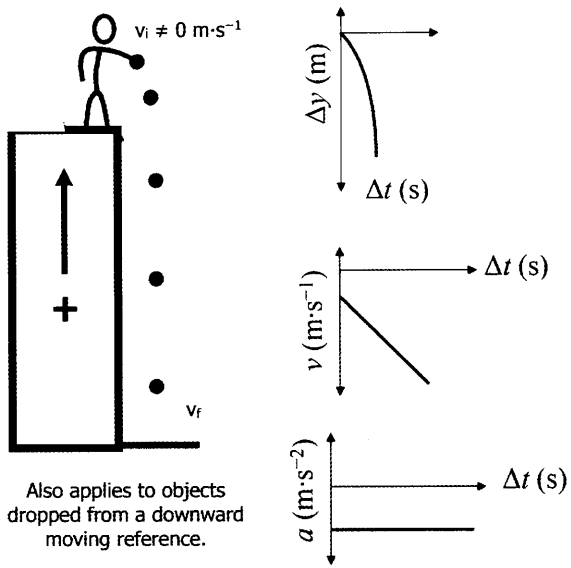
Consider up as (+)	**Consider down as (+)**
g= - 9.8 $m.s^{-2}$	g= +9.8 $m.s^{-2}$
$V_{(object\ move\ upward)}$= +ve	$V_{(object\ move\ upward)}$= -ve
$V_{(object\ move\ downward)}$= -ve	$V_{(object\ move\ downward)}$= +ve
$\Delta y_{(below\ Start\ Point)}$= -ve	$\Delta y_{(below\ Start\ Point)}$=+ve
$\Delta y_{(above\ Start\ Point)}$=+ve	$\Delta y_{(above\ Start\ Point)}$=-ve

NB: choose one direction unless it has been given on the question.

OBJECT DROPPED

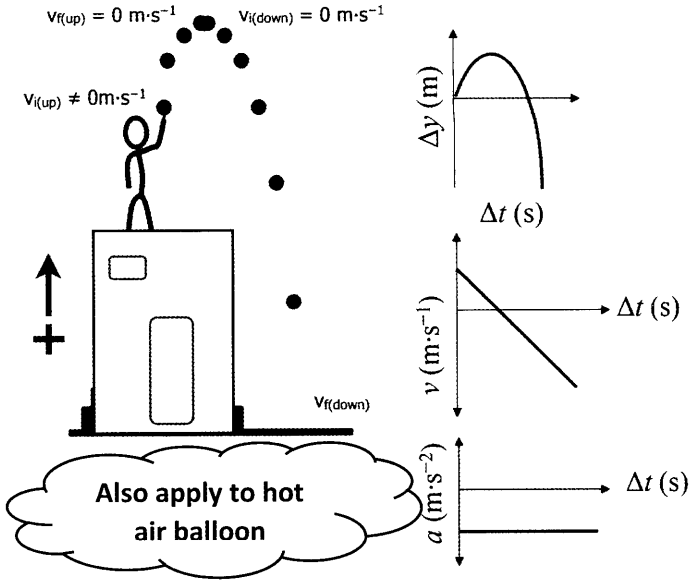


OBJECT THROWN DOWN FROM HEIGHT



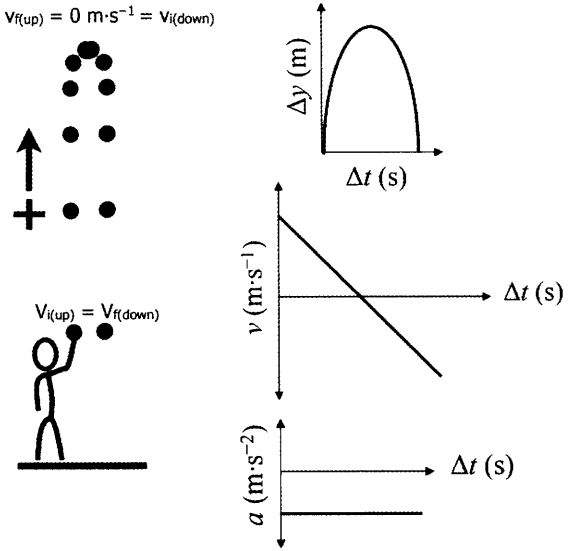
Also applies to objects dropped from a downward moving reference.

OBJECT THROWN UP FROM HEIGHT

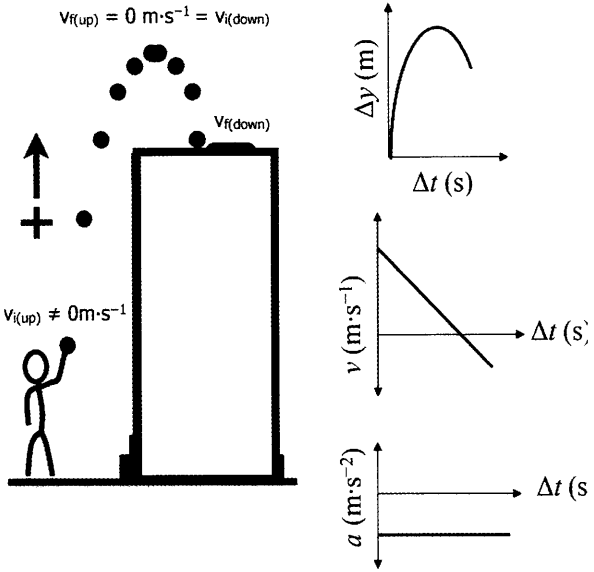


Also apply to hot air balloon

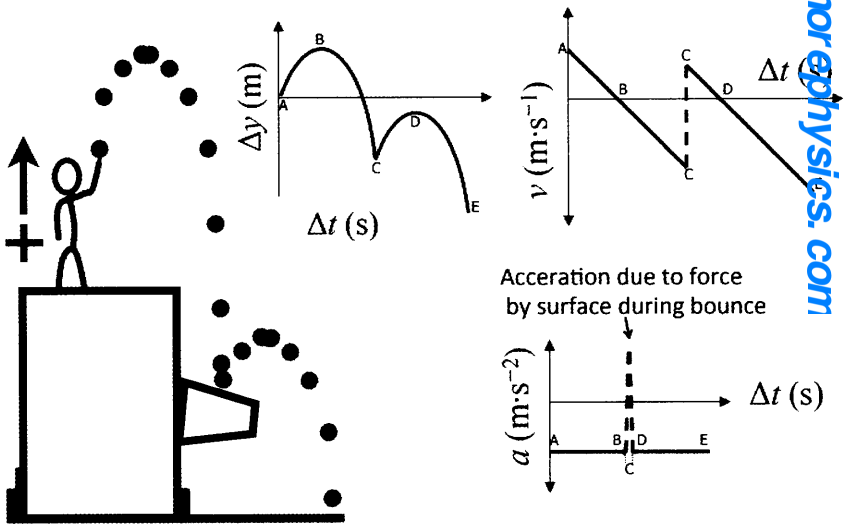
OBJECT THROWN UP AND CAUGHT



OBJECT THROWN UP AND LANDS AT



BOUNCING OBJECT



- The interest is on the object.
- Object is dropped or thrown/projected up or down on a moving hot-air balloon.
- Hot-air balloon will also move up or down.

Consider up as + for a hot-air balloon rising upward

Case 1: An object is dropped from a hot-air balloon rising upward:

$V_i = V_{balloon} + 0$

Case 2: An object is dropped from a hot-air balloon descending with a constant velocity: $V_i = -V_{balloon} + 0$

Case 3: An object is thrown upward from a hot-air balloon ascending with a constant velocity:

$V_i = +V_{balloon} + (+V_{object})$

Case 4: An object is thrown upward from a hot-air balloon descending with a constant velocity:

$V_i = -V_{balloon} + (+V_{object})$

Case 5: : An object is thrown downward from a hot-air balloon ascending with a constant velocity:

$V_i = +V_{balloon} + (-V_{object})$

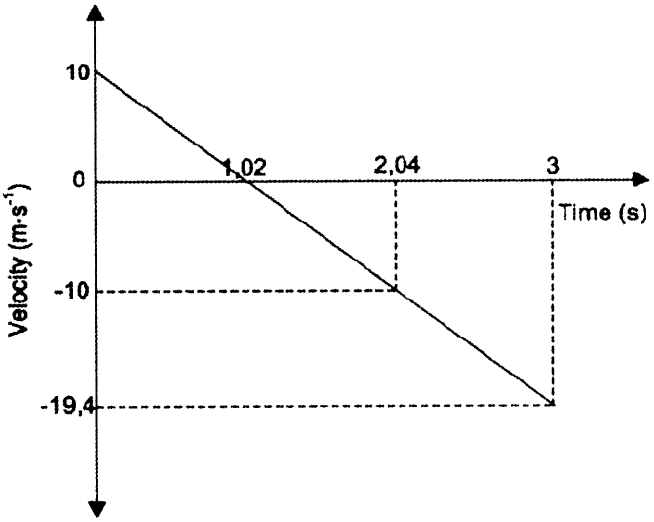
Case 4: An object is thrown downward from a hot-air balloon that is moving downwards:

$V_i = -V_{balloon} + (-V_{object})$

ACTIVITIES: VERTICAL PROJECTILE MOTION

QUESTION 1

A girl throws a stone vertically into the air from the top of a cliff. The stone strikes the ground below after 3 s. The velocity vs. time graph below shows the motion of the stone. Ignore the effect of air resistance.



1.1 How long does the stone take to fall from the height of the cliff to the ground below? (2)

1.2 What is the maximum height that the stone reaches above the ground? (4)

1.3 Calculate the gradient of the graph (2)

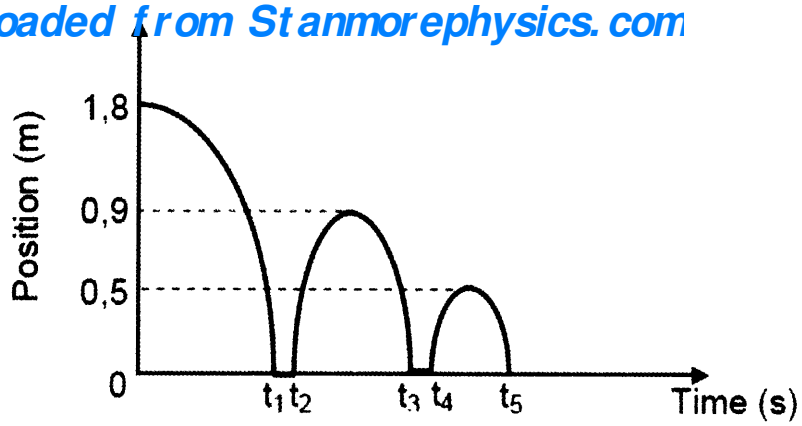
1.4 What physical quantity is represented by gradient? (1)

1.5 Draw a graph of position versus time. Use upwards as negative. (6)

[15]

QUESTION 2

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.



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

2.2 Calculate the magnitude of the time t_1 indicated on the graph. (5)

2.3 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.

2.4 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 $m \cdot s^{-1}$. (4)

2.5 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. (7)

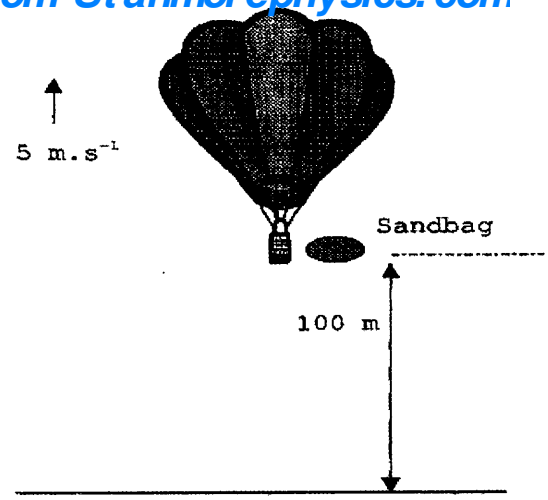
Clearly show the following on your graph:

- 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

[19]

QUESTION 3

3.1 A hot-air balloon is rising upwards at a constant velocity of 5 $m \cdot s^{-1}$. When the balloon is 100 m above the ground, a sandbag is thrown upward from it at 15$m.s^{-1}$. Ignore air resistance.



What is the acceleration of:

3.1.1 The hot-air balloon while the sandbag is in it? (1)

3.1.2 The sandbag the moment it is thrown from the hot-air balloon? (2)

3.2 Determine the maximum height P, *above the ground*, reached by the sandbag after it is thrown from the hot-air balloon. (3)

3.3 Calculate the time taken for the sandbag to reach this maximum height after it has been released. (3)

3.4 Calculate the total time taken for the sandbag to reach the ground after it has been released. (4)

3.5 Will the velocity of the hot-air balloon *INCREASE, DECREASE or REMAIN THE SAME* (4)

3.6 Draw the position time graph for the motion of the sandbag from the moment it was thrown Was got to the ground. Take height it was thrown as reference.

Show the following on the graph:

- Time taken to reach maximum height
- Time taken to return to the ground
- Maximum height reached (5)

[24]

QUESTION 4

Ball B is projected vertically upwards at a velocity of 30 $m.s^{-1}$ from the ground. Ignore the effects of air friction. Use the ground as ZERO POSITION.

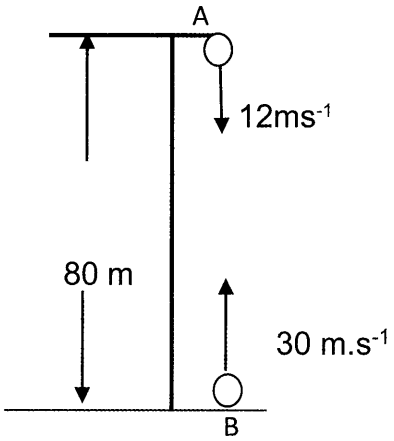
4.1 Calculate the time taken by the ball B to return to the ground. (5)

4.2 Sketch a velocity-time graph for ball B.

Show the following on the graph:

- Initial velocity of ball B.
- Time taken to reach the highest point of the motion.
- Time taken to return to the ground.

One second after ball B is projected upwards, a second ball, A, is thrown vertically downwards at a velocity of 12m·s^{-1} from a balcony 80m above the ground. Refer to the diagram below.

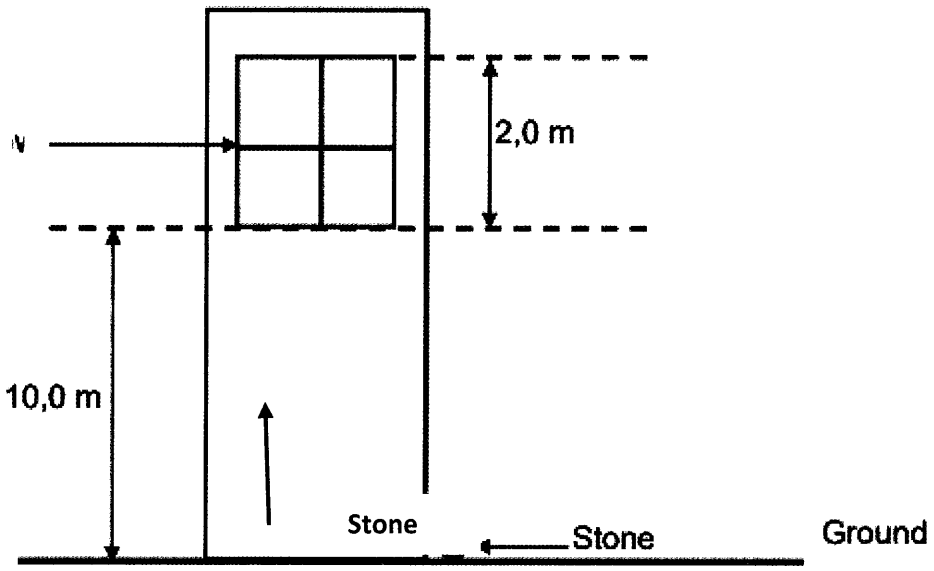


4.3 Calculate how high above the ground ball B will be the instant the two balls pass each other (6)

[11]

QUESTION 5

A stone is thrown vertically from the ground. It passes a 2,0 m high window whose sill is 10,0 m above the ground. The stone takes 0,15 s to travel the 2,0 m height of the window. Diagram is not drawn to scale



Neglect the effects of air resistance (i.e. the stone moves under the influence of gravitational force only).

5.1 Write down the term which describes the bracketed statement. (1)

5.2 USE EQUATIONS OF MOTION to calculate the:

5.2.1 The speed with which of the stone is thrown (5)

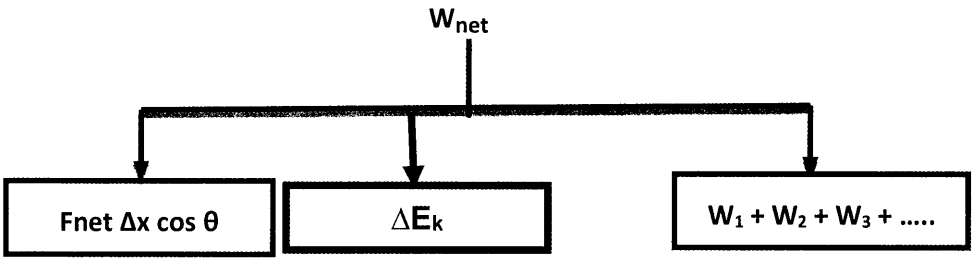
5.2.2 Maximum height above the ground that the stone reaches (4)

5.3 Sketch a velocity versus time graph to illustrate the motion of the stone from the moment it leaves the ground until it reaches its maximum height. (Take upwards as the positive direction). Clearly show the value of the initial velocity on the graph. (3)

5.4 Write down the magnitude and direction of the acceleration of the stone at the maximum height. (2)

[15]

STRATEGY FOR SOVING PROBLEMS USING THE WORK-ENERGY THEOREM



1. Draw a force or free body diagram showing all forces acting on the object.
2. Write down the equation: $W_{net} = \Delta E_k$
3. If the equation in 2 cannot solve the problem, write the following:
   $F_{net}\,\Delta x\cos\theta = \Delta E_k$
4. If the equation in 3 cannot solve the problem, write the following:

   $W_1 + W_2 + \ldots = \Delta E_k$

To use equations in 3 or 4 you will need the following information:

5. Find the resultant force (Fnet) acting on the object. Use a free body diagram to help you. OR identify the individual forces for which F_{net} is the SUM.
6. Find the angle θ between F_{net} (OR each force acting on the object) and Δx. It can ONLY be 0^0 OR 180^0

Note: When …

θ = 0^0: F and Δx have the same direction. F does positive work

θ is between 0^0 and 90^0, F does positive work

θ = 90^0 or 270^0: F is perpendicular to Δx. F does no work on the object.

θ is between 90^0 and 270^0, F does negative work.

θ = 180^0: F and Δx have opposite directions. F does negative work

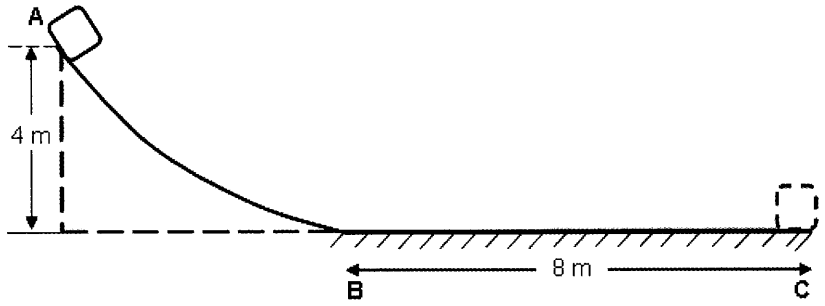
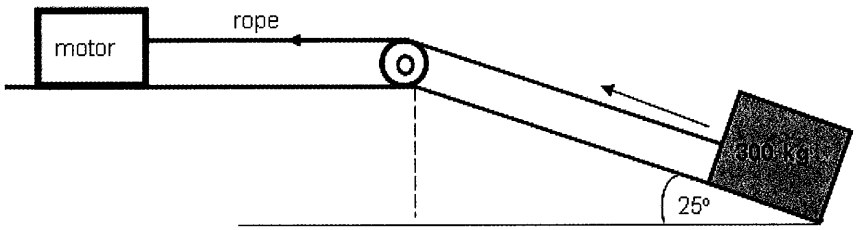
7. If an object moves at a **constant velocity**,
   Wnet = 0, $\Delta E_k = 0$, Fnet = 0, a = 0

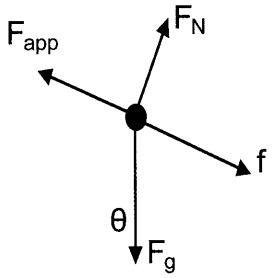
NB. Find the Sum of All the Work Done on the object and equate them to zero and then find the unknown. Always check your answer for correctness.

8. If you are not restricted to use the Work-Energy Theorem, then in addition to the above formulae, apply the relevant formula from the list below to solve the problem:

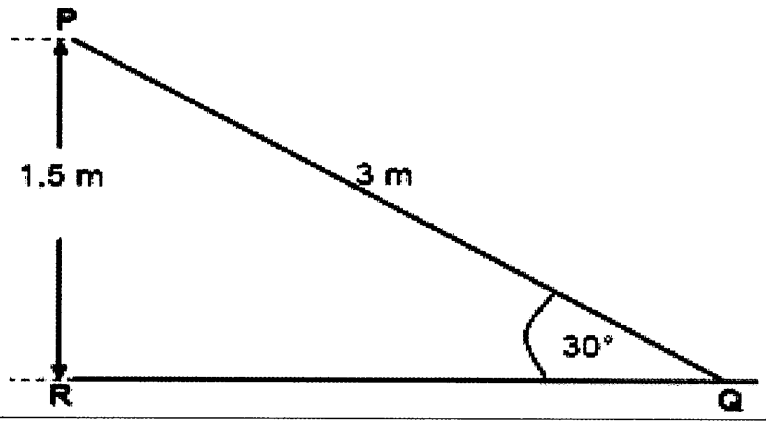
- $v_f^2 = v_i^2 + 2a\Delta x$ (When acceleration is uniform)
- $0 = \Delta U + \Delta K$ (When mechanical energy is conserved)
- $(U + K)_{top} = (U + K)_{bottom}$ (When mechanical energy is conserved)

- $W_{nc} = \Delta U + \Delta K$ (when mechanical energy is not conserved i.e. when non-conservative forces act on the object)

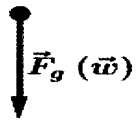
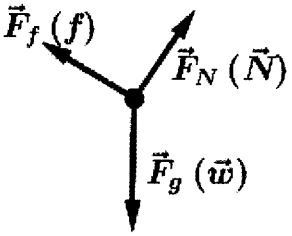
WORKED EXAMPLES		
EXAMPLE 1		
1.1	The diagram below shows a track, ABC. The curved section, AB, is frictionless. The rough horizontal section, BC, is 8 m long.  An object of mass 10 kg is released from point A which is 4 m above the ground. It slides down the track and comes to rest at point C.	
	1.1.1 State the principle of conservation of mechanical energy in words.	(2)
	1.1.2 Is mechanical energy conserved as the object slides from A to C? Write only YES or NO.	(1)
	1.1.3 Using ENERGY PRINCIPLES only, calculate the magnitude of the frictional force exerted on the object as it moves along BC.	(6)
1.2	A motor pulls a crate of mass 300 kg with a constant force by means of a light inextensible rope running over a light frictionless pulley as shown below. The coefficient of kinetic friction between the crate and the surface of the inclined plane is 0,19.	
	 	
	1.2.1 Calculate the magnitude of the frictional force acting between the crate and the surface of the inclined plane.	(3)
	The crate moves up the incline at a constant speed of 0,5 $m \cdot s^{-1}$.	
	1.2.2 Calculate the average power delivered by the motor while pulling the crate up the incline.	(6)
		[18]

	SOLUTION	
1.1.1	In an isolated/closed system, the total mechanical energy is conserved	(2)
1.1.2	No	(1)
1.1.3	$(E_p + E_k)_A = (E_p + E_k)_B$ $(mgh + ½ mv^2)_A = (mgh + ½ mv^2)_B$ $(10)(9,8)(4) + 0 = 0 + ½ (10) v_f^2$ $v_f = 8,85 \text{ m·s}^{-1}$ $W_{net} = \Delta K$ $f\Delta x \cos\theta = \Delta K$ $f(8)\cos 180^o = ½ (10)(0 - 8,85^2)$ $f = 48,95 \text{ N}$	(6)
1.2.1	$f_k = \mu_k N$ $= \mu_k mg\cos\theta$ $= (0,19)(300)(9,8)\cos 25^o$ $= 506,26 \text{ N}$	(3)
1.2.2	 $F_{net} = 0$ $F_{app} + (-F_g \sin\theta) + (-f) = 0$ ✓ $F_{app} - (300)(9,8)\sin 25^o$ ✓ $- 506,26$ ✓ $= 0$ $F_{app} = 1\,748,76 \text{ N}$ $P_{ave} = Fv_{ave}$ ✓ $= 1748,76 \times 0,5$ ✓ $= 874,38 \text{ W}$ ✓	(6)
		[18]

EXAMPLE 2		
	PQ is a slide at a playground. The slide is 3 m long and 1,5 m high. A boy of mass 40 kg and a girl of mass 22 kg stand at the top of the slide at P. The girl accelerates uniformly from rest down the slide. She experiences a constant frictional force of 1,9 N. The boy falls vertically down from the top of the slide through the height PR of 1,5 m. Ignore the effects of air friction.	

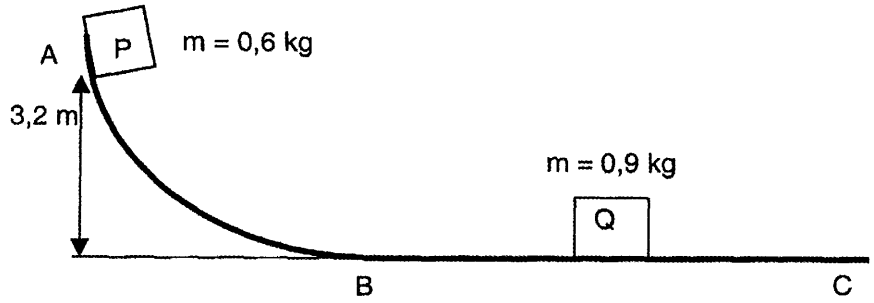
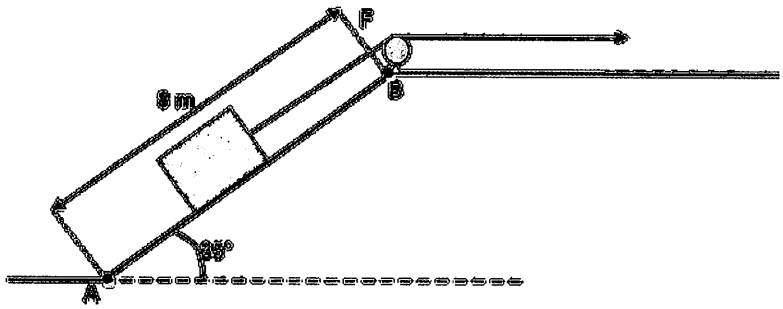


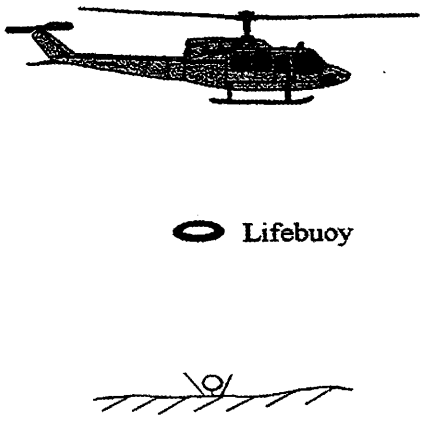
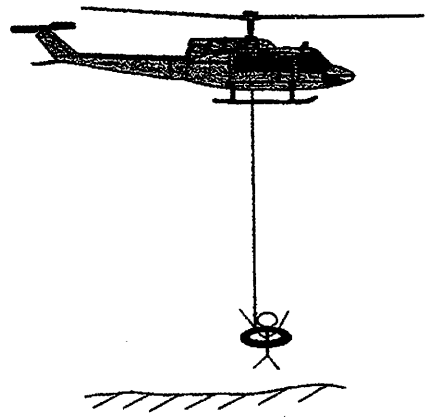
2.1	Write down the principle of conservation of mechanical energy in words.	(2)
2.2	Draw a labelled free-body diagram to show ALL the forces acting on the …	
	a) Boy while falling vertically downwards	(1)
	b) Girl as she slides down the slide	(3)
2.3	Use the principle of CONSERVATION OF MECHANICAL ENERGY to calculate the speed of the boy when he reaches the ground at R.	(2)
2.4	Use the WORK-ENERGY THEOREM to calculate the speed of the girl when she reaches the end of the slide at Q.	
2.5	How would the velocity of the girl at Q compare to that of the boy at R if the slide exerts no frictional force on the girl? Write down only GREATER THAN, LESS THAN or EQUAL TO.	

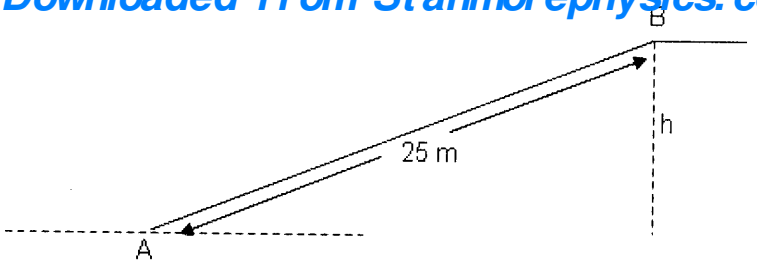
	SOLUTIONS	
2.1	The total mechanical energy in an isolated system remains the same	(2)
2.2	a) 	(1)
	b) 	(3)
2.3	$(Ek + Ep)_P = (Ek + Ep)_R$ $0 + (40)(9,8)(1,5) = (40)v^2 + 0$ $v = 5,422 \text{ m s}^{-1}$	(4)
2.4	There are two forces acting on the girl – gravity and friction	

	Wnet = ΔEk $F_{g\|\|}.\Delta x \cos(\theta) + F_f.\Delta x \cos(\theta) \times \cos(\theta) = \frac{1}{2} m(v_f^2 - v_i^2)$ $(22)(9,8)\sin(30^0)(3)\cos 0^0 + (1,9)(3)\cos(180^0) = \frac{1}{2}(22)(v_f^2 - 0)$ $v_f = 5,374 \text{ m s}^{-1}$	
2.5	With no friction acting, the girl would have the same final velocity as the boy	

EXAMPLE 3		
	During a fire extinguishing operation, a helicopter remains stationary (hovers) above a dam while filling a bucket with water. The bucket, of mass 80 kg, is filled with 1 600 kg of water. It is lifted vertically upwards through a height of 20 m by a cable at a CONSTANT SPEED of 2 $m \cdot s^{-1}$. The tension in the cable is 17 000 N. Assume there is no sideways motion during the lift. Air friction is NOT ignored.	
3.1	Draw a labelled free body diagram showing ALL the forces acting on the bucket of water, while being lifted upwards.	(3)
3.2	Use the WORK ENERGY THEOREM to calculate the work done by air friction on the bucket of water after moving through the height of 20 m.	(5)
		[8]
	SOLUTION	
3.1		(3)
3.2	Wnet = Δ Ek $\Delta W_F + \Delta W_{Fg} + \Delta W_f = \Delta E_k$ $17000.\ 20.\ \text{Cos}\ (0^0) + (1600 + 80)\ (9,\ 8)\ 20.\ \cos(180\ ) + W_f = 0$ $W_f = -\ 10720$ J	(5)
		[8]

	ACTIVITY 2	
	QUESTION 1	
	The track consists of a curved **SECTION AB** and a horizontal **SECTION BC**. The track is frictionless. Body **Q**, mass 0,9 kg, is stationary on **SECTION BC**. A second body **P**, mass 0,6 kg, is placed at point **A**, which is 3,2 m vertically above the horizontal section. It is released and slides down **SECTION AB**.	
		
1.1	State the principle of conservation of mechanical energy in words.	(2)
1.2	Use the energy principles to show that **P** moves at a velocity of 7,92 $m.s^{-1}$ when it reaches body **Q**.	(4)
	Body P collides with body Q. Immediately after collision, Body Q moves towards C at a velocity of 4, 4 $m.s^{-1}$.	
1.3	Calculate the velocity of **P** immediately after the collision.	(5)
1.4	Calculate the average force that **Q** exerts on **P** if the two bodies remain in contact for 0, 8 seconds.	(5)
		[16]
	QUESTION 2	
	The diagram below shows a crate of mass 50 kg being pulled up a slope from point **A** to point **B** at CONSTANT VELOCITY. The slope makes an angle of 35^0 with the horizontal. The frictional force that the surface exerts on the crate is 250 N.	
		
2.1	Draw a labelled free body diagram showing all the forces acting on the crate.	(4)
2.2	Calculate the:	
	2.2.1 Force F applied to pull the crate up the slope from point **A** to point **B**.	(4)
	2.2.2 Work done by force **F** upon reaching point **B**.	(3)
	2.2.3 Power due to force **F** if it takes 2 minutes to move the crate from point **A** to point **B**.	(4)
		[15]

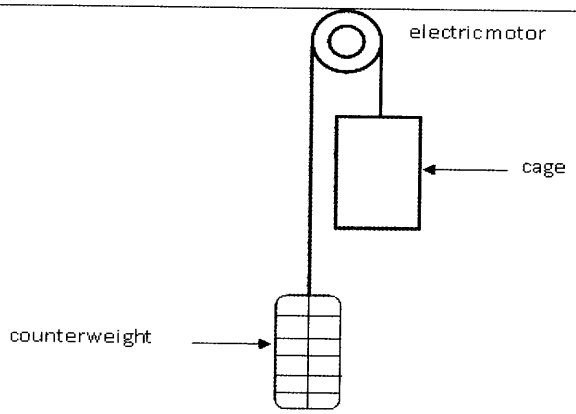
	QUESTION 3	
	A rescue helicopter is stationary (hovering) above the water to rescue a man in difficulties off the Clifton beachfront (**FIGURE 1**). It lowers a a lifebuoy with a mass 2 kg onto the water for the man to cling to it while the crew prepare to bring him aboard the helicopter (**FIGURE 2**). 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	
3.1	Define a *non-conservative force*.	(2)
3.2	Identify TWO *non-conservative forces* acting on the buoy during its downward descent (motion).	(2)
3.3	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)
3.4	Draw a free-body diagram showing ALL the forces acting on the buoy while it is being lowered to the water.	(3)
3.5	Write down the WORK-ENERGY THEOREM in words.	(2)
3.6	Use the work-energy theorem to calculate the acceleration of the buoy as it is lowered to the water.	(6)
		[16]
	QUESTION 4	
	The diagram below shows a truck of mass, 12 000kg free-wheeling,(engine of the truck does no work on the truck) up a straight inclined road of length 25m. The truck experiences a constant frictional force of magnitude 3 400N as it moves up the incline. The truck enters the bottom of the incline, point A, with a speed of 25 $m.s^{-1}$ and reaches the top of the incline, point B, with a speed of 20 $m.s^{-1}$.	



4.1	State the work-energy theorem in words.	(2)
4.2	Draw a labelled force diagram showing all the forces acting on the truck as it moves up the incline.	(3)
4.3	Calculate the net work done on the truck on moving from the bottom of the incline to the top of the incline.	(4)
4.4	What is meant by a non-conservative force?	(2)
4.5	Show that the work done by the non-conservative force is – 85 000 J.	(3)
4.6	Hence calculate the height, h, reached by the truck at the top of the incline.	(5)
		[19]

QUESTION 5

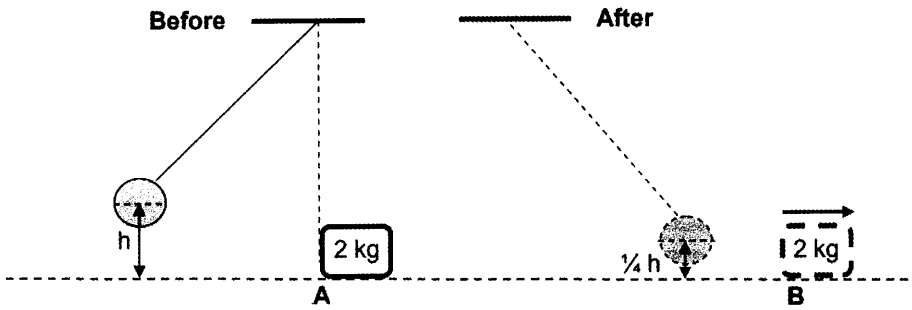
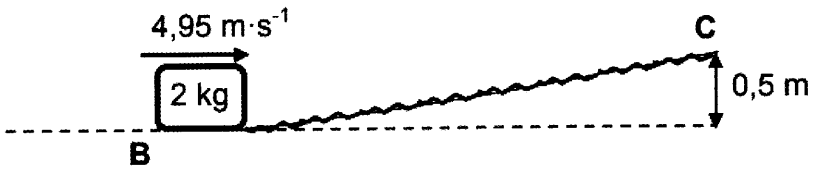
A lift arrangement comprises an electric motor, a cage and its counterweight. The counterweight moves vertically downwards as the cage moves upwards. The cage and counterweight move at the same constant speed. Refer to the diagram below



The cage, carrying passengers, moves vertically upwards at a constant speed, covering 55 m in 3 minutes. The counterweight has a mass of 950 kg. The total mass of the cage and passengers is 1 200 kg. The electric motor provides the power needed to operate the lift system. Ignore the effects of friction.

5.1	Define the term power in words.	(2)
5.2	Calculate the work done by the:	
	5.2.1 Gravitational force on the cage	(3)
	5.2.2 Counterweight on the cage	(2)

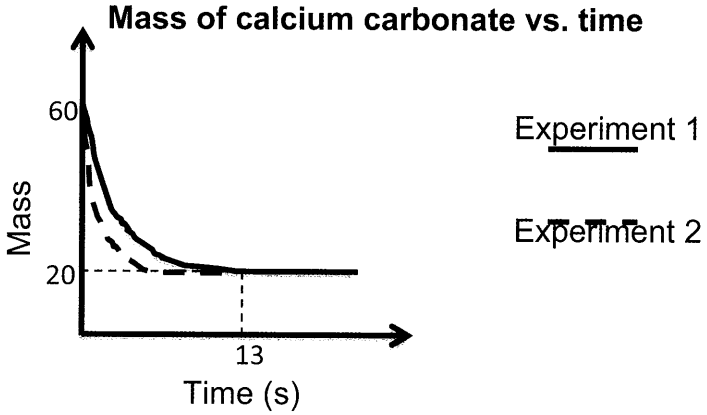
5.3	Calculate the average power required by the motor to operate the lift arrangement in 3 minutes. Assume that there are no energy losses due to heat and sound	(6)
		[13]

	Question 6	
	A pendulum with a bob of mass 5 kg is held stationary at a height h metres above the ground. When released, it collides with a block of mass 2 kg which is stationary at point A. The bob swings past A and comes to rest momentarily at a position ¼ h above the ground. The diagrams below are NOT drawn to scale.	
		
	Immediately after the collision the 2 kg block begins to move from A to B at a constant speed of 4,95 $m \cdot s^{-1}$ Ignore frictional effects and assume that no loss of mechanical energy occurs during the collision.	
6.1	Calculate the:	
	6.1.1 Kinetic energy of the block immediately after the collision	(3)
	6.1.2 Height, h	(4)
	The block moves from point B at a velocity of 4, 95 $m \cdot s^{-1}$ up a rough inclined plane to point C. The speed of the block at point C is 2 $m \cdot s^{-1}$. Point C is 0,5 m above the horizontal, as shown in the diagram below. During its motion from B to C a uniform frictional force acts on the block.	
		
6.2	State the work-energy theorem in words.	(2)
6.3	Use energy principles to calculate the work done by the frictional force when the 2 kg block moves from point B to point C.	(4)
		[13]

WORKED EXAMPLES

Example 1:

The reaction of calcium carbonate ($CaCO_3$) and hydrochloric acid is used to investigate the factors that affect the rate of reaction. In one experiment, powdered calcium carbonate is used and in another, lumps of calcium carbonate are used. The graph below shows the change in the mass of calcium carbonate with time.



1.1. Which experiment (1 or 2) used powdered calcium carbonate? Explain by referring to the collision theory.

1.2. Calculate the rate of reaction for experiment 1 during the first 3 seconds.

Solutions

1.1. **Experiment 2.**

The graph show experiment 2 reached completion faster than experiment 1, meaning experiment 2 has a higher rate.

- An increase in surface area increases in the number of particles exposed at the surface for collisions to occur
- More effective collisions of particles with enough energy and correct orientation per unit time.
- The reaction rate increases.

1.2. Rate = $\frac{-\Delta mass\ of\ reactants}{\Delta time}$

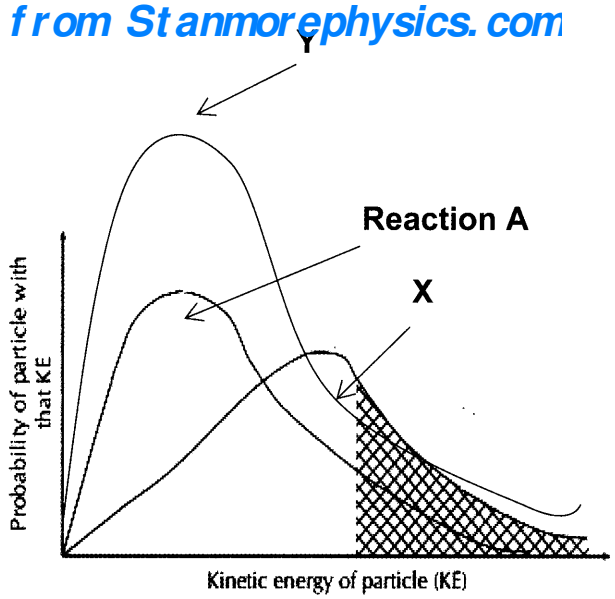
Rate = $\frac{-(20-60)}{13-0}$

Rate = $3.07 g.s^{-1}$

Example 2

The Maxwell-Boltzmann curve below was obtained for three reactions where:

- Reaction A: 0.2 $mol.dm^{-3}$ of sulphuric acid was used at 30^0C.
- Reaction B: 0.2 $mol.dm^{-3}$ of sulphuric acid was used at 40^0C
- Reaction C: 0.35 $mol.dm^{-3}$ of sulphuric acid was used at 30^0C



2.1. Which graph (**X** or **Y**) represents reaction B? Explain your answer.

Solution:

2.1. Reaction X.

- When temperature is increased from 30^0C to 40^0C, the particles' average kinetic energy increases.
- This means the new curve will shift to the right of the energy scale

Example 3

Methanol and Hydrochloric acid react according to the following balanced equation:

$$CH_3OH_{(aq)} + HCl_{(aq)} \rightarrow CH_3Cl_{(aq)} + H_2O_{(l)}$$

3.1. State two factors that increase the rate of reaction for THIS reaction.

3.2. The rate of the reaction between methanol and hydrochloric acid is investigated. The concentration of HCℓ(aq) was measured at different time intervals. The following results were obtained:

TIME (MINUTES)	HCℓ CONCENTRATION (mol·dm^{-3})
0	1,90
15	1,45
55	1,10
100	0,85
215	0,60

Calculate the mass of $CH_3Cl_{(aq)}$ produced in at the end of 215 minutes if the volume of the contents at this stage is 60cm^3.

Solutions:

3.1. Temperature and concentration.

3.2.
- Concentration of HCl reacted = 1,90 – 0,60 = 1,30mol.dm^{-3}
- Moles HCl reacted:

$$c = \frac{n}{V}$$

$$1{,}30 = \frac{n}{0{,}06}$$

$$n = 0{,}078\text{mol}$$

- Moles of CH_3Cl produced = 0,078mol (ratio 1:1)
- Mass of CH_3Cl produced:

$$n = \frac{m}{M}$$

$$0{,}078 = \frac{m}{50{,}5}$$

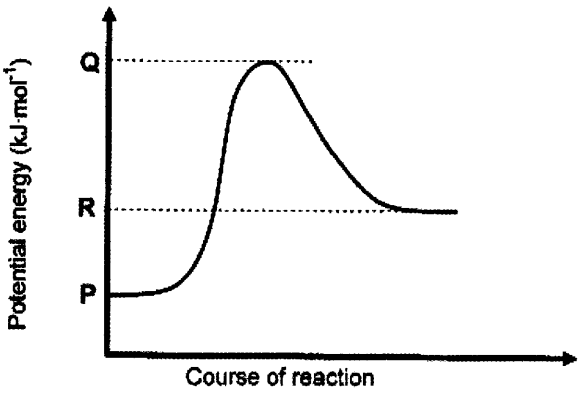
$$m = 3{,}94\text{ g}$$

REACTION RATES MULTIPLE CHOICE QUESTIONS

1. According to the Collision theory, reaction rate increases when decreases.

A. Temperature
B. Concentration
C. Activation Energy
D. Kinetic molecular energy (2)

2. Consider the potential energy graph for the reaction shown below.



The activation energy for the forward reaction in terms of **P, Q** and **R** is:

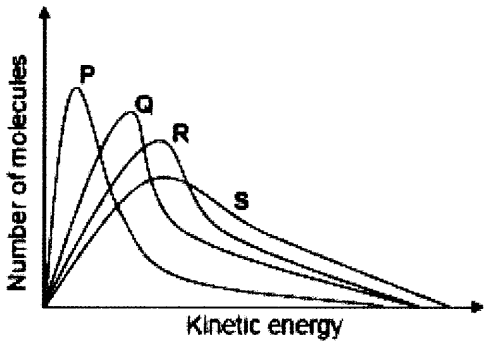
A. Q
B. R – P
C. Q – R
D. Q – P (2)

3. The activation energy can be best described as the minimum energy required to…

   A. Cause effective collisions.
   B. Make reactant molecules collide
   C. Change the orientation of the molecules
   D. Increase the kinetic energy of reactant molecules

   (2)

4. The graphs below represent the molecular distribution for a reaction at different temperatures.



   Which ONE of the graphs represents the reaction at the highest temperature?

   A. P
   B. Q
   C. R
   D. S

   (2)

5. The activation energy for a certain reaction is 50 kJ.mol^{-1}. Energy is absorbed when this reaction takes place. Which ONE of the following is CORRECT for the REVERSE reaction?

	ACTIVATION ENERGY (E_A)	HEAT OF REACTION (ΔH)
A	$E_A > 50$ kJ·mol^{-1}	$\Delta H > 0$
B	$E_A > 50$ kJ·mol^{-1}	$\Delta H < 0$
C	$E_A < 50$ kJ·mol^{-1}	$\Delta H < 0$
D	$E_A < 50$ kJ·mol^{-1}	$\Delta H > 0$

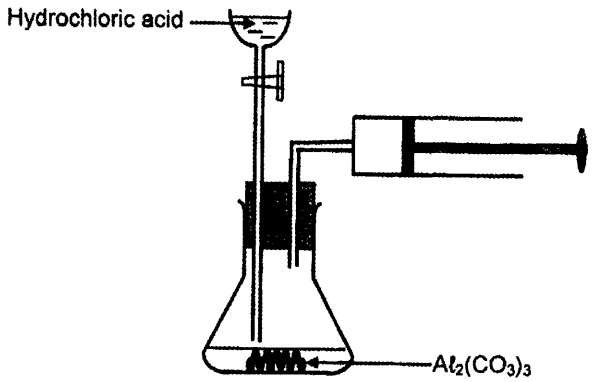
   (2)

QUESTION 1

Two experiments, **I** and **II**, are conducted to investigate one of the factors that affects the rate of reaction of **aluminium carbonate**, $Al_2(CO_3)_3$, with **EXCESS hydrochloric acid**, HCl. The balanced equation for the reaction is:

$$Al_2(CO_3)_{3(S)} + 6HCl_{(aq)} \rightarrow 2AlCl_{3(aq)} + 3H_2O_{(l)} + 3CO_{2(g)}$$

The apparatus used is shown below.



The reaction conditions used for each experiment are as follows:

EXPERIMENT I:

100 cm^3 of 1, 5 $mol.dm^{-3}$ $HC_{(aq)}$ reacts with 0, 016 mol $Al_2(CO_3)_3$ granules at 25^0C.

EXPERIMENT II:

50 cm^3 of 2 $mol.dm^{-3}$ $HC_{(aq)}$ reacts with 0, 016 mol $Al_2(CO_3)_3$ granules at 25^0C.

1.1 Define concentration. (2)

1.2 Using the experimental setup above, state the measurements that must be made to determine the rate of this reaction. (2)

1.3 Use the collision theory to explain how the average reaction rate in **EXPERIMENT I** differs from the average reaction rate in **EXPERIMENT II.** (3)

1.4 The average rate of the reaction in **EXPERIMENT II** during the first 2, 5 minutes is 4, 4 x 10^{-3} $mol.min^{-1}$. Calculate the number of moles of $Al_2(CO_3)_3$ that remains in the flask after 2, 5 minutes. (3)

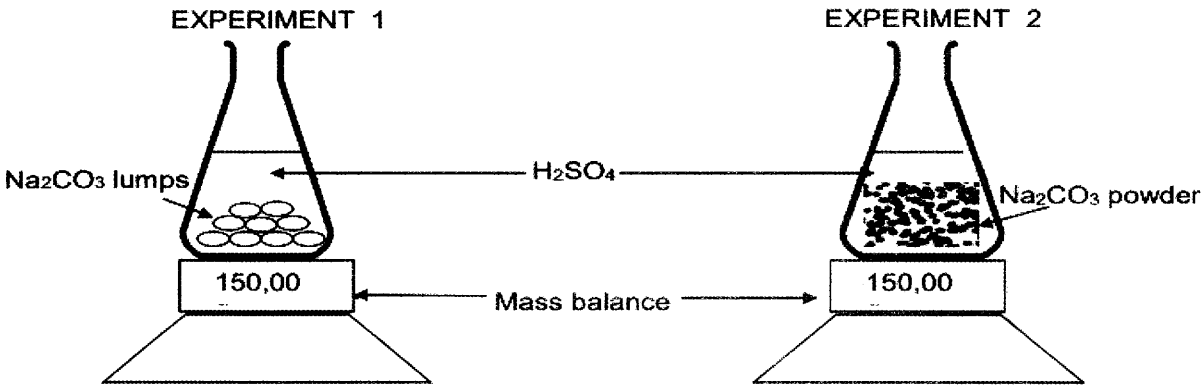
1.5 Calculate the maximum volume of $CO_{2(g)}$ that can be prepared at 25^0C in **EXPERIMENT I.** Take molar gas volume at 25^0C as 24 000 $cm^3.mol^{-1}$. (3)

QUESTION 2

The reaction between **sodium carbonate (Na_2CO_3)** and **sulphuric acid (H_2SO_4)** was used to investigate one of the factors affecting reaction rate. The balanced equation is given below.

$$Na_2CO_{3(s)} + H_2SO_{4(aq)} \rightarrow Na_2SO_{4(aq)} + CO_{2(g)} + H_2O_{(l)}$$

Two experiments are conducted as illustrated below.



In both experiments the same amount of sodium carbonate is added to excess of sulphuric acid solution in a conical flask placed on a mass balance. The mass of the flask together with its contents is recorded every 15 s.

2.1 Define the rate of reaction (2)

2.2 For this investigation described above, write down:

2.2.1. The dependent variable (1)

2.2.2. The independent variable (1)

2.2.3. One controlled variable (1)

The results obtained in EXPERIMENT 1 are shown in the experiment below.

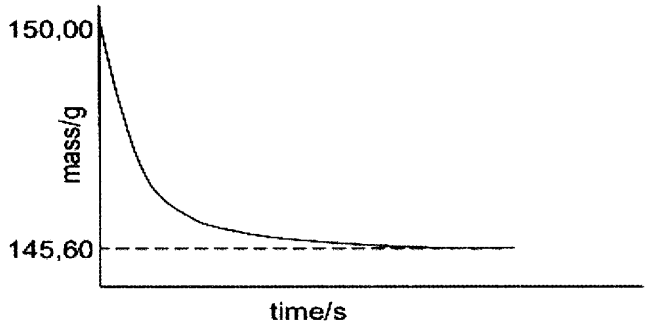
Time(s)	0	15	30	45	60	75	90	105	120
Mass(g)	150,0	147,5	146,6	146,0	145,8	145,7	145,6	145,6	145,6

2.3 Write down the NAME or FORMULA of the substance responsible for the decrease in mass. (1)

2.4 How long does it take for the reaction in EXPERIMENT 1 to be completed? (1)

2.5 How will the rate of the reaction in EXPERIMENT 2 compare to that in EXPERIMENT 1? Write down GRAETER THAN, SMALLER THAN or EQUAL TO. Briefly explain your answer by referring to the collision theory. (3)

2.6 The sketch graph below (**not drawn to scale**) represents the results obtained for EXPERIMENT 1.



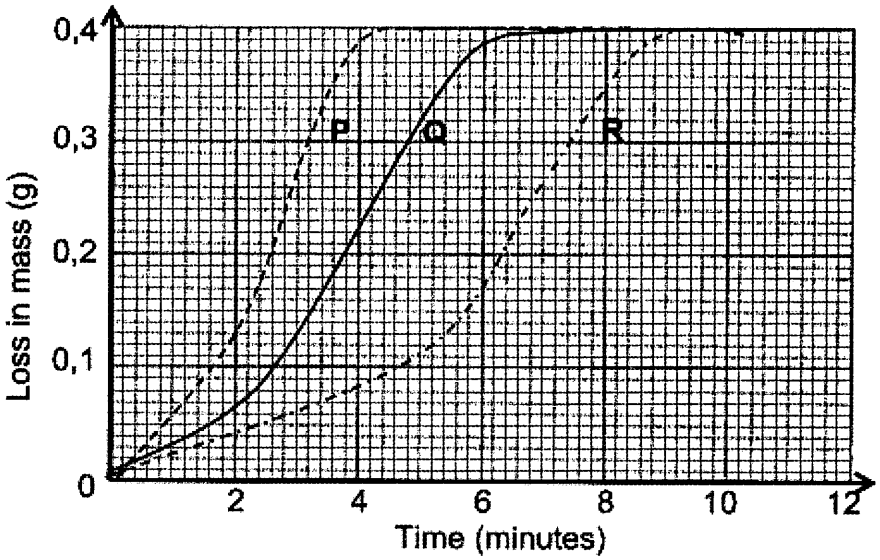
2.6.1. Use the information in the graph to determine the mass of sodium carbonate that has reacted in EXPERIMENT 1. (5)

2.6.2. Redraw the above sketch in your ANSWER BOOK. On the same set of axes, sketch the curve obtained for EXPERIMENT 2.Label your graph as **Exp 2.** (2)

[17]

QUESTION 3

Pieces of marble ($CaCO_3$) with a mass of 1,05 g are placed in a flask are placed in a flask and covered with 10 cm^3 of a 2 $mol.dm^{-3}$ hydrochloric acid solution at 20^0C. The flask is weighed every 2 minutes to determine the loss in the mass due to the production of carbon dioxide. Line graph Q is plotted from these results.



3.1 Define the term *activation energy.* (2)

3.2 Write down the balanced equation for the reaction between the marble and hydrochloric acid. (3)

Use **graph Q** to answer the following questions.

3.3 What mass of carbon dioxide gas is formed after 8 minutes? (1)

3.4 During which ONE of the following time intervals is the reaction rate the highest? Choose from 0-2 minutes, 2-4 minutes, 6-8 minutes, 8-10 minutes. Briefly explain your choice. (2)

3.5 After how many minutes is the loss in mass halved? (1)

3.6 Predict what will happen to the rate of reaction in each of the following cases:

(Choose from INCREASES, DECREASES or REMAINS THE SAME).

3.6.1. The marble pieces are replaced by marble powder. (1)

3.6.2. 20 cm^3 of a 2 $mol.dm^{-3}$ hydrochloric acid solution is used. (1)

The experiment is now repeated with a 1, 5 $mol.dm^{-3}$ hydrochloric acid solution. The reaction runs to completion.

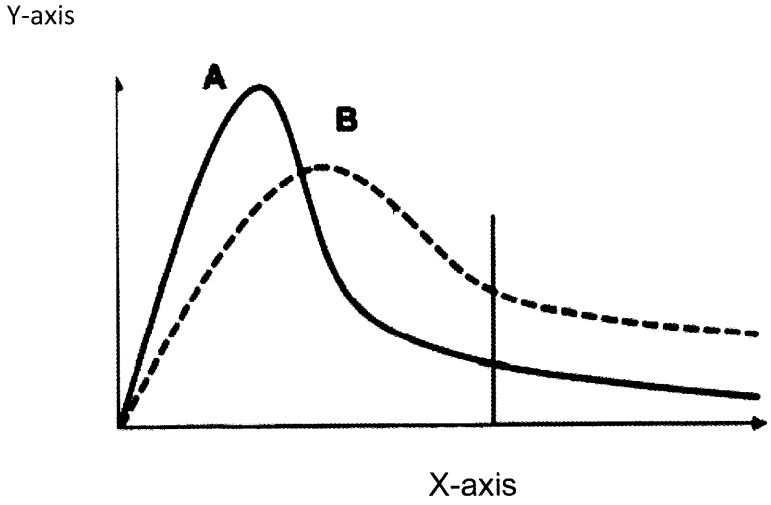
3.7 Which graph**, P** or **R**, is obtained from this experiment? (1)

3.8 Using collision theory explain the answer in 3.7. (4)

[16]

QUESTION 4

The following diagram shows a Maxwell-Boltzmann distribution curve of a gas sample at temperatures A and B.



4.1 Provide labels for the x and y axes of the graph, respectively. (2)

4.2 Which graph (A or B) represents the gas at a higher temperature? (1)

4.3 Using collision theory explain your answer in QUESTION 4.2 (3)

4.4 What would happen to the area under the graph A when a catalyst is added to the reaction mixture? Give a reason. (2)

4.5 Give a reason why the curve goes through the origin? (1)

[7]

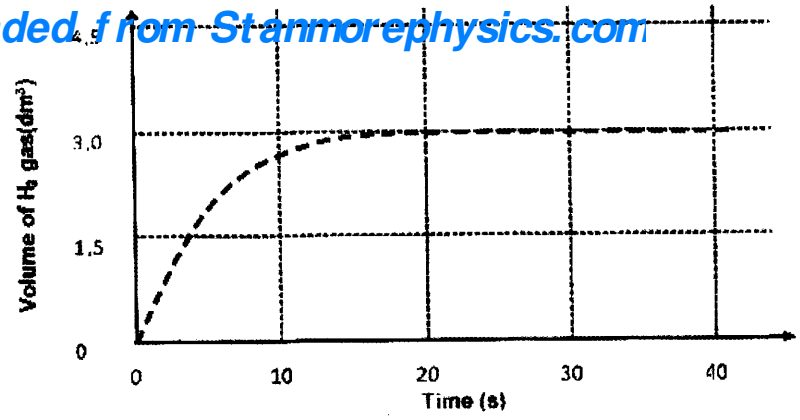
QUESTION 5

A group of learners perform a series of experiments to test the effect of certain factors on reaction rate when magnesium metal is added to EXCESS hydrochloric acid.

$$Mg_{(s)} + 2HCl_{(aq)} \rightarrow 2MgCl_{2(aq)} + H_{2(g)} \qquad \Delta H<0$$

EXPERIMENT	STATE OF MAGNESIUM	MASS OF MAGNESIUM(g)	TEMPERATURE (^{0}C)
1	ribbon	6,0	25
2	ribbon	6,0	15
3	fine powder	4,5	25

The results of **EXPERIMENT 1** were collected and plotted on the graph below:



5.1 Define the term reaction rate. (2)

5.2 What volume of hydrogen gas was collected in EXPERIMENT 1 after 40s? (1)

5.3 Calculate the average rate of reaction (in $dm^3.s^{-1}$) for experiment 1 over the first 20s. (3)

5.4 How will the rate of reaction be affected if a higher concentration of $HCl_{(aq)}$ is used. Assume that the temperature remains constant. (Choose from INCREASES, DECREASES or REMAIN THE SAME). Explain the answer in terms of the Collision Theory. (4)

5.5 Redraw the above graph of EXPERIMENT 1 in your answer book and axes sketch the graphs that will be obtained for EXPERIMENTS 2 and 3. Clearly label your graphs **for each EXPERIMENT as Exp 2 and Exp 3.**

5.5.1 Experiment 2 (2)

5.5.2 Experiment 3 (3)

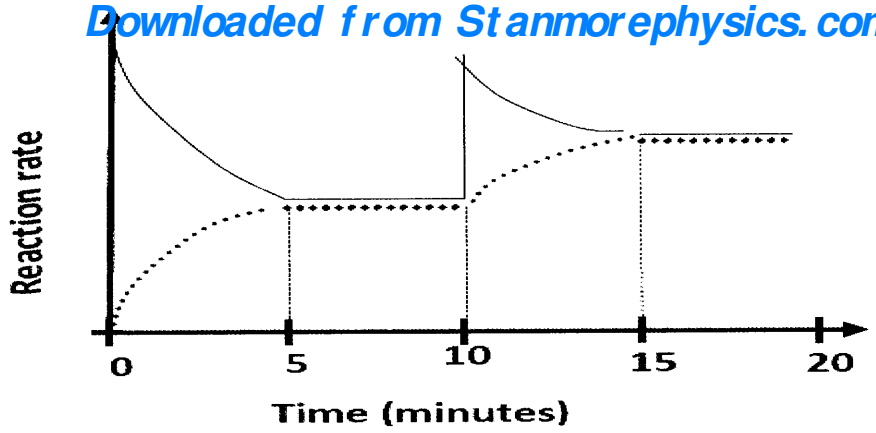
[14]

CHEMICAL EQUILIBRIUM
WORKED EXAMPLES
QUESTION 1

A quantity of SO_3 is sealed in a container at 400^0C and the following reversible reaction occurs :

$2SO_3(g) \rightleftharpoons SO_2(g) + O_2(g)$ $\Delta H > 0$

The accompanying graph shows how the rate of the reaction changes over time.



1.1 State, giving a reason, whether the forward reaction is homogeneous or heterogeneous. (2)
1.2 Write down the equation for the reaction represented by the solid line on the graph. (1)
1.3 How long does it take, from the start of the reaction, for first equilibrium to be established? (1)
1.4 What could possibly have happened to the system during the tenth minute? (2)
1.5 Why is the horizontal part of the graph at a higher level between the fifteenth and twentieth minute compared to between the fifth and tenth minute (2)
1.6 Will an increase in pressure influence the amount of $SO_2(g)$ present at equilibrium? (1)

SOLUTIONS

1.1 reaction is homogeneous because all the reactants are in the same phase(gas) (2)
1.2 $2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$ (1)
1.3 5 minutes (forward reaction=reverse) (1)
1.4 The temperature is increased. Because ΔH > (endothermic) the rate of forward reaction will increase more than the rate of reverse reaction (2)
1.5 At a higher temperature, more molecules have more energy than the activation energy and both reactions will be faster than before the temperature was increased (2)
1.6 Decrease(According to Le Chatelier's Principle increasing pressure favours the less particles side which is reverse reaction will be favored (1)

Increase in temperature

- ► Endothermic reaction is favoured
- ► Forward reaction is endothermic
- ► [Products] > [Reactants]
- ► Kc value Increases

Decrease in temperature

- ► Exothermic reaction is favoured
- ► Forward reaction is exothermic
- ► [Products] < [Reactants]
- ► Kc value decreases

WORKED EXAMPLES

QUESTION 1

A 2 g sample of ammonium hydrogen sulphide is sealed in a 2 dm^3 flask at a temperature of 375K. it dissociates as follows:

$$NH_4HS(s) \rightleftharpoons H_2S(g) + NH_3(g)$$

At equilibrium it is found that the concentration of ammonia is equal to $1,82 \times 10^{-3}$ $mol.dm^{-3}$

1.1 Calculate the equilibrium constant for this reaction. (3)

1.2 It is found that by repeating the experiment at a higher temperature the equilibrium constant increases. Is the forward reaction exothermic or endothermic? (1)

1.3 Explain your answer to 1.2 (2)

SOLUTIONS

1.1 Ratio: $H_2S : NH_3$

1:1

$[H_2S] = 1,82 \times 10^{-3}$

$K_c = [H_2S][NH_3]$ (solids are excluded)

$= (1,82 \times 10^{-3})(1,82 \times 10^{-3})$

$= 3,3 \times 10^{-6}$ (3)

1.2 Endothermic (1)

1.3 To obtain a larger Kc value, more $H_2S(g)$ and $NH_3(g)$ should be produced. According to Le Chatelier's Principle an increase in temperature favors the endothermic reaction. Therefore the forward reaction will be endothermic and $\Delta H > 0$ (2)

WORKED EXAMPLE 2

QUESTION 2

Consider the following hypothetical reaction.

$A(g) + 2\,B(g) \rightleftharpoons C(g) \qquad \Delta H > 0$

Initially 5 mol of A and 10 mol of B are pumped into a 4 dm^3 reaction flask at 650 K. At equilibrium the concentration of C was found to be 1,2 $mol.dm^{-3}$

2.1 Calculate:

The concentration of A at equilibrium. (3)

2.2 The concentration of B at equilibrium. (1)

2.3 The equilibrium constant for this reaction. (3)

SOLUTIONS

2.1

RATIO	1	2	1
INITIAL MOL	5	10	0
CHANGE(mol)	-4,8	-9,6	+4,8 ✓
MOLES AT EQUIL(mol)	0,2	0,4 ✓	4,8
CONCERNTRATION AT EQUILIBRIUM($mol.dm^{-3}$)	0,05	0,1	1,2

$[A]_{Equilibrium} = 0,05\ mol.dm^{-3}$ ✓ (3)

2.2 $[B]_{Equilibrium}$= 0,1 mol.dm-3✓ (1)

2.3 $K_C = \frac{[C]}{[A][B]^2}$

$= \frac{(1,2)}{(0,05)(0,1)^2}$

= 2400

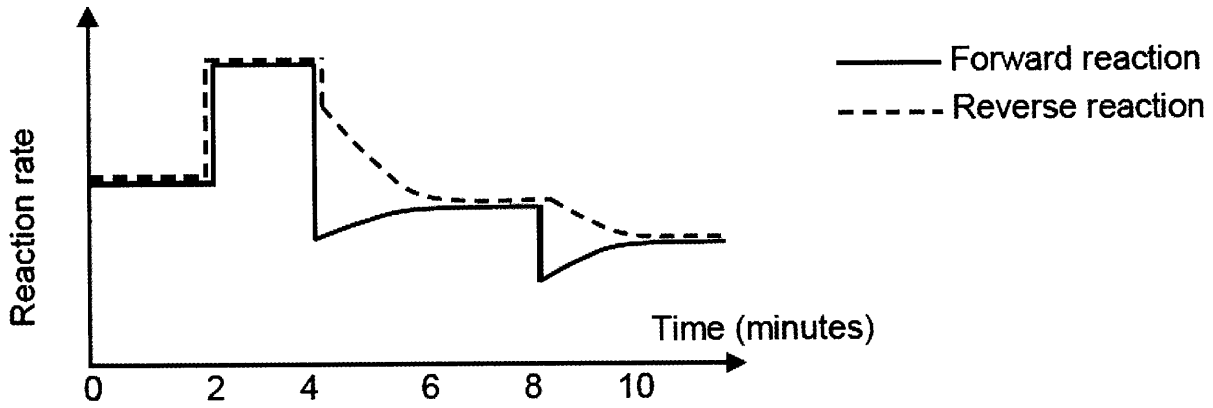
(3)

QUESTION 3

Hydrogen and iodine are sealed in a 2 dm^3 container. The reaction is allowed to reach equilibrium at 700 K according to the following balanced equation: $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

3.1 Give a reason why changes in pressure will have no effect on the equilibrium position. (1)

The reaction rate versus time graph below represents different changes made to the equilibrium mixture.



3.2 What do the parallel lines in the first two minutes indicate? (1)

3.3 State TWO possible changes that could be made to the reaction conditions at t = 2 minutes (2)

3.4 The temperature of the equilibrium mixture was changed at t = 4 minutes.

1.4.1 Is the forward reaction *EXOTHERMIC* or *ENDOTHERMIC*? Fully explain the answer. (3)

1.4.2 How will this change influence the Kc value? Choose from *INCREASES*, *DECREASES* or *REMAINS THE SAME* (1)

3.5 What change was made to the equilibrium mixture at t = 8 minutes? (1)

SOLUTIONS

3.1 Amount / number of moles / volume of (gas) reactants equals amount/number of moles/volume of (gas) products. (1)

3.2 Chemical/dynamic equilibrium (1)

3.3 Addition of a catalyst and increase in pressure (2)

3.4.1 Endothermic (3)

- The rate of the forward reaction decreases more/ The rate of the reverse reaction decreases less.
- A decrease in temperature favours the exothermic reaction

3.4.2 Decreases (1)

3.5 Reactants / H_2 / I_2 removed (1)

ACTIVITIES

QUESTION 1

The rapidly increasing human population is resulting in an ever-increasing demand for food. To meet this demand, farmers apply fertiliser to the same cultivated land EACH YEAR.

Sulphuric acid is an important substance used in the manufacture fertilisers. The equation below represents one of the steps in the industrial preparation of sulphuric acid.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H < 0$$

1.1 Define the term *chemical equilibrium*. (2)

1.2 Is the forward reaction exothermic or endothermic? Give a reason for your answer. (2)

1.3 How will EACH of the following changes affect the number of moles of $SO_3(g)$ at equilibrium?
Choose from INCREASES, DECREASES or REMAINS THE SAME. (2)

1.3.1 The addition of more oxygen. (1)

1.3.2 An increase in temperature
Use Le Chatelier's principle to explain the answer. (4)

The reaction above, reaches equilibrium at a certain temperature in a 2 dm^3 closed container.

On analysis of the equilibrium mixture, it is found that 0,6 mole of $SO_2(g)$, 0,5 mole of $O_2(g)$ and 0,4 mole of $SO_3(g)$ are present in the container.

1.4 List *THREE* changes that can be made to this equilibrium to increase the yield of $SO_3(g)$. (3)

1.5 The temperature is NOW increased and the reaction is allowed to reach equilibrium for the second time at the new temperature.
On analysis of this new equilibrium mixture, it is found that 0,2 mole of $SO_3(g)$ is present in the container.
Calculate the equilibrium constant for this reaction at the new temperature. (8)

[21]

QUESTION 2

Consider the balanced equation below for a hypothetical reaction that takes place in a sealed 2 dm^3 container at 300 K.

$$2P(g) + Q_2(g) \rightleftharpoons 2PQ(g)$$

2.1. State Le Chatelier's principle (2)

2.2 The amount of each substance present in the equilibrium mixture at 300 K is shown in the table below.

	AMOUNT (mol) AT EQUILIBRIUM
P	0.8
Q_2	0.8
PQ	3.2

The temperature of the container is now increased to 350 K.
When a NEW equilibrium is established, it is found that 1,2 mol P(g) is present in the container.

2.2.1 Is the heat of the reaction (ΔH) POSITIVE or NEGATIVE? (1)

2.2.2 Use Le Chatelier's principle to explain the answer to QUESTION 2.2.1. (3)

2.2.3 Calculate the equilibrium constant at 350 K. (8)

2.2.4 How will the equilibrium constant calculated in QUESTION 2.2.3 be affected when the volume of the container is decreased at constant temperature?
Choose from INCREASES, DECREASES or REMAINS THE SAME.
Give a reason for the answer. (2)

2.3 More Q2(g) is now added to the reaction mixture at constant temperature.
How will EACH of the following be affected?
Choose from INCREASES, DECREASES or REMAINS THE SAME.

2.3.1 The yield of PQ(g) (1)

2.3.2 Number of moles of P(g) (1)

[18]

QUESTION 3

3.1 The following reaction reaches equilibrium at a temperature of 327 °C.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2\ NH_3(g)\ \Delta H < 0$$

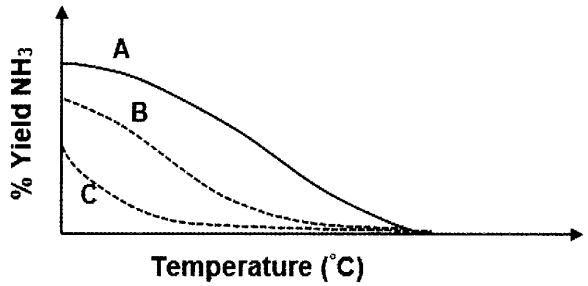
3.1.1 What is the meaning of the double arrow "⇌"? (1)

How does the rate of the forward reaction compare to the rate of the reverse reaction during the following time intervals?
Choose from HIGHER THAN, LOWER THAN or EQUAL TO.

3.1.2 Before equilibrium is reached for the first time (2)

3.1.3 At equilibrium (1)

3.2 The graph below shows how the percentage yield of NH_3 varies with pressure at different temperature values.



Which graph (**A**, **B** or **C**) represents percentage yield values obtained at the HIGHEST pressure?
Explain the answer by referring to Le Chatelier's principle. (4)

3.3 Hydrogen gas, $H_2(g)$, of mass 3,50 g and iodine gas, $I_2(g)$, of mass 635 g were placed in a sealed container of volume 1,50 dm^3 and allowed to react. The reaction reached equilibrium at 300 °C. The balanced equation for the reaction that takes place is given below:
$H_2(g) + I_2(g) \rightleftharpoons 2\,HI(g)$
When equilibrium is reached, 1,45 moles of $I_2(g)$ is present.
Calculate the value of the Equilibrium Constant (Kc) at 300 °C for this reaction. (8)

[16]

QUESTION 4

Carbon dioxide reacts with carbon in a closed system to produce carbon monoxide, CO(g), according to the following balanced equation:

$$CO_2(g) + C(s) \rightleftharpoons 2CO(g) \quad \Delta H > 0$$

4.1 Define a closed system. (2)

4.2 How will the equilibrium constant be affected if more carbon is added at constant temperature?
Choose from INCREASES, DECREASES or REMAINS THE SAME.
Give a reason for the answer. (2)

Initially an unknown amount of carbon dioxide is exposed to hot carbon at 800 °C in a sealed 2 dm^3 container. The equilibrium constant, Kc, for the reaction at this temperature is 14. At equilibrium it is found that 168,00 g carbon monoxide is present.

4.3 How will the equilibrium concentration of the product compare to that of the reactants? Choose from LARGER THAN, SMALLER THAN or EQUAL TO.
Give a reason for the answer. (No calculation is required.) (2)

4.4 Calculate the initial amount (in moles) of $CO_2(g)$ present. (9)

4.5 State how EACH of the following will affect the yield of CO(g) at equilibrium. Choose from INCREASES, DECREASES or REMAINS THE SAME.

4.5.1 More carbon is added at constant temperature. (1)

4.5.2 The pressure is increased. (1)

4.5.3 The temperature is increased. (1)

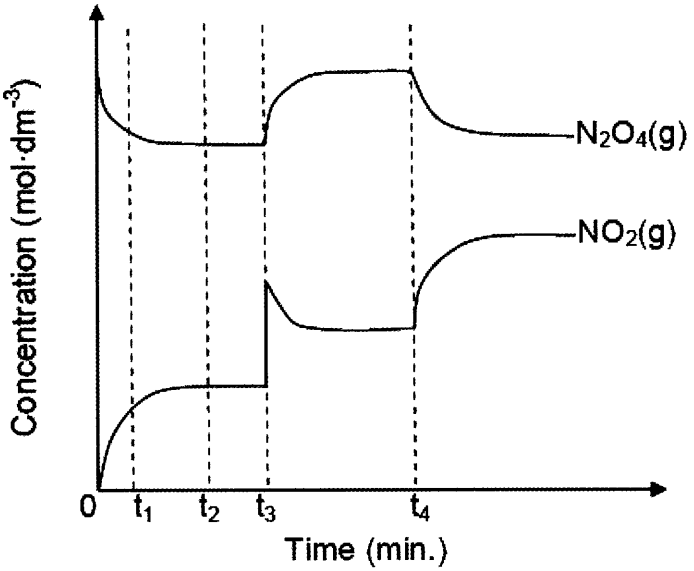
[18]

QUESTION 5

A sample of N_2O_4 gas is sealed in a container and heated. The N_2O_4 gas decomposes to NO_2 gas and the reaction reaches equilibrium according to the following balanced equation:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \quad \Delta H > 0$$

The graph below shows how the concentrations of the two gases change as a result of changes made to the reaction conditions.



5.1 Give a reason why this reaction will only reach equilibrium in a SEALED container (1)

5.2 How does the rate of the forward reaction compare to that of the reverse reaction at each of the following times? Only write down HIGHER THAN, LOWER THAN or EQUAL TO.

5.2.1 t_1 (1)

5.2.2 t_2 (1)

5.3 What change was made to the reaction conditions at each of the following times? In both instances, the equilibrium constant for the reaction did not change.

5.3.1 t_3 (1)

5.3.2 t_4 (1)

5.4 How will an increase in temperature influence the yield of $NO_2(g)$? Write down *INCREASES, DECREASES* or *REMAINS THE SAME*. Use Le Chatelier's principle to explain the answer. (3)

5.5 Initially 0,92 mol N_2O_4 gas is sealed in a 2 dm^3 container and heated to 100 °C. At equilibrium it is found that 20,7% of the N_2O_4 gas has decomposed to NO_2 gas. Calculate the equilibrium constant (K_c) for this reaction at 100 °C. (7)

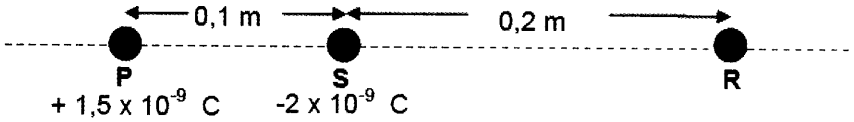
[16]

ACTIVITIES

Question 1

Two point charges, P and S, are placed a distance 0,1 m apart. The charge on P is $+1,5 \times 10^{-9}$ C and that on S is -2×10^{-9} C.

A third point charge, R, with an unknown positive charge, is placed 0,2 m to the right of point charge S, as shown in the diagram below.



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

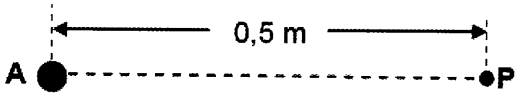
1.2 Draw a labelled force diagram showing the electrostatic forces acting on **R** due to **P** and **S**. (2)

1.3 Calculate the magnitude of the charge on **R**, if it experiences a net electrostatic force of $1,27 \times 10^{-6}$ N to the left.
Take forces directed to the right as positive. (7)

[11]

Question 2

P is a point 0,5 m from charged sphere **A**. The electric field at **P** is 3×10^{7} N·C^{-1} directed towards **A**. Refer to the diagram below.



2.1 Draw the electric field pattern due to charged sphere **A**. Indicate the sign of the charge on the sphere in your diagram. (2)

2.2 Calculate the magnitude of the charge on sphere **A**. (3)

Another charged sphere, **B**, having an excess of 10^{5} electrons, is now placed at point **P**.

2.3 Calculate the electrostatic force experienced by sphere **B**. (7)

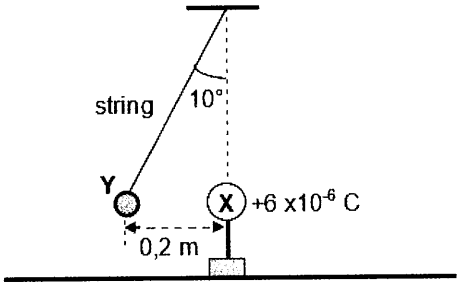
[12]

Question 3

3.1 A small sphere, **Y**, carrying an unknown charge, is suspended at the end of a light inextensible string which is attached to a fixed point. Another sphere,

X, carrying a charge of +6 x10^{-6} C, on an insulated stand is brought close to sphere **Y**.

Sphere **Y** experiences an electrostatic force and comes to rest 0,2 m away from sphere **X**, with the string at an angle of 10° with the vertical, as shown in the diagram below.



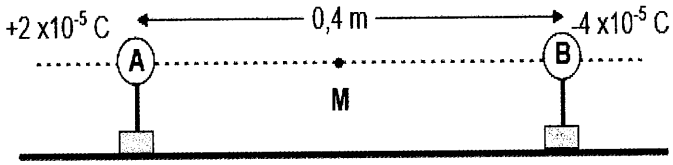
3.1.1 What is the nature of the charge on sphere **Y**? Choose from POSITIVE or NEGATIVE. (1)

3.1.2 Calculate the magnitude of the charge on sphere **Y** if the magnitude of the electrostatic force acting on it is 3,05 N. (3)

3.1.3 Draw a labelled free-body diagram for sphere **Y**. (3)

3.1.4 Calculate the magnitude of the tension in the string. (3)

3.2 Two small charged spheres, **A** and **B**, on insulated stands, with charges +2 x10^{-5} C and -4 x10^{-5} C respectively, are placed 0,4 m apart, as shown in the diagram below. **M** is the midpoint between spheres **A** and **B**.



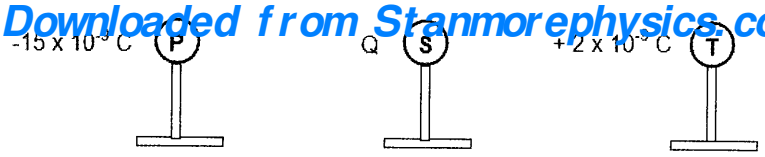
3.2.1 Define the term *electric field at a point*. (2)

3.2.2 Calculate the net electric field at point **M**. (6)

[18]

Question 4

Three small identical metal spheres, **P**, **S** and **T**, on insulated stands, are **initially neutral**. They are then charged to carry charges of -15 x 10^{-9} C, Q and +2 x 10^{-9} C respectively, as shown below.

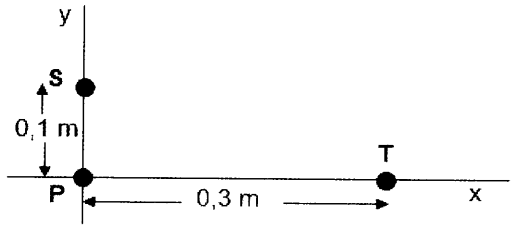


The charged spheres are brought together so that all three spheres touch each other at the same time, and are then separated. The charge on each sphere, after separation, is -3×10^{-9} C.

4.1 Determine the value of charge Q. (2)

4.2 Draw the electric field pattern associated with the charged spheres, **S** and **T**, **after they are separated** and returned to their original positions. (3)

The spheres, each with the **new charge** of -3×10^{-9} C, are now placed at points on the *x*-axis and the *y*-axis, as shown in the diagram below, with sphere **P** at the origin.



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

Calculate the magnitude of the:

4.4 Net electrostatic force acting on sphere **P** (5)

4.5 Net electric field at the origin due to charges **S** and **T** (3)

4.6 ONE of the charged spheres, **P** and **T**, experienced a very small increase in mass **after it was charged initially**.

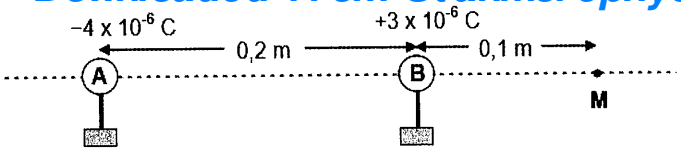
4.6.1 Which sphere, **P** or **T**, experienced this very small increase in mass? (1)

4.6.2 Calculate the increase in mass by the sphere in QUESTION 4.6.1. (3)

[19]

Question 5

Two small charged spheres, **A** and **B**, are placed on insulated stands, 0,2 m apart, as shown in the diagram below. They carry charges of -4×10^{-6} C and $+3 \times 10^{-6}$ C respectively.



M is a point that is a distance of 0,1 m to the right of sphere **B**.

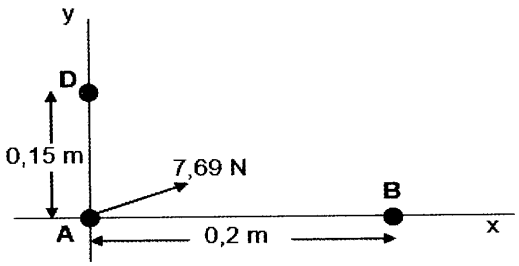
5.1 Calculate the number of electrons in excess on sphere **A**. (3)

5.2 Calculate the magnitude of the electrostatic force exerted by sphere **A** on sphere **B**. (3)

5.3 Describe the term *electric field*. (2)

5.4 Calculate the magnitude of the net electric field at point **M**. (5)

Charged spheres **A** and **B** and another charged sphere **D** are now arranged along a rectangular system of axes, as shown in the diagram below.



The net electrostatic force experienced by sphere **A** is 7,69 N in the direction as shown in the diagram above.

5.5 Is the charge on sphere **D** POSITIVE or NEGATIVE? (1)

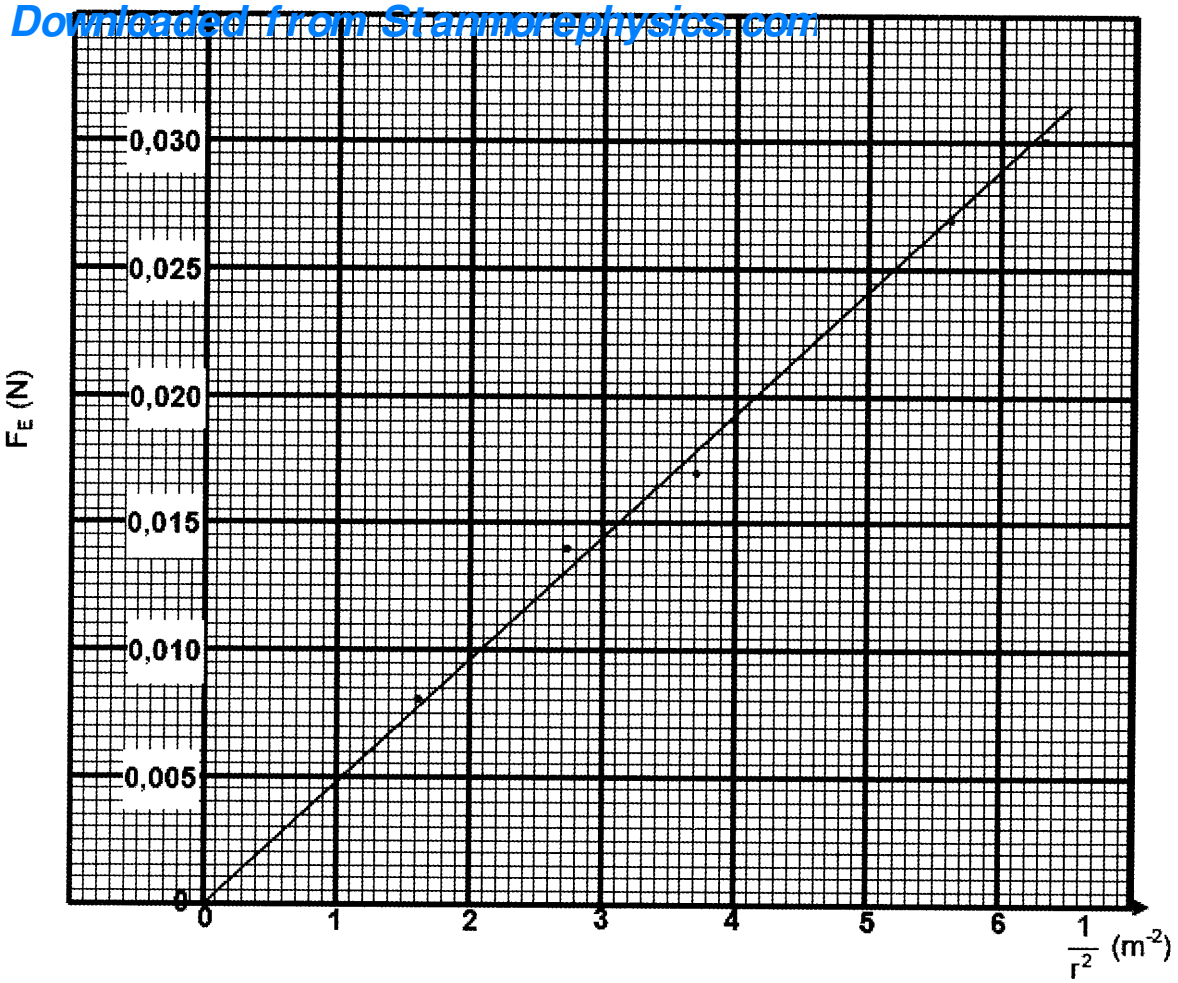
5.6 Calculate the magnitude of the charge on sphere **D**. (3)

[17]

Question 6

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

Graph of F_E versus $\frac{1}{r^2}$



6.1 Write down the dependent variable of the experiment. (1)

6.2 What relationship between the electrostatic force FE and the square of the distance, r^2, between the charged spheres can be deduced from the graph? (1)

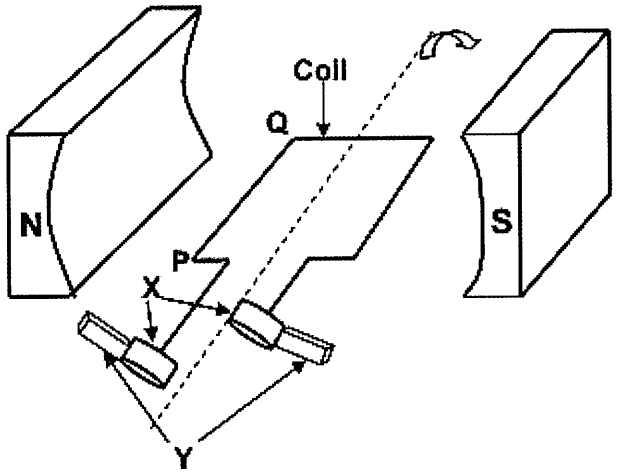
6.3 Use the information in the graph to calculate the charge on each sphere. (6)

[8]

ELECTRODYNAMICS - ACTIVITIES

Question 1

The diagram below is a simplified representation of an AC generator. The coil is rotated in a clockwise direction in the magnetic field



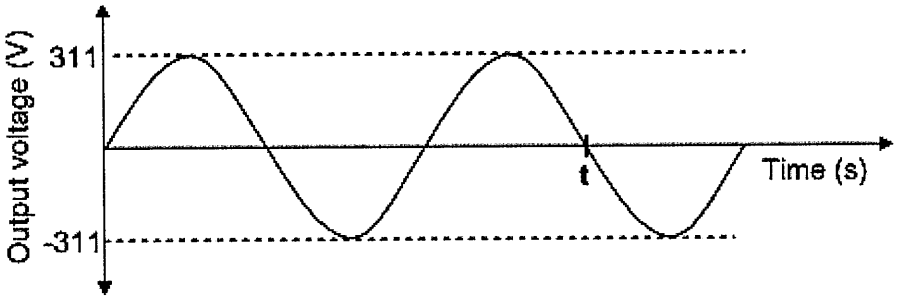
1.1 Write down the name of component X (1)

1.2 Write down the function of component Y. (1)

1.3 Use the relevant principle to explain why an emf is induced in the coil when the coil is rotated in the magnetic field (2)

1.4 The coil rotates CLOCKWISE from the position shown in the diagram. In which direction will current be induced in segment PQ of the coil? Choose from 'P to Q' or 'Q to P'. (2)

The output voltage versus time graph below was obtained for the above generator



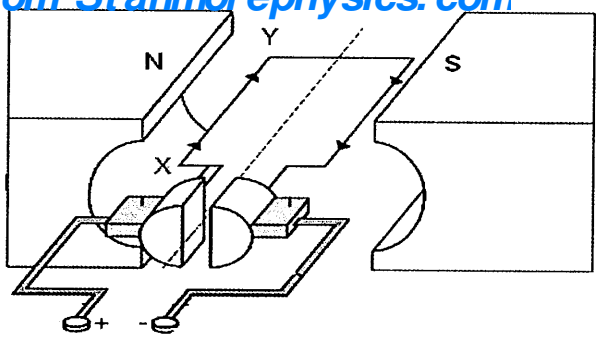
The output voltage is generated at a frequency of 50 Hz.

1.5 Calculate the time t indicated in the above graph. (3)

1.6 The generator is now connected to an appliance with a resistance of 100 Ω. Calculate the energy dissipated when the appliance is in operation for ONE minute. (5)

Question 2

2.1 The diagram below is a simplified representation of a DC motor. The current in the coil is in the direction XY.



2.1.1 Name the component that ensures that the coil rotates continuously in ONE DIRECTION. (1)

2.1.2 In which direction will the coil rotate? Write down only CLOCKWISE or ANTICLOCKWISE. (2)

2.1.3 Write down the energy conversion which takes place while the motor is working (2)

2.2 An AC generator, producing a maximum voltage of 320 V, is connected to a heater of resistance 35 Ω.

2.2.1 Write down the structural difference between an AC generator and a DC generator. (1)

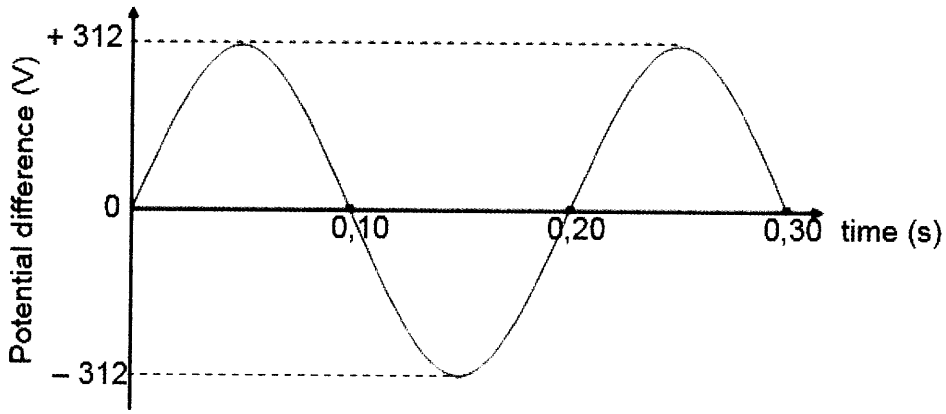
Calculate the:

2.2.2 Root mean square (rms) value of the voltage (3)

2.2.3 Root mean square (rms) value of the current in the heater (4)

Question 3

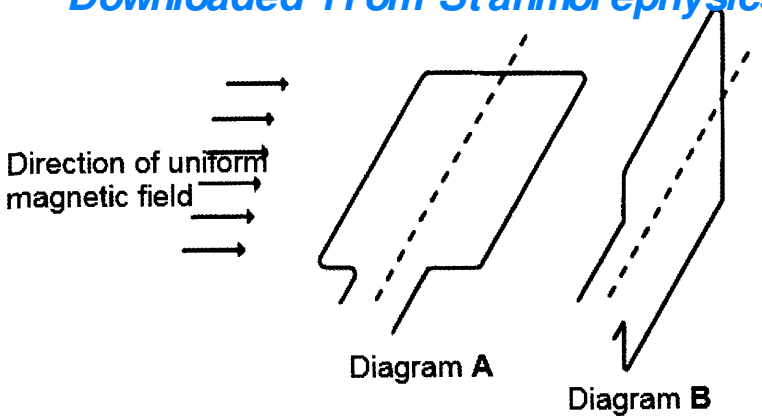
The diagram below shows the voltage output of a generator.



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

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

(1)



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

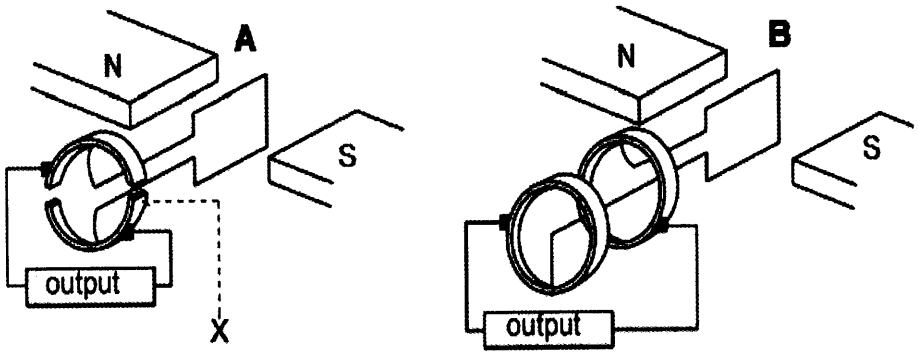
3.4 A device with a resistance of 40 Ω is connected to this generator.
Calculate the:

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

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

Question 4

4.1 Refer to the two devices below. The output of the devices can be measured using a galvanometer.



4.1.1 Write down the name of the principle on which the above devices operate. (1)

4.1.2 Write down the name of part X in device A. (1)

4.2 A 220 V, AC voltage is supplied from a wall socket to an electric kettle of resistance 40,33Ω. Wall sockets provide rms voltages and currents.
Calculate the:

4.2.1 Electrical energy consumed by the kettle per second (4)

4.2.2 Maximum (peak) current through the kettle (3)

Question 5

AC generators at coal-fired power stations supply most of the electrical energy needed in our country.

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

5.2 State ONE structural difference between an AC generator and a DC generator. (1)

5.3 Draw a sketch graph of potential difference versus time for this AC generator. Clearly label the axes and indicate Vmax on the potential difference axis. (2)

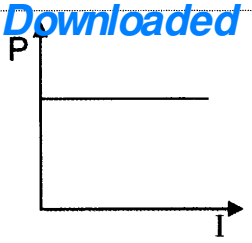
An electric appliance is rated 2 000 W, 230 V. The appliance is connected to an alternating current power source

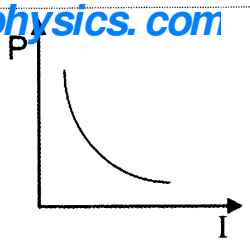
Calculate the:

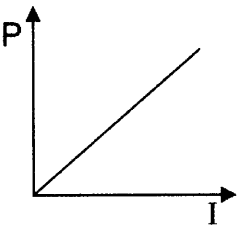
5.4 Maximum current (Imax) produced by the generator (4)

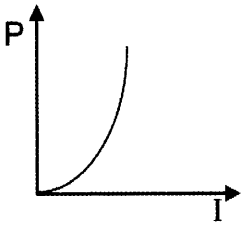
5.5 Peak voltage (Vmax) output of the generator (3)

ELECTRIC CIRCUITS		
ACTIVITIES		
QUESTION 1		
Four possible options are provided as answers to the following questions. Each question has only ONE correct answer. Choose the correct answer		
1.1	The unit of measurement for the energy transferred *PER UNIT TIME* is a…	
	A. Volt B. Ampere C. Watt D. Joule	(2)
1.2	Which ONE of the following graphs best represents the relationship between the electrical power and the current in a given ohmic conductor?	

A 

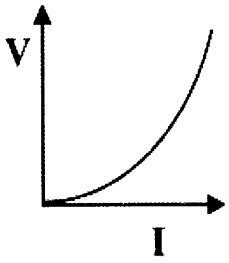
B 

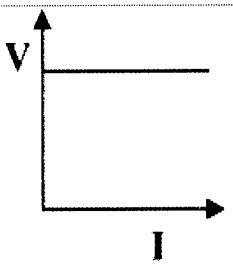
C 

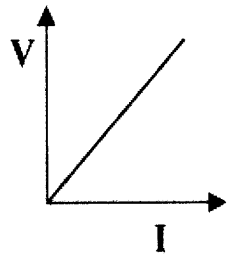
D 

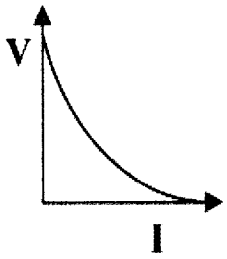
(2)

1.3 Which one of the following graphs best represents the relationship between the potential difference (V) across an ohmic conductor and the current (I) in the conductor at constant temperature?

A 

B 

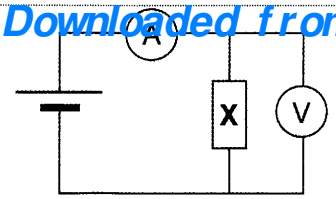
C 

D 

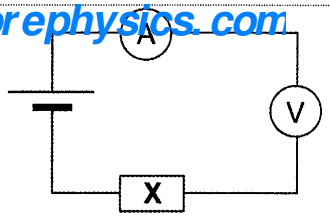
(2)

1.4 Which ONE of the circuits below can be used to measure the current in a conductor X and the potential difference across its ends?

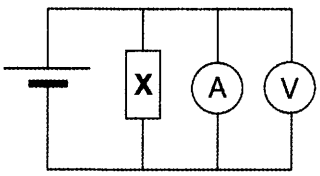
A



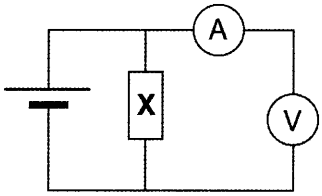
B



C



D



(2)

1.5 The table below shows the current in two different electrical appliances when connected to a 240 V AC (alternating current) supply.

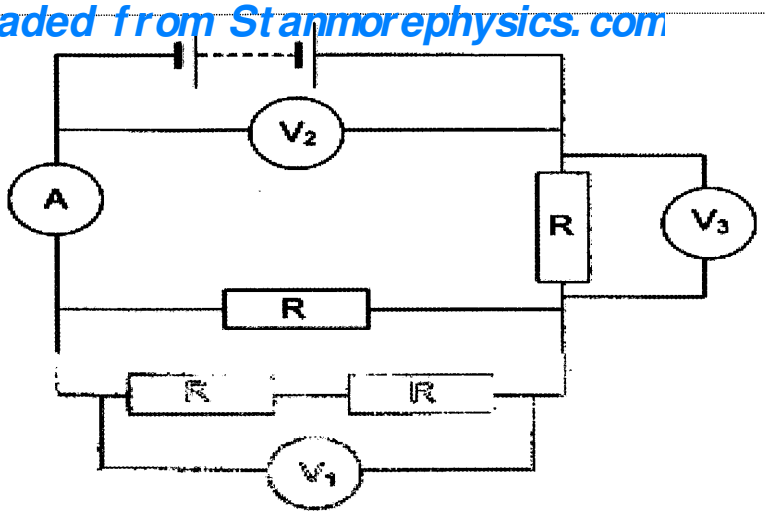
Appliance	Current
Toaster	3,5 A
Kettle	7,8 A

Which ONE of the following combinations is correct for the power dissipated by the appliances and the resistance when the appliances operate at 240 v

	Power dissipated	Resistance
A	Ptoaster > Pkettle	Rtoaster < Rkettle
B	Ptoaster = Pkettle	Rtoaster < Rkettle
C	Ptoaster < Pkettle	Rtoaster > Rkettle
D	Ptoaster = Pkettle	Rtoaster > Rkettle

(2)

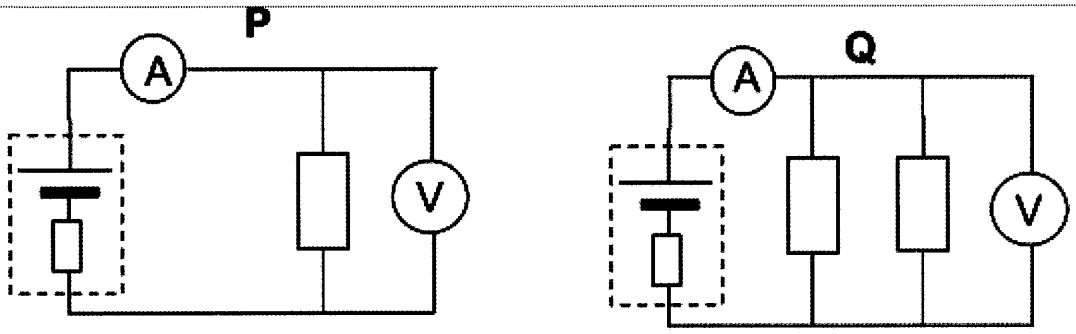
1.6 In the circuit below the battery has internal resistance and all the resistors are identical



Which one of the following statements regarding voltmeter reading is true ? (2)

A. Emf = $V_1 + V_2 + V_3$
B. $V_1 = V_2$ and $V_1 < V_3$
C. $V_2 = V_1 + V_3$
D. Emf = V_2

1.7 In the circuits shown below all resistors and cells are identical.

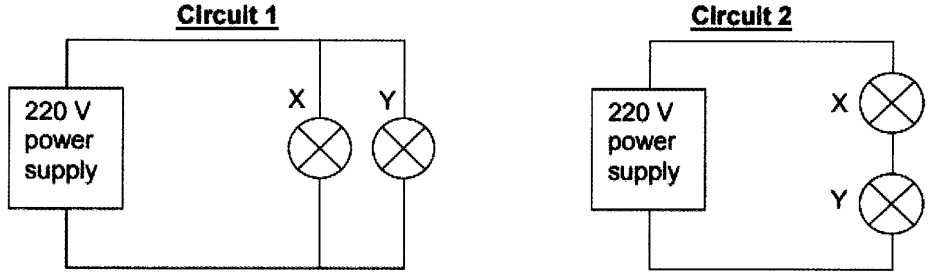


Which ONE of the following gives the correct comparison between the voltmeter and ammeter readings in circuit **P** and **Q**.

	VOLTMETER READING	AMMETER READING
A.	$V_P > V_Q$	$A_P > A_Q$
B.	$V_P > V_Q$	$A_P < A_Q$
C.	$V_P < V_Q$	$A_P = A_Q$
D.	$V_P = V_Q$	$A_P < A_Q$

(2)

1.8 A learner has two light bulbs, X and Y, marked 100 W and 60 W respectively. He first connects them in parallel (circuit 1) and then in series (circuit 2) in order to compare their brightness in each circuit.



Which light bulb, X or Y, glows brighter in each circuit?

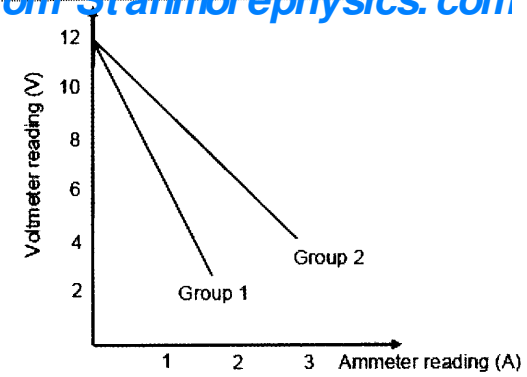
	Bulb that glows brighter in circuit 1	Bulb that glows brighter in circuit 2
A	X	X
B	Y	X
C	X	Y
D	Y	Y

(2)

1.9 Grade 12 learners conduct an experiment to determine the *INTERNAL RESISTANCE* of a battery. The learners are divided into two groups.

Group 1 uses battery 1 with an internal resistance r1.
Group 2 uses battery 2 with an internal resistance r2.

The results of each group are shown in the graph below.



(2)

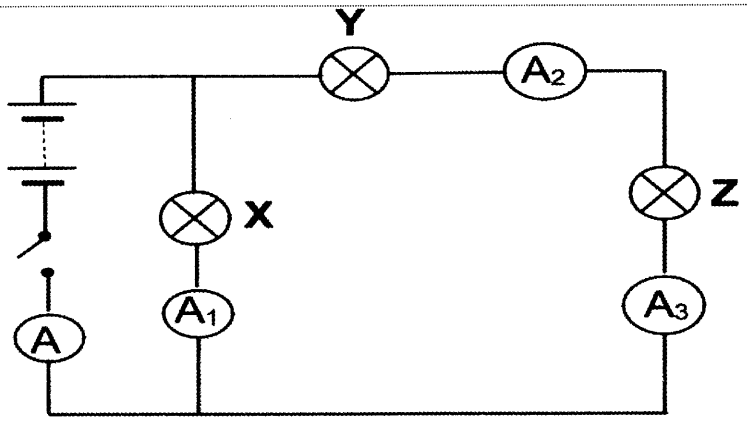
Use the information on the graph and state which option is *CORRECT*

A	Emf1= Emf2	r1 = r2
B	Emf1>Emf2	r1 < r2
C	Emf1= Emf2	r1 > r2
D	Emf1<Emf2	r1 < r2

1.10 Three light bulbs, **X**, **Y** and **Z**, are connected in a circuit as Shown below. **X** and **Y** are identical and both has a Resistance **R**, while the resistance of **Z** is **2R**.

The battery has negligible internal resistance.

When switch **S** is closed, all the bulbs glow. The reading on ammeter **A** is 2,0 A.



Which ONE of the following correctly describes the readings on the ammeters (in amperes) when bulb **Z** burns out?

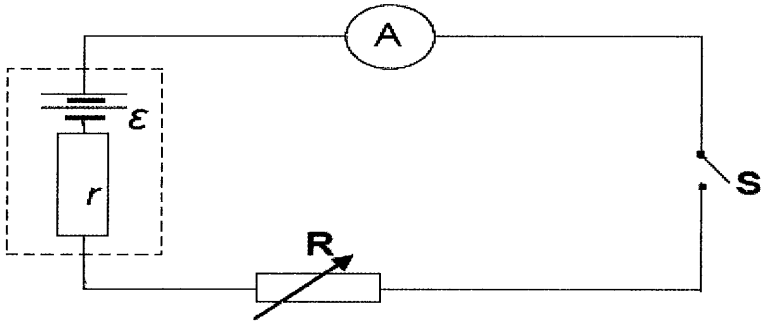
	A_1	A_2	A_3	A
A	2	0	0	2
B	1.5	0	0	1.5
C	0.5	0.5	0	1
D	0.2	0.2	0.2	0.6

(2)

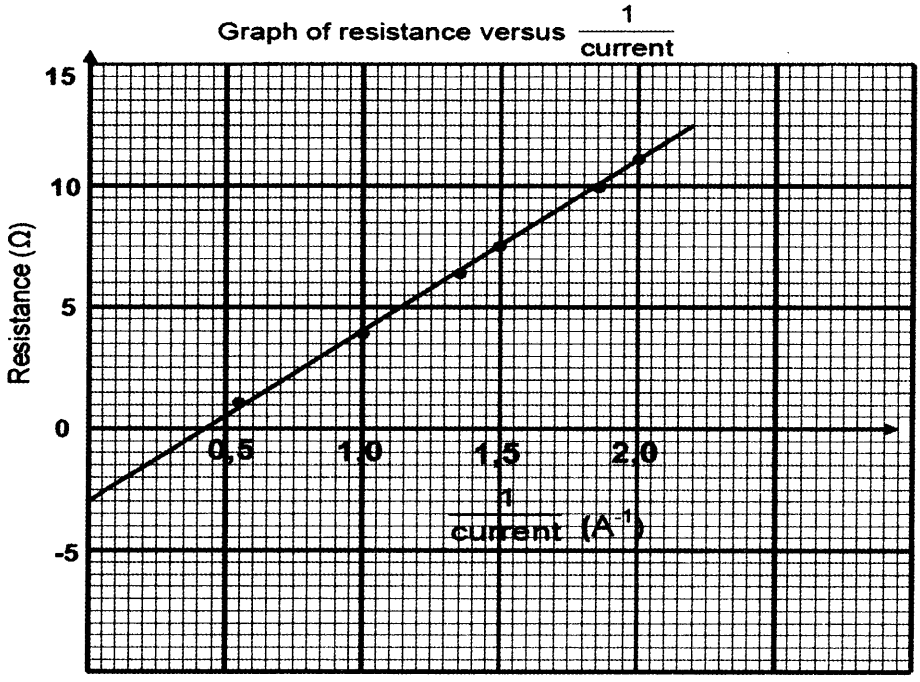
[20]

QUESTION 2

Learners conduct an investigation to determine the emf and the internal resistance of the battery using the circuit below.



The results obtained are shown in the graph below.

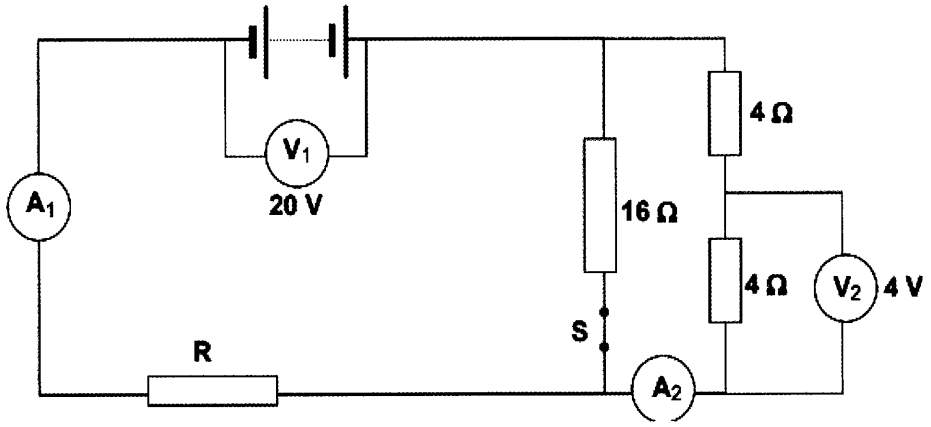


Use the graph to determine the following:

2.1	The equation of the graph in the form of y=mx+c in terms of R,r and E.	(3)
2.2	The value of the internal resistance of the cell*.	(2)
2.3	The emf of the battery.	(3)
		[6]

QUESTION 3

In the circuit represented below, the battery has an **emf of 24 V**. The ammeter and the connecting wires have negligible resistance.

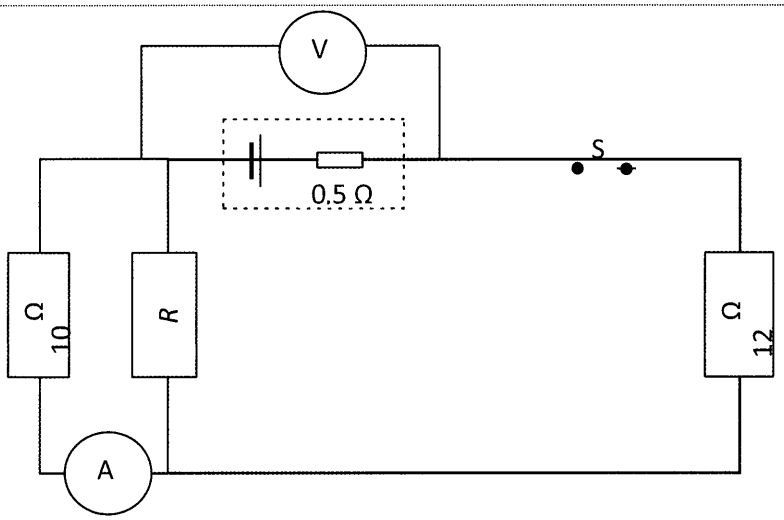


When switch ***S is closed,*** *voltmeter V_1 registers 20 V and V_2 registers 4 V*

3.1	Calculate the :		
	3.1.1	Reading on ammeter A_2	(4)
	3.1.2	Reading on ammeter A_1.	(4)
	3.1.3	Resistance of resistor R	(3)
	3.1.4	Internal resistance of the battery	(3)
	3.1.5	Energy transferred in resistor R in 10 minutes.	(4)
3.2	A hairdryer operates at a potential difference of 240V and a current of 9,5A. It takes a learner 12 minutes to completely dry her hair. Eskom charges energy usage at R1, 47 per unit. Calculate the cost of operating the hairdryer for the 12 minutes (1 unit =1 kW.h)		(4)
3.3	Switch **S is now opened**. State whether the reading on V_1 will *INCREASE, DECREASE OR REMAIN THE SAME*. ***Briefly explain your answer.***		(3)
			[25]

QUESTION 4

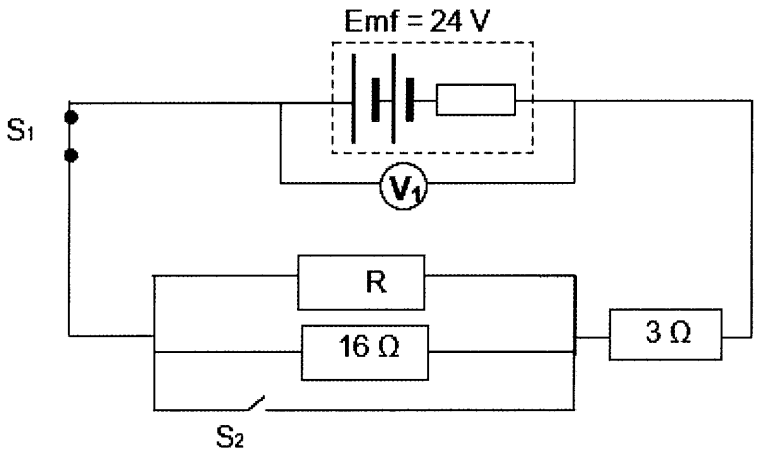
A circuit is connected as shown below. The resistance of *R*, which is connected in parallel with the 10 Ω resistor, is unknown. With switch S closed, the reading on voltmeter, V decreases from 45 V to 43,5 V. The internal resistance of the battery is 0,5 Ω.



4.1	Calculate the reading on ammeter A. Show ALL your calculations.	(8)
4.2	Determine the resistance of resistor *R*.	(3)
	Resistor R burns out how will each of the following be affected? Write *INCREASE, DECREASE OR REMAIN THE SAME*	
4.3	The reading on the ammeter	(1)
4.3	The reading on voltmeter V. ***Give a reason for your answer.***	(4)
		[16]

QUESTION 5

A circuit is connected as shown below. When switch S_1 is closed, $V_{external}$ is equal to 22,5. The internal resistance of the battery is 0.8 Ω

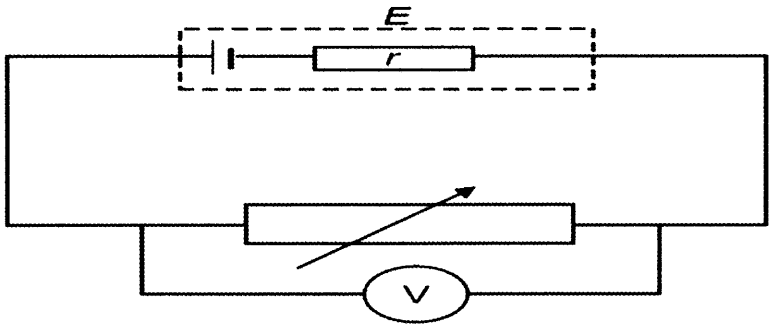


5.1	State ***Ohm's law*** in words	(2)
5.2	Calculate the power dissipated by the 16 Ω resistor	(7)
5.3	Calculate the resistance of R	(3)

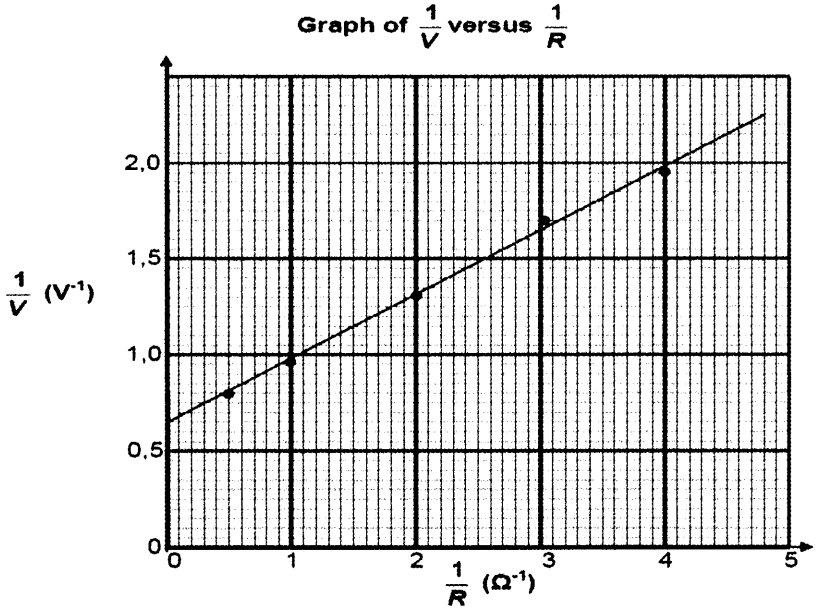
5.4	Switch S_2 is now closed. How will voltmeter reading V_1 be influenced? (Write down only *INCREASE, DECREASE or STAYS THE SAME*.) Give an explanation to your answer.	(4)
		[16]

Question 6

6. In an experiment, learners use the circuit below to determine the internal resistance of a cell.



The circuit consists of a cell of emf E and internal resistance r. A voltmeter is placed across a variable resistor which can be set to known values R. They obtain the graph below.



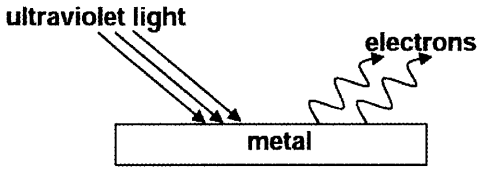
	Use the graph to determine the following:	
6.1	The equation of the graph in the form of y=mx+c in terms of V, R, r and E	(3)
6.2	The mathematical relationship for the slope of the graph	(1)
6.3	Emf of the cell	(2)
6.4	The internal resistance of the cell	(3)
		[7]

PHOTO ELECTRIC EFFECT

WORKED EXAMPLE 1.

1. A metal surface is illuminated with ultraviolet light of wavelength 330 nm. Electrons are emitted from the metal surface.

   The minimum amount of energy required to emit an electron from the surface of this metal is 3.5×10^{-19} J.



1.1. Name the phenomenon illustrated above. (1)

Photoelectric effect

1.2. Give one word for the underlined sentence in the above paragraph. (1)

Work function

1.3. Calculate the frequency of ultraviolet light. (4)

$c = f\lambda$

$3 \times 10^{8} = f\,(330 \times 10^{-9})$

$f = 9.09 \times 10^{14}\ Hz$

OR

$E = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{330 \times 10^{-9}} = 6.03 \times 10^{-19}\ J$

$E = hf$

$6.03 \times 10^{-19} = (6.63 \times 10^{-34})f$

$f = 9.09 \times 10^{14}\ Hz$

1.4. Calculate the kinetic energy of a photoelectric emitted from the surface of the metal when the ultraviolet light shines on it. (4)

$E = W_o + Ek_{max}$

$\frac{hc}{\lambda} = W_o + Ek_{max}$

$\frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{330 \times 10^{-9}} = 3.5 \times 10^{-19} + Ek_{max}$

$Ek_{max} = 2.53 \times 10^{-19} J$

OR

$E = W_o + Ek_{max}$

$hf = W_o + Ek_{max}$

$(6.63 \times 10^{-34})(9.09 \times 10^{14}) = 3.5 \times 10^{-19} + Ek_{max}$

$Ek_{max} = 2.53 \times 10^{-19} J$

1.5. The intensity of the ultraviolet light illuminating the metal is not increased. What effect will this change have on the following:

1.5.1. Kinetic energy of the emitted photoelectrons (Write down only *INCREASES, DECREASES* or *REMAINS THE SAME.)* (1)

Remains the same

1.5.2. Number of photoelectrons emitted per second (Write down only *INCREASES, DECREASES* or *REMAINS THE SAME.*) (1)

Increases

1.6. Over exposure to sunlight causes damage to skin cells.

1.6.1. Which type of radiation in sunlight is said to be primarily responsible for this damage? (1)

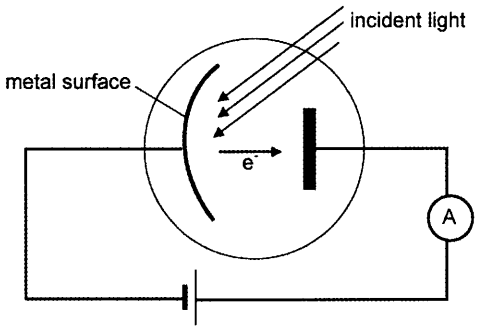
Ultraviolet radiation

1.6.2. Name the property of this radiation responsible for the damage. (1)

High energy

WORKED EXAMPLE 2.

2. In the diagram shown below electrons are released from a metal plate when light of a certain frequency is shone on its surface.



2.1. The frequency of the incident light on a metal is 6.16 x 10^{14} Hz an electron released with kinetic energy of 5.6 x 10^{-20} J.

Calculate the:

2.1.1. The energy the incident photons.

$$E = hf$$
$$E = (6.63 \text{ x } 10^{-34})(6.16 \text{ x } 10^{14})$$
$$E = 4.08 \text{ x } 10^{-19}\ J$$ (3)

2.1.2. Threshold of the metal plate. (5)

$$E = W_o + Ek_{max}$$
$$4.08 \text{ x } 10^{-19} = (6.63 \text{ x } 10^{-34})f_o + 5.6 \text{ x } 10^{-20}$$
$$f_o = 5.31 \text{ x } 10^{14}\ Hz$$

2.2. The brightness of the incident light is now increased. What effect will this change have on the following: (Write down only INCREASE, DECREASE or REMAIN THE SAME)

2.2.1. Reading on the ammeter. Explain your answer. (2)

Increases, more photoelectrons emitted per second.

2.2.2. The kinetic energy of the released photoelectrons. Explain your answer. (2)

Remains the same, intensity does not affect energy/ frequency of light remains the same.

2.3. The incident light releases $2.01 \text{ x } 10^{9}$ photoelectrons per second from the cathode. (4)
Calculate the current flowing through the ammeter.

$$Q = nq_e$$
$$Q = 2.01 \text{ x } 10^{9} \text{x } 1.6 \text{ x } 10^{-19}$$
$$Q = 3.22 \text{ x } 10^{-10} C$$
$$I = \frac{Q}{\Delta t}$$
$$I = \frac{3.22 \text{ x } 10^{-10}}{1}$$
$$I = 3.22 \text{ x } 10^{-10} A$$

WORKED EXAMPLE 3.

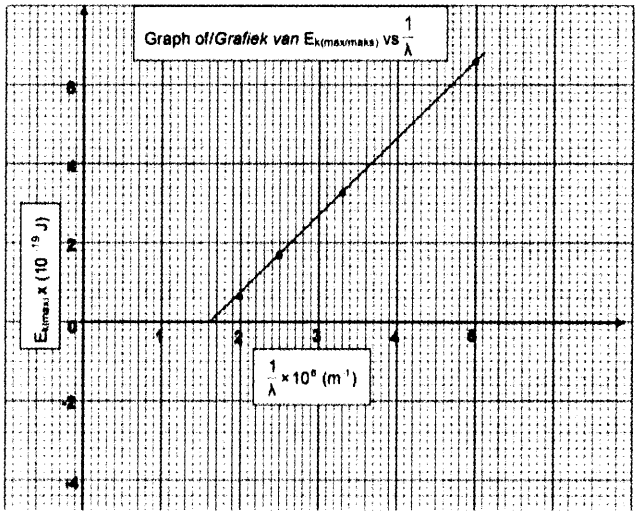
3 . In an experiment to demonstrate the photoelectric effect, light of different wavelengths was shone onto a metal surface of a photoelectric cell. The maximum kinetic energy of the emitted electrons was determined for the various wavelengths and recorded in the table below.

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

3.1. What is meant by the term photoelectric effect? (2)

The process whereby electrons are ejected from a metal surface.

3.2 . Draw a graph of $E_{k(max)}$ (y-axis) versus $\frac{1}{\lambda}$ (x- axis). (3)



3.3 USE THE GRAPH to determine:

.

3.3.1. The threshold frequency of the metal in the photoelectric cell. (4)

$\frac{1}{\lambda} = 1.6 \text{ x } 10^{6} m^{-1}$

$f_o = c\frac{1}{\lambda}$

$f_o = (3 \text{ x } 10^{8})(1.6 \text{ x } 10^{6})$

$f_o = 4.8 \text{ x } 10^{14} Hz$

OR

$W_o = hf_o$

$3.2 \text{ x } 10^{-19} = (6.63 \text{ x } 10^{-34}) f_o$

$f_o = 4.8 \text{ x } 10^{14} Hz$

3.3.2. Planck's constant (4)

$hc = gradient = \frac{\Delta y}{\Delta x}$

$\frac{6.6 \text{ x } 10^{-19} - 0}{(5 - 1.6) \text{x } 10^{6}} = 1.941 \text{ x } 10^{-25}$

$h = \frac{1.941 \text{ x } 10^{-25}}{3 \text{ x } 10^{8}} = 6.47 \text{ x } 10^{-34} J.s$

OR

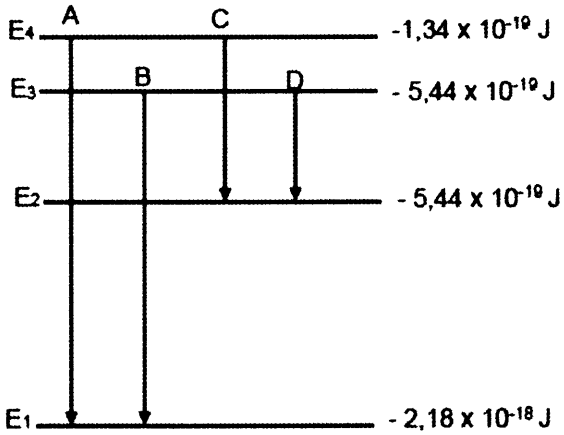
$W_o = hf_o$

$3.2 \text{ x } 10^{-19} = h\,(4.8 \text{ x } 10^{14})$

$h = 6.47 \text{ x } 10^{-34} J.s$

WORKED EXAMPLE 4.

4. The diagram below shows electron transitions between energy levels of an atom.



4.1. A photon of light is released when an electron moves from E_3 state to the E_1 state. Calculate the frequency of this photon. (5)

$\Delta E = E_3 - E_1 = -5.44 \text{ x } 10^{-19} - (-2.18 \text{ x } 10^{-18}) = 1.68 \text{ x } 10^{-18} J$

$E = hf$

$1.68 \text{ x } 10^{-18} = (6.63 \text{ x } 10^{-34}) f$

$f = 2.47 \text{ x } 10^{15} Hz$

4.2. How many different photons can be produced when excited electrons from the E_3 state to the E_1? (1)

3

4.3. The photon in QUESTION 4.1. is incident to the metal surface. The work function of a metal is 2 x 10^{-19} J. Calculate the maximum velocity. (4)

$$E = W_o + Ek_{max}$$

$$hf = hf_o + \frac{1}{2}mv^2{}_{max}$$

$$(6.63 \text{ x } 10^{-34})(2.47 \text{ x } 10^{15}) = 2 \text{ x } 10^{-19} + \frac{1}{2}(9.11 \text{ x } 10^{-31})(v)^2$$

$$v = 1.78 \text{ x } 10^6 m.s^{-1}$$

MULTIPLE CHOICE QUESTIONS

1. Light of a certain frequency is shone onto a metal M and electrons are ejected from the surface. The same source of light is shone onto another metal N.
The electrons ejected from the surface of metal N have a much higher kinetic energy than that from metal M
This means that …

A metal N has the same work function as mental M
B metal N has a larger work function than metal M
C the threshold frequency of metal N is higher than that of metal M
D the threshold frequency of metal N is lower than that of metal M (2)

2. In an experiment on the photoelectric effect, a scientist shines red light on a metal surface and observes that electrons are ejected from the metal surface. Later the scientist shines blue light, with the same intensity as the red light on the same metal surface.
Which ONE of the statements below will be the CORRECT observations as a result of this change?

A The number of ejected electrons per second will increases
B The number of ejected electrons per second will decrease
C The speed of the ejected electrons will decrease
D The maximum kinetic energy of the ejected electrons will increase (2)

3. When light of a certain wavelength is incident on a metal surface, no electrons are ejected. Which ONE of the following changes may result in electrons being ejected from the metal surface?

A Increase the intensity of the light
B Use light with a much shorter wavelength
C Use metal with a larger work function
D Increase the surface area of the metal (2)

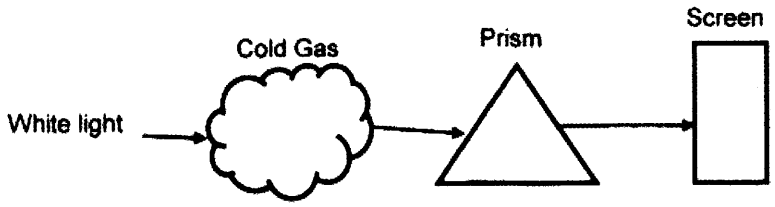
4. In an experiment on the photoelectric effect, the frequency of the incident light is high enough to cause the removal of electrons from the surface of the metal.

The number of electrons ejected from the metal surface is proportional to the

A Kinetic energy of the electrons
B number of incident photons
C work function of the metal
D frequency of the incident light

(2)

5 White light is passed through a cold gas, then through a prism as shown in the sketch



What type of spectrum is observed on the screen?

A Line absorption spectrum
B Line emission spectrum
C Continuous absorption spectrum
D Continuous emission spectrum

(2)

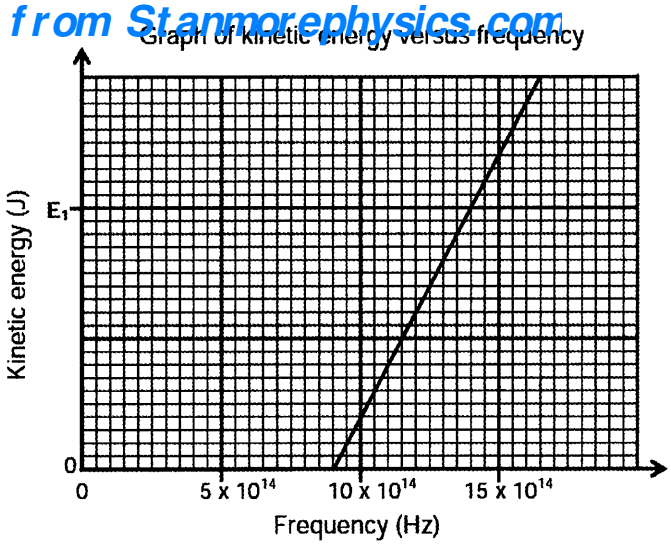
6 Which one of the following combinations correctly links an emission spectrum and absorption spectrum to the energy transition of an electron in an atom?

	EMISSION SPECTRUM	ABSORPTION SPECTRUM
A	From low to high energy levels	From high to low energy levels
B	From low to high energy levels	From low to high energy levels
C	From high to low energy levels	From high to low energy levels
D	From high to low energy levels	From low to high energy levels

LONG QUESTIONS

QUESTION 1

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



1.1 For the investigation write down the following:

1.1.1. Dependent variable (1)

1.1.2. Independent variable (1)

1.1.3. Controlled variable (1)

1.2 Define the term threshold frequency. (2)

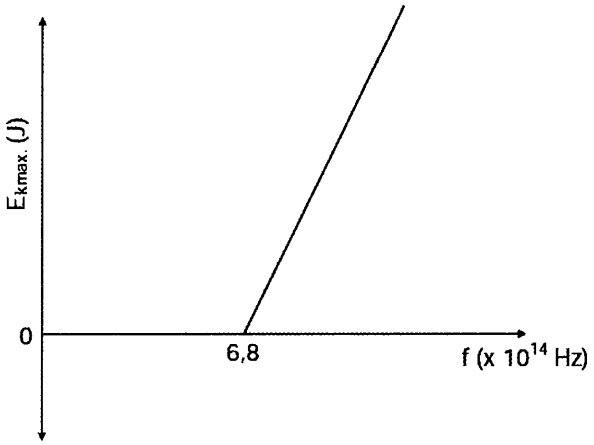
1.3 Use the graph to obtain the threshold frequency of the metal used as a cathode in the photocell. (1)

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

1.5 How will the kinetic energy calculated in question 1.4. be affected if the light of higher intensity is used? Write down only INCREASE, DECREASE or REMAIN THE SAME. (1)

QUESTION 2

2. The graph below is obtained for an experiment on the photoelectric effect using different frequencies of light and a given metal plate.



2.1 What is the threshold frequency of the metal? (1)

In the experiment the brightness of the light incident on the metal surface is increased.

2.2 State how this change will influence the speed of the photoelectrons emitted. Choose form INCREASES, DECREASES or REMAINS THE SAME. (1)

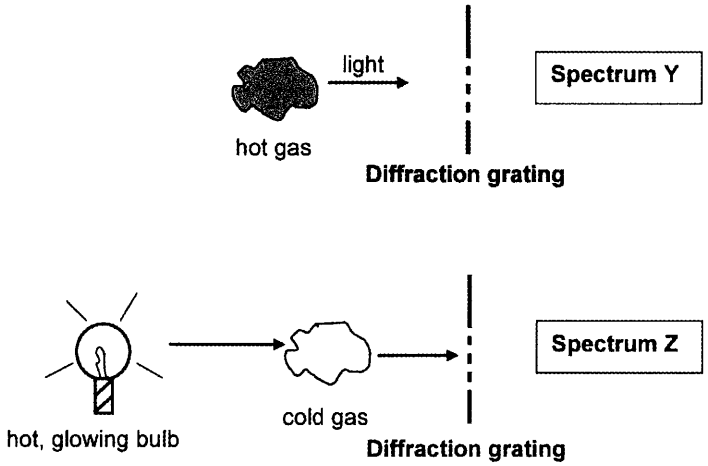
2.3 Show by means of calculation whether the photoelectric effect will be OBSERVED or NOT OBSERVED, if monochromatic light with a wavelength of 6×10^{-7} m is used in this experiment. (5)

One of the radiations used in this experiment has a frequency of 7.8×10^{14} Hz.

2.4 Calculate the maximum speed of an ejected photoelectron. (5)

QUESTION 3

3. A teacher in a science class explains how different types of spectra are obtained. The teacher uses the simplified diagrams shown below for the explanation.



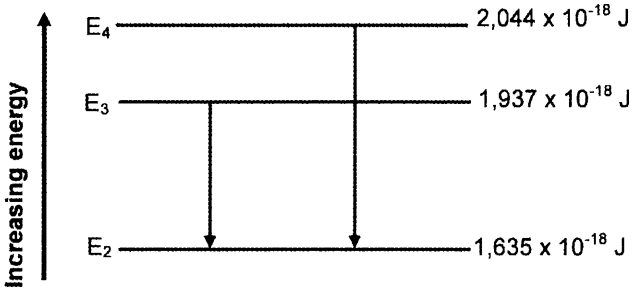
3.1 Name the type of spectrum formed in:

3.1.1. Y (1)

3.1.2. Z (1)

3.2 In an excited atom, electrons can "jump" from lower energy levels to higher energy levels. They can also drop from higher energy levels to lower energy levels.

The diagram below (not drawn to scale) shows some of the transitions for an electron in an excited atom.



3.2.1. Do the transitions indicated in the diagram lead to ABSORPTION or EMISSION spectra? (1)

3.2.2. Calculate the frequency of the photon produced when an electron in an excited atom makes a transition from E_4 to E_2, as shown in the diagram. (4)

The threshold frequency of a metal, Q, is 4.4×10^{14} Hz.

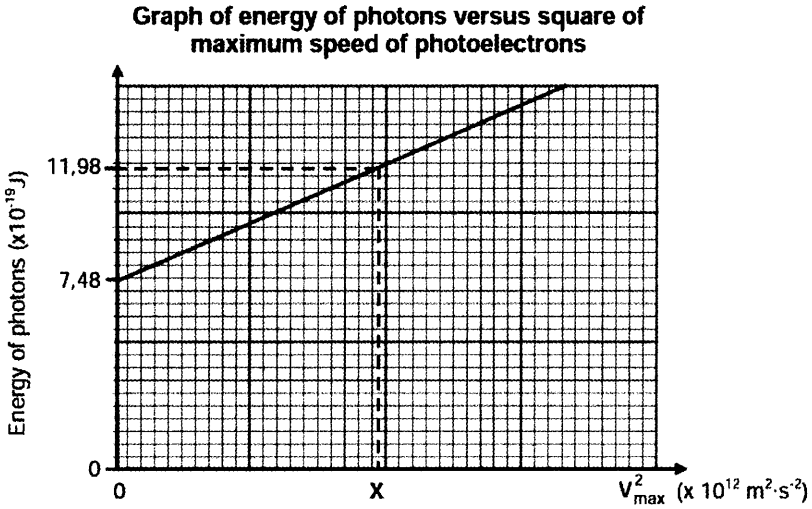
3.2.3. Calculate the kinetic energy of the most energetic electron ejected when the photon produced in QUESTION 3.2.2. is incident on the surface of metal Q. (4)

Another metal, R, has a threshold frequency of 7.5×10^{14} Hz.

3.2.4. Will the photon produced in QUESTION 3.2.2. be able to eject electrons from the surface of metal R? Write down only YES or NO.
Give a reason for the answer. (2)

QUESTION 4

. 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.



4.1 Define the term photoelectric effect. (2)

Use the graph to answer the following questions:

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

4.3 What physical quantity can be measured from the gradient of the graph? (1)

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

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

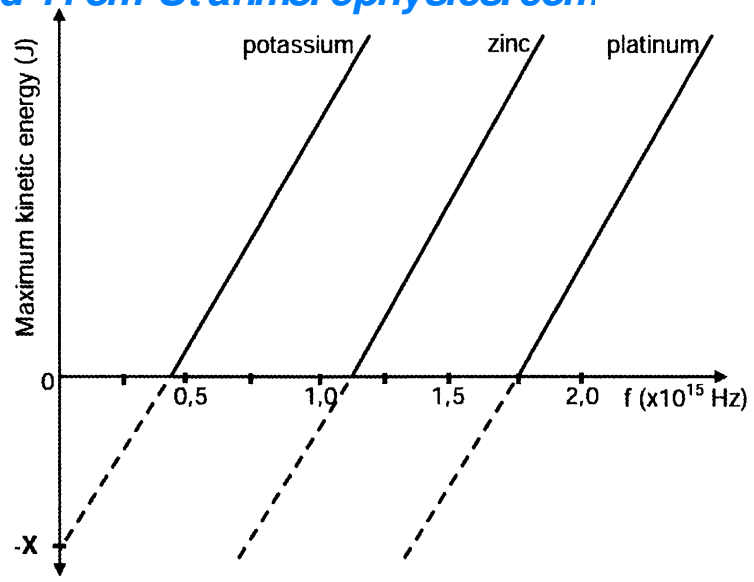
4.5 How will EACH of the following be affected? Choose from INCREASES, DECREASES or REMAINS THE SAME.

4.5.1. The gradient of the graph. (1)

4.5.2. The number of photoelectrons emitted per unit time. (1)

QUESTION 5

5. An experiment is conducted to investigate the relationship between frequency of light incident on a metal and the maximum kinetic energy of the emitted electrons from the surface of the metal. This experiment is conducted for three different metals.
The graph below represents the results obtained.



5.1 Name the physical quantity represented by X on the graph. (1)

5.2 Which ONE of the three metals needs incident light with the largest wavelength for the emission of electrons? (2)
Give a reason for the answer.

5.3 Calculate the:

5.3.1. Work function of platinum. (3)

5.3.2. Frequency of the incident light that will emit electrons from the surface of the platinum with a maximum velocity of $5.6 \times 10^5 m.s^{-1}$. (4)

5.4 Which metal has the largest work function? Explain the answer. (3)

5.5 Name the physical constant represented by the slopes of the graphs. (1)

5.6 If light of the same frequency is shone on each of the metals, in which metal will the ejected photoelectrons have a larger maximum kinetic energy? (1)

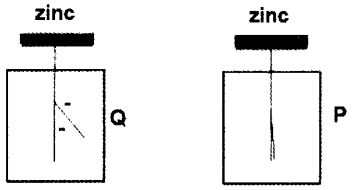
5.7 In a different photoelectric experiment blue light obtained from a light bulb is shone onto a metal plate and electrons are released.
The wavelength of the blue light has 470×10^{-9} m and the bulb is rated at 60 mW. The bulb is only 5% efficient.

5.7.1. Calculate the number of photons that will be incident on the metal plate per second, assuming all the light from the bulb is incident on the metal plate. (5)

5.7.2. Without any further calculation, write down the number of electrons emitted per second from the metal. (1)

QUESTION 6

6. You are investigating the photoelectric effect in your classroom. Two clean pieces of zinc metal are placed on the discs of the electroscopes P and Q. Electroscope P is neutral (leaves are not open), while electroscope Q is negatively charged (leaves are open).



White light is shone on the zinc metal of each electroscope, but **no change is observed** in either of them. However, if the white light replaced by the ultraviolet light and is then shone onto the zinc metal of each electroscope, the leaves of electroscopes Q close.

6.1 Give a reason for the behavior of the leaves of electroscope Q when ultraviolet light is shone onto the zinc. (2)

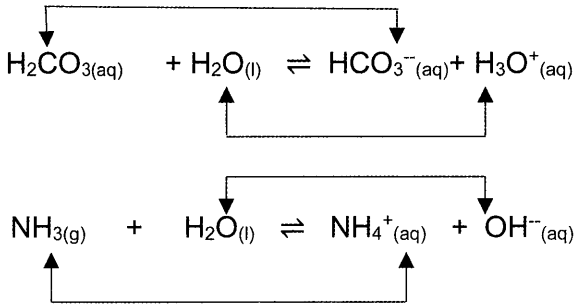
6.2 Describe what happens to the leaves of electroscope P when ultraviolet light is shone onto the zinc. (1)

6.3 Give a reason for your observation in QUESTION 6.2. (2)

6.4 Compare white light and ultraviolet light by referring to the electromagnetic spectrum and the frequency and energy of their photons. (3)

ACIDS AND BASES

Worked example 1: Conjugate acid -base pair



1. Write down the conjugate acid -base pairs
   1.1 $H_3PO_{4(aq)}$ + $H_2O_{(l)}$ ⇌ $H_3O^+{}_{(aq)}$ + $H_2PO_4^-{}_{(aq)}$
   1.2 $HS^-{}_{(aq)}$ + $H_2O_{(l)}$ ⇌ $H_2S_{(g)}$ + $OH^-{}_{(aq)}$
2. Write down the conjugate base of the following acids:
   2.1 H_2CO_3
   2.2 CH_3COOH
   2.3 HX

Worked example 2

1. calculate the pH of 0.1mol.dm^{-3} of HCl

$HCl_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + Cl^-_{(aq)}$

Ratio HCl : H_3O^+

1 : 1

pH = -log [H_3O^+]
pH = -log([0.1)
pH = 1

2. calculate the pH of 0,02 mol.dm^{-3} H_2SO_4

$H_2SO_{4(aq)} + H_2O_{(aq)} \rightleftharpoons 2H_3O^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

Ratio H_2SO_4 : H_3O^+

1 : 2

pH = -log [H_3O^+]
pH = -log([0.04)
pH = 1.40

Auto-ionisation of water

$H_2O_{(l)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$

Equilibrium constant of water(K_w)

$K_w = [H_3O^+][OH^-] = 1x10^{-14}$

Calculating the pH of a base

1. Calculate the pH of a 0.1 mol.dm^{-3} of KOH.

[KOH] = [OH^-]
$[H_3O^+][OH^-] = 1x10^{-14}$
$[H_3O^+](0.1 = 1x10^{-14}$
$[H_3O^+] = 1x10^{-13}$ mol.dm^{-3}

pH = -log [H_3O^+]
pH = -log($1x10^{-13}$)
pH = 13

Worked example 3

A standard solution is prepared by adding 4.5 g of oxalic acid into a 250 cm^3 of distilled water. 25 cm^3 of this solution is then neutralised by 20 cm^3 of sodium hydroxide. The balanced equation for the reaction is

$(COOH)_{2(aq)} + 2NaOH_{(aq} \rightarrow (COONa)_{2(s)} + 2H_2O_{(l)}$

1. What is meant by standard solution?

2. Will the pH of solution at the end point be less than 7, greater than 7 or equal to 7? Justify your answer with a relevant equation.
3. Write down a suitable indicator for the above titration
4. Calculate the concentration of sodium hydroxide neutralised by 25cm^3 of this standard solution

Solution

1. Is a solution of known concentration
2. Greater than 7
   $C_2O_4^{2-}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons C_2HO_4^-{}_{(aq)} + OH^-{}_{(aq)}$
3. Phenolphthalein
4. n = $\frac{m}{M}$
   = 4.5/90
   = 0.05 mols
   25/250 X 0.05
   0.005 mols
   Ratio (COOH)2 : NaOH
   1 : 2
   2 n(NaOH) = 0.01 mol

c = n/v

= 0.01/0.02

= 0.5 mol.dm^{-3}

Worked Example 4: percentage purity

Learners conduct an experiment to find the percentage purity of calcium carbonate. They add 3,5 g sample of calcium carbonate to a 100 cm^3 of a 0.5 mol.dm^{-3} of hydrochloric acid solution. The equation for this reaction is

$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(s)} + H_2O_{(l)} + CO_{2(g)}$

Step 1: c = $\frac{n}{v}$

0,5 = $\frac{n}{0,1}$

n = 0,05 mol

step 2: you must not convert 3.5 g mass to number of moles since it is impure.

Step 3: ratio $CaCO_3$: HCl

1 : 2

n(0,025) : 0,05

step 4: $n = \frac{m}{M}$

$0{,}025 = \frac{m}{100}$

$m = 2{,}5\ g$

percentage purity = $\frac{pure}{impure} \times 100$

$= \frac{2.5}{3.5} \times 100$

$= 71.43\%$

ACTIVITIES

Question 1: Titration

1. During a titration experiment 0.2 mol.dm^{-3} nitric acid with a volume of 50cm^3 react with 0.5 mol.dm^{-3} of sodium hydroxide with volume of 80 cm^3.
   - 1.1 Will the nitric acid used be able to fully neutralize the solution of sodium hydroxide? Show your calculations. (5)
   - 1.2 Which indicator is suitable for the above titration? give a reason for your answer. (2)
   - 1.3 Calculate the pH at the end of the reaction (6)

Question 2

2. 2.1 Define a *strong acid*. (2)
   - 2.2 A solution of an unknown, monoprotic acid has a concentration of 0,01 mol·dm^{-3} and a pH of 3
     - 2.2.1 Calculate the concentration of the hydrogen ions in this solution. (2)
     - 2.2.2 How will the strength of this unknown acid compare to that of hydrochloric acid of the same concentration? Write down only *STRONGER THAN, WEAKER THAN* or *EQUAL TO* (1)
     - 2.2.3 Give a reason for your answer in *QUESTION 2.2.2* (2)
   - 2.3 Ammonium chloride is an example of a salt that can undergo hydrolysis.
     - 2.3.1 Define the underlined term. (2)
     - 2.3.2 Write an equation to show the hydrolysis of ammonium chloride. (3)
     - 2.3.3 Methyl orange is red in an acidic medium and yellow in an alkaline medium. What will the colour of methyl orange be in an ammonium chloride solution? (2)
   - 2.4 A learner adds a sample of calcium carbonate to 50,0 cm^3 of sulphuric acid. The sulphuric acid is in excess and has a concentration of 1,0 mol·dm^{-3}. The balanced equation for the reaction that takes place is:
     $CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + CO_2 + H_2O$ .....
     The reaction is allowed to proceed until all the $CaCO_3$ is used up.

The H_2SO_4 **left over** from REACTION 1 is now neutralised by 28,0 cm^3 of a 0,5 $mol \cdot dm^{-3}$ sodium hydroxide solution.
The balanced equation for this reaction is:
$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$ .....
Calculate the **mass** of calcium carbonate in the sample in REACTION 1. (10)

[24]

Question 3

3.1 Sulphuric acid is a strong acid and an example of an <u>acid which can donate *protons per molecule two.*</u>

3.1.1 Write down one word or term for the underlined phrase.
The equations below represent the ionisation of sulphuric acid.

Equation **I**: $H_2SO_4(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HSO_4^-(aq)$
Equation **II**: $HSO_4^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + SO_4^{2-}(aq)$ (1)

3.1.2 Write down the FORMULA of a species that acts as ampholyte in the above reactions. (1)

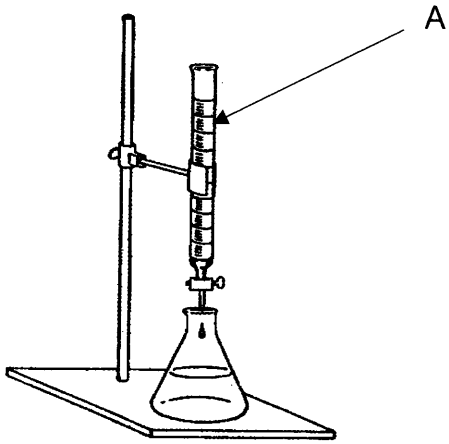
3.1.3 Write down the NAME of the conjugate base of the hydrogen sulphate ion (1)

3.2 A learner adds an impure sample of sodium carbonate into a flask containing 50 cm^3 of a hydrochloric acid solution with a pH = 0. The hydrochloric acid is in excess. The balanced equation for the reaction that takes place is:
$Na_2CO_{3(s)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(s)} + CO_{2(g)} + H_2O_{(l)}$

3.2.1 Calculate the number of moles of hydrochloric acid present in the flask. (5)

3.2.2 Write down a balanced equation that explains why a sodium carbonate solution has a pH greater than 7. (3)

3.2.3 The apparatus illustrated below is used during a titration to determine the mass of sodium carbonate present in the sample.
Write down the name of the apparatus labelled **A**.



(1)

3.2.4 During the titration, the excess hydrochloric acid is neutralised by 30 cm^3 of a 0,4 $mol.\ dm^{-3}$ sodium hydroxide solution. Calculate the mass of sodium carbonate in the sample. (6)

[18]

Question 4

4. You are given the following ionisation reaction of ethanoic acid in water:
$CH_3COOH\ (aq) \rightleftharpoons CH_3COO^-\ (aq) + H^+\ (aq)$ $K_a=1,8 \times 10^{-5}$

4.1 What does the ionisation constant indicate about the strength of the acid?

Ka is very low therefore acid is weak (1)

4.2 What is meant by a *concentrated acid*?

More acid in proportion to the volume of water (2)

4.3 $H_2PO_4^{--}$ → is an ampholyte. (2)

Write an equation to indicate its role as a base.

$H_2PO_4^{--}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3PO_{4(aq)} + OH^-{}_{(aq)}$

4.4 Write down a conjugate acid/base pair from your equation in QUESTION 4.3. (1)

$H_2O \rightarrow OH^-$

4.5 Milk of Magnesia has been used over the ages to relieve stomach ailments caused by excess stomach acid. The active ingredient in Milk of Magnesia is magnesium hydroxide ($Mg(OH)_2$).
A group of learners prepare a solution of magnesium hydroxide.

4.5.1 What mass of $Mg(OH)_2$ must be dissolved in distilled water to prepare 500 cm^3 of a solution with a concentration of 0,20 $mol{\cdot}dm^3$? (5)

c= m/Mv
0.2 =m/(58)(0.5)
m = 5.8 g

4.5.2 What will the concentration of the hydroxide ions in the solution be? Assume 100% dissociation of magnesium hydroxide in water. (2)

$[OH^-] = 2(0.20)$
$[OH^-] = 0.4\ mol.dm^{-3}$

4.5.3 The pH of any medicine safe for human consumption must lie between pH = 4 and pH =9.
Will this solution that the learners prepare be safe for human consumption? Show all calculations. (5)

$[H_3O^+][OH^-] = 1 \times 10^{-14}$
$[H_3O^+](0.4) = 1 \times 10^{-14}$
$[H_3O^+] = 2,5 \times 10^{-14}$
pH = 13.60

5. Anhydrous oxalic acid is an example of a diprotic acid and thus ionises in two steps as represented by the equations below:
I: $(COOH)_2\ (aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + H(COO)^-\ (aq)$
II: $H(COO)^-\ (aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + (COO)^{2-}\ (aq)$

5.1 Write down:

5.1.1 what is meant by a diprotic acid ? (1)

5.1.2 the FORMULAE of each of the TWO bases in reaction II. (2)

5.1.3 the FORMULA of the substance that acts as an ampholyte in reactions I and II. (1)

5.1.3 the FORMULA of the substance that acts as an ampholyte in reactions I and II. (1)

5.2 "*Oxalic acid is a weak acid and thus will always form a dilute solution.*"

5.2.1 Is a weak acid always a dilute acid? (1)

5.2.2 Explain your answer to QUESTION 5.2.1 (2)

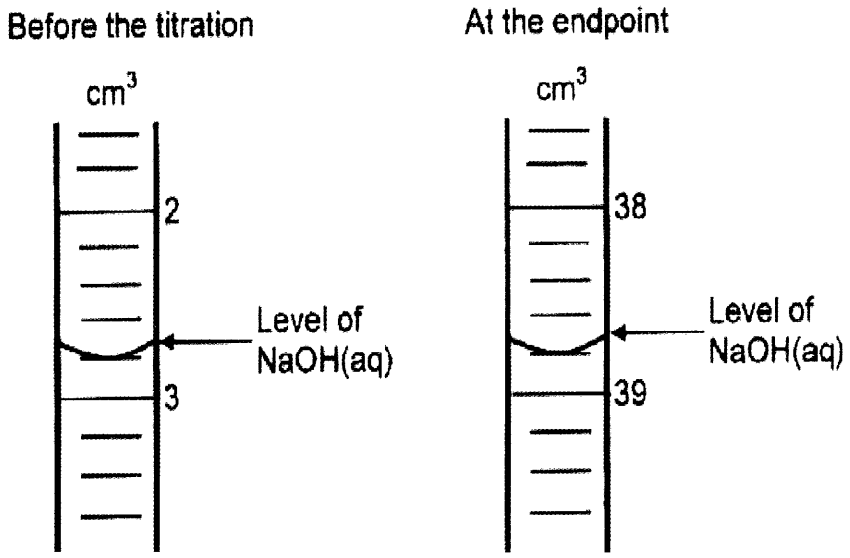
5.3 A standard solution of $(COOH)_2$ of concentration 0,2 mol·dm^{-3} is prepared by dissolving a certain amount of hydrous oxalic acid, $(COOH)_2 \cdot 2H_2O$, in water in a 250 cm^3 volumetric flask. Calculate the mass of oxalic acid needed to prepare the standard solution. (4)

5.4 During a titration 25 cm^3 of the standard solution of $(COOH)_2$ prepared in QUESTION 5.3 is neutralised by a sodium hydroxide solution from a burette.

The balanced equation for the reaction is:

$$(COOH)_2\,(aq) + 2\,NaOH\,(aq) \rightarrow (COONa)_2\,(aq) + 2\,H_2O\,(l)$$

The diagrams below show the burette readings before the titration commenced and at the endpoint respectively.



5.4.1 Explain what is meant by the endpoint of a titration? (1)

5.4.2 Which indicator is most suitable for this titration? Choose from: *phenolphthalein / bromothymol blue / methyl orange*. (1)

5.4.3 Use the burette readings and calculate the concentration of the sodium hydroxide solution. (5)

5.4.4 What will be the pH of the solution at the endpoint? Write only *less than 7 / equal to 7 / greater than 7.* (1)

5.4.5 Write down a balanced equation that explains your answer to QUESTION 5.4.4. (3)

5.4.6 Use the answer obtained in *QUESTION 5.4.3* to calculate the pH of the sodium hydroxide solution. (4)

[26]

6. Two beakers, A and B contain strong bases.

Beaker A: 500cm^3 of barium hydroxide, $Ba(OH)_2$ (aq) of unknown concentration X beaker

Beaker B: 400cm^3 of KOH(aq) of concentration 0,1 mol.dm3

6.1 Define a base according to Arrhenius theory (2)

6.2 Calculate the number of moles of hydroxide ions (OH^-) in beaker B (2)

7. A certain species of fish cannot survive in water having a pH less than 5,5. In a river the hydrogen ion concentration was measured to be 3,2 x 10-5 mol·dm^{-3} .

7.1 Will this species of fish survive in this river? Show clearly how you arrived at the answer.

7.2 A certain compound has ammonium chloride as the main ingredient. A group of learners investigated the amount of ammonium chloride present in a sample of the compound. The learners added 100 cm^3 of a 1,0 mol·dm^{-3} solution of sodium hydroxide to the sample in a flask.

7.2.1 Calculate the amount (in moles) of sodium hydroxide. This mixture was warmed to remove the ammonia formed. The excess sodium hydroxide was then neutralised through a titration by 45 cm^3 of a 0,3 mol·dm^{-3} sulphuric acid solution. The relevant equations are:

$$NH_4^+(aq) + OH^-(aq) \rightleftharpoons NH_3(g) + H_2O(\ell)$$

$$2NaOH(aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(\ell)$$

Calculate the following:

7.2.2 The number of moles of sodium hydroxide that was neutralised by the sulphuric acid solution

7.2.3 The mass (in gram) of ammonium chloride in the sample. The following indicators are available for the titration.

Indicator	pH range in which the colour changes
Methyl orange	3,2 – 4,4
Bromothymol blue	6,0 – 7,6
Phenolphthalein	8,2 – 10,0

7.2.4 Select from the list and write down the best indicator to use for this investigation.

7.2.5 Give a reason for your choice in QUESTION 8.2.4.

ELECTROCHEMISTRY

WORKED EXAMPLES

Question 1

1.1 Consider the electrochemical cell represented by the cell notation below, where X is an unknown metal: Pt(s) | Fe^{2+}(aq), Fe^{3+}(aq) || X^{+}(aq) | X(s) The cell potential of this cell was found to be 0,03 V.

1.1.1 Write down the type of electrochemical cell illustrated above. (1)

1.1.2 What does the single line (|) in the above cell notation represent? (1)

1.1.3 Write down the half-reaction that takes place at the anode in the above cell. (2)

1.1.4 Identify X with the aid of a calculation. (5)

1.2 A Pt(s) | Fe^{2+}(aq), Fe^{3+}(aq) half-cell is connected to a Cu(s) | Cu^{2+}(aq) half-cell.

Write down:

1.2.1 The chemical symbol for the electrode in the cathode half-cell. (1)

1.2.2 The NAME of the oxidising agent. (1)

1.2.3 The overall balanced cell reaction that takes place in this cell. (3)

[14]

SOLUTIONS

1.1 1.1.1 Galvanic cell ✓

1.1.2 Indicates phase boundary/ interphase / phase separator. ✓

1.1.3 $Fe^{2+} \rightarrow Fe^{3+} + e^-$ ✓✓

1.1.4 $E^{\ominus}cell = E^{\ominus}reduction - E oxidation$ ✓

0,03 ✓ $= E^{\ominus}reduction - (0,77)$ ✓

$E^{\ominus}reduction = 0,80$ V ✓

$= E^{\ominus}$ X / X^+

∴ X = Silver/Ag✓

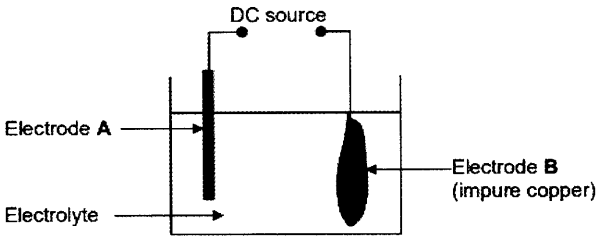
1.2.1 Pt ✓ (1)

1.2.2 Iron (III) (ions)/ ferric ions ✓ (1)

1.2.3 $2Fe^{3+} + Cu$ ✓$\rightarrow 2Fe^{2+} + Cu^{2+}$✓ balancing ✓ (3)

Question 2

2. The simplified diagram below represents an electrochemical cell used for the purification of copper.



2.1 Define the term electrolysis. (2)

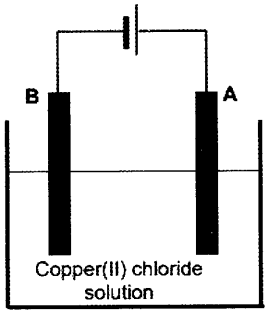
2.2 Give a reason why a direct-current (DC) source is used in this experiment. (1)

2.3 Write down the half-reaction which takes place at electrode (2)

2.4 Due to small amounts of zinc impurities in the impure copper, the electrolyte becomes contaminated with Zn^{2+} ions. Refer to the attached Table of Standard Reduction Potentials to explain why the Zn^{2+} ions will not influence the purity of the copper obtained during this process. (3)

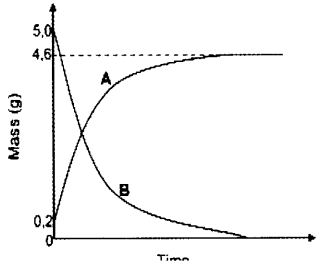
QUESTION 3

The electrochemical cell below is set up to demonstrate the purification of copper.



3.1 Write down the type of electrochemical cell illustrated above. (1)

The graph below represents the changes in mas that occur at electrode A and electrode B in an electrolytic cell during purification of copper.



3.2 Define electrolysis.

3.3 Which graph, A or B, represents the change in mass of the anode during electrolysis? Motivate your answer.

3.4 Write down the equation of the half-reaction that takes place at the cathode of this cell.

3.5 Use the information in the graph to calculate the percentage purity of the impure copper.

SOLUTIONS

3.1 Electrolytic cell ✓

3.2 The chemical process by which electrical energy is converted to chemical energy.✓✓ OR The use of electrical energy to produce a chemical change.

3.3 B. ✓ The anode where oxidation takes place will be eroded and becomes small in size. ✓

3.4 $Cu^{2+} + 2e^- \rightarrow Cu$ ✓✓

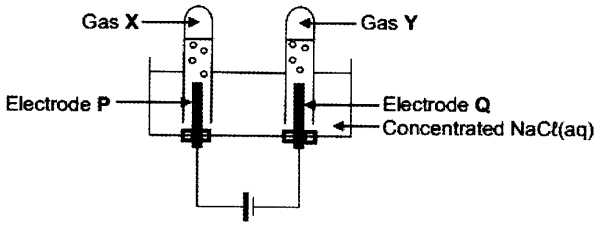
3.5 % Purity = $\frac{m(Cu)}{\text{impure } m(Cu)}$ x 100 %

$= \frac{4,4✓}{5✓}$ x 100 ✓

% Purity = 88%✓

Question 4

In the electrochemical cell below, carbon electrodes are used during the electrolysis of a concentrated sodium chloride solution.



The balanced equation for the net (overall) cell reaction is: $2H_2O(\ell) + 2C\ell^-(aq) \rightarrow C\ell_2(g) + H_2(g) + 2OH^-(aq)$

4.1 Is the reaction EXOTHERMIC or ENDOTHERMIC? (1)

4.2 Is electrode P the ANODE or the CATHODE? Give a reason for the answer. (2)

4.3 Write down the:

4.3.1 NAME or FORMULA of gas X (1)

4.3.2 NAME or FORMULA of gas Y (1)

4.4 Is the solution in the cell ACIDIC or ALKALINE (BASIC) after completion of the reaction? Give a reason for the answer. (2)

[9]

SOLUTIONS

4.1 Endothermic ✓ (1)

4.2 Anode ✓ connected to the positive terminal of the battery.✓ (2)

4.3 4.3.1 Chlorine gas / $C\ell_2$ ✓ (1)

4.3.2 Hydrogen gas /H_2 ✓ (1)

4.3.3 $2H_2O(\ell) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ ✓✓ (2)

4.4 Basic / alkaline ✓ OH− ions form / NaOH forms✓ (2)

[9]

Question 5

5. An electrochemical cell is constructed using the following half reactions:

$Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$ and $Au^{3+}(aq) + 3e^- \rightleftharpoons Au(s)$

5.1 Which is the anode and which the cathode?

5.2 What is the standard cell potential?

5.3 Calculate emf if the cell

Solution

5.1 Using our simple rule …

Anode – oxidation: Pb (lead)

5.2 Cathode – reduction: Au (gold)

5.3 $E^\circ_{cell} = E^\circ_{(cathode)} - E^\circ_{(anode)}$

$= + 1,50 - (-0,13)$

$= 1,63$ V

ACTIVITIES

QUESTION 1

1.1 Which of the following standard electrochemical cells would have the highest emf?

A $2I^- | I_2 || Ag^+ | Ag$

B $Cr | Cr^{2+} || Cu^{2+} | Cu$

C $Mg | Mg^{2+} || Mn^{2+} | Mn$

D Pb(s) | Pb^{2+}(aq) || Mg^{2+}(aq) | Mg(s) (2)

$Mg(s) \mid Mg^{2+}(aq) \parallel H^+(aq) \mid H_2(g) \mid Pt$. Which of the following half-reactions takes place at the cathode?

1.2 Which ONE of the following statements regarding an electrolytic cell is CORRECT?

A An electric current causes a chemical change to occur
B Reduction occurs at the anode
C A spontaneous chemical reaction produces an electric current
D Electrons flow to the electrode where oxidation occurs (2)

1.3 $Fe^{2+}(aq) + Zn(s) \rightarrow Zn^{2+}(aq) + Fe(s)$. Identify the reducing agent in this reaction.

A Fe(s)
B $Fe^{2+}(aq)$
C Zn(s)
D $Zn^{2+}(aq)$ (2)

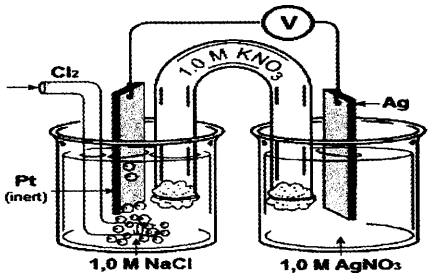
1.4 Which ONE of the following half-reactions occurs at the CATHODE during the electrolysis of a solution of $CuC\ell_2$?

A $C\ell_2 + 2e^- \rightarrow 2C\ell^-$
B $2C\ell^- \rightarrow C\ell_2 + 2e^-$
C $Cu \rightarrow Cu^{2+} + 2e^-$
D $Cu^{2+} + 2e^- \rightarrow Cu$ (2)

1.5 When a galvanic (voltaic) cell delivers current, the salt bridge …

A allows electrons to move in the cell.
B ensures electrical neutrality in the cell.
C prevents the two solutions from mixing.
D allows electrons to travel from the cathode to the anode.

1.6 The voltaic cell represented below functions at standard conditions. (2)
The diagram applies to this and the next two questions. Which of the following represents the anode half reaction?



A $Ag^+ + e^- \rightarrow Ag$
B $Ag \rightarrow Ag^+ + e^-$
C $2Cl^- \rightarrow Cl_2 + 2e^-$
D $Cl_2 + 2e^- \rightarrow 2Cl^-$ (2)

1.7 What changes in mass occur to the anode and cathode?

	Anode Mass	Cathode Mass
A	Increases	No change
B	Decreases	Increases
C	Decreases	No change
D	Increases	Decreases

(2)

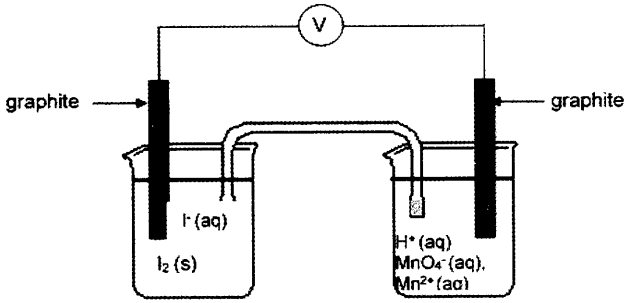
QUESTION 2

Consider a voltaic cell that is set up between aluminium (Al) and lead (Pb)

2.1 What metal will form the cathode of this cell? (1)
2.2 Name a suitable electrolyte for the lead half-cell. (1)
2.3 Which metal electrode will corrode during the operation of this cell? (1)
2.4 Write the anode, cathode and nett reaction for this cell.
2.4.1 Anode (2)
2.4.2 Cathode (2)
2.4.3 Nett (3)
2.5 Why are the iron (Fe) atoms oxidised but not the silver (Ag) and gold (Au) atoms? (2)
2.6 Give the cell notation for this cell (include standard conditions). (3)
2.7 Calculate the emf (E^o_{cell}) of this cell. (4)
2.8 What will happen to the emf of this cell as the cell reaction approaches equilibrium? (1)
2.9 How will the emf of the cell be affected if the concentration of Al^{3+} ions is increased in the aluminium half-cell? Explain. (2)

[20]

QUESTION 3:



3.1 Write down the concentration of H^+ (aq) in the one half-cell. (1)
3.2 Solids present in half-cells are usually used as electrodes. Give a reason why I_2(s) is not suitable to be used as an electrode. (1)
3.3 Write down TWO properties of graphite, other than being a solid, that makes it suitable for use as electrodes in the above voltaic cell (2)
3.4 For the above voltaic cell, write down the:
3.4.1 NAME of the oxidizing agent (1)

3.4.2 Net cell reaction (3)

3.4.3 Cell notation (3)

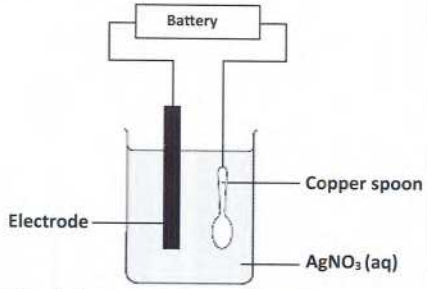
3.5 Calculate the cell potential of the above cell. (4)

3.6 How will the reading on the voltmeter be affected if the concentration of MnO_4^- decreases? Only write down INCREASES, DECREASES or NO EFFECT. (1)

[16]

QUESTION 4

Electroplating is one of the uses of electrolysis. The diagram below shows an electrolytic cell that can be used to plate a copper spoon with silver



4.1 Define the term *oxidation* in terms of electron transfer. (2)

4.2 What type of half-reaction takes place at the copper spoon? Write down only OXIDATION or REDUCTION. (1)

4.3 Write down a half-reaction that explains the change that occurs on the surface of the copper spoon during electrolysis. (2)

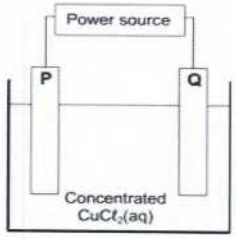
4.4 Name the metal that is labelled 'electrode'. (1)

4.5 Give a reason why the concentration of the $AgNO_3$(aq) remains constant during electrolysis. (2)

[8]

QUESTION 5

The simplified diagram below represents an electrochemical cell used to refine copper. One of the electrodes consists of impure copper



5.1 What type of power source, AC or DC, is used to drive the reaction in this cell? (1)

5.2 When an electric current passes through the $CuC\ell_2$ (aq), the mass of electrode P increases. Is electrode P the cathode or the anode? Write down the relevant half-reaction to support your answer. (3)

5.3 The impure copper contains zinc impurities that are oxidised to zinc ions. Refer to the relative strengths of oxidising agents to explain why zinc ions will not influence the quality of the pure copper produced in this cell. (3)

5.4 Electrodes P and Q are now replaced by carbon electrodes

5.4.1 What will be observed at electrode Q? (2)

5.4.2 How will the concentration of the electrolyte change as the reaction proceeds? Choose from increases, decreases or remains the same (2)

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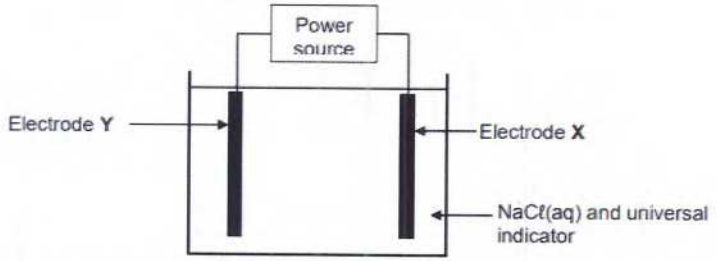
QUESTION 6

The apparatus below is used to demonstrate the electrolysis of a concentrated sodium chloride solution. Both electrodes are made of carbon. A few drops of universal indicator are added to the electrolyte. The equation for the net cell reaction is:

$$2NaC\ell(aq) + 2H_2O(\ell) \rightarrow C\ell_2(g) + H_2(g) + 2NaOH(aq)$$



Initially the solution has a green colour. Universal indicator becomes red in acidic solutions and purple in alkaline solutions.

6.1 Define the term electrolyte. (2)

When the power source is switched on, the colour of the electrolyte around electrode Y changes from green to purple.

6.2 Write down the:

6.2.1 Half-reaction that takes place at electrode Y (2)

6.2.2 NAME or FORMULA of the gas released at electrode X (1)

6.3 Refer to the Table of Standard Reduction Potentials to explain why hydrogen gas, and not sodium, is formed at the cathode of this cell. (2)

[7]