

PHYSICAL SCIENCES

GRADE 12

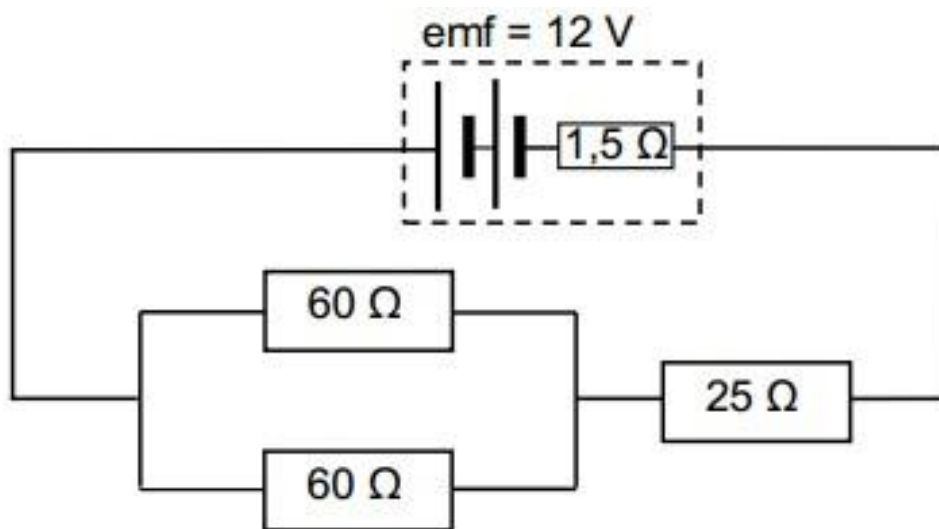
TERM 3

WEEKEND CLASSES 2017



*MOVING BEYOND THE LIMITS, SETTING THE STANDARD AND
LEAVING NO CHILD BEHIND*

ELECTRIC CIRCUITS



*MOVING BEYOND THE LIMITS, SETTING THE STANDARD AND
LEAVING NO CHILD BEHIND*

FORMULAE

$R = \frac{V}{I}$	$\text{emf } (\varepsilon) = I(R + r)$
$R_s = R_1 + R_2 + \dots$ $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$	$q = I\Delta t$
$W = Vq$ $W = VI\Delta t$ $W = I^2R\Delta t$ $W = \frac{V^2\Delta t}{R}$	$P = \frac{W}{\Delta t}$ $P = VI$ $P = I^2R$ $P = \frac{V^2}{R}$

TERMINOLOGY

1.1 The relationship between current, potential difference (voltage) and resistance at constant temperature

1.1.1 Resistance

Resistance is a measure of the opposing force which is applied to flow of charge in a circuit. Resistance in a wire is the opposition of a wire to the flow of charge. It is caused by collisions between the electrons and the atoms in the wire. Motors, light globes, and heating coils are all examples. The symbol used for resistance is R and it is measured in ohm (Ω).

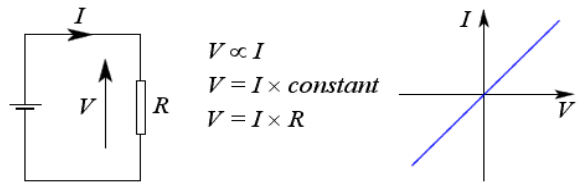
The resistance of the conductor depends on

- The type of material used
- The length of the conductor – the longer the conductor, the greater the resistance
- The thickness of the conductor – the thicker the conductor, the smaller the resistance
- The temperature of the conductor – the higher the temperature, the greater the resistance

1.1.2 Ohm's Law

The current (I) through a conductor is directly proportional to the potential difference (V) across it, provided the temperature remains constant.

The value $\frac{V}{I}$ is the resistance R of the conductor and is a constant.



$$\text{Resistance} = \frac{\text{potential difference}}{\text{current}}$$

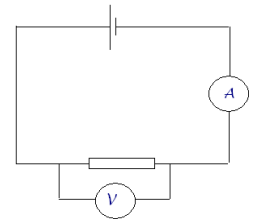
$$\text{In symbols: } R = \frac{V}{I}$$

1.2 Ohmic and non-ohmic conductors

Materials that obey Ohm's Law are often called **ohmic conductors** or **linear conductors**. A graph of current versus potential difference (voltage) of an ohmic conductor is a straight line through the origin. The gradient ($\frac{1}{R}$) is constant – thus the resistance is constant.

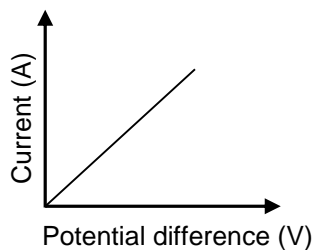
Metals and alloys obey Ohm's Law. Carbon is a non-metal that also obeys Ohm's Law. For most other materials the resistance is not a constant and changes with the applied potential difference (voltage). An example of a non-ohmic conductor is a tungsten light bulb.

We can easily measure potential difference (voltage) and current and then use the data to plot **current versus potential difference (voltage) graphs**. We use a circuit represented by the accompanying circuit diagram.

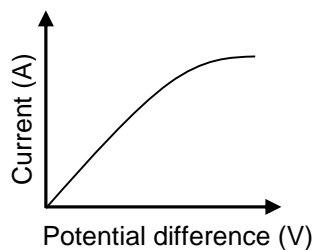


The current versus potential difference graph for an **Ohmic** conductor is a straight line through the origin. The straight line shows a **constant ratio** between current and potential difference - Ohm's Law is obeyed.

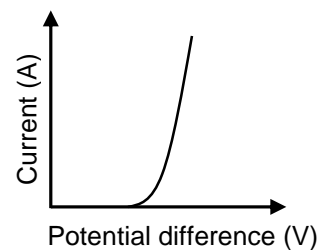
For a filament lamp the resistance does not remain constant, but **increases** as the filament gets **hotter**, which is shown by the **gradient getting steeper**. A filament lamp does not obey Ohm's law.



Ohmic conductor



Filament lamp



Diode

A **diode** only allows current to flow in one direction and only then it will only let current pass until a certain minimum voltage has been reached. However small increases in voltage after the minimum voltage result in large increases in current.

2. Resistance, equivalent resistance

2.1 Calculate the equivalent resistance of series and parallel arrangements of resistors.

Series Circuits

Resistances are arranged so that current must pass through each resistance, one after the other – current has no choice of path. There are no branches in the circuit, and hence the electricity can only travel in one route.

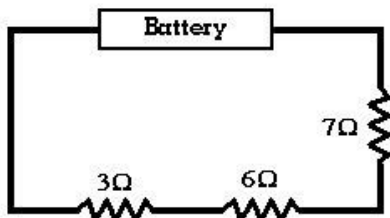
The total resistance is the sum of all the values for each individual resistor:

$$R_{total} = R_1 + R_2 + R_3 + \dots$$

The total resistance of a set of resistances in series will always be LARGER than the largest value resistor.

Example

Calculate the total resistance for the circuit represented by the circuit diagram below.



Answer: $R_t = 3 + 6 + 7 = 16 \Omega$

Effect of adding more resistors in series

- Total resistance increases
- Total voltage increases
- Total current decreases

Parallel Circuits

Resistances are arranged so that current has a choice of path through several resistances – the greatest current passing through the resistance of least value and the smallest current passing through the resistance of greatest value.

Parallel circuits are circuits which have more than one branch, or pathway which current can travel through.

The total resistance is the reciprocal of the sum of the reciprocals of each resistor.

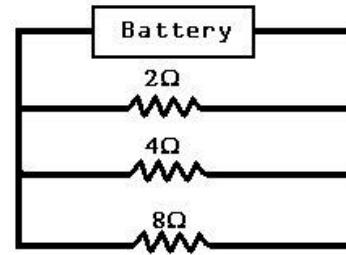
$$\frac{1}{R_{parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

Effect of adding more resistors in parallel

- Total resistance decreases
- Total voltage is the same
- Total current increases

Example

Calculate the total resistance for the given circuit



Answer:

$$\frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots = \frac{1}{2} + \frac{1}{4} + \frac{1}{8}$$

$$\therefore \frac{1}{R_{\text{total}}} = \frac{7}{8} \therefore R_{\text{total}} = \frac{8}{7} = 1,143 \Omega$$

2.2 Resistance for circuits containing arrangements of resistors in series and in parallel.

Resistance

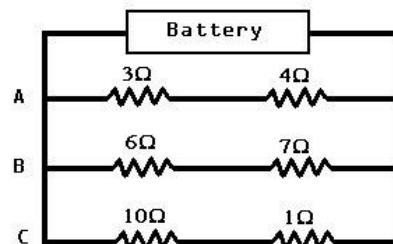
Step 1: For each individual series path, calculate the total resistance for that path using the series resistance formula.

Step 2: Using these values, then calculate the total resistance of the circuit using the parallel resistance formula.

Basically, just try to break the circuit up into portions of series and parallel, then calculate values for these portions, and use these values to calculate the resistance of the entire circuit.

Example

Calculate the total resistance for the given circuit.



Answer:

Resistance in path A: $R_A = 3 + 4 = 7 \Omega$

Resistance in path B: $R_B = 6 + 7 = 13 \Omega$

Resistance in path C: $R_C = 10 + 1 = 11 \Omega$

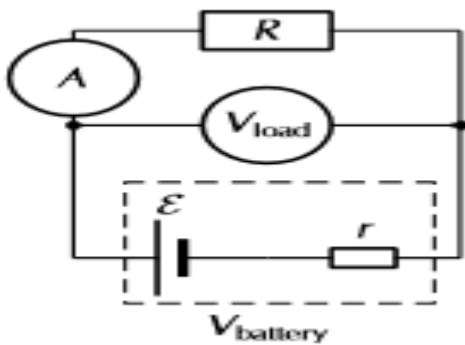
$$\frac{1}{R_{\text{total}}} = \frac{1}{7} + \frac{1}{13} + \frac{1}{11} \therefore R_T = 3,22 \Omega$$

INTERNAL RESISTANCE AND EMF

Internal resistance is the opposition to the flow of current with the cell/ battery due its chemical compasion.

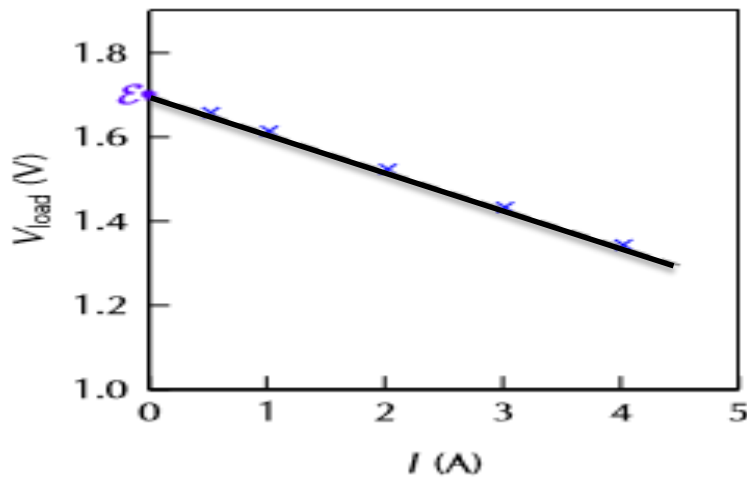
EMF is the total energy supplied per coulomb of charge that passes through the cell.

$$\mathcal{E} = V_{\text{load}} + V_{\text{internal resistance}} \text{ OR } \mathcal{E} = IR_{\text{ext}} + Ir$$



$$V = -Ir + \mathcal{E} \text{ in the form } y = mx + c ;$$

A graph of V versus I



$$\text{slope} = -r$$

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

Intercept on the v axis is the emf (\mathcal{E}) of the cell.

POWER

Power is the rate of doing work. The unit of power is Watt (W).

$$P = \frac{W}{t} \text{ now becomes } P = \frac{V.I.t}{t}$$

$$P = V.I$$

Which can be developed to:

$$P = I^2R$$

$$P = VI$$

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

From the equation $P = W/t$, $W = P \cdot t$ or energy = power multiplied by time.

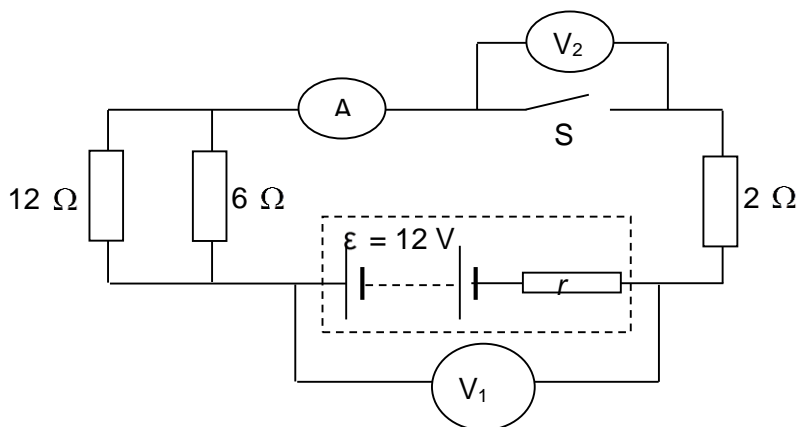
When ESCOM sells electrical energy to the consumer, the unit JOULE is too small a unit to use, so they rather use the KILOWATT.HOUR. This is still power multiplied by time, so it is an energy unit.

Example: If an oven of power 3 000W was run for 4h, it uses $3 \text{ kW} \cdot 4\text{h} = 12 \text{ kW} \cdot \text{h}$ or 12 UNITS of energy.

If this were charged out at 50c per unit: cost = $12 \text{ kW} \cdot \text{h} \times 50 \text{ c} \cdot \text{kW} \cdot \text{h}^{-1}$
 $= 600\text{c}$
 $= \text{R}6$

WORKED EXAMPLES

The battery in the circuit diagram below has an EMF of 12 V and an unknown internal resistance r . Voltmeter V_1 is connected across the battery and voltmeter V_2 is connected across the switch S . The resistance of the connecting wires and the ammeter is negligible.



1.1.1 Write down the respective readings on voltmeters V_1 and V_2 when switch S is open

Switch S is now closed. The reading on voltmeter V_1 changes to 9 V.

1.1.2 What will the new reading on V_2 be?

1.1.3 Calculate the total external resistance of the circuit.

1.1.4 Calculate the internal resistance, r , of the battery.

1.1.1 $V_1 = 12\text{ V} \checkmark$

$V_2 = 12\text{ V} \checkmark$

(2)

1.1.3 $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} \checkmark \therefore \frac{1}{R_p} = \frac{1}{12} + \frac{1}{6} \checkmark \therefore R_p = 4\ \Omega$

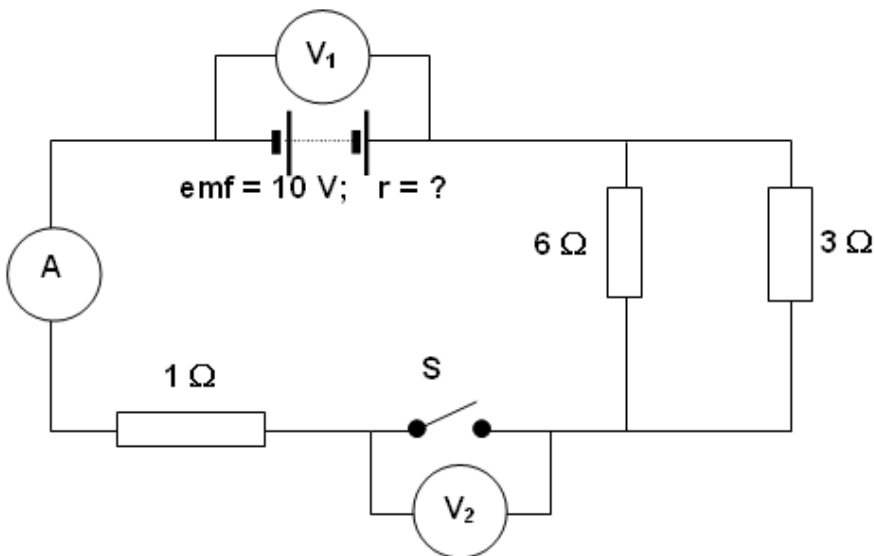
(+)

$R(\text{total}) = 4 + 2 \checkmark = 6\ \Omega \checkmark$

(1)

QUESTION 2

In the circuit represented below, the battery has an emf of 10 V and an unknown internal resistance. Voltmeter V_1 is connected across the battery and voltmeter V_2 is connected across the open switch S. The resistance of the connecting wires and ammeter can be ignored.



2.1 What is the reading on V_1 ?

2.2 What is the reading on V_2 ?

WHEN SWITCH S IS CLOSED, the reading on V_1 drops to 7,5 V.

2.3 What is the reading on V_2 ?

2.4 Calculate the reading on the ammeter.

2.5 Calculate the internal resistance of the battery.

SOLUTION

2.1 10 V

2.2 10 V

2.3 0 V

2.4

$$\frac{1}{R_p} = \frac{1}{R} + \frac{1}{R} \checkmark$$

$$= \frac{1}{6} + \frac{1}{3} \checkmark$$

$$R_p = 2 \Omega \checkmark$$

$$R_{\text{ext}} = R_1 + R_p = 1 + 2 = 3 \Omega$$

$$R_{\text{ext/ekst}} = \frac{V_1}{I} \checkmark$$

$$3 = \frac{7,5}{I} \checkmark$$

$$I = 2,5 \text{ A}$$

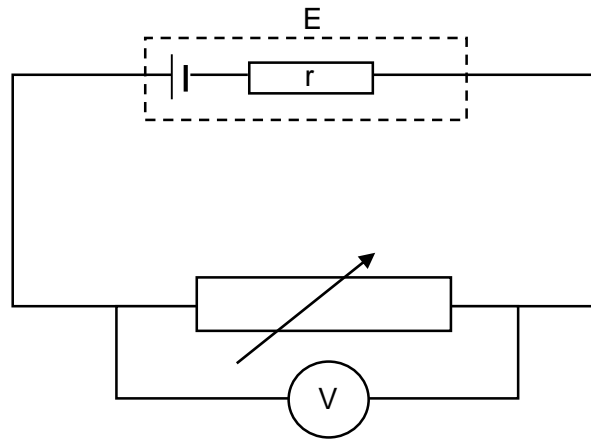
2.5 $\varepsilon = I(R + r)$

$10 = 2,5 (3 + r)$

$r = 0,83 \Omega$

QUESTION 3

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



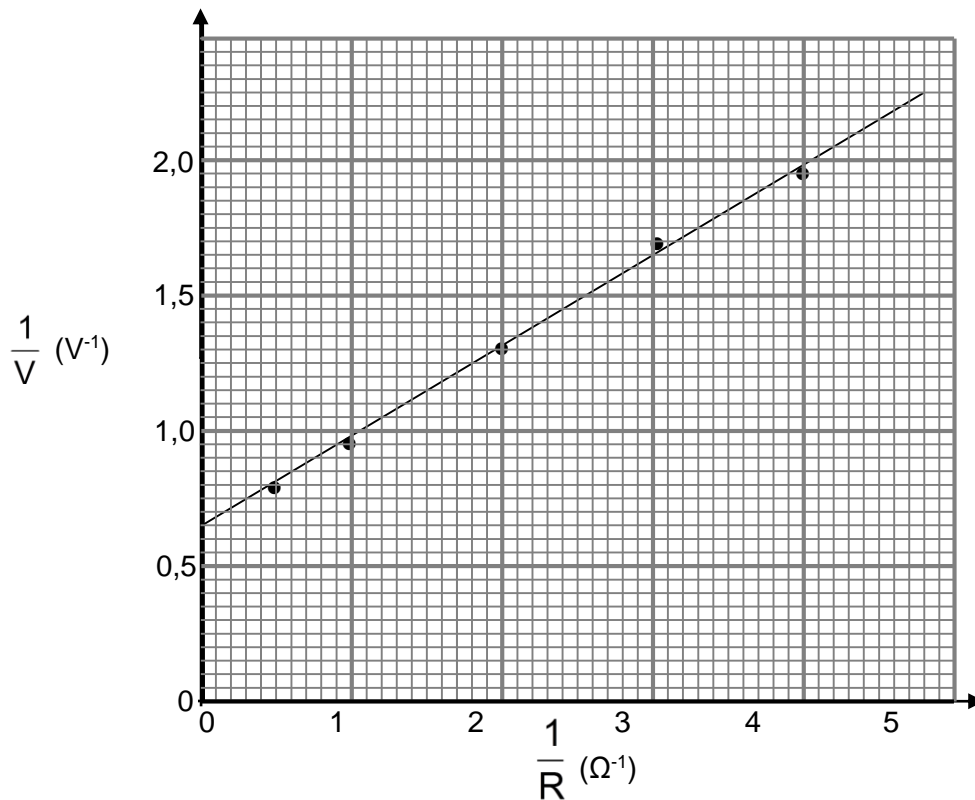
The circuit consists of a cell of emf E and internal resistance r . A voltmeter is placed across a variable resistor which can be set to *known values* R .

The equation used by the learners is:

$$\frac{1}{V} = \frac{r}{ER} + \frac{1}{E}$$

They obtain the graph below.

Graph of $\frac{1}{V}$ versus $\frac{1}{R}$



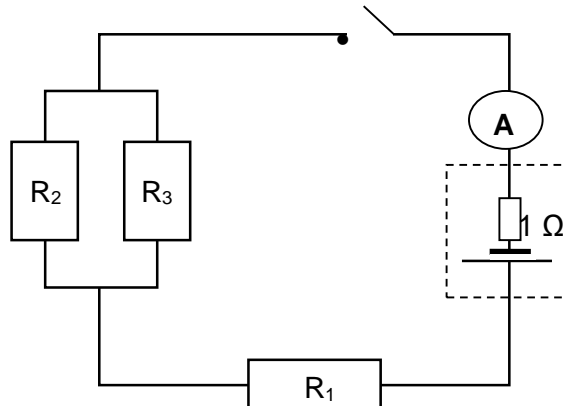
- 3.1.1 Write down a mathematical relationship for the slope of the graph. (1)

Use the information in the graph and calculate the:

3.1.2 Emf of the cell (2)

3.1.3 Internal resistance of the cell (3)

3.2 In the electrical circuit shown below, the battery has an emf of 6 V and an internal resistance of 1 Ω. The total external resistance of the circuit is 9 Ω.



3.2.1 Calculate the current in R_1 when the switch is closed. (3)

The power dissipated in resistor R_1 is 1,8 W. The resistance of resistor R_3 is 4 times that of resistor R_2 . ($R_3 = 4R_2$)

3.2.2 Calculate the resistance of resistor R_2 . (5)

3.3 A hair dryer operates at a voltage of 240 V and a current of 9,5 A.

It takes a learner 12 minutes to completely dry her hair. ESKOM charges energy usage at R1,47 per unit. Calculate the cost of operating the dryer for the 12 minutes. (1 unit = 1 kW·h)

(4)
[18]

SOLUTION

3.1

3.1.1 $\text{Slope} = \frac{r}{E} \checkmark$ (1)

3.1.2 $\frac{1}{E} = 0,65 \checkmark$
 $\therefore E = 1,54 \text{ V} \checkmark$ (2)

3.1.3 $\frac{r}{E} = \frac{2-1}{4-1} \checkmark$
 $\therefore r = 0,51 \Omega \checkmark$ (3)

3.2

$$\begin{aligned}
 3.2.1 \quad \text{Emf} &= I(R + r) \checkmark \\
 6 &= I(9 + 1) \checkmark \\
 \therefore I &= 0,6 \text{ A} \checkmark
 \end{aligned}$$

(3)

$$\begin{aligned}
 3.2.2 \quad P &= I^2 R \checkmark \\
 1,8 &= (0,6)^2 R_1 \checkmark \\
 R_1 &= 5 \Omega
 \end{aligned}$$

$$R_p = 9 - 5 = 4 \Omega \checkmark$$

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{4} = \frac{1}{R_2} + \frac{1}{4R_2} \checkmark$$

$$\therefore R_2 = 5 \Omega \checkmark$$

(5)

$$\begin{aligned}
 3.3 \quad W &= VI\Delta t \checkmark \\
 &= (9,5)(240)(12)(60) \checkmark \\
 &= 1,64 \times 10^6 \text{ J}
 \end{aligned}$$

$$\text{Cost} = \frac{1,64 \times 10^6}{3,6 \times 10^6} \times 1,47 \checkmark$$

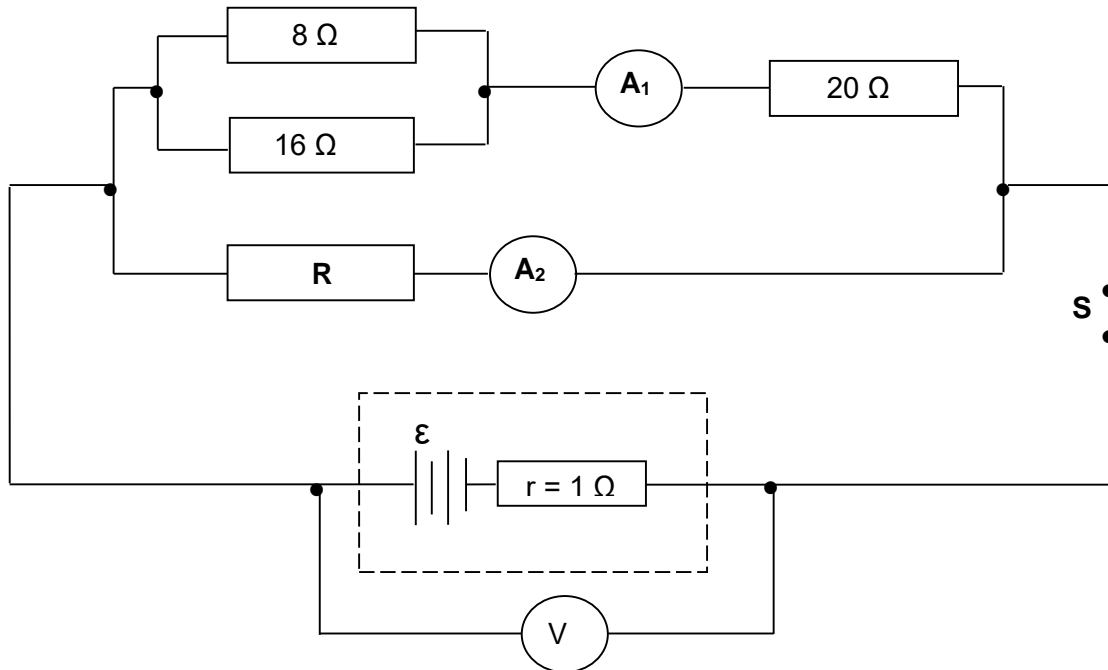
$$= R0,67 \text{ or/of 67 cents} \checkmark$$

(4)

[18]

QUESTION 4

A battery with an internal resistance of 1Ω and an unknown emf (ϵ) is connected in a circuit, as shown below. A high-resistance voltmeter (V) is connected across the battery. A_1 and A_2 represent ammeters of negligible resistance.



With switch S closed, the current passing through the 8Ω resistor is $0,5 \text{ A}$.

- 4.1 State Ohm's law in words. (2)
 - 4.2 Calculate the reading on ammeter A_1 . (4)
 - 4.3 If device R delivers power of 12 W , calculate the reading on ammeter A_2 . (5)
 - 4.4 Calculate the reading on the voltmeter when switch S is open. (3)
- [14]

SOLUTION

4.1 The potential difference across a conductor is directly proportional to the current in the conductor at constant temperature. (provided temperature and all other physical conditions are constant) **OR**

Ratio of potential difference to current is constant at constant temperature

Accept

The current in a conductor is directly proportional to the potential difference across the conductor at constant temperature. (provided temperature and all other physical conditions are constant)

4.2

<p><u>OPTION 1</u></p> $V = IR \checkmark$ $V_8 = (0,5)(8) \checkmark = 4 \text{ V}$ $V_8 = V_{16}$ $\therefore V_{16} = 4 \text{ V}$ $I_{16} = \frac{V}{R} = \frac{4}{16} = 0,25 \text{ A}$ $I_{\text{tot//}} = A_1 = (0,5 + 0,25) \checkmark = 0,75 \text{ A} \checkmark$	<p><u>OPTION 2</u></p> $V = IR \checkmark$ $V_8 = (0,5)(8) \checkmark = 4 \text{ V}$ $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$ $= \frac{1}{8} + \frac{1}{16} \checkmark$ $R = 5,33 \ \Omega$ $I_{\text{tot//}} = \frac{4}{5,33}$ $A_1 = 0,75 \text{ A} \checkmark$
<p><u>OPTION 3</u></p> $I_1 R_1 = I_2 R_2 \checkmark$ $(0,5)(8) = I_{16}(16) \checkmark$ $I_{16} = \frac{(8)(0,5)}{16} = 0,25 \text{ A}$ $I_{\text{tot//}} = A_1 = (0,5 + 0,25) \checkmark = 0,75 \text{ A} \checkmark$	<p><u>OPTION 4</u></p> $2R_{8\Omega} = R_{16\Omega} \checkmark$ $\therefore I_{R16} = \frac{1}{2} I_{R8} \checkmark$ $\therefore I_{R16} = \frac{1}{2} (0,5) = 0,25 \text{ A}$ $A_1 = (0,5 + 0,25) \checkmark = 0,75 \text{ A} \checkmark$

4.3

OPTION 1

$$V = IR$$

$$V_{20\Omega} = (0,75)(20) \checkmark = 15 \text{ V} \rightarrow$$

$$V_{//tot} = (15 + 4) \checkmark = 19 \text{ V}$$

$$V_R = 19 \text{ V}$$

$$P = VI \checkmark$$

$$12 = (19)I \checkmark$$

$$I_R = A_2 = 0,63 \text{ A} \checkmark$$

(5)

OPTION 2

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{8} + \frac{1}{16} \checkmark$$

$$R_{//} = 5,33 \Omega$$

$$R_{//} + R_{20} = (5,33 + 20) \checkmark = 25,33 \Omega$$

$$V_{//tot} = I(R_{//} + R_{20})$$

$$= (0,75)(25,33)$$

$$= 19 \text{ V}$$

$$P = VI$$

$$12 \checkmark = I(19) \checkmark$$

$$I_R = A_2 = 0,63 \text{ A} \checkmark$$

OR/OF

$$R_{//} = \frac{R_1 R_2}{R_1 + R_2} = \frac{8 \times 16}{8 + 16} \checkmark = 5,33 \Omega$$

(5)

OPTION 3

$$V = IR$$

$$V_{20\Omega} = (0,75)(20) \checkmark = 15 \text{ V} \rightarrow$$

$$V_{//tot} = (15 + 4) \checkmark = 19 \text{ V}$$

$$V_R = 19 \text{ V}$$

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

$$12 = \frac{(19)^2}{R}$$

$$R = 30,08 \Omega$$

$$P = I^2 R \checkmark$$

$$12 = I^2(30,08) \checkmark$$

$$I = 0,63 \text{ A} \checkmark$$

(5)

4.4

OPTION 1

$$(\varepsilon) = I(R + r) \checkmark$$

$$= V_{//tot} + V_{int}$$

$$= 19 + (0,75 + 0,63)(1) \checkmark$$

$$= 20,38 \text{ V} \checkmark$$

OPTION 2

$$V_{int} = Ir$$

$$= (0,75 + 0,63)(1) \checkmark$$

$$= 1,38 \text{ V}$$

$$\varepsilon = V_{//tot} + V_{int} \checkmark$$

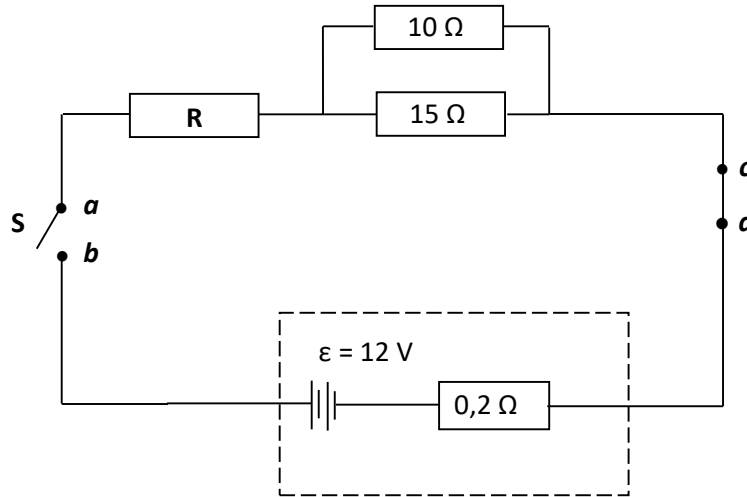
$$= 19 + 1,38$$

$$= 20,38 \text{ V} \checkmark$$

(3)

QUESTION 5

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



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

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

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

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

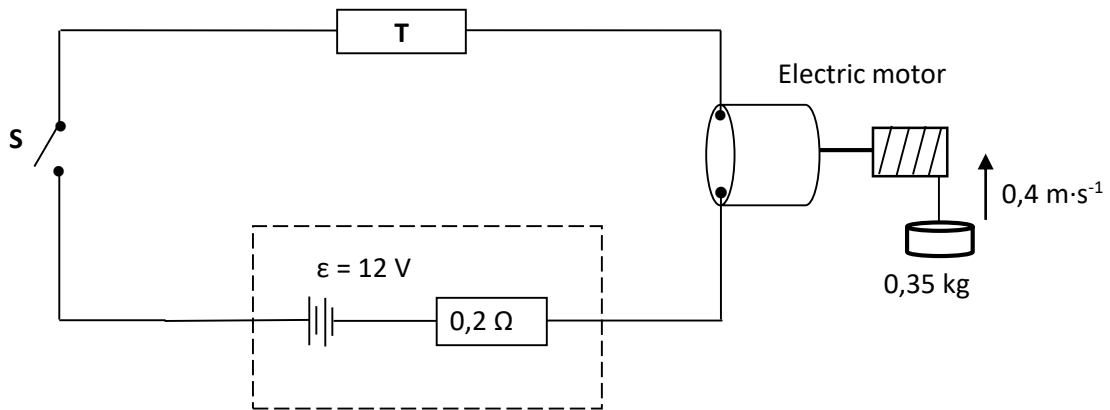
Calculate the:

5.1.4 Current in the battery (3)

5.1.5 Effective resistance of the parallel branch (2)

5.1.6 Resistance of resistor R (4)

- 5.2 A battery with an emf of 12 V and an internal resistance of 0,2 Ω are connected in series to a very small electric motor and a resistor, T, of unknown resistance, as shown in the circuit below.
The motor is rated X watts, 3 volts, and operates at optimal conditions.



When switch S is closed, the motor lifts a 0,35 kg mass vertically upwards at a constant speed of 0,4 m·s⁻¹. Assume that there is no energy conversion into heat and sound.

Calculate the value of:

- 5.2.1 X (5)
5.2.2 The resistance of resistor T [21]

SOLUTION

- 5.1.1 (Maximum) energy provided (work done) by a battery per coulomb/unit charge passing through it. ✓✓(2 or 0) (2)
- 5.1.2 12 (V)✓ (1)
- 5.1.3 0 (V) / Zero ✓ (1)
- 5.1.4 $\left. \begin{aligned} \epsilon &= I(R + r) \\ \epsilon &= V_{\text{ext}} + V_{\text{int}} \end{aligned} \right\} \checkmark$
 $12 = 11,7 + Ir$
 $\underline{0,3 = I_{\text{tot}}(0,2)} \checkmark$
 $I_{\text{tot}} = 1,5 \text{ A} \checkmark$
- OR
 $V = IR \checkmark$ (Accept/Aanvaar: $V_{\text{lost}} = Ir$)
 $\underline{0,3 = I_{\text{tot}}(0,2)} \checkmark$
 $I_{\text{tot}} = 1,5 \text{ A} \checkmark$ (3)

5.1.5

OPTION 1/OPSIE 1

$$\left. \begin{aligned} \frac{1}{R_{//}} &= \frac{1}{R_1} + \frac{1}{R_2} \\ \frac{1}{R} &= \frac{1}{10} + \frac{1}{15} \end{aligned} \right\} \checkmark \text{Any one}$$

$$R = 6 \Omega \checkmark$$

OPTION 2/OPSIE 2

$$\left. \begin{aligned} R_{//} &= \frac{R_1 R_2}{R_1 + R_2} \\ &= \frac{(10)(15)}{10 + 15} \end{aligned} \right\} \checkmark \text{Any one}$$

$$= 6 \Omega \checkmark$$

(2)

5.1.6

OPTION1

$$\begin{aligned} V &= IR \checkmark \\ 11,7 \checkmark &= \underline{1,5(6 + R)} \checkmark \\ R &= 1,8 \Omega \checkmark \end{aligned}$$

OR

$$\begin{aligned} V &= IR \checkmark \\ \underline{11,7 = 1,5R} \checkmark \\ R &= 7,8 \Omega \end{aligned}$$

$$\begin{aligned} &\downarrow \\ R_R &= 7,8 - 6 \checkmark \quad (\text{for subtraction}) \\ &= 1,8 \Omega \checkmark \end{aligned}$$

OPTION 2

$$\begin{aligned} \varepsilon &= I(R + r) \checkmark \\ \underline{12 = 1,5(R + 0,2)} \checkmark \\ R &= 7,8 \Omega \end{aligned}$$

$$\begin{aligned} &\downarrow \\ R_R &= 7,8 - 6 \checkmark \quad (\text{for subtraction}) \\ &= 1,8 \Omega \checkmark \end{aligned}$$

OPTION 3

$$\begin{aligned} V_{//} &= IR_{//} \checkmark \\ &= (6)(1,5) \checkmark \\ &= 9 \text{ V} \end{aligned}$$

$$\begin{aligned} V_R &= IR \checkmark \\ \underline{(11,7 - 9) = (1,5)R} \checkmark \\ R &= 1,8 \Omega \checkmark \end{aligned}$$

(4)

5.2.1

$$\begin{aligned} P_{\text{ave/gemid}} &= Fv_{\text{ave/gemid}} \checkmark = mg(v_{\text{ave/gemid}}) \\ &= (0,35)(9,8)(0,4) \checkmark \\ &= 1,37 \text{ W} \checkmark \end{aligned}$$

OR

$$P = \frac{W_{nc}}{\Delta t} \checkmark = \frac{\Delta E_k + \Delta E_p}{\Delta t} = \frac{0 + (0,35)(9,8)(0,4 - 0)}{1} \checkmark = 1,37 \text{ W} \checkmark$$

OR

$$P = \frac{W}{\Delta t} \checkmark = \frac{E_p}{\Delta t} = \frac{(0,35)(9,8)(0,4)}{1} \checkmark = 1,37 \text{ W} \checkmark$$

(3)

5.2.2

OPTION 1

$$P = VI$$

$$1,37 = (3)I \checkmark$$

$$I = 0,46 \text{ A}$$

$$\begin{aligned} \varepsilon &= V_{\text{ext}} + V_{\text{int}} \\ &= V_T + V_X + V_{\text{int}} \end{aligned}$$

$$12 = V_T + 3 + (0,2)(0,46) \checkmark$$

$$V_T = 8,91 \text{ V}$$

$$V_T = IR_T$$

$$8,91 = (0,46)R_T \checkmark$$

$$R_T = 19,37 \Omega \checkmark$$

✓ Any one

OPTION 2

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

$$1,37 = \frac{3^2}{R} \checkmark$$

$$R = 6,57 \Omega$$

$$P = VI$$

$$1,37 = (3)I \checkmark$$

$$I = 0,46 \text{ A}$$

$$\varepsilon = I(R + r)$$

$$12 = 0,46(6,57 + R_T + 0,2) \checkmark$$

$$R_T = 19,38 \Omega \checkmark$$

✓ Any one

OPTION 3

$$P = VI \checkmark$$

$$1,37 = (3)I \checkmark$$

$$I = 0,46 \text{ A}$$

$$P_{\text{tot}} = P_r + P_{\text{motor}} + P_T$$

$$(12)(0,46) \checkmark = (0,46)^2(0,2) + 1,37 + (0,46)^2 R_T \checkmark$$

$$R_T = 19,41 \Omega \checkmark$$

OR

$$P = VI \checkmark$$

$$1,37 = (3)I \checkmark$$

$$I = 0,46 \text{ A}$$

$$P_{\text{tot}} = P_r + P_{\text{motor}} + P_T$$

$$(12)(0,46) = (0,46)^2(0,2) + 1,37 + P_T \checkmark$$

$$P_T = 4,07 \text{ W}$$

$$P = I^2 R$$

$$4,07 = (0,46)^2 R_T \checkmark$$

$$R_T = 19,49 \Omega \checkmark$$

(19,33 Ω - 19,49 Ω)

OPTION 4/OPSIE 4

$$P = VI$$

$$1,37 = (3)I \checkmark$$

$$I = 0,46 \text{ A}$$

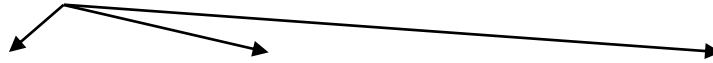
$$\varepsilon = I(R + r)$$

$$12 = (0,46)(R + 0,2) \checkmark$$

✓ Any one

(5)

$$R = 25,87 \Omega$$



$$V = IR$$

$$3 = (0,46)R \checkmark$$

$$R = 6,52 \Omega$$

$$R_T = 25,87 - 6,52 \\ = 19,35 \Omega \checkmark$$

$$P = I^2R$$

$$1,37 = (0,46)^2R \checkmark$$

$$R = 6,47 \Omega$$

$$R_T = 25,87 - 6,47 \\ = 19,4 \Omega \checkmark$$

$$P_{\text{motor}} = \frac{V^2}{R}$$

$$1,37 = \frac{3^2}{R} \checkmark$$

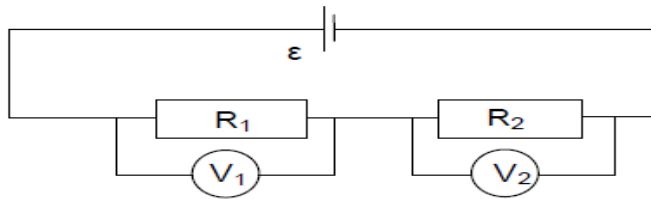
$$R = 6,56 \Omega$$

$$R_T = 25,87 - 6,56 \\ = 19,31 \Omega \checkmark$$

TYPICAL EXAM QUESTIONS

QUESTION 1 MULTIPLE CHOICE QUESTIONS

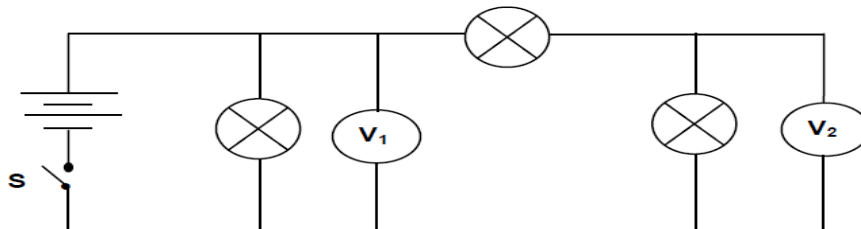
- 1.1 The diagram below shows a cell of emf (ϵ), and two resistors, R_1 and R_2 , in series, with $R_1 < R_2$. The cell has negligible internal resistance and the voltmeters have very high resistances.



Which ONE of the following is CORRECT?

- A $V_1 = V_2 = \epsilon$ B $V_1 > V_2$ C $\frac{V_1}{R_1} = \frac{V_2}{R_2}$ D $\frac{V_1^2}{R_1} > \frac{V_2^2}{R_2}$ (2)

- 1.2 Three identical light bulbs are connected in a circuit as shown below. The resistances of the battery and connecting wires can be ignored.

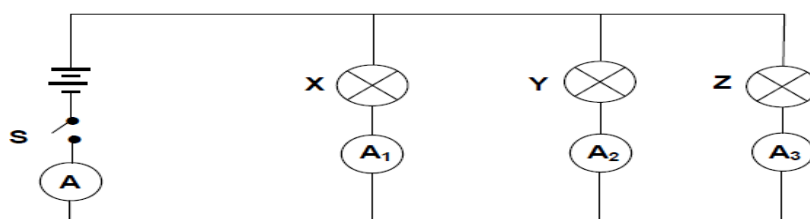


Which ONE of the following statements is CORRECT when switch S is closed?

The reading on V_1 is ...

- A half that on V_2 . B equal to that on V_2 .
C twice that on V_2 . D three times that on V_2 . (2)

- 1.3 Three light bulbs, X, Y and Z with resistances R , $2R$ and R respectively, are connected in a circuit as shown below. The battery has negligible internal resistance.



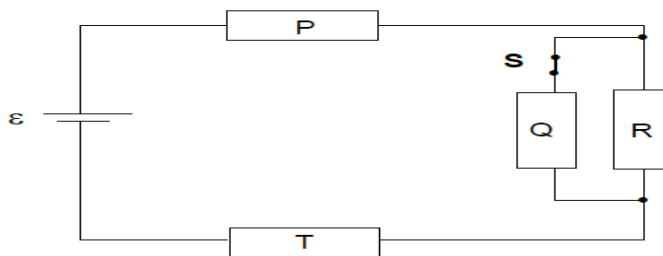
When switch S is closed, all the bulbs light up. The reading on ammeter A is 2,5 A.

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

	A₁	A₂	A₃	A
A	1,25	1,25	0	2,5
B	1,6	0,8	0,1	2,5
C	0,75	0,75	0	1,5
D	1	0,5	0	1,5

(2)

- 1.4 The four resistors P, Q, R and T in the circuit below are identical. The cell has an emf ϵ and negligible internal resistance. The switch is initially CLOSED.

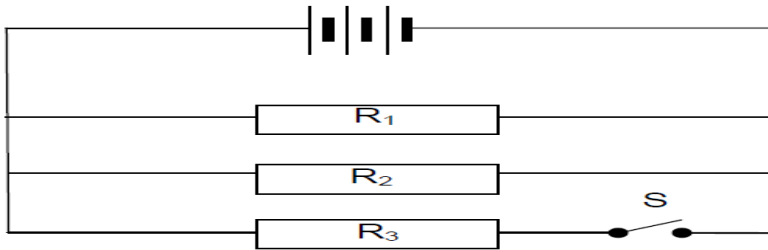


Switch S is now OPENED. Which ONE of the following combinations of changes will occur in P, R and T?

	CURRENT IN P	CURRENT IN R	CURRENT IN T
A	Decreases	Remains the same	Decreases
B	Increases	Remains the same	Increases
C	Increases	Increases	Increases
D	Decreases	Increases	Decreases

(2)

1.5 Consider the circuit diagram below.



Which ONE of the following correctly describes the change in total resistance and total current when switch S is closed?

	TOTAL RESISTANCE	TOTAL CURRENT
A	Decreases	Decreases
B	Increases	Increases
C	Decreases	Increases
D	Increases	Decreases

(2)

1.6 Two resistors of equal resistance are connected in SERIES to a battery with negligible internal resistance. The current through the battery is I .

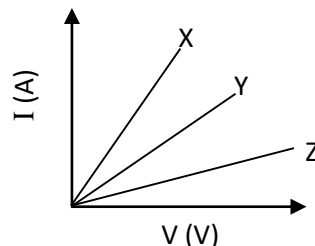
When the two resistors are connected in PARALLEL to the same battery, the current through the battery will be ...

A $\frac{1}{2}I$. B I . C $2I$. D $4I$ (2)

1.7 Learners investigate the relationship between current (I) and potential difference (V) at a constant temperature for three different resistors, X, Y and Z.

They obtain the graphs shown below.

The resistances of X, Y and Z are R_X , R_Y and R_Z respectively.

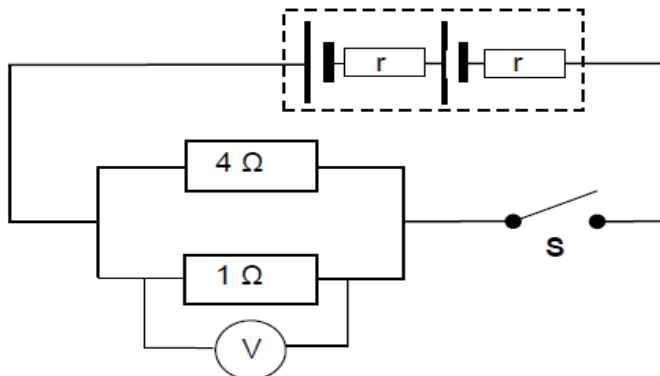


Which ONE of the following conclusions regarding the resistances of resistors is CORRECT? the

- A $R_z > R_Y > R_x$ B $R_X = R_Y = R_Z$
 C $R_X > R_Y > R_Z$ D $R_X > R_Y$ and $R_Y < R_Z$ (2)

QUESTION 2

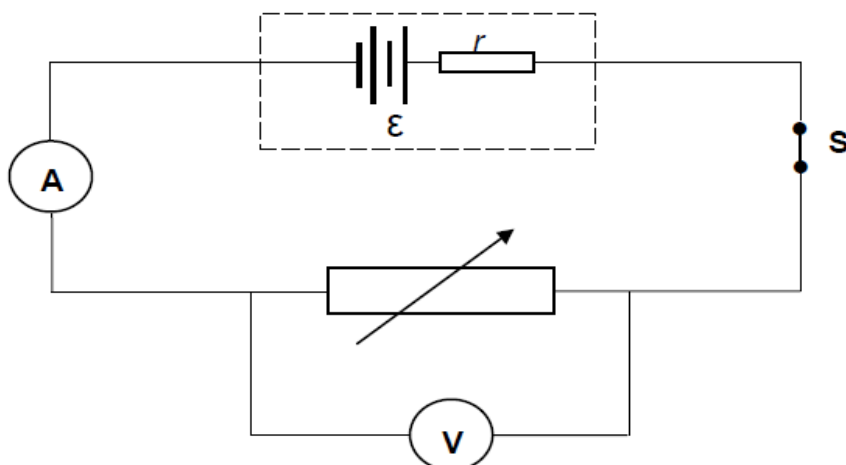
Two identical cells, EACH with an emf of 1,5 V and an internal resistance r , are connected in series with each other and to the resistors as shown below.



- 2.1 Define, in words, the term *electromotive force* (emf) (2)
 2.2 When switch **S** is closed, the potential difference across the 4 Ω resistor is 2,8 V.
 2.2.1 Calculate the total current in the circuit. (4)
 2.2.2 Calculate the internal resistance r of EACH cell. (5)

QUESTION 3

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



- 3.1.1 State ONE factor which must be kept constant during the experiment. (1)
 3.1.2 Using the information in the table above, plot the points and draw the line of best fit on the attached GRAPH SHEET. (3)

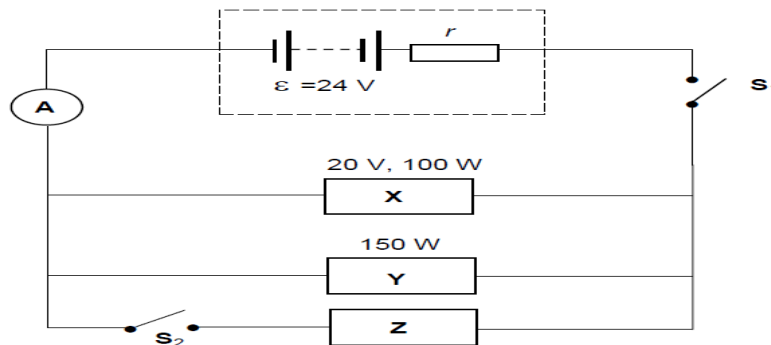
READING ON VOLTMETER (V)	READING ON AMMETER (A)
2	0,58
3	0,46
4	0,36
5	0,24
6	0,14

Use the graph drawn in QUESTION 3.1.2 to determine the following:

3.1.3 Emf of the battery ϵ (1)

3.1.4 Internal resistance of the battery (3)

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



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

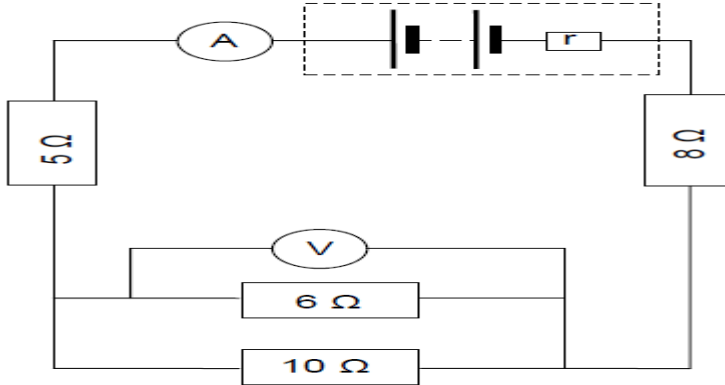
Calculate the:

3.2.1 Current in X (3)

3.2.3 Resistance of Y (3)

QUESTION 4

In the circuit represented below, a battery of emf 30 V and unknown internal resistance r are connected to resistors, as shown. Ignore the resistance of the ammeter and the connecting wires.



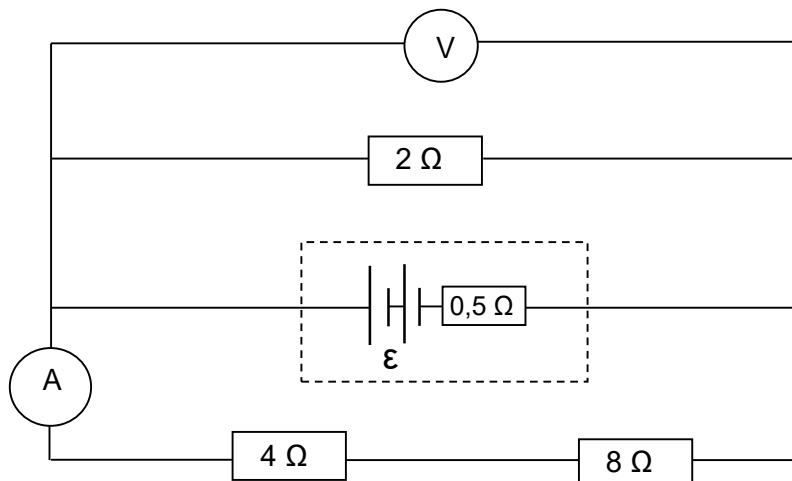
The current passing through the 10Ω resistor is $0,6 \text{ A}$.

Calculate the:

- 4.1 Equivalent resistance of the two resistors in parallel (3)
- 4.2 Current through the 8Ω resistor (3)
- 4.3 Internal resistance of the battery (5)

QUESTION 5

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



The reading on the ammeter is 0,2 A.

5.1 Calculate the:

5.1.1 Reading on the voltmeter (3)

5.1.2 Total current supplied by the battery (4)

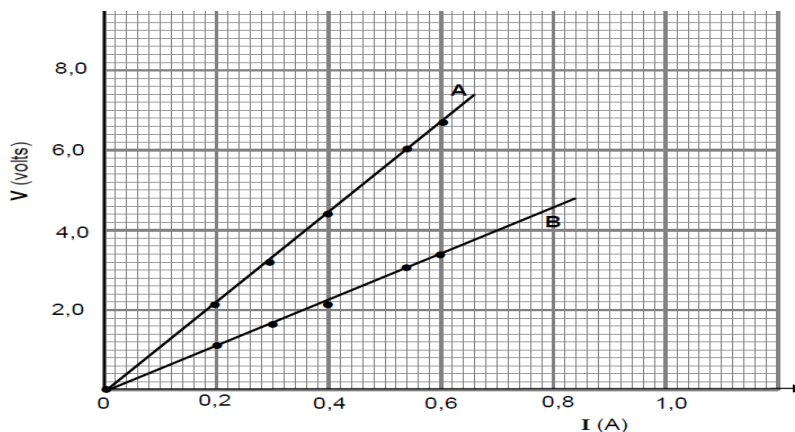
5.1.3 Emf of the battery (5)

5.2 How would the voltmeter reading change if the $2\ \Omega$ resistor is removed from the circuit? Write down INCREASE, DECREASE or REMAIN THE SAME. Explain the answer. (3)

QUESTION 6

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

Graph of V versus I for resistors A and B

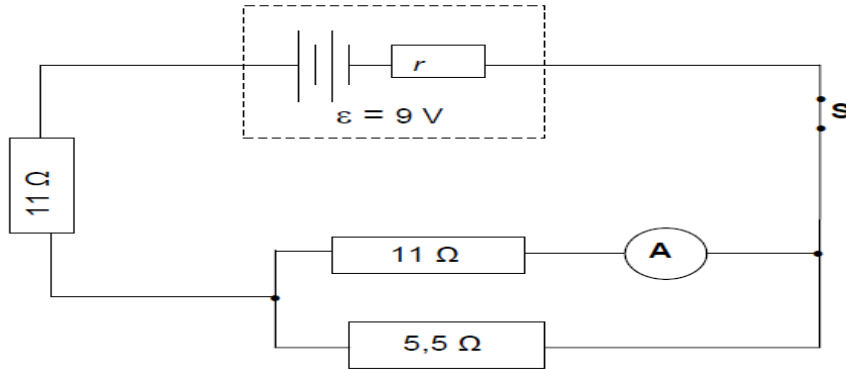


6.1.1 Apart from temperature, write down TWO other factors that the learners should consider to ensure a fair test when choosing which wire to use.

6.1.2 Assuming all other factors are kept constant, state which ONE of the two wires will be the most suitable to use in the heater.

Use suitable calculations to show clearly how you arrive at the answer.

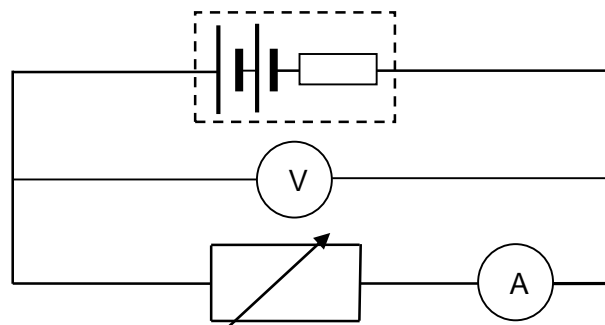
In the circuit below the reading on ammeter **A** is 0,2 A. The battery has an emf of 9 V and internal resistance r .



- 6.2 Calculate the current through the 5,5 Ω resistor.
 6.3 Calculate the internal resistance of the battery

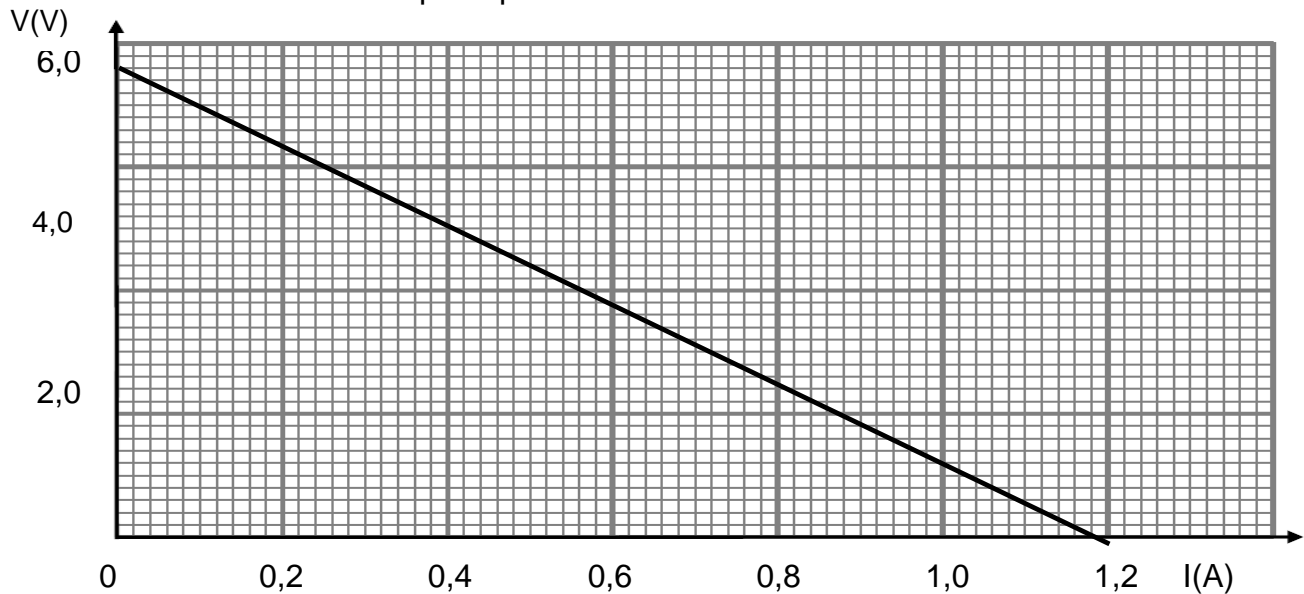
QUESTION 7

- 7.1 A group of learners conducts an experiment to determine the internal resistance of a battery. They connect the battery to a rheostat, an ammeter and a voltmeter as shown in the diagram below.



The data obtained are shown in the graph below.

Graph of potential difference versus current



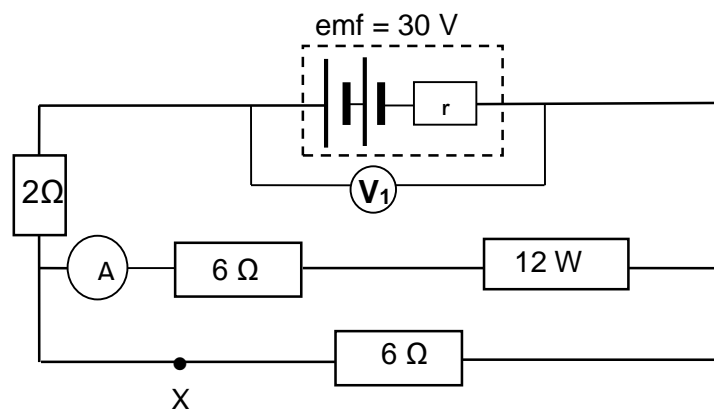
7.1.1 Explain the purpose of the rheostat. (2)

7.1.2 Name the independent variable in the experiment. (1)

7.1.3 What is the value of the emf of the battery? (1)

7.1.4 Calculate V_{internal} if the current in the circuit is equal to 0,8 A. (2)

7.2 Three resistors and an electrical device are connected to a 30 V battery with internal resistance r as shown in the circuit diagram below. The ammeter has a reading of 2 A.

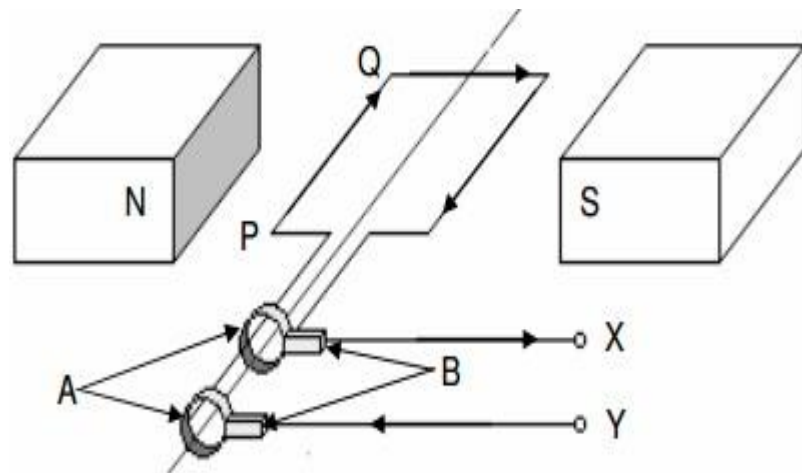


- 7.2.1 Define the term emf of a battery. (2)
- 7.2.2 Calculate voltmeter reading V_1 . (8)
- 7.2.3 Calculate the internal resistance of the battery. (3)
- 7.2.4 An additional resistor is connected at position X as indicated in the diagram. How will voltmeter reading V_1 be affected? Write down only INCREASE, DECREASE or STAYS THE SAME. (4)
- Give an explanation for your answer. (4)

PHYSICAL SCIENCES

GRADE 12

ELECTRICAL MACHINES



*MOVING BEYOND THE LIMITS, SETTING THE STANDARD AND
LEAVING NO CHILD BEHIND*

ELECTRICAL MACHINES

FORMULAE

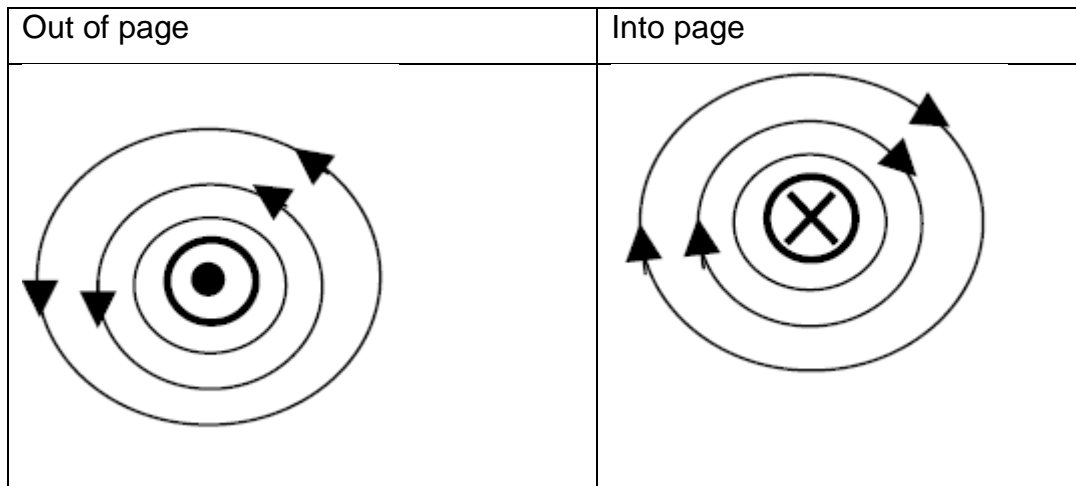
ALTERNATING CURRENT

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

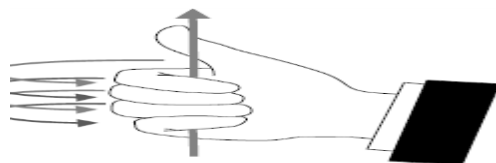
TERMINOLOGY

MOTOR EFFECT

There is a magnetic field a round all current carrying conductors

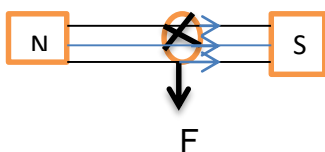


The direction of the magnetic field is given by Fleming left hand gripe/ right hand rule.



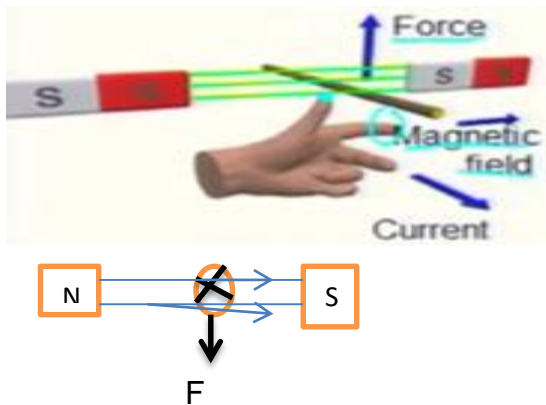
Place a current carrying conductor between two magnets.

The current carrying conductor experiences a force, due to interaction between the magnetic field due conductor and magnetic field due to the magnet



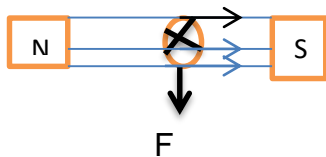
This effect/ principle is called the motor effect. It is through this principle that we get motors used in CD players, fans radios

Fleming's left hand rule (motor)



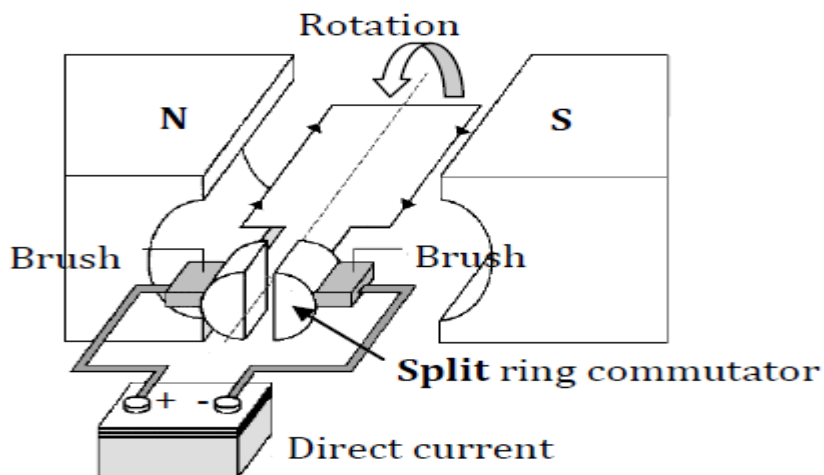
Right hand rule

If the right hand is stretched out with the four fingers pointing in the direction of the magnetic field and the thumb pointing in the direction of the convectional current, the perpendicular direction away from the palm of the hand will give the direction of the force experienced by the conductor.



DC motors

Motor converts electrical energy into mechanical energy.



- The split ring commutator serves as a change switch that reverses the current after every half revolution. (ensures continuous rotation of the coil)
- The brushes maintain electrical contact between the battery and the turning commutator.
- The current in the coil flows through the magnetic field in the opposite direction.
- The coil will therefore turn clockwise until it is vertical.

- In the vertical position, the gaps between the commutator segments are bridged by the brushes and the current is therefore short-circuit for a moment through the commutator, and no current flows in the coil.
- The momentum of the coil carries it past this position.
- As soon as the coil passes the vertical position, each one of the brushes makes contact with the other commutator segment.
- The direction of the current in the coil is therefore reversed and the coil continues turning.
- After every half revolution the current through the coil is reversed and in this way the coil continues turning clockwise.

The force experienced by the coil can be increased by

1. Increasing the number of turns on the coil
2. Increasing the current in the coil
3. Increasing the strength of the magnets

AC motors

An AC motor is very similar to a DC motor, except that the split ring commutator is replaced by a slip ring commutator and the current is now an alternating current and not a direct current.

ELECTRIC GENERATORS

Use steam, gas, wind or water to turn the turbine.

Turbines turns a coil relative to the magnetic field .

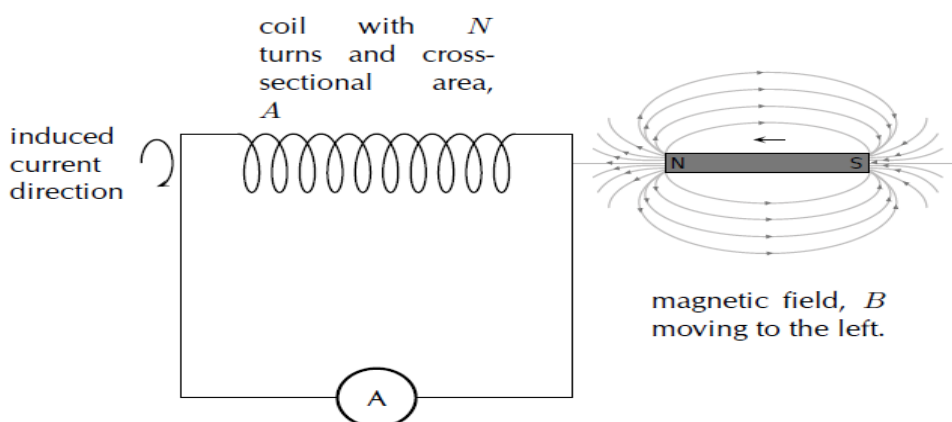
Emf is induced across the ends of the coil.

Generators operate on the principle of electromagnetic induction.

Convert mechanical energy to electrical energy.

Electromagnetic induction

Faraday's law



For current to be generated, there must be relative motion between the magnet and the coil.

The emf induced in the coil is directly proportion to the rate of change of magnetic flux.

$$\mathcal{E} = -N \frac{\Delta\phi}{\Delta t}$$

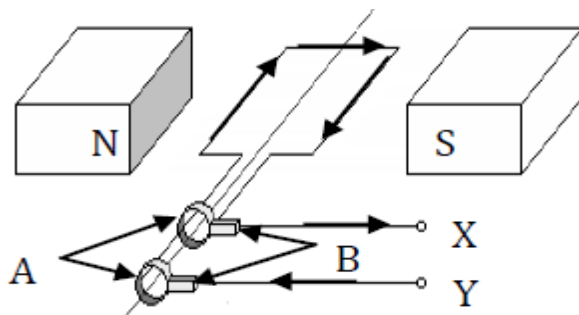
The magnitude of the induced emf depends on the following

1. Number of turns on the coil
2. The relative speed at which the coil and magnet move
3. Strength of the magnetic field.

THE AC GENERATOR

The principle of rotating a conductor in a magnetic field is used in electrical generators.

A generator converts mechanical energy into electrical energy.



- N = North Pole magnet
- S = South Pole magnet
- A = **slip** ring commutators
- B = carbon brushes

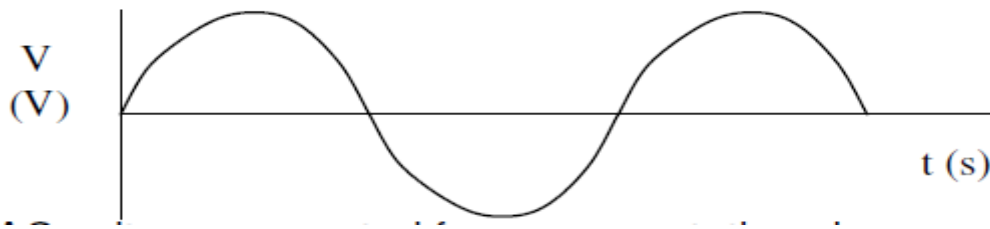
The coil is connected to **slip ring commutators**.

The commutators make contact with the carbon brushes, which ensures that the current can flow.

As the coil rotates in the magnetic field, it experiences an **induced emf**.

According to Fleming's Right Hand Rule, **an induced current** will now flow.

The induced current **changes in magnitude and direction** as the coil is turned in the magnetic field. of the coil. Each slip ring is connected to one end of the coil. The slip ring commutator is continuously in contact with the brushes. The induced emf moves in an alternating direction. It starts from zero to a maximum, returns and moves past zero to a minimum, and back to zero according to the following graph:

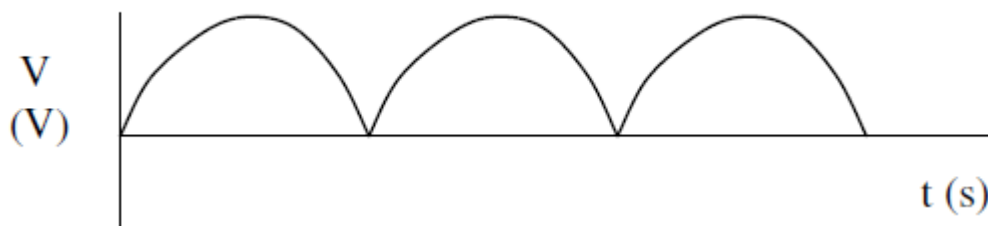


Right hand rule

If the right hand is stretched out with the four fingers point in the direction of the magnetic field and the thumb pointing in the direction of motion of the coil, the perpendicular direction away from the palm of the hand will give the direction of the induced current in the coil.

DC generators

A simple DC generator is constructed in the same way as an AC generator except that the slip ring commutator is now replaced by a **split ring commutator**. The split ring commutator only allows current to flow in one direction. A DC generator is actually the same as the DC motor explained above. However, the current-carrying conductor inside the magnetic field is now turned mechanically, and the output on the brushes is an emf induced onto the conductor. The current generated moves in one direction but generally increases from zero to a maximum, and then drops back to zero according to the following graph:

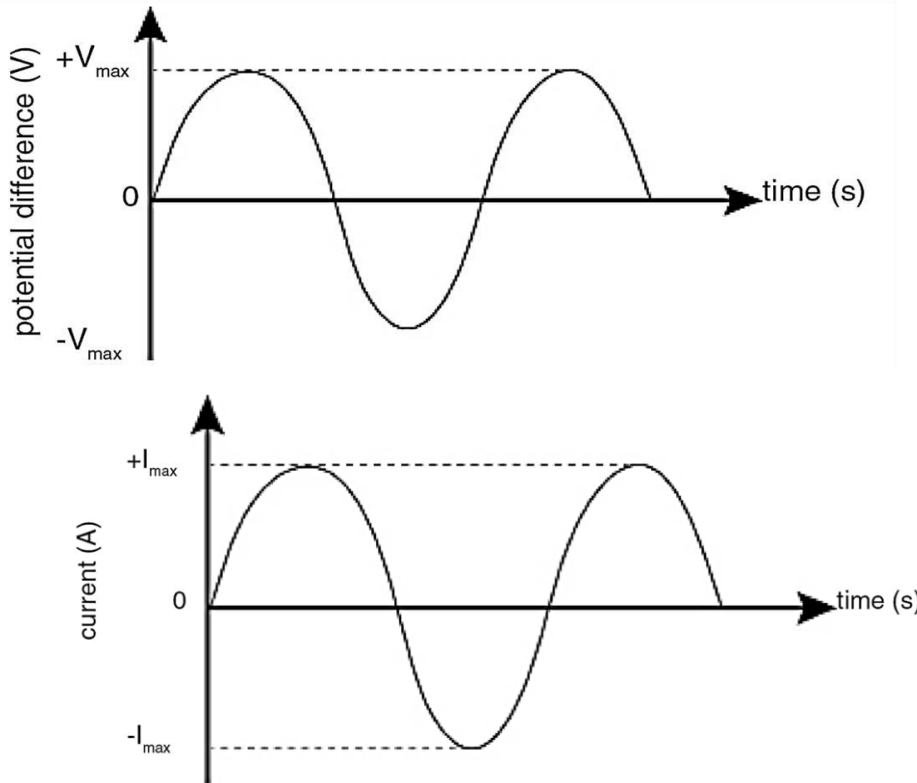


Difference between a DC motor and AC generator

	DC Motor	AC generator
Energy conversation	Electrical to mechanical energy	Mechanical to electrical energy
Connection	Split ring commutator	Slip ring
Current	Input	Out put
Principle	Motor effect	Electromagnetic induction

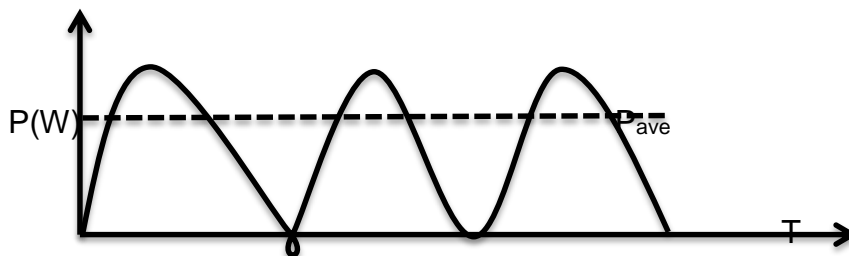
ALTERNATING CURRENT (AC)

In alternating current circuits, both the potential difference and current continuously fluctuate between positive and negative maximums over a period of time. The graphs below show how this occurs.



If we took an average voltage or average current, this will equal to zero since the values of the graphs above the axis are exactly equal to the values below the axis.

To overcome this problem, we square the values making them positive and then divide by 2 and then take the square root. This is called the root mean square (rms). This special average is shown on the graph as dotted line.



$$P = I_{\max} \cdot V_{\max}$$

$$P_{\text{ave}} = \frac{1}{2} P$$

$$P_{\text{ave}} = \frac{1}{2} I_{\max} \cdot V_{\max} \dots\dots\dots i$$

$$I_{rms} = \sqrt{\frac{I_{max}^2}{2}} = \frac{I_{max}}{\sqrt{2}}$$

$$V_{rms} = \sqrt{\frac{V_{max}^2}{2}} = \frac{V_{max}}{\sqrt{2}}$$

$$P_{ave} = I_{rms} \cdot V_{rms} \dots \dots \dots ii$$

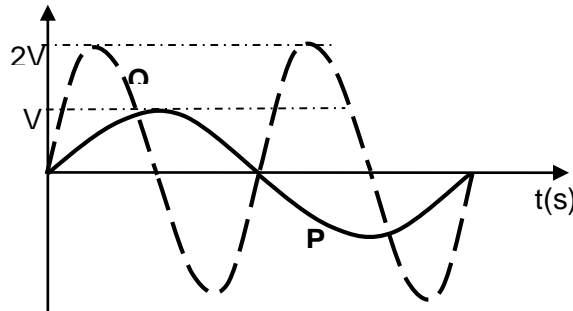
$$P_{ave} = I_{rms}^2 R \dots \dots \dots iii$$

In most of south African households, the voltage delivered across the terminals of a wall plug is 220V and frequency of 50Hz. This is the rms value that appliances operate on. It's not the maximum value.

Root mean square value: It is the value of the voltage in a DC circuit that will have the same heating effect as an AC circuit.

- Easier and cheaper to convert from AC to DC
- It can be transmitted at high voltage over long distance with minimum energy loss
- Higher frequency used in AC makes it suitable for motors.
- Much more power can be generated from AC than DC.
- AC can be stepped up or down using transformers

- 1.4 Which ONE of the following changes may lead to an increase in the emf of an AC generator without changing its frequency?
- A Decrease the resistance of the coil. B Increase the area of the coil.
 C Increase the resistance of the coil. D Decrease the speed of rotation.
- 1.5 Graph P represents the output emf of an AC generator. Graph Q is the output emf after a change has been made using the SAME generator.



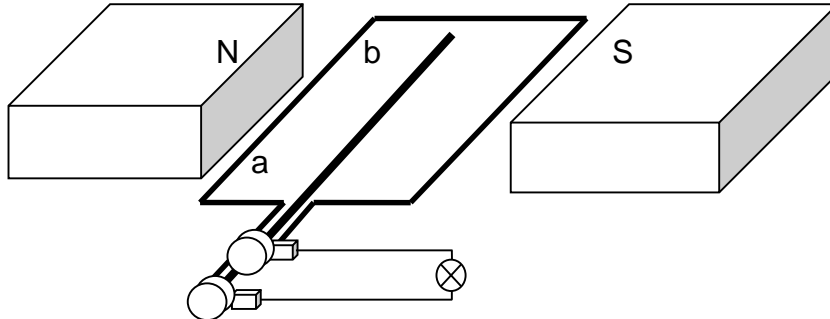
- 1.6 The speed of rotation of the coils in an AC generator is increased. Which ONE of the following combinations of frequency and output voltage for the generator will occur as a result of the change?

	FREQUENCY	OUTPUT VOLTAGE
A	Increases	Increases
B	No change	Increases
C	Decreases	Decreases
D	Increases	No change

- 1.7 A DC generator operates at 80 Hz. The number of times the output voltage reaches a maximum in 1 second is ...
- A 40. B 80. C 120. D 160 (2)
- 1.8 A lamp connected to an AC supply lights up with the same brightness as it does when connected to a X volt DC source. The power dissipated by the lamp, is equal to ...
- A $\frac{1}{2}(X)(I_{max})$ B $(X)\frac{I_{max}}{\sqrt{2}}$ C $\frac{(X)}{\sqrt{2}}I_{max}$ D $(X)(I_{max})$. (2)

QUESTION 2

2.1 A simplified diagram of an AC generator is shown below. The direction of the current in the coil is from **b** to **a**.



2.1.1 In which direction is the coil being rotated?
Write only **CLOCKWISE** or **ANTICLOCKWISE**. (1)

2.1.2 A maximum voltage is generated if the coil moves through the position indicated in the diagram above. Give an explanation for this observation. (2)

2.1.3 Starting from the position shown in the diagram above, sketch a graph of output voltage versus time for one complete cycle of the coil. (2)

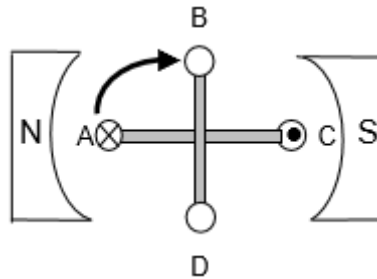
2.1.4 State **ONE** way in which the generator shown above can be used to produce a higher output voltage. (1)

2.1.5 Give **ONE** advantage for the use of alternating current. (1)

2.2 An electric fan with a power rating of 80 W is connected to an AC source which produces 7 A maximum current. Calculate the resistance of the fan. (5)

QUESTION 3

The diagram below shows a coil that is rotated through a magnetic field.
Name the principle demonstrated in the above diagram?



231.2 The maximum emf is generated at position A of the rotation cycle. Give an explanation for this observation. (2)

3.1.3 Name one structural difference between a DC and AC generator. (2)

3.1.4 Use the positions indicated in the diagram above and sketch a graph of current versus position for one complete rotation of a DC generator. (Indicate the positions A, B, C and D on the graph.) (4)

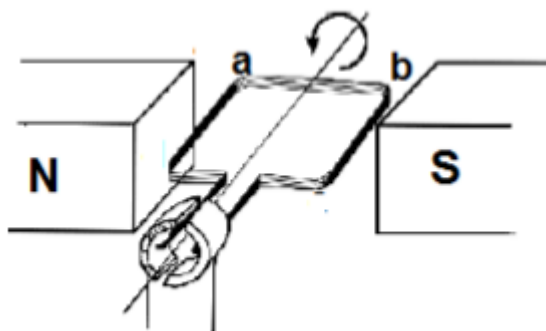
3.2 When an AC supply is connected to a lamp, it lights up with the same brightness as it does when connected to a 18 V battery (DC source). The power dissipated by the lamp is equal to 60 W.

3.2.1 What is the rms voltage of the AC supply? (1)

3.2.2 Calculate the peak current delivered by the AC source. (5)

QUESTION 4

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



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

4.1.2 Name the rule you used to answer QUESTION 4.1.1.

4.1.3 Which component in the diagram must be replaced in order for the device to operate as an AC generator?

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

4.2.1 State the energy conversion that takes place when the AC generator is in operation.

4.2.2 Calculate the root mean square value of the current passing through the resistor.

QUESTION 5

The output potential difference of an AC generator is $100\ \text{V}$ at $20\ \text{Hz}$. A simplified diagram of the generator is shown below. The direction of the current in the coil is from a to b.

In which direction is the coil rotating? Write only **CLOCKWISE** or **ANTICLOCKWISE**.

5.1.2 Starting from the position shown in the diagram, sketch a graph of the output potential difference versus time when the coil completes **TWO** full cycles. On the graph, clearly indicate the maximum potential difference ($100\ \text{V}$) and the time taken to complete the two cycles.

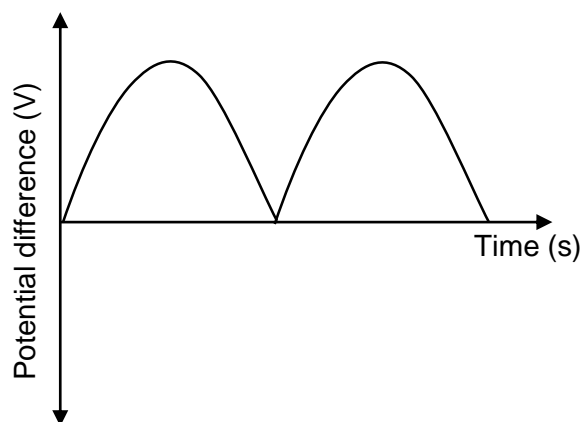
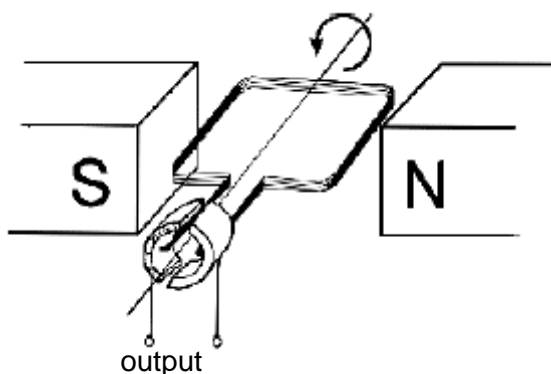
5.1.3 State **ONE** way in which this AC generator can be used to produce a lower output potential difference.

5.2 An electrical device is rated $220\ \text{V}$, $1\ 500\ \text{W}$.

Calculate the maximum current output for the device when it is connected to a $220\ \text{V}$ alternating current source.

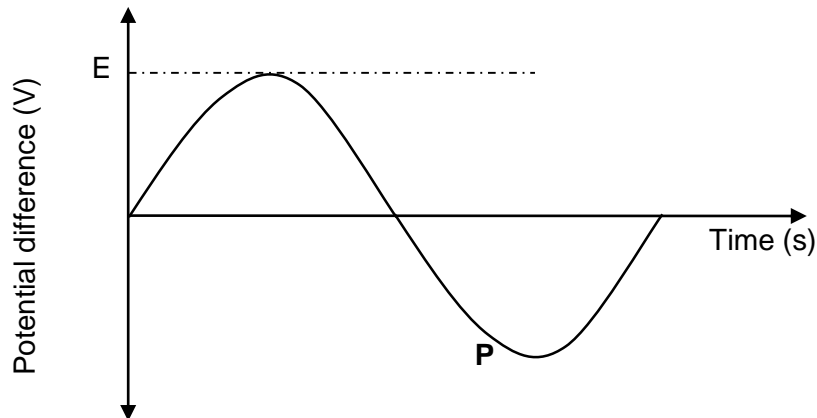
QUESTION 6

A simplified diagram of a DC generator and a graph of its output potential difference for one cycle is shown below.



6.1 Write down **ONE** way in which the output of this generator can be increased. (1)

A specific change is made to the structure of the DC generator in QUESTION 6.1 above. As a result of this change the output potential difference obtained is shown below..



6.2 Write down the change that was made to the DC generator. (1)

6.3 Copy graph **P** into your answer book.

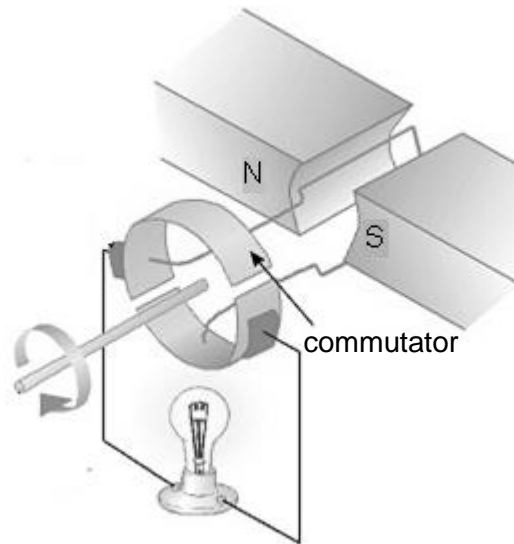
On the same axes, sketch the graph of the output potential difference that will be obtained when the new generator is rotated at TWICE its original speed.

Label this graph as **Q**. (2)

6.4 A certain generator operates at a maximum voltage of 340 V. A 120 W appliance is connected to the generator. Calculate the resistance of the appliance. (4)

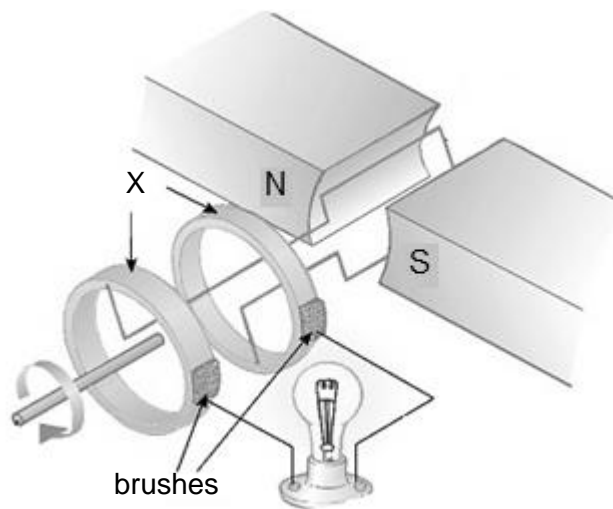
QUESTION 7

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

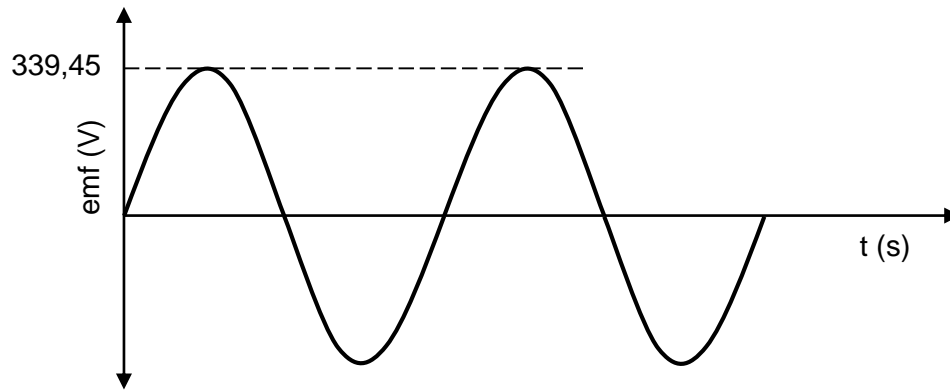


- 7.1 Name the principle on which the machine operates. (1)
- 7.2 State ONE way in which to make this bulb burn brighter. (1)

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



- 7.3 Name part X in the new device. (1)
- 7.4 The graph of output emf versus time obtained using the device in QUESTION 7.3 is shown below.



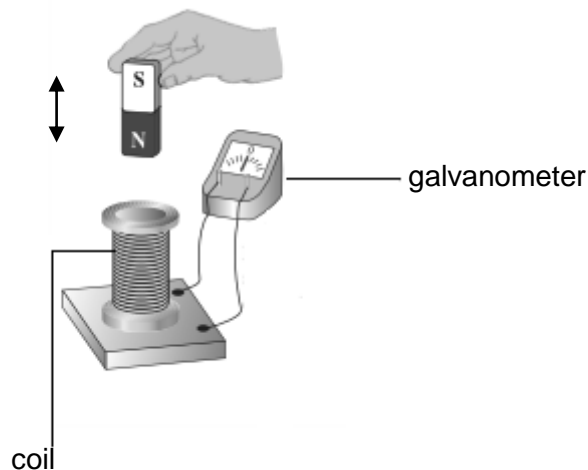
7.4.1 Define the term *root mean square value* of an AC voltage. (2)

7.4.2 Calculate the rms voltage. (3)

[8]

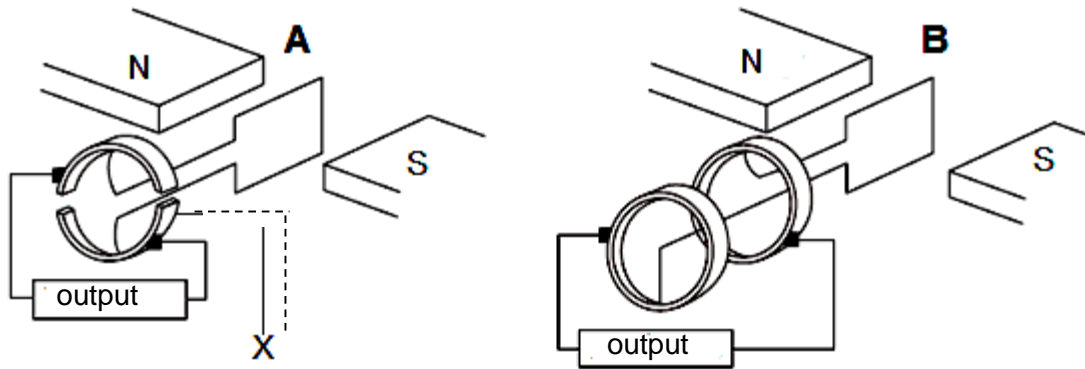
QUESTION 8

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



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

The two devices, **A** and **B**, below operate on the principle described in QUESTION 8.1.1 above.



8.1.2 Write down the name of the principle. (1)

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

8.2 A 220 V, AC voltage is supplied from a wall socket to an electric kettle of resistance $40,33 \Omega$. Wall sockets provide rms voltages and currents.

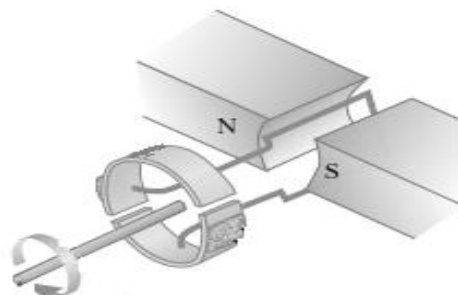
Calculate the:

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

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

QUESTION 9

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

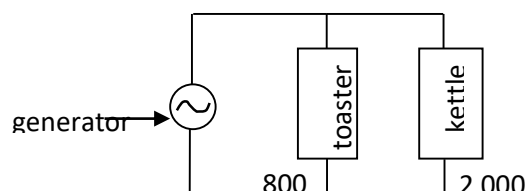


9.1.1 Is the generator above AC or DC? Give a reason for the answer. (2)

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

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

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



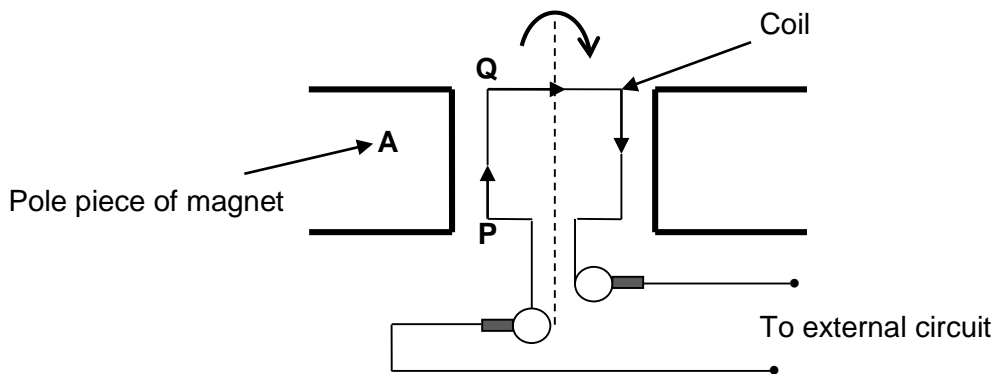
Calculate the:

9.2.1 rms current passing through the toaster (3)

9.2.2 Total rms current delivered by the generator (4)

QUESTION 10

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



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

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

10.1.2 The coil is rotated through 180° .

Will the direction of the current in segment **PQ** be from **P** to **Q** or **Q** to **P**? (1)

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

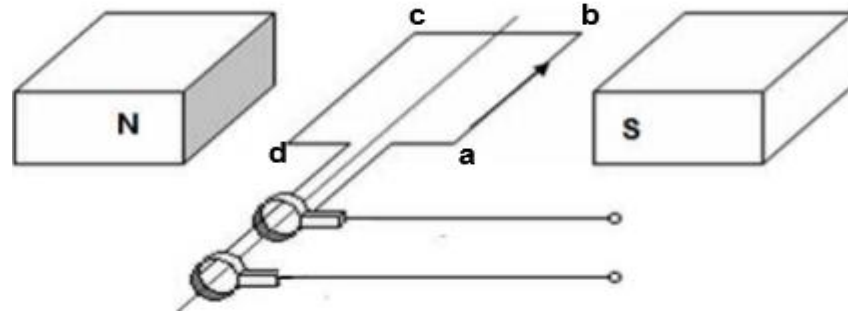
Calculate the:

10.2.1 Resistance of the device (5)

10.2.2 Energy the device consumes in two hours (5)

QUESTION 11

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



In which direction is the coil rotating? Write only CLOCKWISE or ANTICLOCKWISE. (1)

11.1.2 Starting from the position shown in the diagram, sketch a graph of the output potential difference versus time when the coil completes TWO full cycles. On the graph, clearly indicate the maximum potential difference (100 V) and the time taken to complete the two cycles. (3)

11.1.3 State ONE way in which this AC generator can be used to produce a lower output potential difference. (1)

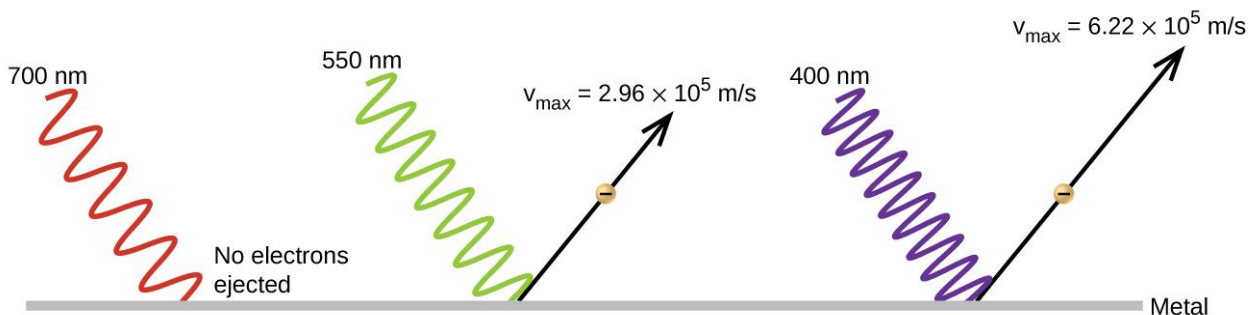
11.2 An electrical device is rated 220 V, 1 500 W.

Calculate the maximum current output for the device when it is connected to a 220 V alternating current source.

PHYSICAL SCIENCES

GRADE 12

OPTICAL PHENOMENA AND PROPERTIES OF MATERIAL



*MOVING BEYOND THE LIMITS, SETTING THE STANDARD AND
LEAVING NO CHILD BEHIND*

PHOTOELECTRIC EFFECT

FORMULAE

WAVES, SOUND AND LIGHT

$v = f \lambda$	$T = \frac{1}{f}$
$f_L = \frac{v \pm v_L}{v \pm v_s} f_s$ $f_L = \frac{v \pm v_L}{v \pm v_b} f_b$	$E = hf$ or /of $E = \frac{hc}{\lambda}$
$E = W_o + E_{k(max)}$ or/of $E = W_o + K_{max}$ where $E = hf$ and $W_o = hf_o$ and $E_{k(max)} = \frac{1}{2}mv_{max}^2$ or/of $K_{max} = \frac{1}{2}mv_{max}^2$	

TERMINOLOGY

Photoelectric effect is the process where by electrons are ejected from a metal surface when light of suitable frequency is incident on that surface.

When a photon with a specific quantum of energy strikes the surface of a metal, all the energy of the photon ($E = hf$) is transferred to an electron on the metal surface. If the energy of the photon is enough to overcome the electrostatic attraction between the electron and the nuclei of the metal, the electron will be able to break free from the metal.

Threshold(cut-off) frequency

Only light of sufficiently high frequency can eject electrons from a metal plate. This minimum frequency is called threshold or cut off frequency (f_o).

Threshold frequency, f_o , as the minimum frequency of light needed to emit electrons from a certain metal surface. $C = f\lambda$, the threshold frequency corresponds to the maximum wave length of the incident light.

work function(W_o)

work function, W_o , as the minimum energy that an electron in the metal needs to be emitted from the metal surface. $W_o = hf_o$

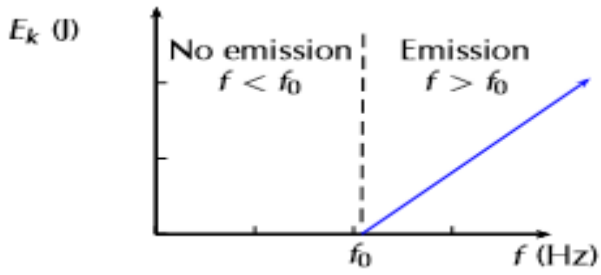
The energy of a photon of the incident light = work function of metal + kinetic energy of the photoelectrons leaving the metal

$$E = W_o + K_{max}, \text{ where } E = hf \text{ and } W_o = hf_o \text{ and } K_{max} = \frac{1}{2}mv_{max}^2$$

h is planck's constant = $6,63 \times 10^{-34}$ J·s

$$E_{k \max} = hf - W_0 \text{ in the form } y = mx + c$$

A graph of E_k versus frequency



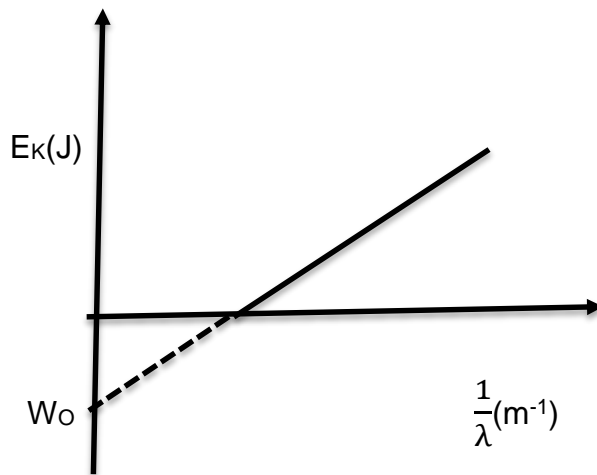
Slope = h (planck's constant).

Intercept of f axis = f_0

$$E_{k \max} = \frac{hc}{\lambda} - W_0 \text{ in the form } y = mx + c \text{ where } m = hc \text{ and } c = -w_0$$

$$E_{k \max} = hc \cdot \left(\frac{1}{\lambda}\right) - W_0$$

A graph of E_k versus $\frac{1}{\lambda}$



$$\text{Slope} = \frac{\Delta E}{\Delta \frac{1}{\lambda}} = hc$$

Intercept on E_k axis = $-w_0$

$$\text{Intercept on } \frac{1}{\lambda} \text{ axis} = \frac{1}{\lambda_0}$$

Effect of increasing intensity of incident light

Increasing intensity, increases the number of photo electrons ejected per unit time hence increases the current (ammeter reading)

Explanation: more photons strike the surface of the metal per unit time hence more electrons ejected per time leading to increased current.

Increasing intensity has no effect on the kinetic energy /frequency/ wave length of the incident photons. The energy of the photon remains unchanged.

Effect of increasing frequency of incident light

Increasing frequency, increases the kinetic energy of the incident photons.

Has no effect on the number of electrons ejected per unit time/ ammeter reading.

DUAL NATURE OF LIGHT:

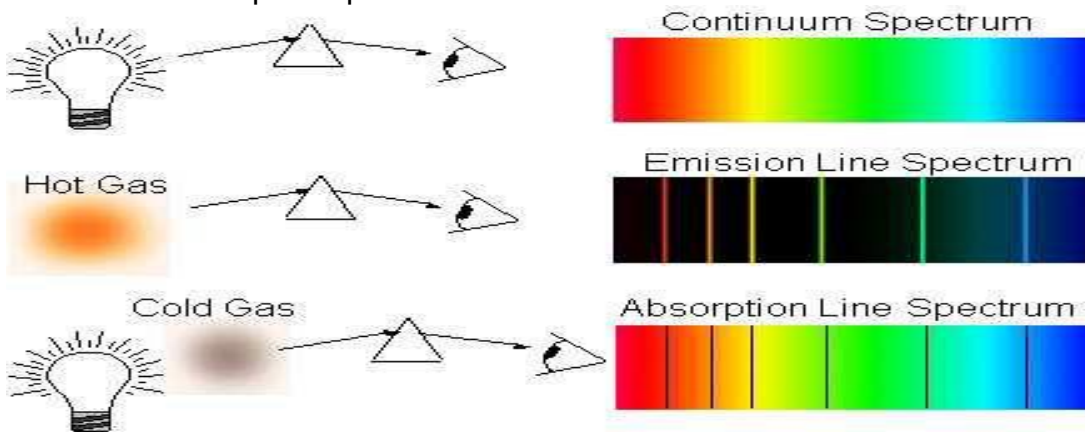
Light thus undergoes refraction and diffraction and this demonstrates its wave nature.

The photoelectric effect demonstrates the particle nature of light.

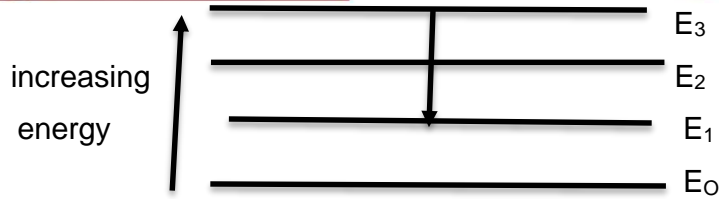
EMISSION AND ABSORPTION SPECTRA

There are three different types of spectra:

- Continuous emission spectra
- Line emission spectrum
- Line absorption spectrum



An electron may absorb energy and it can now move up one or more energy levels inside the atom. The electron is said to be **“excited”**. When this electron returns to its ground state, a photon of energy is released. If the involved atoms in the discharge tube emit photons having only certain specific energies, it implies that the internal energy of the atom will only **increase or decrease** in steps, or that the internal energy of an atom is distinctive by certain discrete energy levels. When an atom gains internal energy, the internal energy jumps between **energy level increases**. When an atom loses internal energy, it emits energy as a photon that contains energy.



$$E = E_3 - E_1$$

Where, E is the energy of the photon $E_3 - E_1$ is the total internal energy between two energy levels which energy jump took place.

An atomic absorption spectrum is formed when certain frequencies of electromagnetic radiation that passes through a medium, e.g. a cold gas, is absorbed.



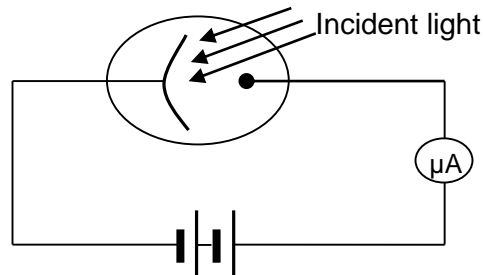
The dark lines correspond to the frequencies of light that have been absorbed by the gas. As the photons of light are absorbed by electrons, the electrons move into higher energy levels.

An atomic emission spectrum is formed when certain frequencies of electromagnetic radiation are emitted due to an atom's electrons making a transition from a high-energy state to a lower energy state. The amount of energy absorbed by the electron to move into a higher level is the same as the amount of energy released when returning to the original energy level.

WORKED EXAMPLES
QUESTION 1

An investigation was conducted to determine the effects of changes in frequency AND intensity on the current generated in a photoelectric cell when light is incident on it.

The apparatus used in the investigation is shown in the simplified diagram below.



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

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

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

1.2 Identify an independent variable. (1)

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

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

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

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

1.5 What conclusion can be made from this observation? (2)

SOLUTION

1.1 It is the minimum energy that an electron in the metal needs to be emitted from the metal surface

1.2 Frequency/Intensity

1.3 The minimum frequency required to remove an electron from the surface of the metal

1.4 $E = W_0 + E_k$

$$hf = hf_0 + E_k$$

$$(6,63 \times 10^{-34})(6,50 \times 10^{14}) = (6,63 \times 10^{-34})(5,001 \times 10^{14}) + \frac{1}{2}(9,11 \times 10^{-31})v^2$$

$$\therefore v = 4,67 \times 10^5 \text{ m}\cdot\text{s}^{-1}$$

OR $E_k = E_{\text{light}} - W_0$

$$= hf_{\text{light}} - hf_0 = (6,63 \times 10^{-34})(6,50 \times 10^{14} - 5,001 \times 10^{14})$$

$$= 9,94 \times 10^{-20} \text{ J}$$

$$E_k = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{2(9,94 \times 10^{-20})}{9,11 \times 10^{-31}}}$$

$$v = 4,67 \times 10^5 \text{ m}\cdot\text{s}^{-1}$$

1.5 The photocurrent is directly proportional to the intensity of the incident light.

QUESTION 2

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



What property of light is illustrated by the photoelectric effect? (1)

2.1.2 Without any calculation, give a reason why the maximum kinetic energy of an ejected electron, using blue light, is GREATER THAN that obtained using green light, for the same metal surface. (2)

2.2 The wavelength associated with the cut-off (threshold) frequency of a certain metal is 330 nm.

Calculate:

2.2.1 The work function of the metal. (4)

2.2.2 The maximum speed of an electron ejected from the surface of the metal when light of frequency $1,2 \times 10^{15}$ Hz is shone on the metal (5)

SOLUTION

2.1.1 The particle nature of light

2.1.2 Shorter wavelength

OR Higher frequency OR Higher energy

2.2.1 OPTION 1

$$W_0 = h \frac{c}{\lambda_0} \checkmark$$

$$= \frac{(6,63 \times 10^{-34})(3 \times 10^8)}{330 \times 10^{-9}} \checkmark$$

$$W_0 = 6,03 \times 10^{-19} \text{ J} \checkmark$$

OPTION2

$$c = f\lambda \quad 3 \times 10^8 = f_0(330 \times 10^{-9})$$

$$f_0 = 9,09 \times 10^{14} \text{ Hz}$$

$$W_0 = hf_0 = (6,63 \times 10^{-34})(9,09 \times 10^{14})$$

$$= 6,03 \times 10^{-19} \text{ J}$$

2.2.2 OPTION 1

$$E = W_0 + E_k$$

$$hf = hf_0 + E_k$$

$$hf = hf_0 + \frac{1}{2} mv^2$$

$$E = W_0 + \frac{1}{2} mv^2 \quad (6,63 \times 10^{-34})(1,2 \times 10^{15})$$

$$= (6,03 \times 10^{-19}) + \frac{1}{2}(9,11 \times 10^{-31})v^2$$

$$\therefore v = 6,5 \times 10^5 \text{ m}\cdot\text{s}^{-1}$$

OPTION 2

$$E_k = E_{\text{light}} - W_0$$

$$= hf_{\text{light}} - hf_0 = (6,63 \times 10^{-34})(1,2 \times 10^{15}) - 6,03 \times 10^{-19}$$

$$= 1,926 \times 10^{-19} \text{ J}$$

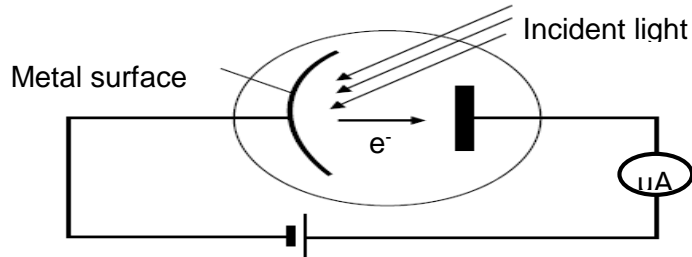
$$E_k = \frac{1}{2} mv^2 \quad 1,926 \times 10^{-19} = \frac{1}{2} (9,11 \times 10^{-31})v^2$$

$$\therefore v = 6,5 \times 10^5 \text{ m}\cdot\text{s}^{-1}$$

TYPICAL EXAM QUESTIONS

QUESTION 1 MULTIPLE CHOICE QUESTIONS

- 1.1 When light of a certain frequency is incident on the cathode of a photocell, the ammeter in the circuit registers a reading.



The frequency of the incident light is now increased while keeping the intensity constant. Which ONE of the following correctly describes the reading on the ammeter and the reason for this reading?

	Ammeter reading	Reason
A	Increases	More photoelectrons are emitted per second
B	Increases	The speed of the photoelectrons increases.
C	Remains the same	The number of photoelectrons remains the same.
D	Remains the same	The speed of photoelectrons remains the same.

(2)

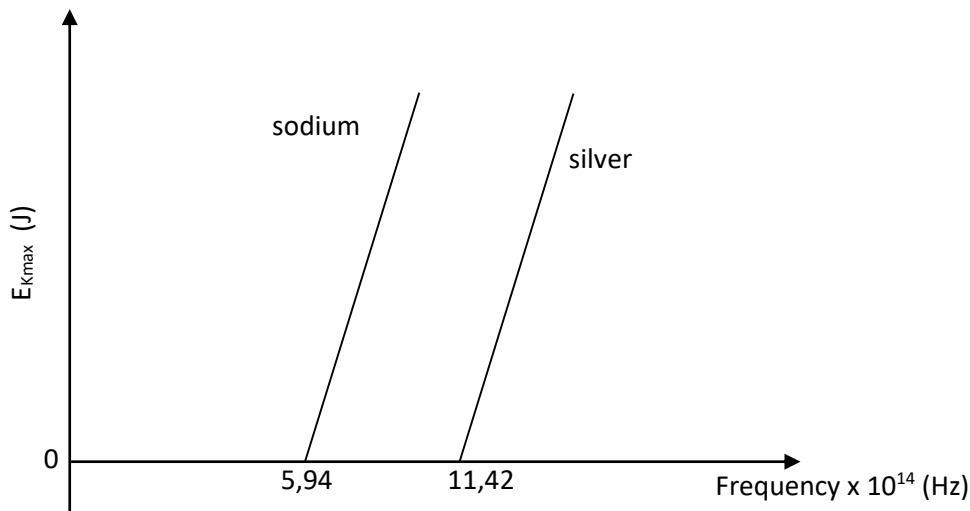
- 1.2 A line emission spectrum is formed when an excited atom moves from a ...
- A higher to a lower energy level and releases energy.
 - B higher to a lower energy level and absorbs energy.
 - C lower to a higher energy level and releases energy.
 - D lower to a higher energy level and absorbs energy. (2)
- 1.3 The wavelength of a monochromatic light source P is twice that of a monochromatic light source Q. The energy of a photon from source P will be ... of a photon from source Q.
- A a quarter of the energy
 - B half the energy
 - C equal to the energy
 - D twice the energy (2)

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

2.3.2 Planck's constant (4)

QUESTION 3

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



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

3.1.2 Which metal, sodium or silver, has the larger work function? Explain the answer. (3)

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

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

3.2 In a different photoelectric experiment blue light obtained from a light bulb is shone onto a metal plate and electrons are released.

The wavelength of the blue light is 470×10^{-9} m and the bulb is rated at 60 mW. The bulb is only 5% efficient.

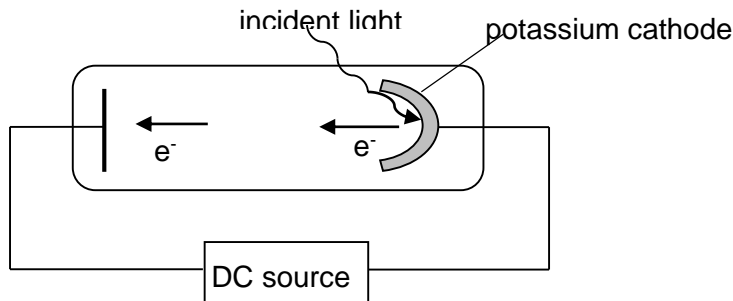
3.2.1 Calculate the number of photons that will be incident on the metal plate per second, assuming all the light from the bulb is incident on the metal plate. (5)

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

[13]

QUESTION 4

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



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

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

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

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

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

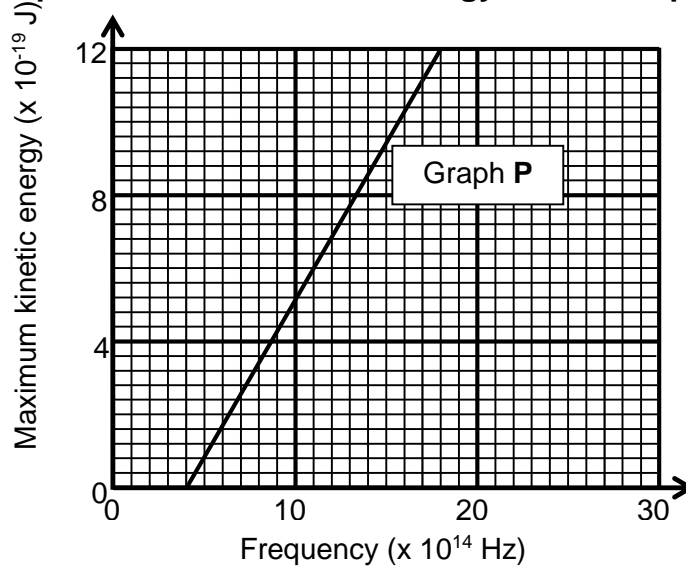
4.4 Explain the answer to QUESTION 4.3. (3)

[11]

QUESTION 5

Graph **P** below shows how the maximum kinetic energy of electrons emitted from the cathode of a photoelectric cell varies with the frequency of the incident radiation.

Graph of maximum kinetic energy versus frequency



- 5.1 Define the term *work function*. (2)
- 5.2 Calculate the:
- 4.2.1 Work function of the metal used as cathode in the photocell (3)
- 4.2.2 Velocity of photoelectrons emitted when the frequency of the incident light is 8×10^{14} Hz (5)
- 5.3 The photocell is now replaced with another one in which the work function of the cathode is TWICE that of the metal in the first cell.

The maximum kinetic energy versus frequency graph, **Q**, for this cathode is now drawn on the same set of axes as graph **P**.

- 5.3.1 How will the gradient of graph **Q** compare to that of graph **P**? Write down GREATER THAN, SMALLER THAN or EQUAL TO. Explain the answer. (2)
- 5.3.2 What will the value of the x intercept of graph **Q** be? Explain how you arrived at the answer. (2)

QUESTION 6

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

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

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

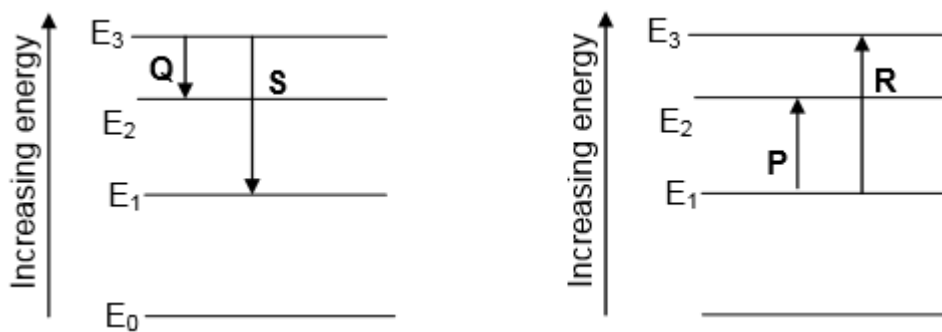
METAL	THRESHOLD WAVELENGTH (λ_0) IN METRES
Silver	$2,88 \times 10^{-7}$
Calcium	$4,32 \times 10^{-7}$
Sodium	$5,37 \times 10^{-7}$

The wavelength corresponding with the threshold frequency is referred to as threshold wavelength. The table below gives the values of threshold wavelengths for three different metals.

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

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

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

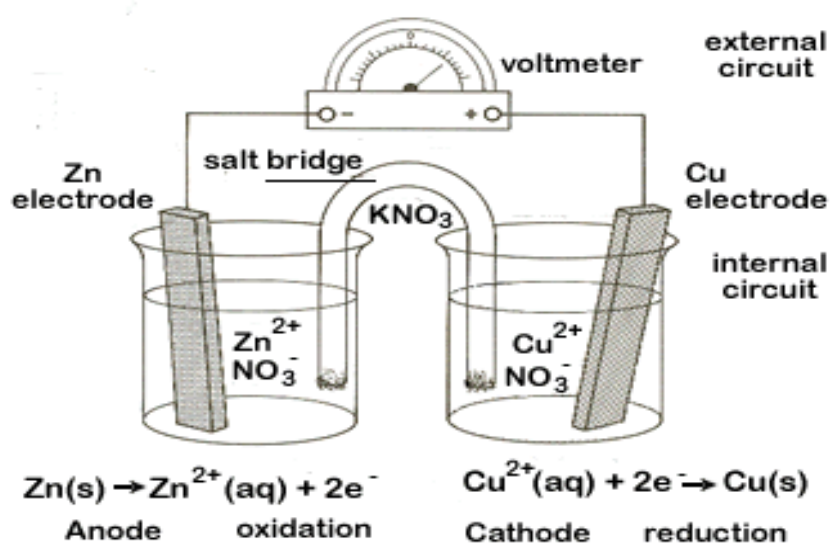


Using the letters P, Q, R and S, identify the lines that CORRECTLY show transitions that will result in the atom giving off an EMISSION SPECTRUM. Give a reason for the answer.

PHYSICAL SCIENCES

GRADE 12

ELECTROCHEMICAL REACTIONS



*MOVING BEYOND THE LIMITS, SETTING THE STANDARD AND
 LEAVING NO CHILD BEHIND*

ELECTROCHEMICAL REACTIONS

FORMULAE

$$E_{\text{cell}}^{\theta} = E_{\text{cathode}}^{\theta} - E_{\text{anode}}^{\theta} / E_{\text{sel}}^{\theta} = E_{\text{katode}}^{\theta} - E_{\text{anode}}^{\theta}$$

or

$$E_{\text{cell}}^{\theta} = E_{\text{reduction}}^{\theta} - E_{\text{oxidation}}^{\theta} / E_{\text{sel}}^{\theta} = E_{\text{reduksie}}^{\theta} - E_{\text{oksidasie}}^{\theta}$$

or

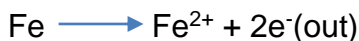
$$E_{\text{cell}}^{\theta} = E_{\text{oxidisingagent}}^{\theta} - E_{\text{reducingagent}}^{\theta} / E_{\text{sel}}^{\theta} = E_{\text{oksideermiddel}}^{\theta} - E_{\text{reduseermiddel}}^{\theta}$$

TERMINOLOGY

Electrochemical reactions involve the transfer of electrons. In this type of chemical reaction, one chemical substance loses electrons while another receives them. The processes of losing and receiving electrons happen at the same time. All ionic compounds are made in redox reactions. The word "redox" refers to reduction and oxidation.

Oxidation is the loss of electrons.(OIL)

Oxidation: An increase in oxidation number



Iron lose two electrons and is oxidised to Fe^{2+}

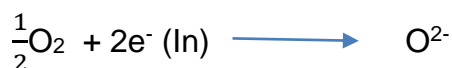


Cu is being oxidised, Cu is a reducing agent

Reduction is the gain of electrons.

Reduction: A decrease in oxidation number

The oxygen atom changes to O^{2-} by gaining two electrons



Oxygen gains two electrons and is reduced to O^{2-}

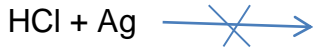


Gain electrons = reduction(RIG)

Br_2 is being reduced, Br_2 is an oxidising agent

Reducing agent is a substance that is oxidised/loses electrons. A strong reducing agent has a conjugate oxidising agent. Zn conjugate Zn^{2+}

Oxidising agent is a substance that is reduced/gains electrons. A strong oxidising agent has a weak reducing agent. Cu^{2+} has Cu has a weak conjugate reducing agent.



H_2 is a strong reducing agent than Ag hence it is oxidised

Redox reaction is a reaction in which electrons are transferred from the reducing agent to the oxidising agent.

The anode is the electrode where oxidation takes place

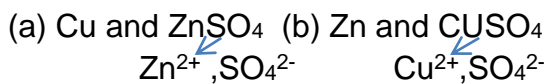
The cathode is the electrode where reduction takes place.

HOW TO TELL IF A REACTION IS SPONTANEOUS?

Steps

1. Identify the chemical species on the table(circle only the chemical species)
2. Pick the best reactants
3. Write out the reaction from the ones you have chosen
4. Balance the electrons and add the reactions.

Will the following combination of metals and ions react?

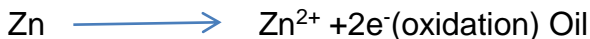


Part of redox table

$H_2O + 2e^- = H_2 + 2OH^-$	-0,83	↑
$Zn^{2+} + 2e^- = Zn$	-0,76	
$Cr^{3+} + 3e^- = Cr$	-0,74	
$Fe^{2+} + 2e^- = Fe$	-0,44	
$Cu^{2+} + e^- = Cu^+$	+0,16	
$SO_4^{2-} + 4H^+ + 2e^- = SO_2 + 2H_2O$	+0,17	
$Cu^{2+} + 2e^- = Cu$	+0,34	

POSTIVE SLOPE SPONTANEOUS REACTION (Zn and CUSO₄)

Start from the chosen reactants to the opposite side when writing out the half reaction

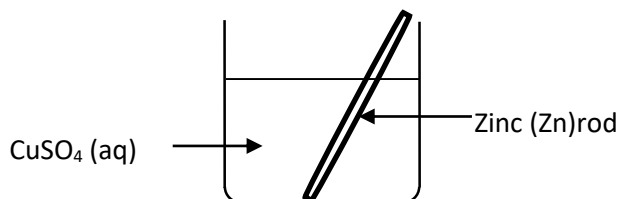


Over all equation

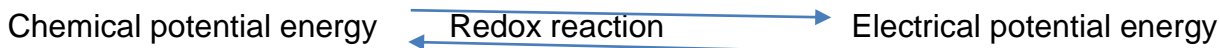


Direct Transfer of Electrons

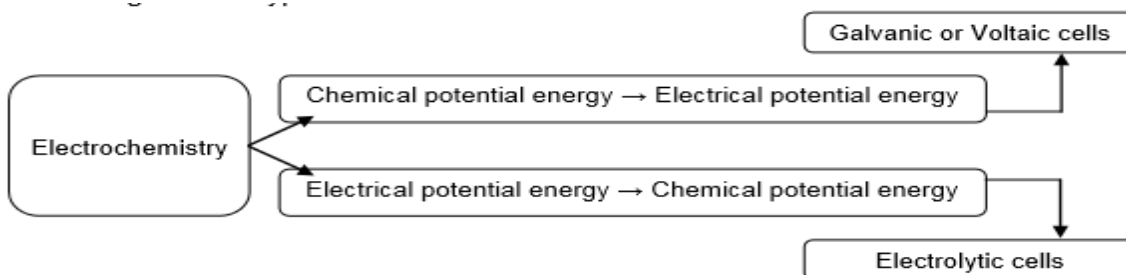
When a zinc plate is placed in a copper solution, the zinc atoms lose electrons. The oxidation process that occurs, is represented as follows; $\text{Zn(s)} \rightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{e}^{-}$. On the other hand, the copper ions in solution are receiving (gaining) the electrons from the zinc atoms. This reduction process is represented as follows: $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Cu(s)}$. If this oxidation-reduction process between zinc and copper ions is allowed to continue for a longer time, loss of mass in the zinc plate will be observed while the blue colour of the solution, due to the presence of Cu^{2+} ions, will lose its colour.



All chemical reactions involve a change in energy as well as a change in chemical composition. In redox reactions, electrons are transferred from one substance to another while the substances themselves undergo changes. All these processes deal with changes in energy. The changes in energy during redox reactions can be summarised as follows: Redox reactions are exothermic



We distinguish two types of electrochemical cells as summarised below.



3. Two types of cells: electrolytic and galvanic cells

Both electrolytic and galvanic cells make use of redox reactions.

Electrolytic cells use electrical energy to initiate chemical reactions. Electrical energy is converted to chemical energy.

Galvanic (voltaic) cells use chemical reactions to produce electrical energy. Chemical energy is converted to electrical energy.

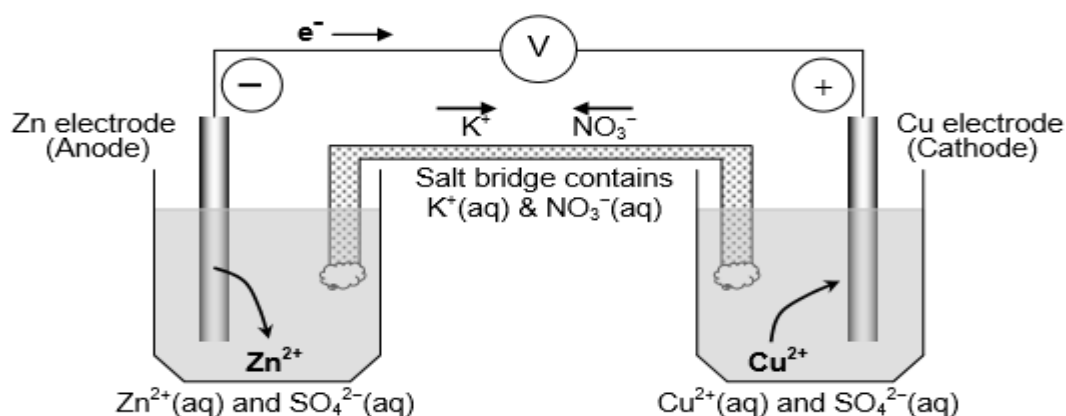
3.1 Galvanic cells (voltaic cells) indirect transfer of electrons

A galvanic cell is a cell in which chemical energy is converted to electrical energy. Galvanic cells make use of spontaneous redox reactions. The oxidising and reducing agents are separated and the electron transfer from the reducing agent to the oxidising agent takes place through an electrical conductor between them. The current in the conductor can be used to do useful work.

3.1.1 Composition and functioning of galvanic cells

Any galvanic cell consists of the following main parts: Two half-cells: The one half-cell contains the reducing agent and the other half-cell contains the oxidising agent. A salt bridge – an internal connection between the two half-cells. Ions can move freely through the salt bridge. An electrical conductor – an external connection between the two half-cells. Electrons flow through this conductor from the half-cell containing the reducing agent to the half-cell containing the oxidising agent.

A sketch of a copper-zinc galvanic cell is shown below.



The following components can be distinguished in the above galvanic cell:

- Zinc half-cell i.e. a Zn rod (called an electrode) placed into a Zn^{2+} solution - Zn is the reducing agent
- Copper half-cell i.e. a Cu rod (called an electrode) placed into a Cu^{2+} solution – $\text{Cu}^{2+}(\text{aq})$ is the oxidising agent

- Salt bridge – the internal circuit. The salt bridge consists of a U tube filled with an electrolyte e.g. KNO_3 . It can also be a porous separation between the two half cells.
- An external circuit i.e. conducting wires connecting the two half-cells

In this cell, the Zn rod and the Cu rod are the electrodes. The reaction takes place between the Zn rod and the Cu^{2+} ions. The Cu rod serves as a link between the wire and the Cu^{2+} solution. No reaction will take place between the Cu rod and the Cu^{2+} solution. The Zn rod is placed in a Zn^{2+} solution – no reaction will take place between the Zn rod and the Zn^{2+} solution. The Zn electrode supplies electrons according to:

$\text{Zn} \rightarrow \text{Zn}^{2+} + 2\text{e}^-$ Therefore it is the negative terminal. Any electrode where oxidation takes place is called the anode in electrochemistry. Hence, the Zn electrode is the anode of this galvanic cell. The electrons flow from the Zn electrode through the metallic conductor to the Cu electrode. More Zn^{2+} ions enter the solution in the zinc half-cell, causing the Zn electrode to erode gradually (its mass decreases).

At the Cu electrode, the electrons react with the Cu^{2+} ions in the copper half-cell according to:

$\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$ The Cu electrode is the positive terminal. The electrode where reduction takes place is called the cathode in electrochemistry. Hence, the Cu electrode is the cathode of this galvanic cell. The concentration of Cu^{2+} ions in the copper half-cell decreases, while the copper that is formed is deposited on the Cu electrode, causing the mass of the Cu electrode to gradually increase.

The reading on the voltmeter is positive if the negative terminal is connected to Zn.

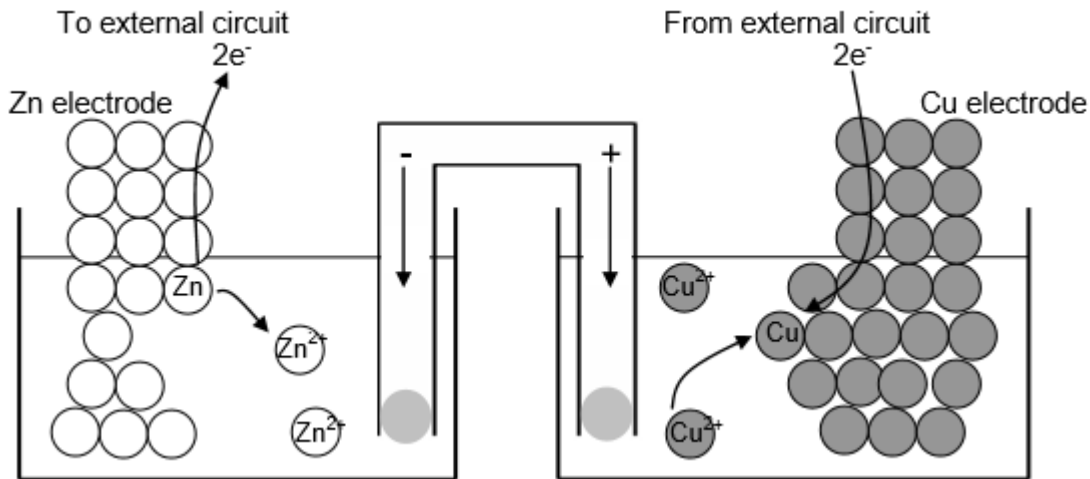
A positive reading on the voltmeter is therefore associated with a spontaneous redox reaction.

Functions of the salt bridge

- It completes the circuit. Electrons flow through the external conductor from the anode to the cathode of the cell.
- It maintain electrical neutrality within the solutions in the cell.
- It separates the two electrolytes

A salt bridge is a u-tube consisting of soluble salts like NaNO_3 , KNO_3 , KCl

3.1.2 Microscopic events in a copper-zinc galvanic cell Electrons released during oxidation of Zn flow through the external conductor from the Zn electrode to the Cu electrode. At the Cu electrode, the Cu^{2+} ions accept the electrons to form Cu that is deposited on the Cu electrode. The diagram below illustrates these microscopic events in the cell.

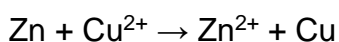


Due to the oxidation of Zn, more Zn²⁺ ions enter the solution in the Zn half-cell. This will result in a built-up of positive ions in the Zn half-cell. Negative ions must be found to balance these newly generated positive ions. Otherwise the cell will stop functioning.

Reduction of Cu²⁺ ions in the Cu half-cell leaves behind negative ions that were associated with the Cu²⁺ ions. This will result in a built-up of negative ions in the Cu half-cell. Positive ions must be found to balance these excess in negative ions. The salt bridge is needed to prevent the building-up of positive and negative charges in the half-cells. It allows ions to move freely between the half-cells to keep both solutions neutral. Therefore, NO₃⁻ ions flow in the direction of the Zn electrode (the anode), while K⁺ (and Zn²⁺ and Cu²⁺) flow in the direction of the Cu electrode (the cathode). Positive ions move through the salt bridge to the cathode and negative ions move to the anode to keep the cell electrically neutral.

3.1.3 Cell reaction

The combination of the two reactions which take place in each of the half-cells produces the net cell reaction that takes place in the cell. negative electrode (anode):



3.1.4 Cell notation

A galvanic cell can be represented by abbreviated method, known as cell notation.

When writing cell notation, the following convention should be used:

- The H₂|H⁺ half-cell is treated just like any other half-cell.
- Cell terminals (electrodes) are written on the outside of the cell notation.

- Active electrodes: reducing agent | oxidised species || oxidising agent | reduced species
- Inert electrodes (usually Pt or C): Pt | reducing agent | oxidised species || oxidising agent | reduced species | Pt

Example: Pt | Cl⁻(aq) | Cl₂(g) // F₂(g) / F⁻(aq) | Pt

The cell notation for the above copper-zinc galvanic cell is as follows:

Zn(s) | Zn²⁺(aq) || Cu²⁺(aq) | Cu(s) Key parts of the notation are:

. If half-cell components are in the same phase e.g. H⁺(aq), MnO₄⁻(aq), they are separated by a comma.

3.1.5 STANDARD ELECTRODE POTENTIAL

The Standard Electrode Potential table ranks the half reactions from lowest to highest.

These are reduction potentials - the likelihood that the reaction would undergo reduction.

Half-reactions		E ^θ (V)
Li ⁺ + e ⁻	⇌ Li	- 3,05
K ⁺ + e ⁻	⇌ K	- 2,93
Cs ⁺ + e ⁻	⇌ Cs	- 2,92
Ba ²⁺ + 2e ⁻	⇌ Ba	- 2,90
Sr ²⁺ + 2e ⁻	⇌ Sr	- 2,89
Ca ²⁺ + 2e ⁻	⇌ Ca	- 2,87
Na ⁺ + e ⁻	⇌ Na	- 2,71
Mg ²⁺ + 2e ⁻	⇌ Mg	- 2,36
Al ³⁺ + 3e ⁻	⇌ Al	- 1,66
Mn ²⁺ + 2e ⁻	⇌ Mn	- 1,18
Cr ²⁺ + 2e ⁻	⇌ Cr	- 0,91
2H ₂ O + 2e ⁻	⇌ H ₂ (g) + 2OH ⁻	- 0,83
Zn ²⁺ + 2e ⁻	⇌ Zn	- 0,76
Cr ³⁺ + 3e ⁻	⇌ Cr	- 0,74
Fe ²⁺ + 2e ⁻	⇌ Fe	- 0,44
Cr ³⁺ + e ⁻	⇌ Cr ²⁺	- 0,41
Cd ²⁺ + 2e ⁻	⇌ Cd	- 0,40
Co ²⁺ + 2e ⁻	⇌ Co	- 0,28
Ni ²⁺ + 2e ⁻	⇌ Ni	- 0,27
Sn ²⁺ + 2e ⁻	⇌ Sn	- 0,14
Pb ²⁺ + 2e ⁻	⇌ Pb	- 0,13
Fe ³⁺ + 3e ⁻	⇌ Fe	- 0,06
2H ⁺ + 2e ⁻	⇌ H ₂ (g)	0,00
S + 2H ⁺ + 2e ⁻	⇌ H ₂ S(g)	+ 0,14
Sn ⁴⁺ + 2e ⁻	⇌ Sn ²⁺	+ 0,15
Cu ²⁺ + e ⁻	⇌ Cu ⁺	+ 0,16
SO ₄ ²⁻ + 4H ⁺ + 2e ⁻	⇌ SO ₂ (g) + 2H ₂ O	+ 0,17
Cu ²⁺ + 2e ⁻	⇌ Cu	+ 0,34
2H ₂ O + O ₂ + 4e ⁻	⇌ 4OH ⁻	+ 0,40
SO ₂ + 4H ⁺ + 4e ⁻	⇌ S + 2H ₂ O	+ 0,45
Cu ⁺ + e ⁻	⇌ Cu	+ 0,52

↑
 Increasing reducing ability

Notice how the reactions are ranked from left to right.

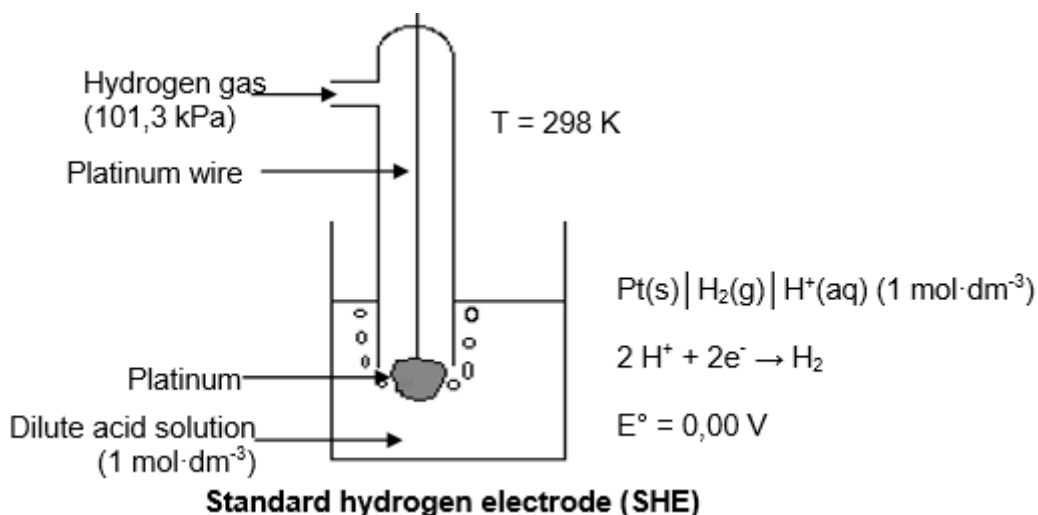
This table was manufactured under standard conditions. These conditions are:

- (Temperature) 25 °C/298 K
- (Concentration) 1 mol·dm⁻³
- pressure 101,3 kpa

3.1.6 Standard hydrogen electrode

The standard hydrogen electrode is used as a reference electrode against which all other half-cells are measured. The reference half-reaction is the reduction of H⁺(aq) to H₂(g) under standard conditions. A standard reduction potential of 0,00 V is allocated to this half-reaction: $2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$ or reduction $E = 0,00\text{ V}$

The standard hydrogen electrode, producing this half-reaction, consists of a platinum wire that is connected to a piece of platinum metal which serves as an inert electrode for the reaction. This electrode is in a glass tube. Hydrogen gas is bubbled over the platinum and through the 1 mol·dm⁻³ H⁺ solution under standard conditions. A sketch of the hydrogen halfcell is shown below:

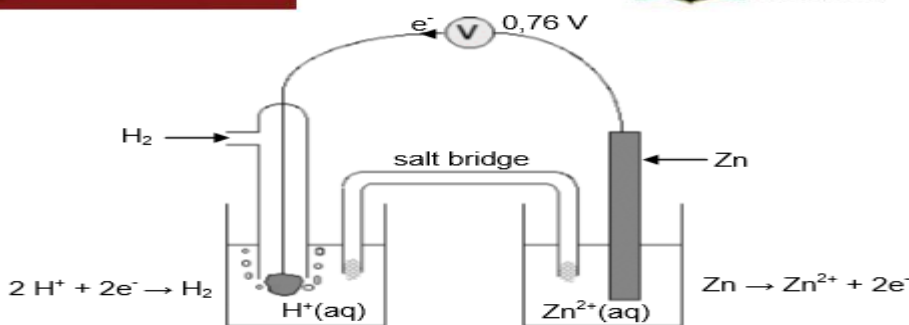


Platinum is used as an electrode in the SHE because

- platinum is a conductor of electricity
- platinum is inert
- platinum has a high affinity for hydrogen

3.1.7 Compiling a list of standard reduction potentials

Standard reduction potentials are determined by connecting the half-cell in which a particular half-reaction takes place, to the standard hydrogen electrode (SHE). The diagram below shows a zinc half-cell connected to the SHE.



The spontaneous reaction, which takes place when a positive voltmeter reading is registered, involves the oxidation of Zn and the reduction of $\text{H}^+(\text{aq})$. Zn is therefore the anode and the SHE is the cathode. The measured cell potential is + 0,76 V. Since the SHE has a reduction potential of 0,00 V the reduction potential of the Zn^{2+}/Zn half- $E^{\ominus}_{\text{cell}} = E^{\ominus}_{\text{cathode}} - E^{\ominus}_{\text{anode}}$

$$+ 0,76 = 0,00 - E^{\ominus}_{\text{anode}}$$

$$E^{\ominus}_{\text{anode}} = - 0,76 \text{ V}$$

3.1.8 Cell potential

By using the numbers on the table, we can calculate the voltage, or emf, that we can expect from a combination of two electrodes.

$$E_{\text{cell}} = E_{\text{cathode}} - E_{\text{anode}}$$

So, first you need to find out where oxidation is taking place (anode) and then reduction (cathode).

Hint: Always substitute using brackets as the signs may need to change.

3.1.9 Reduction potentials.

Reduction potential is the tendency for a chemical species to gain electrons.

Oxidation potential is the tendency for a chemical species to lose electrons (to be oxidised) $E_{\text{cell}} = \text{reduction potential} + \text{oxidation potential}$

An oxidation half reaction is the reverse reaction of the particular reduction half reaction. Therefore the oxidation potential of a particular half reaction is equal to the negative of the reduction potential.

Oxidation potential for half reaction = – reduction potential for half reaction

3.1.9 Using the tables of standard reduction potentials to predict cell potential

With the help of the information from Table 4A or 4B, there are two ways to calculate the cell potential of a galvanic cell under standard conditions.

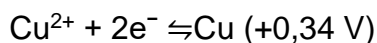
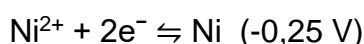
Method 1: Using the derived formula for cell potential

- Identify the relevant half-reactions
- Determine from this the relevant oxidising and reducing agents (or oxidation and reduction half-reactions, or the half-reactions taking place at the anode and cathode)
- Substitute the E° values as they appear on the table into one of the formulae above.

Example 1

A voltaic cell is constructed using $\text{Ni}^{2+}|\text{Ni}$ and $\text{Cu}^{2+}|\text{Cu}$ half-cells. Determine the cell potential at standard conditions and write down the cell notation.

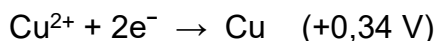
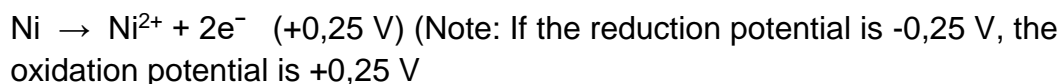
Solution From the Table of Standard Reduction potentials:



Method 1:

The copper half-reaction has the more positive cell potential and thus Cu^{2+} is a stronger oxidising agent than Ni^{2+} . The copper half-reaction will be reduction and the nickel half-reaction will be the oxidation.

The half-reactions will therefore take place as follows:

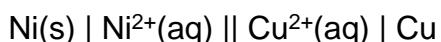


$$E^\circ_{\text{cell}} = 0,59 \text{ V}$$

Method 2: From this: Cu^{2+} is a stronger oxidising agent than Ni^{2+} . Therefore, Cu^{2+} behaves as the oxidising agent and Ni as the reducing agent.

$$E^\circ_{\text{cell}} = E^\circ_{\text{oxidising agent}} - E^\circ_{\text{reducing agent}} = +0,34 - (-0,25) = 0,59 \text{ V}$$

For the cell notation: Ni undergoes oxidation; therefore Ni is the anode.



Example 2

Consider the following unbalanced equation that takes place in an electrochemical cell: $\text{Ag(s)} + \text{Cu}^{2+}(\text{aq}) \rightarrow \text{Cu(s)} + \text{Ag}^+(\text{aq})$

Use the cell potential to determine whether this reaction proceeds spontaneously from left to right at standard conditions.

Solution According to the information in the equation, Ag is oxidised to Ag⁺ and Cu²⁺ is reduced to Cu. Therefore, Ag is the reducing agent and Cu²⁺ the oxidising agent.

$$E^{\circ}_{\text{cell}} = E^{\circ}_{\text{oxidising agent}} - E^{\circ}_{\text{reducing agent}}$$

$$= +0,34 - (+0,80) = -0,46 \text{ V}$$

OR The E^o value for the oxidation of Ag is -0,80 V The E^o value for the reduction of Cu²⁺ is +0,34 V

$$E^{\circ}_{\text{cell}} = -0,46 \text{ V}$$

The reaction cannot take place spontaneously.

3.1.10 Factors which influence cell potential

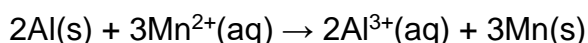
The cell potential of a galvanic cell depends on the following factors:

- Specific reactions that take place at the anode and the cathode
- Concentrations of reactants and products
- Temperature

Specific reactions at the anode and cathode

The relative strength of oxidising and reducing agents influences the cell potential. The stronger the oxidising and reducing agent that are combined, the greater the cell potential will be.

Concentration of reactants and products Under standard conditions the concentration of all solutions in a galvanic cell is 1 mol·dm⁻³. The galvanic cell described by the cell reaction below has a cell potential of 0,48 V.



If the concentration of the Mn²⁺ ions increases (greater than 1 mol·dm⁻³) the forward reaction will be favoured as can be predicted by using Le Chatelier's principle. Consequently the cell potential will be greater than 0,48 V.

If the concentration of the Al³⁺ ions increases (greater than 1 mol·dm⁻³) the reverse reaction will be favoured as can be predicted by using Le Chatelier's principle. Consequently the cell potential will be less than 0,48 V.

Initially the concentration of the reactants in a galvanic cell is high and the cell potential is at its maximum. As the reaction progresses the concentration of reactants decreases and the concentration of products increases. The result is a decrease in cell potential.

We can therefore say that an increase in the concentration of the reactants will increase the cell potential and that an increase in the concentration of the

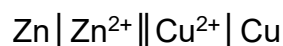
products will decrease the cell potential. When equilibrium is reached, the cell potential has dropped to 0 V.

Temperature Electrochemical reactions in galvanic cells are all exothermic reactions. According to Le Chatelier's principle an increase in temperature will favour the endothermic reaction, i.e. the reverse reaction, and lead to a drop in cell potential.

TYPICAL EXAM QUESTIONS

QUESTION 1 MULTIPLE CHOICE QUESTIONS

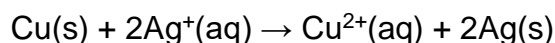
- 1.1 Consider the cell notation of the galvanic cell below.



Which ONE of the following statements regarding this cell is TRUE?

- A Copper is formed at the cathode.
- B Copper is formed at the anode.
- C Zinc is formed at the anode.
- D Zinc is formed at the cathode. (2)
- 1.2 Which ONE of the following metals will NOT react spontaneously with sulphuric acid?
- A Zn B Mg C Cu D Fe (2)
- 1.3 Which ONE of the following CANNOT act as a reducing agent?
- A Mg B Fe^{2+} C Br^- D MnO_4^- (2)
- 1.4 An electrochemical cell is used to electroplate an iron spoon with nickel.
- Which ONE of the following half-reactions takes place at the positive electrode of this cell?
- A $\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Fe}(\text{s})$
- B $\text{Fe}(\text{s}) \rightarrow \text{Fe}^{2+}(\text{aq}) + 2\text{e}^-$
- C $\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Ni}(\text{s})$
- D $\text{Ni}(\text{s}) \rightarrow \text{Ni}^{2+}(\text{aq}) + 2\text{e}^-$ (2)

- 1.5 Consider the reaction represented by the balanced equation below:

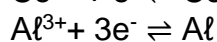
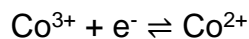


In the above reaction, Cu(s) is the ...

- A oxidising agent and is reduced.
- B oxidising agent and is oxidised.

- C reducing agent and is reduced.
- D reducing agent and is oxidised. (2)

1.6 The following half-reactions take place in a galvanic cell:



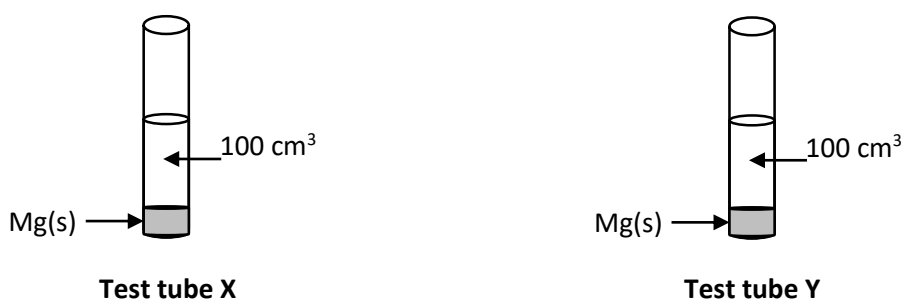
Which ONE of the following is the cell notation for this cell?

- A $\text{Al} \mid \text{Al}^{3+} \parallel \text{Co}^{3+}, \text{Co}^{2+}$
- B $\text{Al} \mid \text{Al}^{3+} \parallel \text{Co}^{3+}, \text{Co}^{2+} \mid \text{Pt}$
- C $\text{Al} \mid \text{Al}^{3+} \parallel \text{Co}^{2+}, \text{Co}^{3+} \mid \text{Pt}$
- D $\text{Pt} \mid \text{Co}^{2+}, \text{Co}^{3+} \parallel \text{Al}^{3+} \mid \text{Al}$ (2)

1.7 Chlorine gas (Cl_2) is bubbled through a potassium iodide solution (KI). The reducing agent in this reaction is:

- A Potassium ions
- B Chlorine gas
- C Iodide ions
- D Chloride ions (2)

1.8 Equal amounts of magnesium (Mg) powder react respectively with equal volumes and equal concentrations of $\text{HCl}(\text{aq})$ and $\text{H}_2\text{SO}_4(\text{aq})$, as shown below.



The magnesium is in EXCESS.

Consider the following statements regarding these two reactions:

I: The initial rate of the reaction in test tube X equals the initial rate of the reaction in test tube Y.

II: After completion of the reactions, the mass of magnesium that remains in test tube X will be greater than that in test tube Y.

III: The amount of hydrogen gas formed in **X** is equal to the amount of hydrogen gas formed in **Y**.

Which of the above statements is/are TRUE?

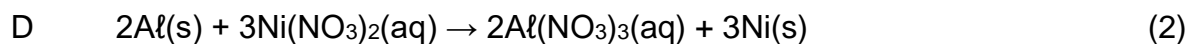
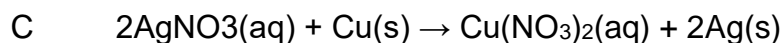
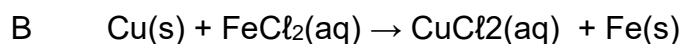
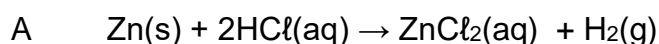
A **I** only

B **II** only

C **III** only

D **I** and **III** only

1.9 Which ONE of the following is a NON-SPONTANEOUS redox reaction? Refer to the Table of Standard Reduction Potentials (Table 4A or 4B). (2)



1.10 A galvanic cell consists of the following half-cells: $\text{Pt(s)} | \text{Cl}_2\text{(g)} | \text{Cl}^-\text{(aq)}$ AND $\text{Cu}^{2+}\text{(aq)} | \text{Cu(s)}$. Which ONE of the following statements is TRUE while the cell is functioning?

A Cu(s) is oxidised.

B $\text{Cl}^-\text{(aq)}$ is reduced.

C $\text{Cl}_2\text{(g)}$ acts as reducing agent.

D Cu(s) acts as oxidising agent. (2)

QUESTION 2

An electrochemical cell consisting of half-cells A and B is assembled under standard conditions as shown below.

Half-cell A	$\text{Pt, Cl}_2 (101,3 \text{ kPa}) \text{Cl}^- (1 \text{ mol}\cdot\text{dm}^{-3})$
Half-cell B	$\text{Mg}^{2+} (1 \text{ mol}\cdot\text{dm}^{-3}) \text{Mg(s)}$

2.1 At which half-cell, A or B, are electrons released into the external circuit? (1)

2.2 Write down the:

2.2.1 Reduction half-reaction that takes place in this cell (2)

2.2.2 NAME or FORMULA of the substance whose oxidation number DECREASES (1)

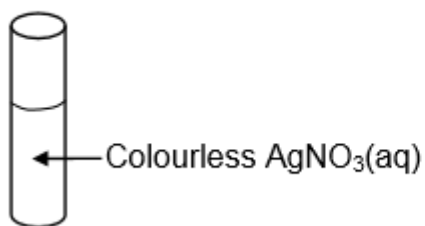
2.3 Calculate the initial cell potential of this cell when it is in operation. (4)

QUESTION 3

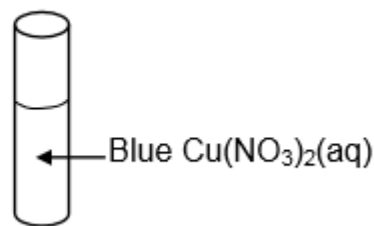
A learner conducts two experiments to investigate the reaction between copper (Cu) and a silver nitrate solution, $\text{AgNO}_3(\text{aq})$.

EXPERIMENT 1 The learner adds a small amount of copper (Cu) powder to a test tube containing silver nitrate solution, $\text{AgNO}_3(\text{aq})$. The solution changes from colourless to blue after a while.

Before addition of Cu(s)



After addition of Cu(s)

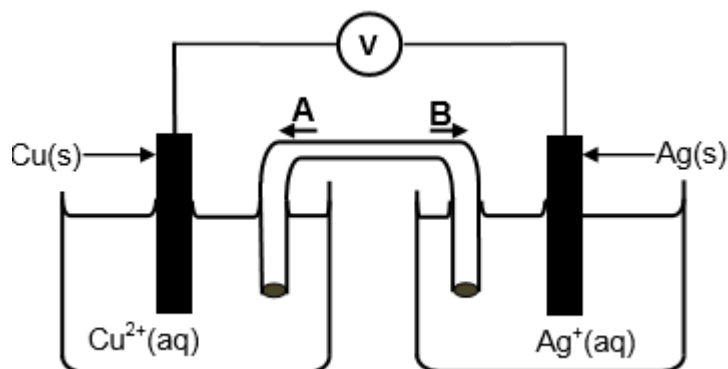


3.1 Define the term oxidising agent. (2)

3.2 Explain why the solution turns blue by referring to the relative strength of oxidising agents. (4)

EXPERIMENT 2

The learner now sets up a galvanic cell as shown below. The cell functions under standard conditions.



3.3 Write down the energy conversion that takes place in this cell. (1)

3.4 In which direction (A or B) will ANIONS move in the salt bridge? (1)

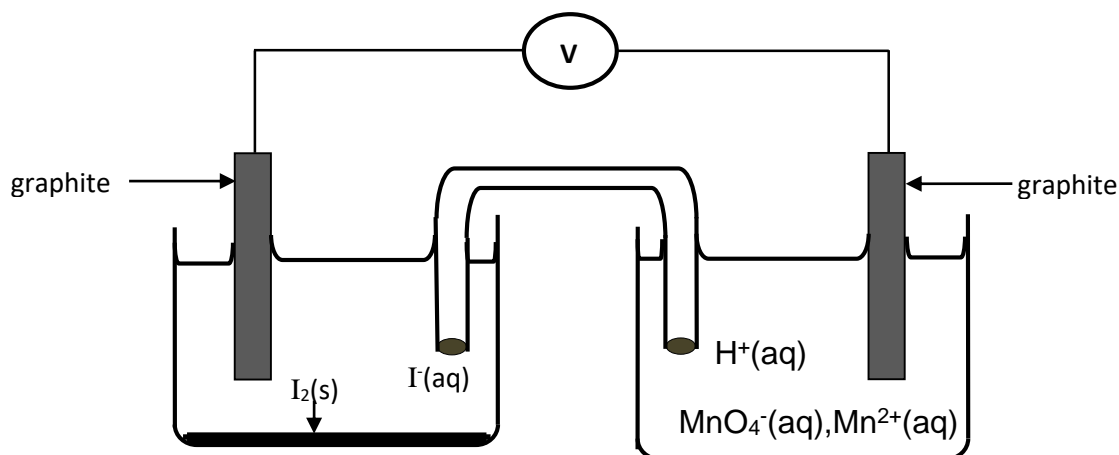
3.5 Calculate the emf of the above cell under standard conditions. (4)

3.6 Write down the balanced equation for the net cell reaction that takes place in this cell. (3)

- 3.7 How will the addition of 100 cm^3 of a $1 \text{ mol}\cdot\text{dm}^{-3}$ silver nitrate solution to the silver half-cell influence the initial emf of this cell? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1)

QUESTION 4

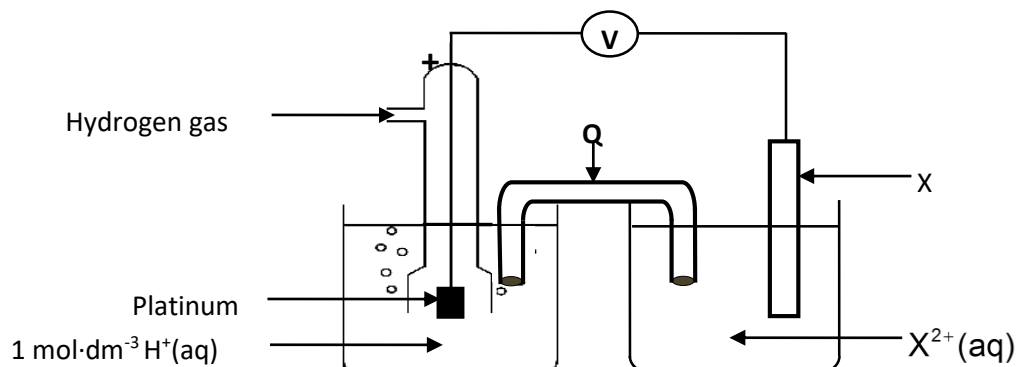
The voltaic cell represented below functions at standard conditions.



- 4.1 Write down the concentration of the $\text{H}^+(\text{aq})$ in the one half-cell. (1)
- 4.2 Solids present in half-cells are usually used as electrodes. Give a reason why $\text{I}_2(\text{s})$ is not suitable to be used as electrode. (1)
- 4.3 Write down TWO properties, other than being a solid, of graphite that makes it suitable to be used as electrodes in the above voltaic cell. (2)
- 4.4 For the above voltaic cell, write down the:
- 4.4.1 NAME of the oxidising agent (1)
- 4.4.2 Net cell reaction (3)
- 4.4.3 Cell notation (3)
- 4.5 Calculate the cell potential of the above cell. (4)
- 4.6 How will the reading on the voltmeter be affected if the concentration of decreases? Only write down INCREASES, DECREASES or NO EFFECT. (1)

QUESTION 5

A standard electrochemical cell is set up using a standard hydrogen half-cell and a standard $X|X^{2+}$ half-cell as shown below. A voltmeter connected across the cell, initially registers 0,31 V.



- 5.1 Besides concentration write down TWO conditions needed for the hydrogen half-cell to function under standard conditions. (2)
- 5.2 Give TWO reasons, besides being a solid, why platinum is suitable to be used as electrode in the above cell. (2)
- 5.3 Write down the:
- 5.3.1 NAME of component **Q** (1)
- 5.3.2 Standard reduction potential of the $X|X^{2+}$ half-cell (1)
- 5.3.3 Half-reaction that takes place at the cathode of this cell (2)
- 5.4 The hydrogen half-cell is now replaced by a $M|M^{2+}$ half-cell. The cell notation of this cell is:
 $M(s) | M^{2+}(aq) || X^{2+}(aq) | X(s)$
- The initial reading on the voltmeter is now 2,05 V.
- 5.4.1 Identify metal **M**. Show how you arrived at the answer. (5)
- 5.4.2 Is the cell reaction EXOTHERMIC or ENDOTHERMIC? (1)
- 5.5 The reading on the voltmeter becomes zero after using this cell for several hours. Give a reason for this reading by referring to the cell reaction. (1)

[15]

QUESTION 6

Learners are given the following two unknown half-cells:

Half-cell 1: $\text{Q}^{2+}(\text{aq}) \mid \text{Q}(\text{s})$

Half-cell 2: $\text{Pt} \mid \text{R}_2(\text{g}) \mid \text{R}^-(\text{aq})$

During an investigation to identify the two half-cells, the learners connect each half-cell alternately to a $\text{Cd}^{2+}(\text{aq}) \mid \text{Cd}(\text{s})$ half-cell under standard conditions. For each combination of two half-cells, they write down the net cell reaction and measure the cell potential.

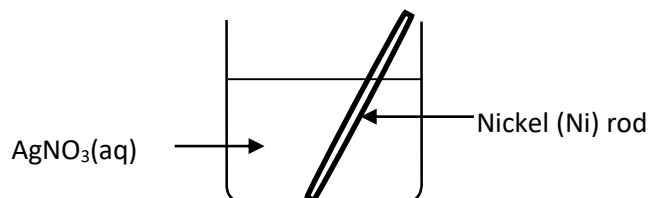
The results obtained for the two half-cell combinations are given in the table below.

COMBINATION	NET CELL REACTION	CELL POTENTIAL
I	$\text{Q}^{2+}(\text{aq}) + \text{Cd}(\text{s}) \rightarrow \text{Cd}^{2+}(\text{aq}) + \text{Q}(\text{s})$	0,13 V
II	$\text{R}_2(\text{g}) + \text{Cd}(\text{s}) \rightarrow \text{Cd}^{2+}(\text{aq}) + 2\text{R}^-(\text{aq})$	1,76 V

- 6.1 Write down THREE conditions needed for these cells to function as standard cells. (3)
- 6.2 For **Combination I**, identify:
- 6.2.1 The anode of the cell (1)
- 6.2.2 **Q** by using a calculation (5)
- 6.3 For **Combination II**, write down the:
- 6.3.1 Oxidation half-reaction (2)
- 6.3.2 NAME or FORMULA of the metal used in the cathode compartment (1)
- 6.4 Arrange the following species in order of INCREASING oxidising ability:
 Q^{2+} ; R_2 ; Cd^{2+}
- Explain fully how you arrived at the answer. A calculation is NOT required. (4)

QUESTION 7

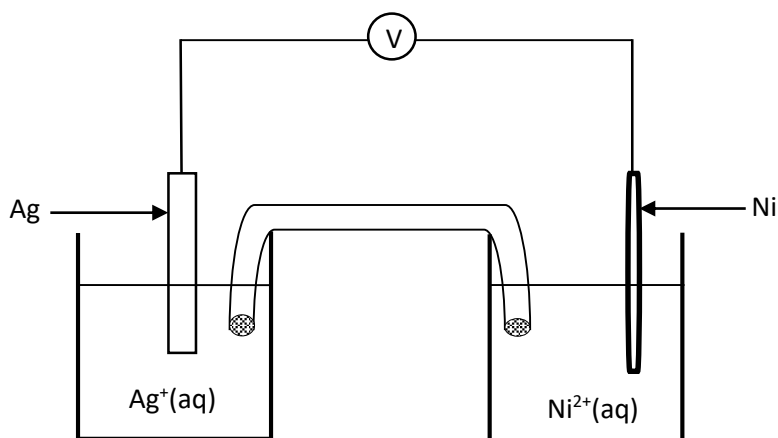
- 7.1 A nickel (Ni) rod is placed in a beaker containing a silver nitrate solution, $\text{AgNO}_3(\text{aq})$ and a reaction takes place.



Write down the:

- 7.1.1 NAME or FORMULA of the electrolyte (1)
- 7.1.2 Oxidation half-reaction that takes place (2)
- 7.1.3 Balanced equation for the net (overall) redox reaction that takes place (3)

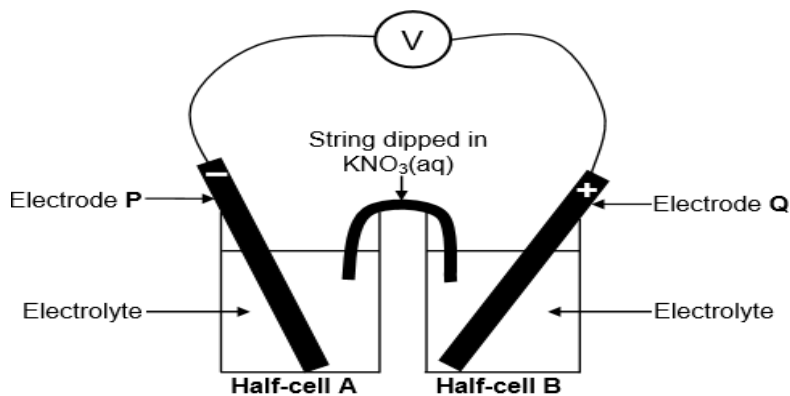
- 7.2 A galvanic cell is now set up using a nickel half-cell and a silver half-cell.



- 7.2.1 Which electrode (**Ni** or **Ag**) must be connected to the negative terminal of the voltmeter? Give a reason for the answer. (2)
- 7.2.2 Write down the cell notation for the galvanic cell above. (3)
- 7.2.3 Calculate the initial reading on the voltmeter if the cell functions under standard conditions. (4)
- 7.2.4 How will the voltmeter reading in QUESTION 7.2.3 be affected if the concentration of the silver ions is increased? Choose from INCREASES, DECREASES or REMAINS THE SAME. (1)

QUESTION 8

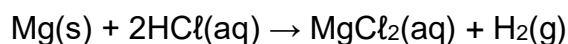
Learners set up an electrochemical cell, shown in the simplified diagram below, using magnesium and lead as electrodes. Nitrate solutions are used as electrolytes in both half-cells.



- 8.1 What type of reaction (NEUTRALISATION, REDOX or PRECIPITATION) takes place in this cell? (1)
- 8.2 Which electrode, P or Q, is magnesium? Give a reason for the answer. (2)
- 8.3 Write down the:
- 8.3.1 Standard conditions under which this cell functions (2)
- 8.3.2 Cell notation for this cell (3)
- 8.3.3 NAME or FORMULA of the oxidising agent in the cell (1)
- 8.4 Calculate the initial emf of the cell above under standard conditions. (4)
- 8.5 How will the voltmeter reading change if the: (Write down only INCREASES, DECREASES or REMAINS THE SAME.)
- 8.5.1 Size of electrode P is increased (1)
- 8.5.2 Initial concentration of the electrolyte in half-cell B is increased (1)

QUESTION 9

Magnesium (Mg) reacts with a dilute hydrochloric acid solution, $\text{HCl}(\text{aq})$, according to the following balanced equation:



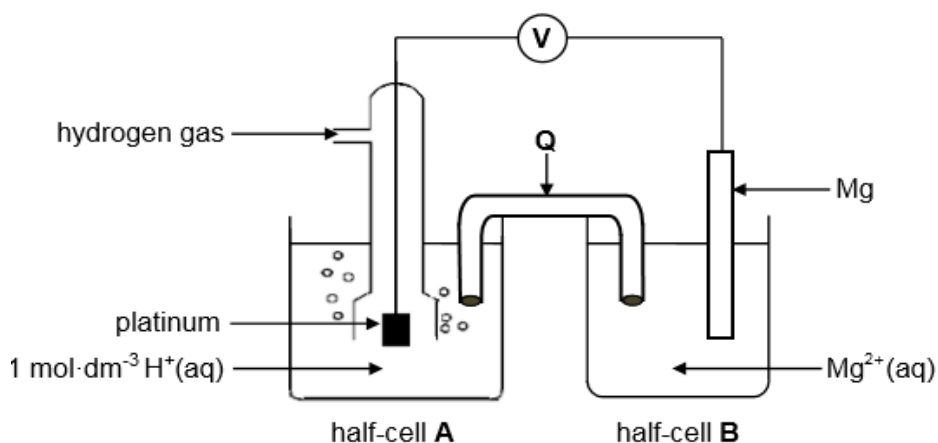
9.1 Give a reason why the reaction above is a redox reaction. (1)

9.2 Write down the FORMULA of the oxidising agent in the reaction above. (1)

It is found that silver does not react with the hydrochloric acid solution.

9.3 Refer to the relative strengths of reducing agents to explain this observation. (3)

The reaction of magnesium with hydrochloric acid is used in an electrochemical cell, as shown in the diagram below. The cell functions under standard conditions.



9.4 What is the function of platinum in the cell above? (1)

9.5 Write down the:

9.5.1 Energy conversion that takes place in this cell (1)

9.5.2 Function of Q (1)

9.5.3 Half-reaction that takes place at the cathode (2)

9.5.4 Cell notation of this cell (3)

9.6 Calculate the initial emf of this cell. (4)

9.7 How will the addition of concentrated acid to half-cell A influence the answer to QUESTION 9.6? Choose from INCREASES, DECREASES or REMAINS THE SAME. (1)

Electrolytic cells

The electrolytic cell is a cell in which electrical energy is converted into chemical energy. The process during which electrical energy is converted into chemical energy is called 'electrolysis'.

Electrolysis: The chemical process in which electrical energy is converted to chemical energy OR the use of electrical energy to produce a chemical change.

An electrolyte as a solution/liquid/dissolved substance that conducts electricity through the movement of ions

In electrolytic cells, oxidation-reduction reactions take place in a direction in which they do NOT OCCUR SPONTANEOUSLY. Electrical energy is used to drive a non-spontaneous reaction.

For electrolysis to take place, the following is necessary:

- Two electrodes, either inert (does not take part in the reaction) or active (takes part in the reaction)
- An electrolyte - a substance that dissolves in water to form positive (cations) and negative ions (anions) OR a substance having free positive (cations) and negative ions (anions) when melted
- A source of direct electric current, e.g. cells or a battery

The battery acts as an 'electron pump', pulling electrons from one electrode and pushing electrons into the other electrode. Withdrawing electrons from an electrode gives the electrode a positive charge, and adding electrons to an electrode gives it a negative charge.

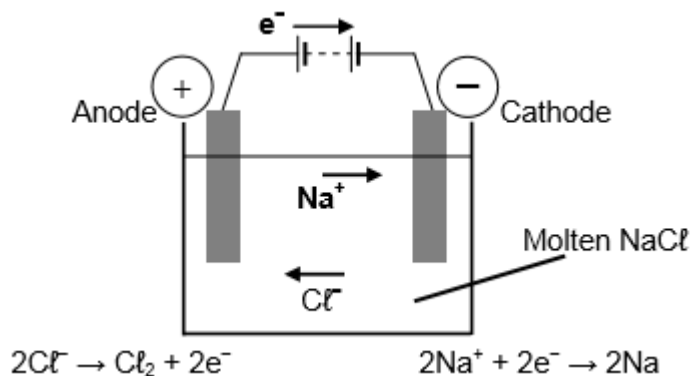
In an electrolytic cell the battery therefore determines which electrode is negative and which one is positive (polarity).

Ionic substances in the solid state cannot conduct an electric current. The electrolyte is obtained by melting an ionic substance or by dissolving it in water in order to enable the cations (positive ions) and anions (negative ions) to move freely.

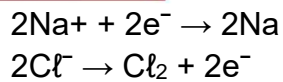
3.2.1 Electrolysis of molten salts using inert electrodes Inert electrodes do not take part in the electrolysis reaction. Carbon or platinum are usually used as inert electrodes.

3.2.1.1 Electrolysis of molten sodium chloride

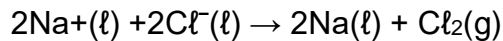
The diagram below shows a simple electrolytic cell using molten sodium chloride as electrolyte. Wires from a battery are connected to electrodes dipped into molten sodium chloride. The electrodes are inert and do not take part in the reaction.



- In the above diagram, electrons flow from the negative terminal of the battery. The electrode connected to the negative terminal of the battery is the negative electrode. The electrode connected to the positive terminal of the battery is the positive electrode.
- The electrolyte (NaCl) contains positive (Na^+) and negative (Cl^-) ions that are, when melted, free to move around in the solution. These are the only ions present in the melt.
- When electrons flow in the external circuit, negative ions in the electrolyte move to /are attracted to the positive electrode. In the above cell, the Cl^- ions will move to the positive electrode.
- When electrons flow in the external circuit, positive ions in the electrolyte move to /are attracted to the negative electrode. In the above cell, the Na^+ ions will move to the negative electrode.
- At the positive electrode: Negative ions lose electrons at the positive electrode according to the following half-reaction: $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$. A loss of electrons is oxidation. Oxidation takes place at the anode – therefore the positive electrode in an electrolytic cell is the anode.
- Chlorine is a product of the oxidation. Chlorine is a gas – bubbles will thus be observed at the positive electrode.
- At the negative electrode: The negative electrode has an excess of electrons. The positive ions gain electrons at the negative electrode according to the following halfreaction: $\text{Na}^+ + \text{e}^- \rightarrow \text{Na}$. A gain of electrons is a reduction. Reduction takes place at the cathode – therefore the negative electrode in an electrolytic cell is the cathode.
- Sodium is a product of the reduction. Sodium is a solid and will be deposited on the negative electrode. The mass of the negative electrode will increase.
- The net cell reaction is obtained by balancing the two half-reactions:



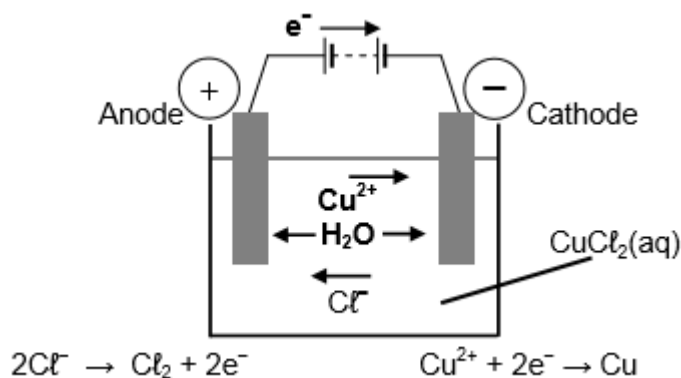
(Reduction; with Na^+ the oxidising agent)
(Oxidation; with Cl^- the reducing agent)



- The products of the electrolysis of molten NaCl are liquid sodium metal (Na) and chlorine gas (Cl_2). A specially designed cell, called the 'Downs cell' is used to prepare these products commercially.

3.2.1.2 Electrolysis of concentrated copper (II) chloride solution

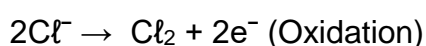
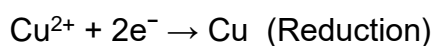
In the simplified electrolytic cell below, an electric current passes through a solution of copper (II) chloride in water. Cu^{2+} ions, Cl^- ions and water molecules are present in the solution. Carbon rods are used as electrodes.



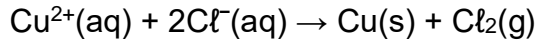
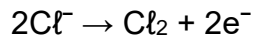
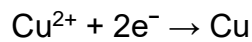
Part of redox Table

H_2O	$+ 2\text{e}^- \rightleftharpoons \text{H}_2 + 2\text{OH}^-$	-0,83	↑
Zn^{2+}	$+ 2\text{e}^- \rightleftharpoons \text{Zn}$	-0,76	
Cr^{3+}	$+ 3\text{e}^- \rightleftharpoons \text{Cr}^+$	-0,74	
Fe^{2+}	$+ 2\text{e}^- \rightleftharpoons \text{Fe}$	-0,44	
Cu^{2+}	$+ \text{e}^- \rightleftharpoons \text{Cu}^+$	+0,16	
SO_4^{2-}	$+ 4\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{SO}_2 + 2\text{H}_2\text{O}$	+0,17	
Cu^{2+}	$+ 2\text{e}^- \rightleftharpoons \text{Cu}$	+0,34	
Cl_2	$+ 2\text{e}^- \rightleftharpoons 2\text{Cl}^-$	+1,36	

Two half-reactions are:

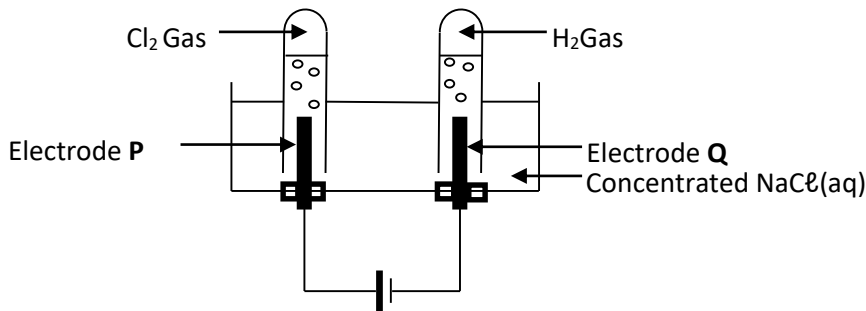


The net cell reaction is therefore:



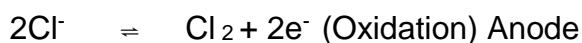
3.2.1.3 Electrolysis of concentrated solution of sodium chloride (brine)

Na^{+} ions, Cl^{-} ions and water molecules are present in the solution. Carbon rods are used as electrodes.



Part of redox Table

$\text{Na}^{+} + \text{e}^{-} \rightleftharpoons \text{Na}$	-2,71
$\text{Mg}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Mg}$	-2,36
$\text{H}_2\text{O} + 2\text{e}^{-} \rightleftharpoons \text{H}_2 + 2\text{OH}^{-}$	-0,83
$\text{Zn}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Zn}$	-0,76
$\text{Cr}^{3+} + 3\text{e}^{-} \rightleftharpoons \text{Cr}^{+}$	-0,74
$\text{Fe}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Fe}$	-0,44
$\text{Cu}^{2+} + \text{e}^{-} \rightleftharpoons \text{Cu}^{+}$	+0,16
$\text{SO}_4^{2-} + 4\text{H}^{+} + 2\text{e}^{-} \rightleftharpoons \text{SO}_2 + 2\text{H}_2\text{O}$	+0,17
$\text{Cu}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Cu}$	+0,34
$\text{Cl}_2 + 2\text{e}^{-} \rightleftharpoons 2\text{Cl}^{-}$	+1,36
$\text{H}_2\text{O} + 2\text{H}^{+} + 2\text{e}^{-} \rightleftharpoons 2\text{H}_2$	+1,77



Net Reaction

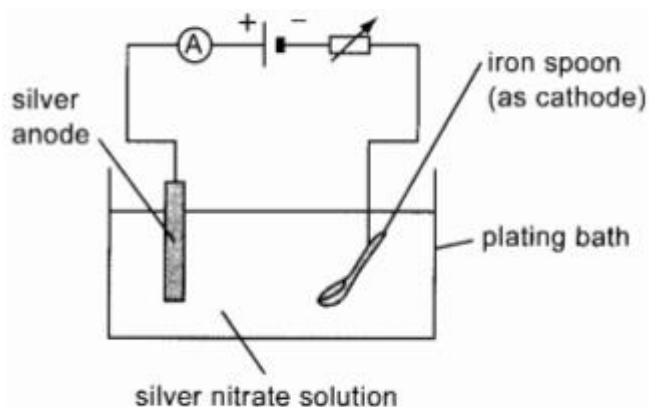


Major reactions in the chlor-alkali industry

Industrial Applications of Electrolysis

Electroplating: It is a process to plate one metal with a thin, even layer of another metal. A metal is electroplated to protect against corrosion and/or to improve appearance.

Refer to the following diagram to plate an iron spoon with silver:

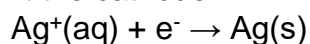


- The metal object to be electroplated (the iron spoon) is made the cathode.
- The plating metal (silver) is made the anode.
- The electrolytic cell contains the plating metal solution (silver nitrate) as the electrolyte.

At the anode



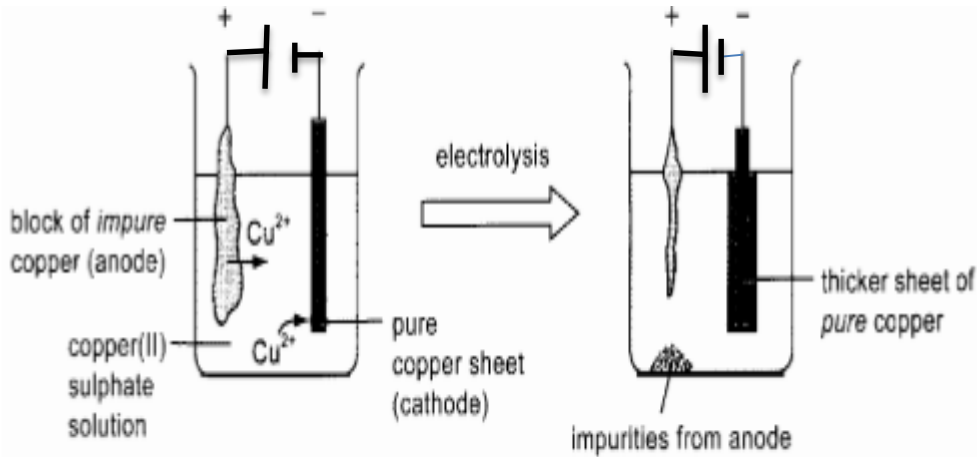
At the cathode



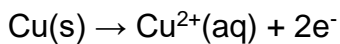
PURIFICATION OF METALS

Electrolytic refining could be used to purify metals such as lead and copper.

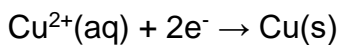
In the refining of copper, an aqueous solution of copper (II) sulphate is used as the electrolyte. A block of impure copper is used as the anode. A sheet of pure copper is used as the cathode. Refer to the following diagram:



At the anode



At the cathode

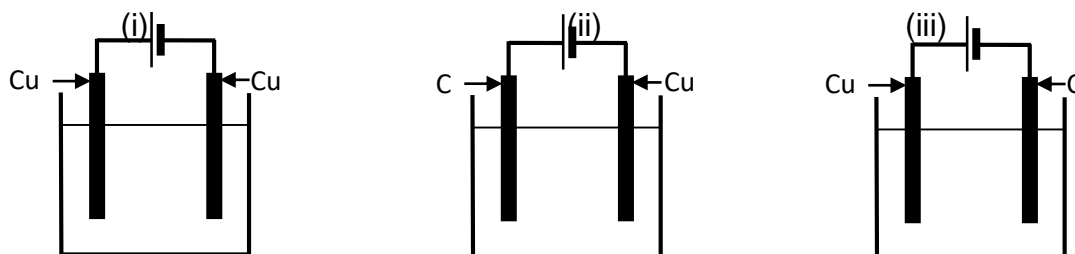


Impure metals from the impure copper block will fall down the electrolyte as sludge.

TYPICAL EXAM QUESTIONS

QUESTION 1 MULTIPLE CHOICE QUESTIONS

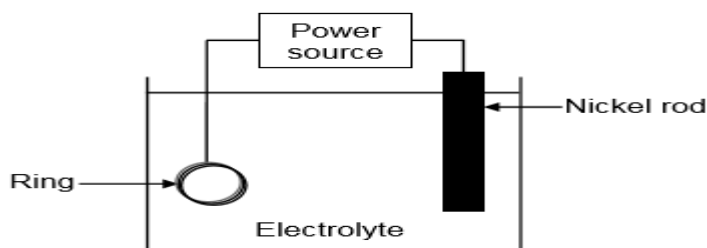
1.1 In each of the electrolytic cells below, copper (II) sulphate is used as the electrolyte. The electrodes are either carbon (C) or copper (Cu).



In which cell(s) will the concentration of the electrolyte remain constant during electrolysis?

- A (i) only
- B (i) and (ii) only
- C (i) and (iii) only
- D (ii) and (iii) only (2)

1.2 A learner wants to electroplate a copper ring with nickel. He uses the experimental set-up shown in the simplified diagram below.



Which ONE of the following is CORRECT?

	ANODE	CATHODE	ELECTROLYTE
A	Copper ring	Nickel rod	CuSO_4
B	Nickel rod	Copper ring	CuSO_4
C	Copper ring	Nickel rod	NiSO_4
D	Nickel rod	Copper ring	NiSO_4

(2)

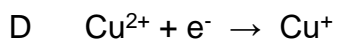
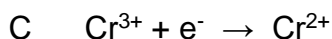
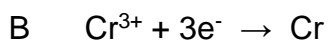
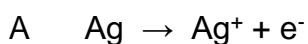
1.3 A sample of silver contains impurities of gold. During purification by electrolysis, the impure silver is made into an electrode.

Which ONE of the following is the best choice of anode and cathode for this process?

	Cathode	Anode
A	Pure gold	Impure silver
B	Impure silver	Pure gold
C	Pure silver	Impure silver
D	Impure silver	Pure silver

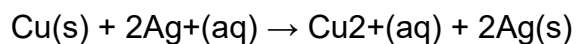
(2)

1.4 Which ONE of the equations below represents the half-reaction occurring at the CATHODE of an electrochemical cell that is used to electroplate an object?



(2)

1.5 Consider the reaction represented by the balanced equation below:



In the above reaction, Cu(s) is the ...

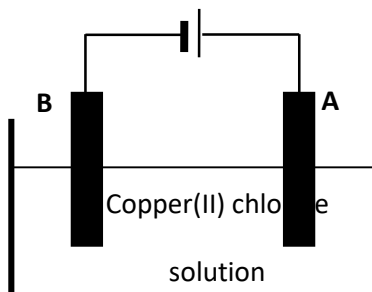
A oxidising agent and is reduced. B oxidising agent and is oxidised.

C reducing agent and is reduced. D reducing agent and is oxidised. (2)

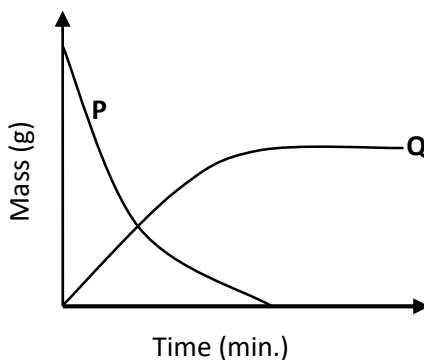
QUESTION 2

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

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



The graphs below show the change in mass of the electrodes whilst the cell is in operation.



2.2 Define a reducing agent in terms of electron transfer. (2)

2.3 Which graph represents the change in mass of electrode A? (1)

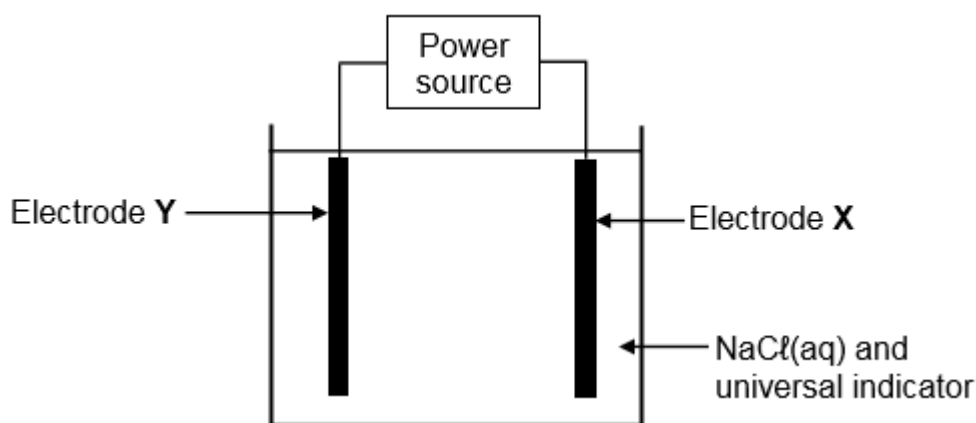
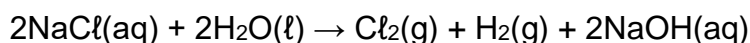
2.4 Write down the half-reaction that takes place at electrode A. (2)

2.5 Electrodes A and B are now replaced by graphite electrodes. It is observed that chlorine gas (Cl_2) is released at one of the electrodes.

At which electrode (A or B) is chlorine gas formed? Fully explain how it is formed.

QUESTION 3

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:



Initially the solution has a green colour. Universal indicator becomes red in acidic solutions and purple in alkaline solutions.

3.1 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.

3.2 Write down the:

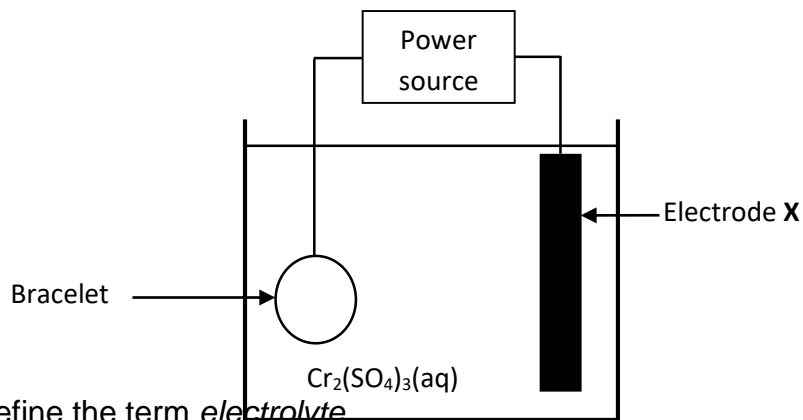
3.2.1 Half-reaction that takes place at electrode Y (2)

3.2.2 NAME or FORMULA of the gas released at electrode X (1)

3.3 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)

QUESTION 4

A technician is plating a bracelet with chromium in an electrolytic cell containing $\text{Cr}_2(\text{SO}_4)_3(\text{aq})$. The simplified diagram of the electrolytic cell is shown below.

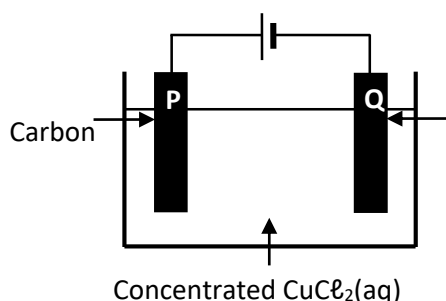


- 4.1 Define the term *electrolyte*. (2)
- 4.2 Which electrode, the BRACELET or X, is the cathode? (1)
- 4.3 Write down the:
- 4.3.1 Metal of which electrode X is made (1)
- 4.3.2 Reduction half-reaction (2)
- 4.4 During the process, the bracelet is plated with 0,86 g chromium. Calculate the number of electrons transferred during the process. (6)
- [12]**

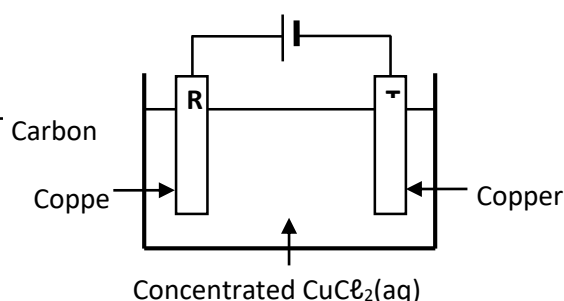
QUESTION 5

The simplified diagrams below represent two electrochemical cells, **A** and **B**. A concentrated copper(II) chloride solution is used as electrolyte in both cells.

ELECTROCHEMICAL CELL A



ELECTROCHEMICAL CELL B

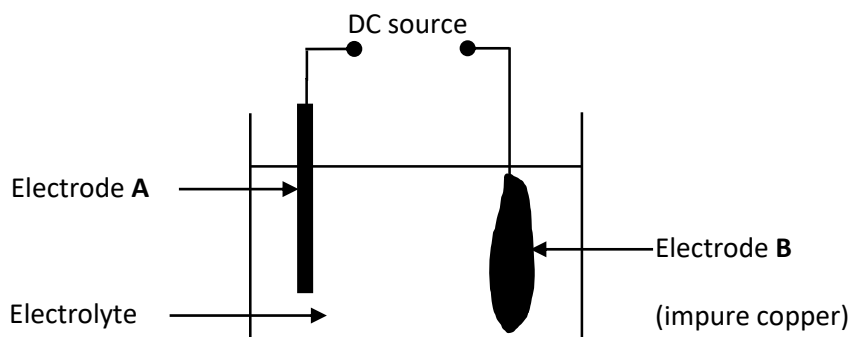


- 5.1 Are **A** and **B** ELECTROLYTIC or GALVANIC cells? (1)
- 5.2 Which of the electrodes (**P**, **Q**, **R** or **T**) will show a mass increase? Write down a half-reaction to motivate the answer. (4)

- 5.3 Write down the NAME or FORMULA of the product formed at:
- 5.3.1 Electrode **P** (1)
- 5.3.2 Electrode **R** (1)
- 5.4 Fully explain the answer to QUESTION 5.3.2 by referring to the relative strengths of the reducing agents involved. (3)
- [10]**

QUESTION 6

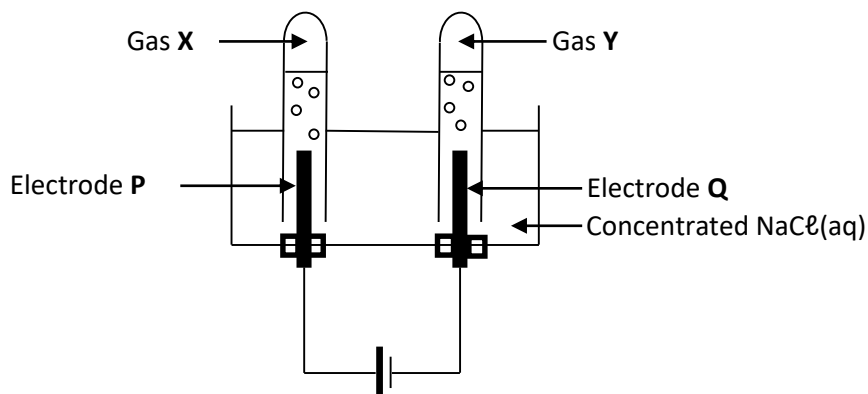
The simplified diagram below represents an electrochemical cell used for the purification of copper.



- 6.1 Define the term *electrolysis*. (2)
- 6.2 Give a reason why a direct-current (DC) source is used in this experiment. (1)
- 6.3 Write down the half-reaction which takes place at electrode **A**. (2)
- 6.4 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)
- 6.5 After the purification of the impure copper was completed, it was found that $2,85 \times 10^{-2}$ moles of copper were formed.
- The initial mass of electrode **B** was 2,0 g. Calculate the percentage of copper that was initially present in electrode **B**. (4)

QUESTION 7

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



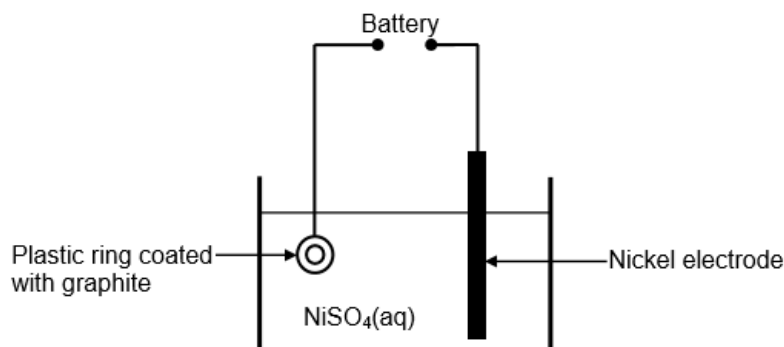
The balanced equation for the net (overall) cell reaction is:



- 7.1 Is the reaction EXOTHERMIC or ENDOTHERMIC? (1)
- 7.2 Is electrode **P** the ANODE or the CATHODE? Give a reason for the answer. (2)
- 7.3 Write down the:
- 7.3.1 NAME or FORMULA of gas **X** (1)
- 7.3.2 NAME or FORMULA of gas **Y** (1)
- 7.3.3 Reduction half-reaction (2)
- 7.4 Is the solution in the cell ACIDIC or ALKALINE (BASIC) after completion of the reaction? Give a reason for the answer. (2)

QUESTION 8

The diagram below shows a simplified electrolytic cell that can be used to electroplate a plastic ring with nickel. Prior to electroplating the ring is covered with a graphite layer.



8.1 Define the term electrolyte. (2)

8.2 Give ONE reason why the plastic ring must be coated with graphite prior to electroplating. (1)

8.3 Write down the:

8.3.1 Half-reaction that occurs at the plastic ring (2)

8.3.2 NAME or FORMULA of the reducing agent in the cell. Give a reason for the answer. (2)

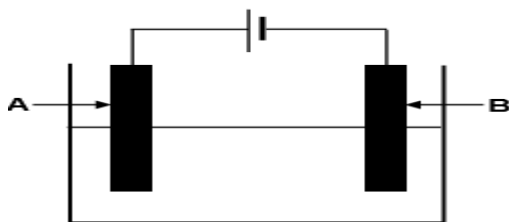
8.4 Which electrode, the RING or NICKEL, is the cathode? Give a reason for the answer.

The nickel electrode is now replaced with a carbon rod.

8.5 How will the concentration of the electrolyte change during electroplating? Write down only INCREASES, DECREASES or NO CHANGE. Give a reason for the answer. (2)

QUESTION 9

The diagram below shows an electrochemical cell used to purify copper. A solution that conducts electricity is used in the cell.



9.1 Write down:

9.1.1 ONE word for the underlined phrase above the diagram (1)

9.1.2 The type of electrochemical cell illustrated above (1)

9.2 In which direction (from A to B or from B to A) will electrons flow in the external circuit? (1)

9.3 Which electrode (A or B) is the:

9.3.1 Cathode (1)

9.3.2 Impure copper (1)

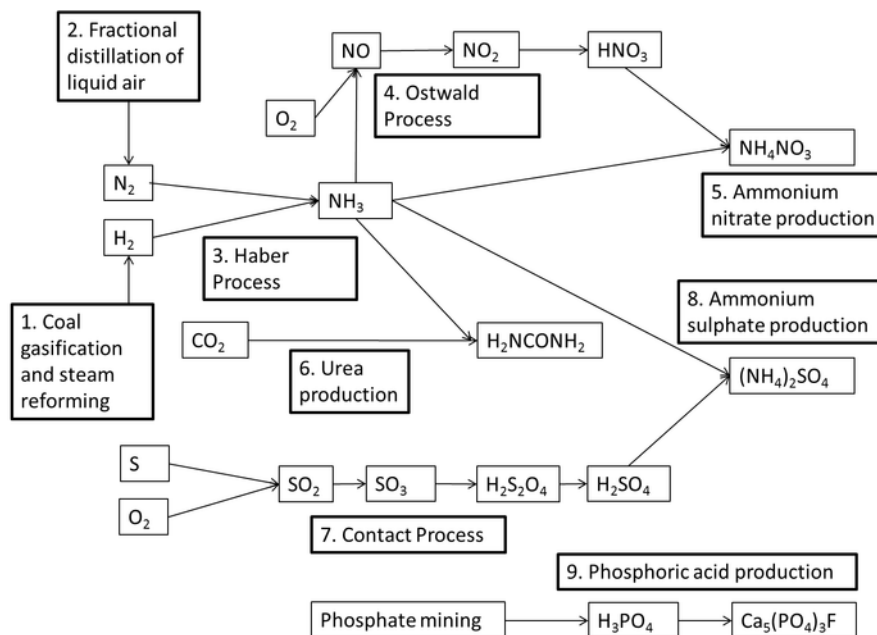
9.4 How will the mass of electrode A change as the reaction proceeds? Choose from INCREASES, DECREASES or REMAINS THE SAME.

Give a reason for the answer. (2)

PHYSICAL SCIENCES

GRADE 12

FERTILISER INDUSTRY



*MOVING BEYOND THE LIMITS, SETTING THE STANDARD AND
LEAVING NO CHILD BEHIND*

CHEMICAL INDUSTRY

FERTILIZERS

TERMINOLOGY:

A fertilizer is a chemical compound that is given to a plant to promote growth.

Fertilizer provide basically 3 major plant nutrients (primary nutrients) are NPK Nitrogen, potassium and phosphorous.

Nutrients are absorbed as dissolved salts from the soil. Without nutrients plants would not be able to make food for animals.

Fertilizers are grouped into organic and inorganic fertilizers.

Organic fertilizers are made from natural products like manure.

Inorganic fertilizers are industrially produced compounds.

Importance of primary nutrients

Nitrogen

Absorbed as nitrates and ammonium salts. Nitrogen helps plants to have healthy leaves and stems.(for leaf system)

Plants use nitrogen to produce proteins and vitamins

Phosphorous

Plants make use of phosphorous for the development of roots and cells.

(for root system).

Potassium

Potassium helps plants in the process of cell division, production of carbohydrates and in the uptake of nitrogen as a nutrient.

Potassium is needed for flowers and fruit development.(fruits and flowers)

Fertilizers are needed to replace the nutrients plants remove from the soil.

Natural sources of fertilizers

- Animal manure and plant composite(plant decompose)
- Guano(bird dropping)
- Bone meal

NPK RATIOS AND PERCENTAGE COMPOSITION

The nutrient quantity in fertilizer bags are determined by using the given ratios. Fertilizer packing contains a set of numbers 6:1:5. These numbers are called N:P:K ratio and they give the mass ratio of nitrogen, potassium and phosphorous in the fertilizer.

NPK is the ratio (proportion) in which nitrogen, phosphorous and potassium occurs in a certain quantity of fertilizer.

A number in the brackets after the ratio indicates the percentage by mass of fertilizer.

3:1:5(38)

38 is the total percentage by mass of fertilizer

Depending on the type of plants you are growing and the growth stage they are in, you may need to use a fertilizer with different ratio.

For root growth, use a fertilizer with a greater ratio of phosphorous in it.

For leaf growth fertilizer with a greater ratio of nitrogen and for fruits a fertilizer with a greater ratio of potassium.

Worked examples

1. Calculate the mass of nitrogen present in the 500g of fertilizer with a NPK ratio 5:2:3(40)

$$\text{Mass of fertilizer} = 0,4 \times 500 = 200\text{g}$$

$$\text{Mass of nitrogen} = \frac{5}{10} \times 200 = 100\text{g}$$

- 1 A bag of fertilizer is marked as follows 3:1:4(26). Calculate the percentage composition of nitrogen, potassium and phosphorous.

$$\text{Total ratio} = 3+1+4 = 8$$

$$\%N = \frac{3}{8} \times 26 = 9,75\%$$

$$\%K = \frac{4}{8} \times 26 = 13\%$$

$$\%P = \frac{1}{8} \times 26 = 3,25\%$$

- 2 A 50kg bag of fertilizer is labelled as 3:1:5(30). Calculate the mass of phosphorous in this bag of fertilizer.

$$\text{Mass of fertilizer} = 0,3 \times 50 = 15\text{kg}$$

$$\text{Mass of P} = \frac{5}{9} \times 15 = 8,33\text{kg}$$

Option 2

$$\%P = \frac{5}{9} \times 30 = 16,67\%$$

$$\text{Mass of P} = 0,1667 \times 50 = 8,33\text{kg}$$

- 3 Two 50kg bags containing fertilizers P and Q respectively are labelled as

Fertilizer P: 5: 2: 3(25)

Fertilizer Q: 1:3:4(20)

What does the number 25 and 20 on the labels represent?

Total percentage of fertilizer

Using calculations determine which fertilizer (P or Q) contains the greater mass of potassium

$$\text{Mass of fertilizer in P} = 0,25 \times 50 = 12,5 \text{ kg}$$

$$\text{Mass of K in fertilizer P} = \frac{3}{10} \times 12,5 = 3,75\text{kg}$$

$$\text{Mass of fertilizer in Q} = 0,2 \times 50 = 10\text{kg}$$

$$\text{Mass of K in fertilizer Q} = \frac{4}{8} \times 10 = 5 \text{ kg}$$

Fertilizer Q has more potassium per mass than fertilizer P

- 4 Thabo wants to start a vegetable garden in his community. The department of agriculture donates the four fertilizers described below

A: 7:1:3(21)

B; 3:2:1(28)

C: 2:3:4 (22)

D: ammonium sulphate

What is the meaning of 21 indicated at fertilizer A? Total percentage of fertilizer

From fertilizers A; B and C, choose a fertilizer which is most suitable for

Spinach A (nitrogen)

Tomatoes C (potassium)

Maize C (phosphorous)

Calculate the

- (a) Percentage of nitrogen in fertilizer B

$$\%N = \frac{3}{6} \times 28 = 14\%$$

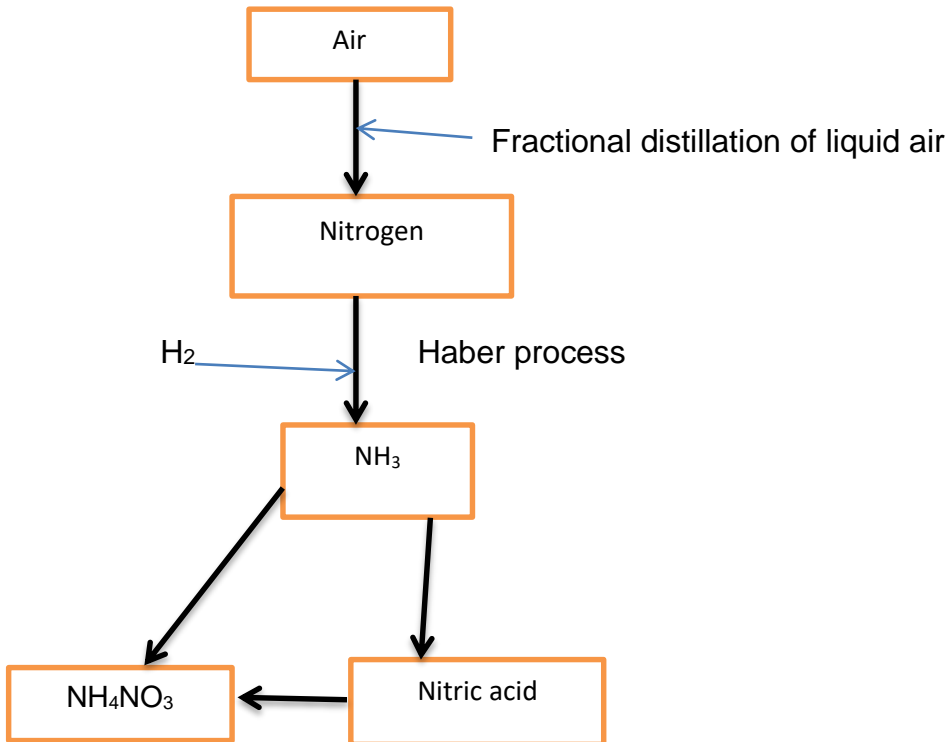
- (b) Mass of potassium present in a 20kg bag of fertilizer C

$$\text{Mass of fertilizer} = 0,22 \times 20 = 4,4\text{kg}$$

$$\%K = \frac{4}{9} \times 4,4 = 1,96\text{kg}$$

Nitrogen based fertilizers

Production of ammonium nitrate

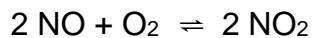


1. Production of nitric acid (OSTWARD Process)

Ammonia is oxidised by heating it with oxygen in presence of platinum catalyst to form NO and H₂O



The NO is oxidised again to yield nitrogen dioxide

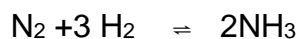


The NO₂ is absorbed by water to produce HNO₃

Un reacted NO is recycled and acid is concentrated to the required strength.

2. Production of NH₃(Haber process)

N₂ and H₂ gas react to produce NH₃ gas in presence of iron as a catalyst under high pressure of 200 atmospheres and temperature 450-500°C



3 Production of H₂

H₂ is produced by steam reforming of CH₄ gas

At high temperatures (700-1100°C) steam reacts with methane to yield a mixture of CO and H₂



During second stage, taking place at 130°C additional H₂ is produced



Production of NH₄NO₃

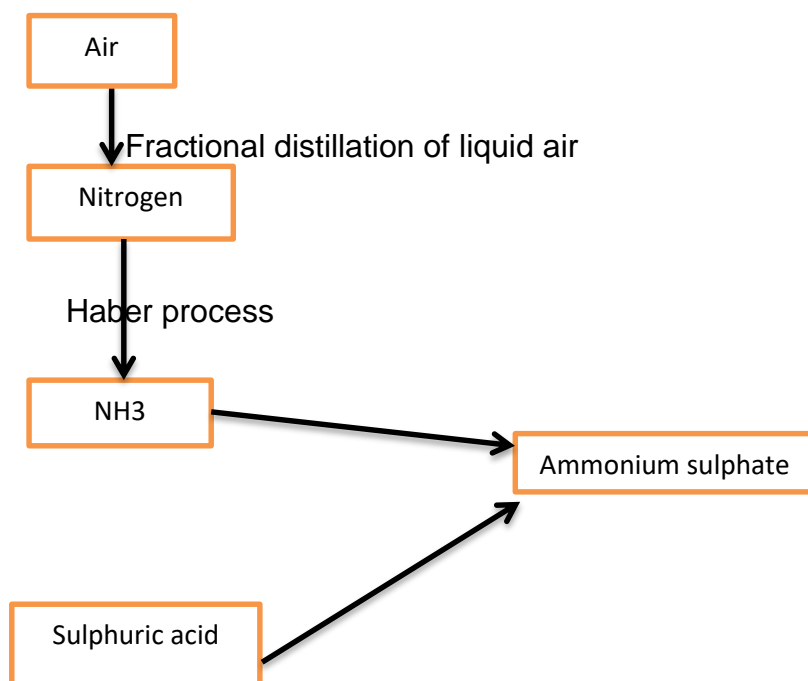
HNO₃ acid reacts with NH₃ to form the salt



UREA (NH₂)₂CO

It is produced by reaction of CO₂ with NH₃

Production of (NH₄)₂SO₄



Production of sulphuric acid (contact process)

Sulphur is burned to produce SO₂

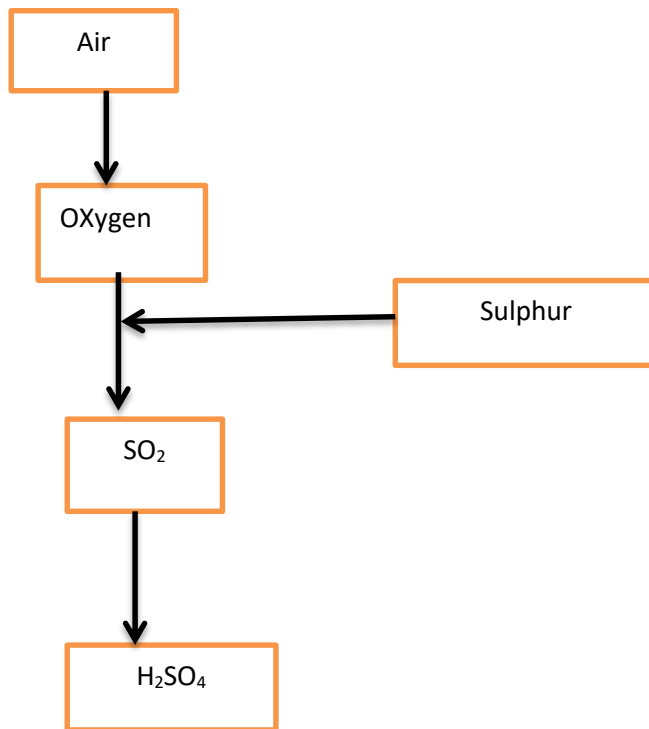


SO₂ is oxidized to SO₃ using O₂ in presence of vanadium (v) oxide



SO₃ is not dissolved in water to produce the acid because the reaction is highly exothermic and forms acid mist.

FLOW DIAGRAM



AMMONIUM SULPHATE

H_2SO_4 is reacted with ammonia to produce a solution of ammonium sulphate $(\text{NH}_4)_2\text{SO}_4$

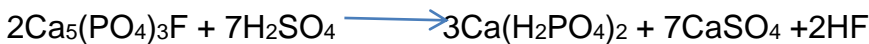
Potassium base fertilizers

The potassium containing fertilizers used industrially in agriculture are potassium chloride, potassium sulphate and potassium nitrate. Potassium is not available in SA so it is imported from other countries.

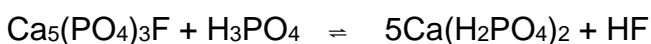
Phosphorous base fertilizers

Come from phosphate salt mined at phalaborwa in SA. The natural phosphate rock is insoluble in water and therefore not accessible to plants.

The phosphate rock is dissolved in sulphuric acid to form super phosphate that can be absorbed by plants



If phosphoric acid is reacted with the rock triple super phosphate is produced



ENVIRONMENTAL IMPACT OF ARTIFICIAL FERTILIZERS

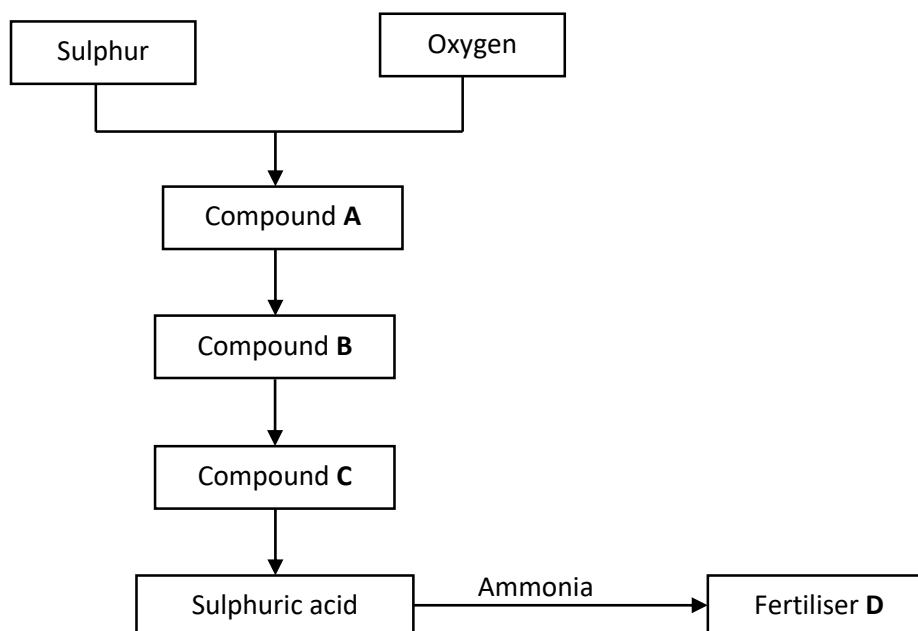
- The excessive use of artificial fertilizers leads to eutrophication.
Rain leaches excessive fertilizers into rivers and dams causing the growth of algae to increase. When algae dies and decomposes, it depletes the oxygen in the water. This leads to suffocation of aquatic animals such as fish and they eventually die. These areas are called dead zones.
- Fertilisers in water leads to excess of nitrates in water resulting in blue baby syndrome/cancer.

EXAM TYPE QUESTIONS**QUESTION 1 MULTIPLE CHOICE QUESTIONS**

- 1.1 The primary nutrient needed by plants for the promotion of root growth is...
- A Nitrogen B Phosphorus
C Potassium D Calcium (2)
- 1.2 Which ONE of the following is a primary nutrient for plants?
- A Oxygen B Carbon
C Potassium D Magnesium (2)
- 1.3 Which ONE of the following pairs of reactants is used in a reaction during the contact process?
- A $N_2(g)$ and $H_2(g)$ B $SO_2(g)$ and $O_2(g)$
C $NH_3(g)$ and $O_2(g)$ D $H_2SO_4(l)$ and $NH_3(g)$ (2)
- 1.4 Which ONE of the following compounds is produced in the Ostwald process?
- A $N_2(g)$ B $NH_3(g)$
C $HNO_3(l)$ D $NH_4NO_3(s)$ (2)
- 1.5 Eutrophication involves the following stages:
- (i) Increase in growth of algae
(ii) Increase in nitrate concentration
(iii) Death of fish
(iv) Decrease in oxygen concentration
- Which ONE of the following CORRECTLY represents the order in which these stages occur?
- A (i) (ii) (iii) (iv) B (i) (ii) (iv) (iii)
C (ii) (i) (iii) (iv) D (ii) (i) (iv) (iii) (2)
- 1.6 A gardener needs a fertiliser with the highest percentage of the relevant nutrient to obtain a green lawn.
- Which ONE of the following NPK fertilisers will give the best results?
- A 8 : 1 : 5 B 7 : 1 : 1
C 3 : 2 : 3 D 3 : 1 : 5 (2)

QUESTION 2

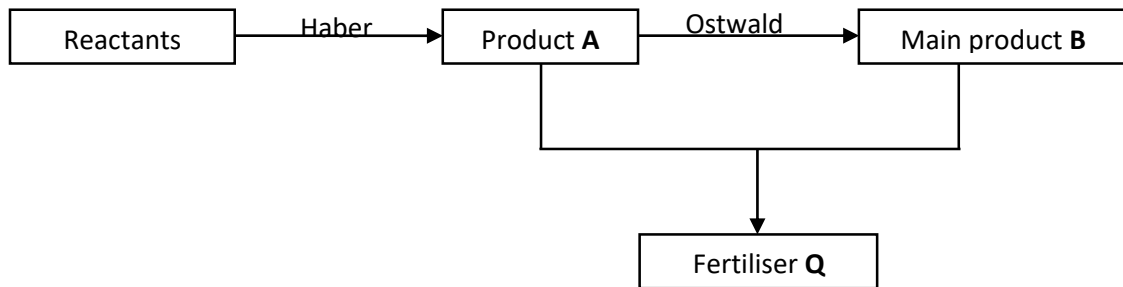
Sulphuric acid is used, amongst others, in the manufacturing of fertilisers. The flow diagram given below shows how fertiliser D can be prepared using sulphuric acid as one of the reagents.



- 2.1 Write down the NAME of the industrial process for the preparation of sulphuric acid. (1)
- 2.2 Compound A is formed when sulphur burns in oxygen. Write down the NAME or FORMULA of compound A. (1)
- 2.3 Compound B is formed when compound A reacts with oxygen in the presence of a catalyst. Write down the:
 - 2.3.1 NAME or FORMULA of the catalyst (1)
 - 2.3.2 Balanced equation for the reaction which takes place (3)
- 2.4 Compound B is dissolved in concentrated sulphuric acid to form compound C. Write down the:
 - 2.3.1 NAME or FORMULA of compound C (1)
 - 2.3.2 Reason why compound B is not dissolved in water to form sulphuric acid
- 2.5 Write down the NAME or FORMULA of fertiliser D. (1)
- 2.6 Inorganic fertilisers are soluble in water. This can result in eutrophication if they are washed off into rivers during heavy rain. Write down ONE negative impact of eutrophication on the economy of a country. (2)

QUESTION 3

The flow diagram below shows the processes involved in the industrial preparation of fertiliser Q.

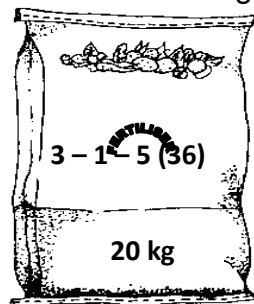


Write down the:

3.1.1 NAMES or FORMULAE of the reactants used in the Haber process (2)

3.1.2 Balanced equation for the formation of fertiliser Q (3)

3.2 The diagram below shows a bag of NPK fertiliser.



Calculate the mass of nitrogen in the bag. (4)

QUESTION 4

Ammonia is an important fertiliser. Large amounts are prepared from hydrogen and nitrogen in industry.

4.1 For the industrial preparation of ammonia, write down:

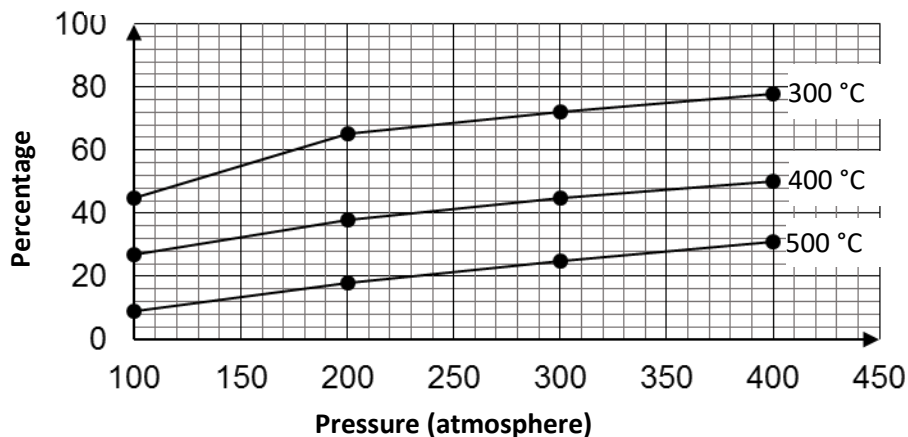
4.1.1 The name of the process used (1)

4.1.2 A balanced equation for the reaction that occurs (3)

4.1.3 The source of nitrogen (1)

4.2 The yield of ammonia changes with temperature and pressure during its industrial preparation. The graphs below show how the percentage of ammonia in the reaction mixture that leaves the reaction vessel varies under different conditions.

GRAPHS OF THE PERCENTAGE OF AMMONIA IN THE REACTION MIXTURE VERSUS PRESSURE



4.2.1 Use the appropriate graph to estimate the percentage of ammonia present in the reaction mixture at 240 atmosphere and 400 °C. (1)

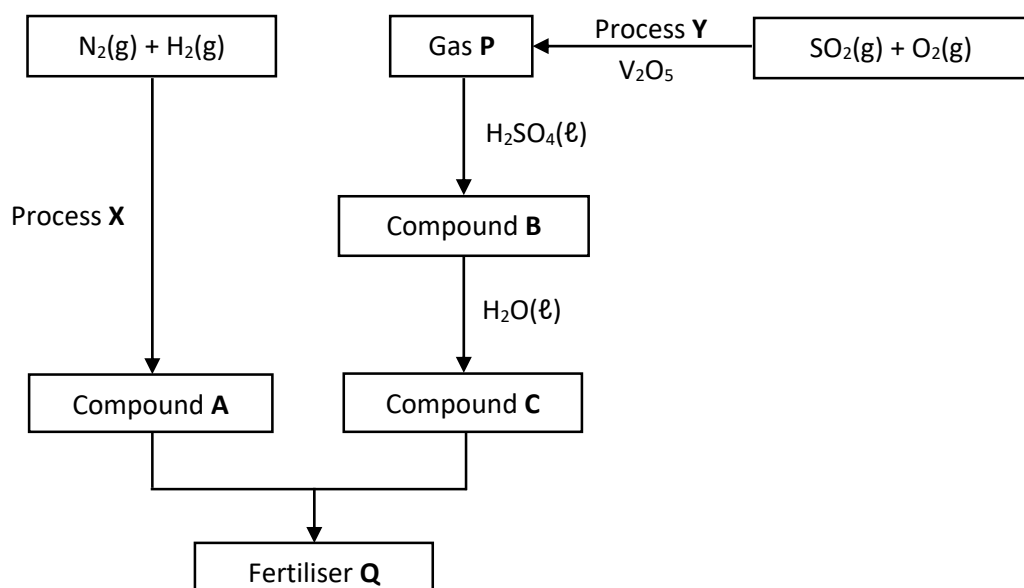
4.2.2 State TWO advantages of using high pressure in the preparation of ammonia. (2)

4.2.3 The advantage of using a low temperature is the large percentage of ammonia formed. What is the disadvantage of using a low temperature?

4.3 Ammonia is also used in the preparation of other fertilisers such as ammonium nitrate. Calculate the mass of nitrogen in a 50 kg bag of pure ammonium nitrate fertiliser. (3)

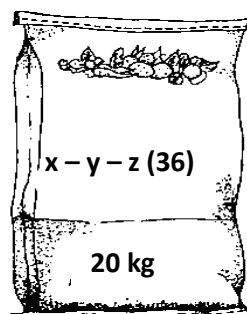
QUESTION 5

The flow diagram below shows the processes involved in the industrial preparation of fertiliser Q.



Write down the:

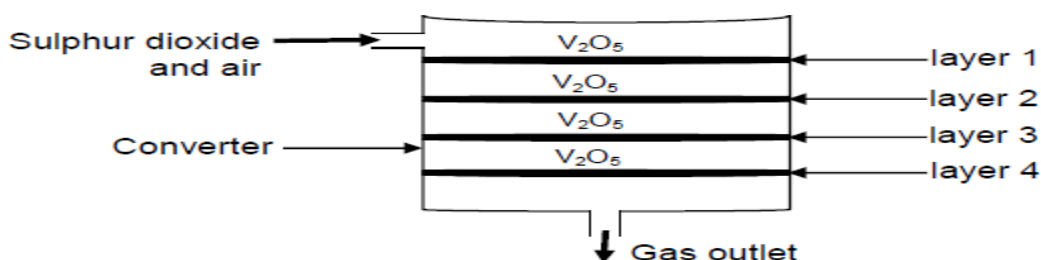
- 5.1.1 Name of process X (1)
 - 5.1.2 Name of process Y (1)
 - 5.1.3 NAME or FORMULA of gas P (1)
 - 5.1.4 Balanced equation for the formation of compound B (3)
 - 5.1.5 Balanced equation for the formation of fertiliser Q (4)
- 5.2 The diagram below shows a bag of NPK fertiliser of which the NPK ratio is unknown. It is found that the mass of nitrogen in the bag is 4,11 kg and the mass of phosphorus is 0,51 kg.



Calculate the NPK ratio of the fertiliser.

QUESTION 6

The industrial process for the preparation of sulphuric acid involves a series of stages. The second stage in this process involves the conversion of sulphur dioxide into sulphur trioxide in a converter as illustrated below. In the converter the gases are passed over vanadium pentoxide (V_2O_5) placed in layers as shown below.



Write down the:

- 6.1.1 Balanced equation for the reaction taking place in the converter (3)
- 6.1.2 Function of the vanadium pentoxide (1)

The table below shows data obtained during the second stage.

VANADIUM PENTOXIDE LAYER	TEMPERATURE OF GAS BEFORE THE REACTION (°C)	TEMPERATURE OF GAS AFTER THE REACTION (°C)	PERCENTAGE OF REACTANT CONVERTED TO PRODUCT
1	450	600	66
2	450	518	85
3	450	475	93
4	450	460	99,5

6.2 Is the reaction in the second stage EXOTHERMIC or ENDOTHERMIC? Refer to the data in the table to give a reason for the answer. (2)

6.3 After the conversion at each layer the gases are cooled down to 450 °C. Fully explain why the gases must be cooled to this temperature. (3)

6.4 During the third stage sulphur trioxide is dissolved in sulphuric acid rather than in water to produce oleum.

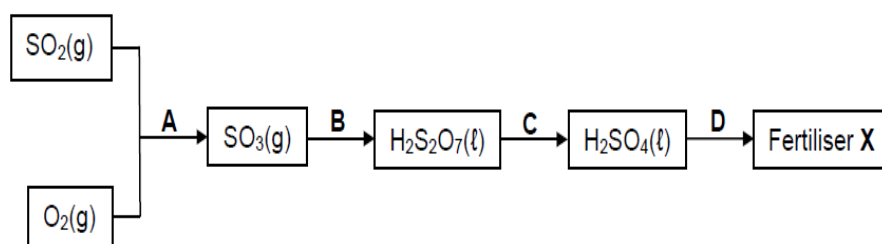
6.4.1 Write down the FORMULA of oleum. (1)

6.4.2 Give a reason why sulphur trioxide is not dissolved in water. (1)

6.5 Sulphuric acid reacts with ammonia to form a fertilizer. Write down a balanced equation for this reaction. (3)

QUESTION 7

Reactions A, B, C and D in the flow diagram below represent the manufacturing of Fertiliser X.



7.1 Write down the name of the industrial preparation of sulphuric acid

7.2 Write down the:

7.2.1 NAME or FORMULA of the catalyst used in reaction A

7.2.2 Balanced equation for reaction C

7.3 Ammonia is one of the reactants used in reaction D to make Fertiliser X.

Write down:

7.3.1 A balanced equation for reaction D

7.3.2 The NAME of Fertiliser X

QUESTION 8

Ammonium nitrate is an important fertiliser. It is produced by reacting nitric acid with ammonia. Both nitric acid and ammonia are prepared on a large scale in industry.

8.1 Write down the name of the industrial preparation of nitric acid. (1)

8.2 The catalytic oxidation of ammonia is one of the steps in the process named in QUESTION 8.1.

Write down the NAMES or FORMULAE of the TWO products formed in this step. (2)

8.3 Write down a balanced equation for the preparation of ammonium nitrate. (3)

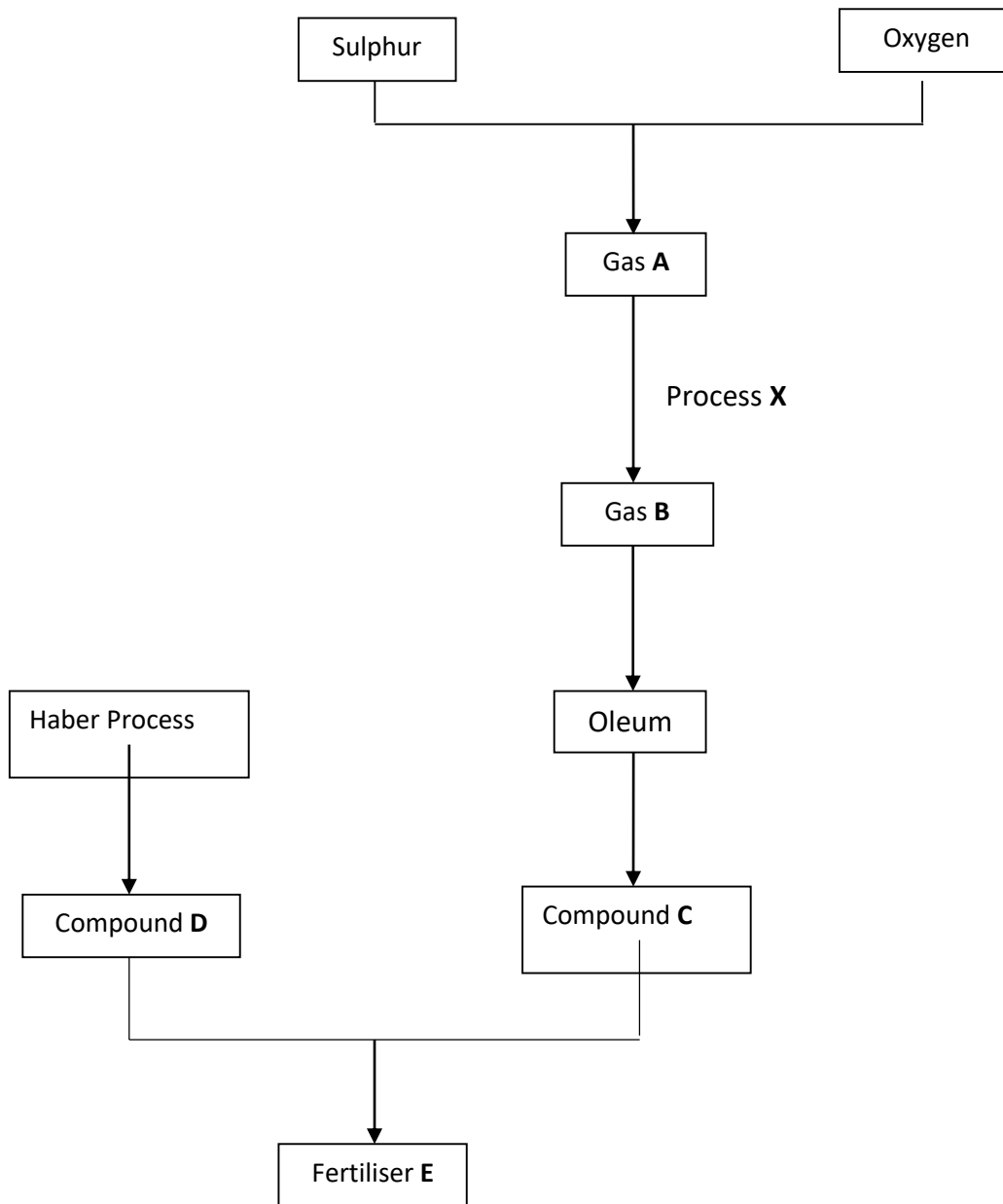
8.4 Calculate the mass, in kilogram, of ammonium nitrate that can be made from $6,8 \times 10^4$ kg of ammonia and excess nitric acid.

(One mole of ammonia produces one mole of ammonium nitrate.) (3)

8.5 Ammonium nitrate is often mixed with potassium chloride and ammonium phosphate. Give a reason why it is mixed with these compounds. (1)

QUESTION 9

Different processes used in the preparation of fertiliser **E** are represented in the flow diagram below.



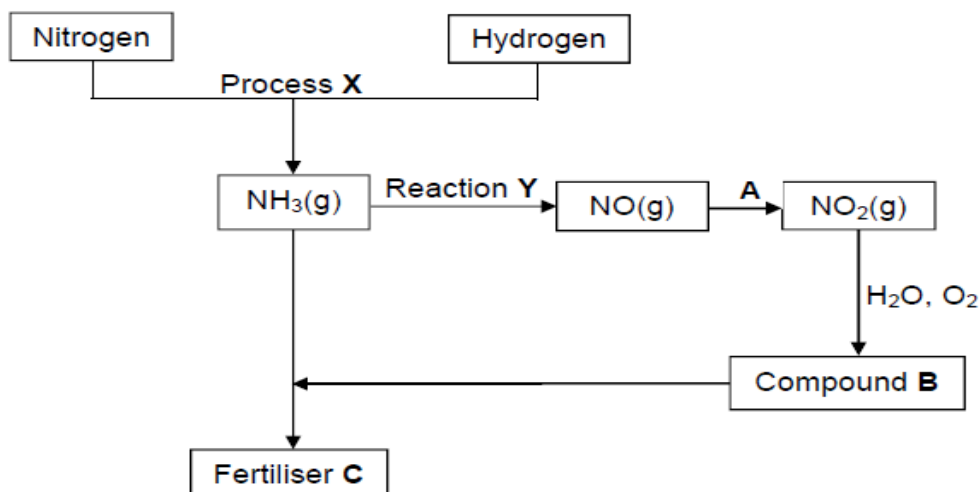
9.1 Use the above information and write down the:

- 9.1.1 NAME or FORMULA of gas **A** (1)
- 9.1.2 Name of process **X** (1)
- 9.1.3 NAME or FORMULA of the catalyst used in process **X** (1)
- 9.1.4 FORMULA of oleum (2)

- 9.2 Describe ONE negative impact on humans when fertiliser runs off into dams and rivers as a result of rain. (2)
- 9.3 Write down the NAME of the most important primary nutrient required to enhance:
- 9.3.1 Leaf growth of spinach (1)
- 9.3.2 Flower and fruit production of peach trees (1)
- 9.4 Which ONE of the three primary nutrients is absorbed by plants the least? (1)

QUESTION 10

Different processes used in the preparation of fertiliser C are represented in the flow diagram below



Use the above information and write down the:

- 10.1 NAME of the industrial preparation of nitrogen (1)
- 10.2 NAME of process X (1)
- 10.3 NAME of reaction Y (1)
- 10.4 NAME or FORMULA of compound A (1)
- 10.5 Balanced equation for the preparation of compound B from NO₂(g) (3)
- 10.6 Balanced equation for the preparation of fertiliser C (3)

SOLUTIONS TO TYPICAL EXAM QUESTIONS

1. ELECTRIC CIRCUITS

QUESTION 1

1.1 C 1.2 C 1.3 D 1.4 D 1.5 C 1.6 D 1.7 A

QUESTION 2

2.1 Is the maximum amount of energy given per colomb of charge passing through the battery. (2)

2.2.1

OPTION 1	OPTION 2
$V_P = 2,8V$ $I_{4\Omega} = \frac{2,8}{4} = 0,7A$ $I_{1\Omega} = \frac{2,8}{1} = 2,8A$ $I_T = 0,7 + 2,8 = 3,5 A$	$\frac{1}{R_{//}} = \frac{1}{R_1} + \frac{1}{R_2}$ $\frac{1}{R_{//}} = \frac{1}{4} + \frac{1}{1}$ $R = 0,8 \Omega \checkmark$ $V_{//} = R_{//} \cdot I_T$ $2,8 = 0,8 \cdot I_T$ $I_T = 3,5A$

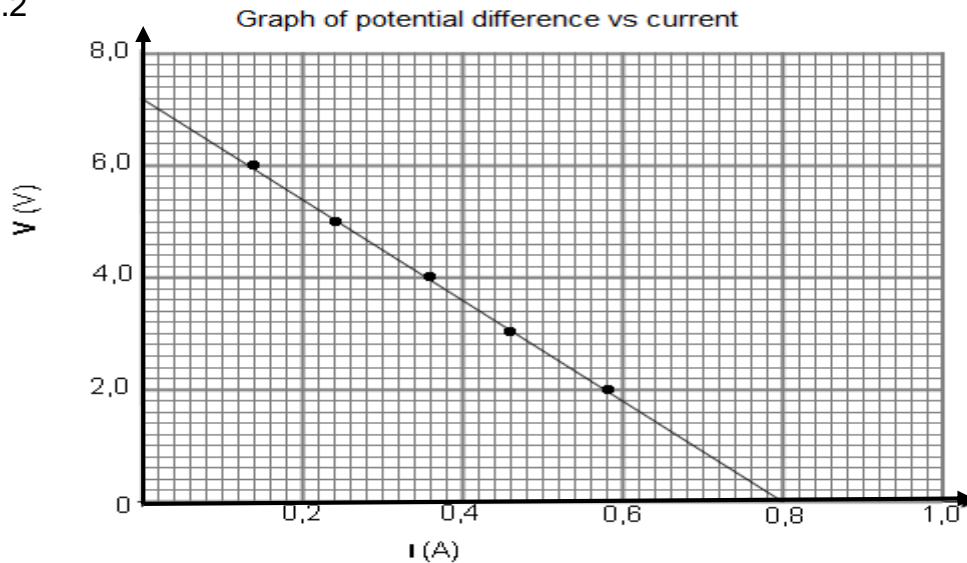
2.2.2

OPT1ION 1	OPTION 2
$\mathcal{E} = I_T (R_{ext} + r_T)$ $3 = 3,5(0,8 + r_T)$ $r_T = 0,06\Omega$ for each cell = $0,03\Omega$	$V_r = 3 - 2,8 = 0,2 V$ $V_r = I_T \cdot r_T$ $0,2 = 3,5 \cdot r_T$ $r_T = 0,06\Omega$ each cell = $0,03\Omega$

QUESTION 3

3.1.1 Keep the temperature (of battery) constant ✓ (1)

3.1.2



3.1.3 7,2 v ✓ (1)

3.1.4 Slope = $\frac{\Delta V}{\Delta I}$
 $= \frac{0,7,2}{0,8 - 0} = -9$
 $r = 9 \Omega$ ✓

3.2.1 $P = VI$ ✓
 $100 = 20(I)$ ✓
 $I = 5 \text{ A}$ ✓

3.2.2

OPTION 1

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

$$R = \frac{(20)^2}{150} \checkmark$$

$$= 2,67 \Omega \checkmark$$

(3)

OPTION 2

$$P = VI$$

$$150 = (20)I$$

$$I = 7,5 \text{ A}$$

$$V = IR$$

$$20 = (7,5)R \checkmark$$

$$R = 2,67 \Omega \checkmark$$

✓ Both formulae

OR/OF

$$P = I^2R$$

(3)

$$150 = (7,5)^2 R \checkmark$$

$$R = 2,67 \Omega \checkmark$$

OPTION 3

$$I_X : I_Y$$

$$5 : 7,5$$

$$1 : 1,5$$

$$R_X : R_Y$$

$$1,5 : 1 \checkmark$$

$$4 \checkmark : 2,67 \Omega \checkmark$$

(3)

QUESTION 4

$$4.1 \frac{1}{R_{//}} = \frac{1}{R_1} + \frac{1}{R_2} \checkmark$$

$$\frac{1}{R_{//}} = \frac{1}{6} + \frac{1}{10} \checkmark$$

$$R_{//} = 3,75 \Omega \checkmark$$

(3)

$$4.2 V_{10\Omega} = I_{10\Omega} \cdot R_{10\Omega} \checkmark$$

$$= 10(0,6) \checkmark = 6 \text{ V}$$

$$V_{10\Omega} = V_{6\Omega} = V_{//}$$

$$V_{//} = R_{//} \cdot I_T$$

$$6 = (3,75) \cdot I_T \checkmark$$

$$I_T = 1,6 \text{ A} \checkmark$$

(4)

$$4.3 R_{\text{ext}} = R_{//} + R_1 + R_2$$

$$= 3,75 + 8 + 5 = 16,75 \Omega$$

$$\mathcal{E} = I_T (R_{\text{ext}} + r)$$

$$30 = 1,6(16,75 + r)$$

$$r = 2\Omega$$

QUESTION 5

$$5.1.1 V_{//} = R_s \cdot I_s$$

$$\begin{aligned} V_{//} &= 0,2(4 + 8) \\ &= 2,4 \text{ V} \end{aligned}$$

$$5.1.2 R_{12\Omega} : R_{2\Omega}$$

$$12 : 2$$

$$6 : 1$$

$$I_{2\Omega} = 0,2(6) = 1,2 \text{ A}$$

$$I_T = 1,2 + 0,2 = 1,4 \text{ A}$$

$$5.1.3 \mathcal{E} = V_{\text{ext}} + I_T \cdot r$$

$$\begin{aligned} &= 2,4 + 0,5(1,4) \\ &= 3,1 \text{ V} \end{aligned}$$

5.2 INCREASE

Removing the 2Ω resistor increases the total resistance of the circuit. Thus the total current decreases, decreasing the V_{int} (V_{lost}). Therefore the voltmeter reading increases

QUESTION 6

6.1.1 Ensure that the wires are of the same length; same thickness.

6.1.2 Wire A

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

$$R_A = \frac{4,4}{0,4} = 11\Omega$$

$$R_B = \frac{2,2}{0,4} = 5,5\Omega$$

$$E = I^2 R \Delta t$$

For the same time and current, the heating in A will be higher because of its resistance is higher than that of B.

6.2.1

OPTION 1	OPTION 2
$I_{5,5\Omega} : I_{11\Omega}$ $2 : 1$ $I_{5,5\Omega} = 0,2 \times 2$ $= 0,4 \text{ A}$	$V = IR$ $V_{11\Omega} = 0,2 \times 11$ $= 2,2 \text{ V}$ $V_{5,5\Omega} = V_{11\Omega} = 2,2 \text{ V}$ $I_{5,5\Omega} = \frac{2,2}{5,5} = 0,4 \text{ A}$

6.2.2

OPTION 1	OPTION 2
$V = I \cdot R$ $I_T = 0,4 + 0,2 = 0,6 \text{ A}$ $\frac{1}{R_{//}} = \frac{1}{R_1} + \frac{1}{R_2}$ $\frac{1}{R_{//}} = \frac{1}{11} + \frac{1}{5,5}$ $R_{//} = 3,67\Omega$ $R_T = R_{//} + R_A$ $= 3,67 + 11 = 14,67\Omega$ $\mathcal{E} = I_T(R_{\text{ext}} + r)$ $9 = 0,6(14,67 + r)$ $R = 0,33\Omega$	$I_T = 0,4 + 0,2 = 0,6 \text{ A}$ $V_{\text{ext}} = V_{11\Omega} + V_{//}$ $= I_T(R_{11} + 3,67)$ $= 0,6(11) + 2,2$ $= 8,8 \text{ V}$ $\mathcal{E} = V_{\text{ext}} + I_T \cdot r$ $9 = 8,8 + 0,6 r$ $R = 0,33\Omega$

6.2.3 Decreases, total resistance increases

QUESTION 7

7.1.1 To change/vary the external resistance in the circuit in order to change/vary the (total) current through the battery.

7.1.2 Current

7.1.3 6V

7.1.4 $V_i = 6 - 2 = 4V$

7.2.1 It is an indication of the maximum amount of energy given per colomb of charge passing through the battery.

$$\begin{aligned}
 7.2.2 \quad P &= VI \checkmark \\
 12 &= V(2) \checkmark \\
 V_{12w} &= 6V
 \end{aligned}$$

$$\begin{aligned}
 V_{6\Omega} &= IR \\
 &= (2)(6) \checkmark \\
 &= 12V \\
 V_p &= 12 + 6 = 18V
 \end{aligned}$$

$$\begin{aligned}
 P &= \frac{V^2}{R} \\
 12 &= \frac{6^2}{R} \checkmark \\
 R_{12w} &= 3\Omega
 \end{aligned}$$

<p>RATIO: $R_{9\Omega} : R_{6\Omega}$ $3 : 2$ $I_{9\Omega} : I_{6\Omega}$ $2 : 3$ } \checkmark $I_{6\Omega} = 3A$</p>	$I_{6\Omega} = V/R$ $= 18/6$
$I_t = 3 + 2 \checkmark = 5A$	

OR

$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$ $= \frac{1}{9} + \frac{1}{6} \checkmark$ $R_p = 3,6$ $I_{9\Omega} = \frac{R_p}{R} I$
--

$$\begin{aligned}
 V_s &= IR \\
 &= (5)(2) \checkmark = 10V \\
 V_{ekst} &= V_p + V_s \\
 &= 18 + 10 \\
 &= 28V \checkmark
 \end{aligned}$$

(8)

7.2.3

OPTION 1

$$r_i = \frac{V_i}{I} \quad \checkmark$$

$$= \frac{30 - 28}{5} \quad \checkmark$$

$$I = 0,4 \text{ A} \quad \checkmark$$

OPTION 2

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

$$30 = 5(5,6 + r) \quad \checkmark$$

$$r = 0,4 \Omega \quad \checkmark$$

(3)

7.2.4 Increase ✓

Total resistance in circuit increase and the total current decrease. ✓

V_{internal} will decrease. ✓

Therefore: V_{external} will increase because emf stays constant. ✓

2. ELECTRO-DYNAMICS

QUESTION 1

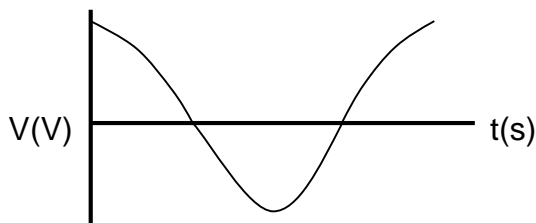
- 1.1 A 1.2 A 1.3 C 1.4 B 1.5 C 1.6 A
- 1.7 D 1.8 B

QUESTION 2

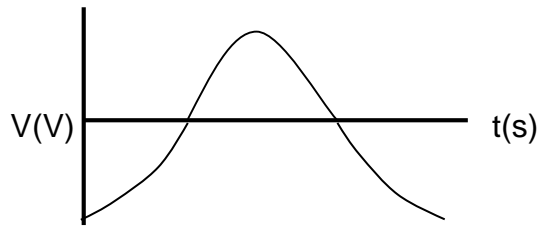
2.1.1 Anticlockwise ✓ (1)

2.1.2 The rate of change in the magnetic flux ✓ is a maximum ✓ at this position. (2)

2.1.3 **OPTION 1**



OPTION 2



(2)

2.1.4 Increase the rotation speed of the coil. ✓

(1)

2.1.5 Electrical energy can be transmitted over long distances (with the use of transformers). ✓ OR
The voltage can easily be adapted for different needs (by means of transformers.)

2.2

$$I_{rms} = \frac{I_{max}}{\sqrt{2}} \checkmark$$

$$= \frac{7}{\sqrt{2}} \checkmark$$

$$I_{rms} = 4,95 \text{ A}$$

$$P_{ave} = I_{rms}^2 R \checkmark$$

$$80 = 4,95^2 (R) \checkmark$$

$$R = 3,26 \text{ A} \checkmark$$

QUESTION 3

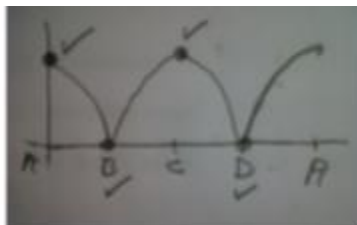
3.1.1 Electromagnetic Induction

3.1.2 The rate of change in the magnetic flux is a maximum at position A.

3.1.3 DC generator : split ring commutator

AC generator : slip rings

3.1.4



3.2.1 18 V

3.2.2 $P_{ave} = V_{rms} I_{rms}$

$$60 = 18(I_{rms})$$

$$(I_{rms}) = 3,33 \text{ A}$$

$$I_{rms} = \frac{I_{max}}{\sqrt{2}}$$

$$3,33 = \frac{I_{max}}{\sqrt{2}} \checkmark$$

$$I_{max} = 4,71 \text{ A} \checkmark$$

QUESTION 4

4.1.1 a to b ✓

4.1.2 Fleming's left hand rule /Left hand motor rule ✓

ACCEPT

Right hand rule

4.1.3 Split rings /commutator ✓

4.2.1 Mechanical/Kinetic energy to electrical energy. ✓✓ (2 or/of 0)

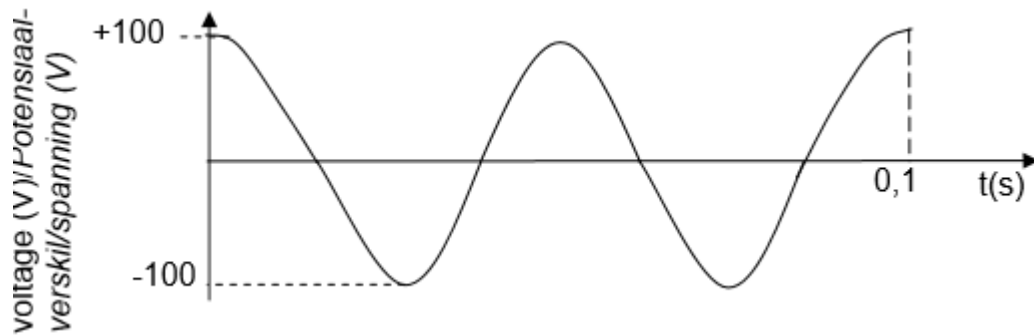
4.2.2

<p>OPTION 1</p> $V_{rms} = \frac{V_{max}}{\sqrt{2}} \checkmark$ $= \frac{430}{\sqrt{2}} \checkmark$ $= 304,06 \text{ V}$ $I = \frac{V}{R} \checkmark$ $= \frac{304,06}{400} \checkmark$ $= 0,76 \text{ A} \checkmark$	<p>OPTION 2</p> $V_{max} = I_{max}R \checkmark$ $430 = I_{max}(400) \checkmark$ $I_{max} = 1,075$ $I_{rms} = \frac{I_{max}}{\sqrt{2}} = \frac{1,075}{\sqrt{2}} \checkmark$ $= 0,76 \text{ A} \checkmark$
<p>OPTION 3</p> $V_{rms} = \frac{V_{max}}{\sqrt{2}} \checkmark$ $= \frac{430}{\sqrt{2}} \checkmark = 304,06 \text{ V}$ $P_{average} = \frac{V_{rms}^2}{R} = \frac{(304,06)^2}{400}$ $= 231,13 \text{ W}$ $P_{ave} = I_{rms}V_{rms} \checkmark$ $231,13 = I_{rms} (304,06) \checkmark$ $I_{rms} = 0,76 \text{ A} \checkmark$	<p>OPTION 4</p> $V_{rms} = \frac{V_{max}}{\sqrt{2}} \checkmark$ $= \frac{430}{\sqrt{2}} \checkmark = 304,06 \text{ V}$ $P_{average} = \frac{V_{rms}^2}{R} = \frac{(304,06)^2}{400}$ $= 231,13 \text{ W}$ $P_{ave} = I_{rms}^2R \checkmark$ $231,13 = I_{rms}^2 (400) \checkmark$ $I_{rms} = 0,76 \text{ A} \checkmark$

QUESTION 5

5.1.1 Anticlockwise

5.1.2



5.1.3 Decrease the frequency/ speed of rotation

5.2

$$P_{\text{average/gemiddeld}} = V_{\text{rms}} I_{\text{rms}} \checkmark$$

$$1\,500 = (220)(I_{\text{rms}}) \checkmark$$

$$I_{\text{rms}} = 6,82 \text{ A}$$

$$I_{\text{rms}} = \frac{I_{\text{max/maks}}}{\sqrt{2}} \checkmark$$

$$I_{\text{max/maks}} = (\sqrt{2})(6,82) \checkmark$$

$$= 9,65 \text{ A} \checkmark$$

QUESTION 6

6.1 Increase the speed of rotation. ✓

OR

Increase the number of coils.

OR

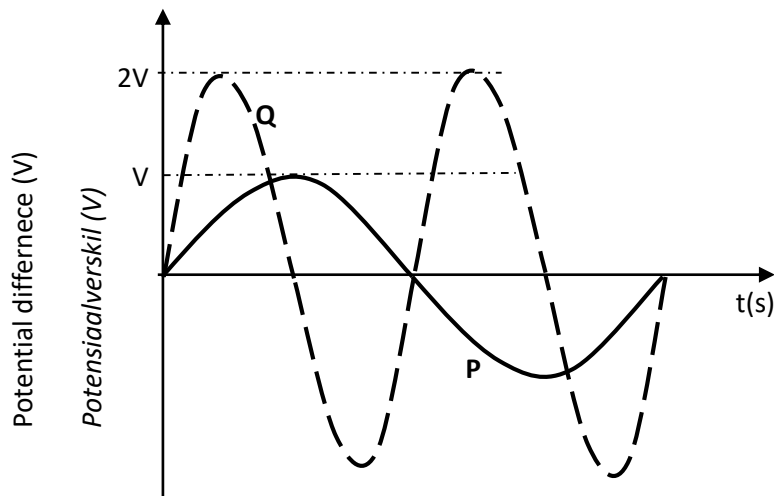
Increase the strength of the magnetic field..

6.2 Commutators replaced by slip rings. ✓

OR

Slip rings were used ✓

6.3



6.4

$$P_{\text{ave}} = \frac{V_{\text{rms}}^2}{R} \checkmark = \frac{\left(\frac{V_{\text{max}}}{\sqrt{2}}\right)^2}{R} \checkmark$$

$$120 = \frac{\left(\frac{340}{\sqrt{2}}\right)^2}{R} \checkmark$$

$$R = 481,52 \, \Omega \checkmark$$

7.1 Electromagnetic induction ✓

7.2 Rotate the coil faster/Increase the number of coils/ Increase the strength of the magnetic field.

7.3 Slip rings ✓

 7.4.1 It is the value of the voltage in a DC circuit ✓ that will have the same heating effect as an AC circuit. ✓

$$V_{\text{rms}} = \frac{V_{\text{max}}}{\sqrt{2}} \checkmark$$

$$= \frac{339,45}{\sqrt{2}} \checkmark$$

$$V_{\text{rms}} = 240,03 \, \text{V} \checkmark \quad \text{Accept}(240,03 - 240,74)$$

 8.1.1 Move the bar magnet very quickly ✓✓ **OR** up and down inside the coil ✓✓

8.1.2 Electromagnetic induction ✓

Accept
Faraday's Law (of electromagnetic induction)

8.1.3 Commutator/ split ring✓

8.2.1

<p>OPTION 1</p> $P_{\text{average}} = \frac{V_{\text{rms}}^2}{R} \checkmark$ $= \frac{220^2}{40,33} \checkmark$ $= 1\,200,10 \text{ W (J}\cdot\text{s}^{-1}) \checkmark$	$W = \frac{V_{\text{rms}}^2}{R} \Delta t \checkmark$ $= \frac{220^2}{40,33} (1) \checkmark$ $= 1\,200,10 \text{ J} \checkmark$
<p>OPTION 2</p> $I_{\text{rms}} = \frac{V_{\text{rms}}}{R} \checkmark$ $= \frac{220}{40,33} \checkmark$ $= 5,45 \text{ A}$ $P_{\text{average}} = I_{\text{rms}}^2 R \checkmark$ $= (5,45^2)(40,33) \checkmark$ $= 1\,197,9 \text{ W OR/OF } 1\,200,10 \text{ W} \checkmark$	$I_{\text{rms}} = \frac{V_{\text{rms}}}{R} \checkmark$ $= \frac{220}{40,33} \checkmark$ $= 5,45 \text{ A}$ $W = I_{\text{rms}}^2 R \Delta t \checkmark$ $= (5,45^2)(40,33)(1) \checkmark$ $= 1\,197,9 \text{ J OR/OF } 1\,200,10 \text{ J} \checkmark$
<p>OPTION 3</p> $I_{\text{rms}} = \frac{V_{\text{rms}}}{R} \checkmark$ $= \frac{220}{40,33} \checkmark$ $= 5,45 \text{ A}$ $P_{\text{average}} = V_{\text{rms}} I_{\text{rms}} \checkmark$ $= (220)(5,45) \checkmark$ $= 1\,199 \text{ W or/of } 1\,200,10 \text{ W} \checkmark$	$I_{\text{rms}} = \frac{V_{\text{rms}}}{R} \checkmark$ $= \frac{220}{40,33} \checkmark$ $= 5,45 \text{ A}$ $W = V_{\text{rms}} I_{\text{rms}} \Delta t \checkmark$ $= (220)(5,45)(1) \checkmark$ $= 1\,199 \text{ J or/of } 1\,200,10 \text{ J} \checkmark$
<p>8.2.2</p> <p>OPTION 1</p> $V_{\text{rms}} = \frac{V_{\text{max}}}{\sqrt{2}}$ $220 = \frac{V_{\text{max}}}{\sqrt{2}}$ $V_{\text{max}} = 311,13 \text{ V}$	<div style="border: 1px solid black; padding: 5px; width: fit-content; margin: auto;">1 mark for any formula</div>

$$I_{\max} = \frac{V_{\max}}{R} = \frac{331,13}{40,33} \checkmark$$

$$= 7,71 \text{ A} \checkmark$$

OR/OF

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

$$1200,1 = \frac{(311,13) I_{\max}}{2}$$

$$I_{\max} = 7,71 \text{ A}$$

OPTION 2

$$P_{\text{average}} = V_{\text{rms}} I_{\text{rms}} \checkmark$$

$$1200,1 = (220) I_{\text{rms}} \checkmark$$

$$I_{\text{rms}} = 5,455 \text{ A}$$

$$I_{\max} = \sqrt{2} (5,455)$$

$$= 7,71 \text{ A} \checkmark \quad (7,715 \text{ A})$$

OPTION 3/

$$P_{\text{average}} = I_{\text{rms}}^2 R \checkmark$$

$$1200,1 = I_{\text{rms}}^2 (40,33) \checkmark$$

$$I_{\text{rms}} = 5,455 \text{ A}$$

$$I_{\max} = \sqrt{2} I_{\text{rms}}$$

$$= \sqrt{2} (5,455)$$

$$= 7,71 \text{ A} \checkmark$$

OPTION 4

$$V_{\text{rms}} = I_{\text{rms}} R \checkmark$$

$$220 = I_{\text{rms}} (40,33) \checkmark$$

$$I_{\text{rms}} = 5,455 \text{ A}$$

$$I_{\max} = \sqrt{2} I_{\text{rms}}$$

$$= \sqrt{2} (5,455)$$

$$= 7,71 \text{ A} \checkmark$$

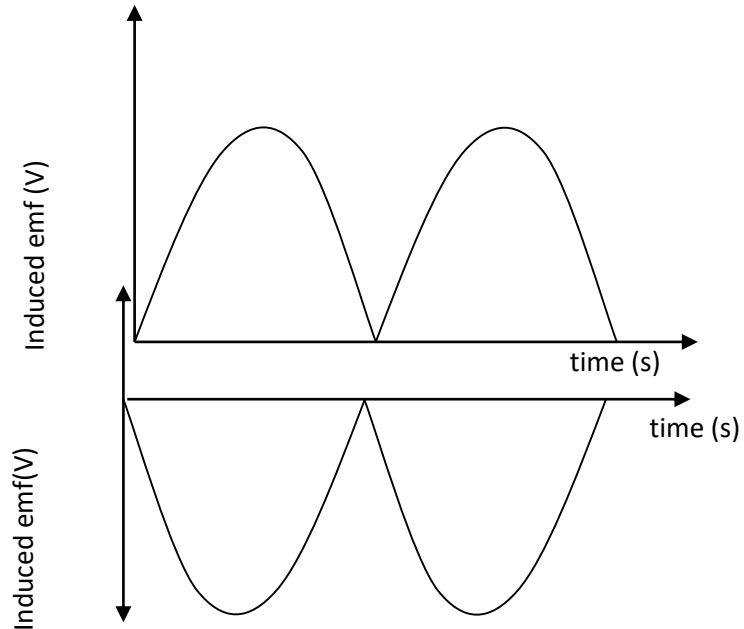
QUESTION 9

9.1.1 DC generator
Uses split ring/commutator

(2)

9.1.2

OR



NOTE:

Curve starts at zero to first peak ✓
Shape and one complete DC cycle

9.2.1

<p>OPTION 1</p> $V_{rms/wgk} = \frac{V_{max/maks}}{\sqrt{2}}$ $P_{ave/gem} = V_{rms/wgk} I_{rms/wgk} \checkmark$ $800 = \frac{340}{\sqrt{2}} (I_{rms/wgk}) \checkmark$ <hr style="width: 50%; margin-left: 0;"/> $I_{rms/wgk} = 3,33 \text{ A} \checkmark$	<p>OR/OF</p> $V_{rms/wgk} = \frac{V_{max/maks}}{\sqrt{2}} = \frac{340}{\sqrt{2}} = 240,416$ $P_{ave/gem} = V_{rms/wgk} I_{rms/wgk} \checkmark$ $800 = I_{rms/wgk} (240,416) \checkmark$ $I_{rms/wgk} = 3,33 \text{ A} \checkmark$
<p>OPTION 2</p> $P_{ave/gem} = \left(\frac{V_{rms/wgk}^2}{R} \right) = \frac{(V_{max/maks}^2)}{(2)(R)}$ $800 = \frac{(340)^2}{(\sqrt{2})^2 (R)}$ $R = 72,25 \Omega$ $V_{rms/wgk} = I_{rms/wgk} R$	
<div style="border: 1px solid black; padding: 5px; display: inline-block;"> $P_{ave/gem} = I_{rms/wgk}^2 R$ $800 = I_{rms/wgk}^2 (72,25) \checkmark$ </div>	

$$I_{rms/wgk} = \frac{240,416}{72,25} \checkmark$$

$$= 3,33 \text{ A} \checkmark$$

9.2.2

<p>OPTION 1</p> $P_{ave/gemid} = V_{rms/wgk} I_{rms/wgk} \checkmark$ <p>for the kettle/vir die ketel:</p> $2000 = \frac{340}{\sqrt{2}} (I_{rms/wgk}) \checkmark$ $I_{rms/wgk} = 8,32 \text{ A}$ $I_{tot} = (8,32 + 3,33) \checkmark$ $= 11,65 \text{ A} \checkmark$	<p>OPTION 2</p> $P_{ave/gemid} = V_{rms/wgk} I_{rms/wgk} \checkmark$ $= \frac{V_{max/maks} I_{max/maks}}{2}$ $2\ 800 \checkmark = \frac{(340) I_{max/maks} \checkmark}{2}$ $I_{max/maks} = 16,47 \text{ A}$ $I_{rms} = \frac{I_{max/maks}}{\sqrt{2}} = \frac{16,47}{\sqrt{2}}$ $I_{rms/wgk} = 11,65 \text{ A} \checkmark$
<p>OPTION 3</p> $P_{ave/gemid} = \left(\frac{V_{rms/wgk}^2}{R} \right) \checkmark = \frac{(V_{max/maks}^2)}{(2)(R)}$ $800 = \frac{(340)^2}{(\sqrt{2})^2 (R)} \checkmark \quad R = 72,25 \Omega$ $2\ 000 = \frac{(340)^2}{(\sqrt{2})^2 (R_{2000})}$ $R = 28,9 \Omega$ $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} \longrightarrow R = \frac{(28,9)(72,25)}{(28,9 + 72,25)} = 20,64 \Omega$ $V_{rms/wgk} = I_{rms/wgk} R$ $240,42 = I_{rms/wgk} (20,64) \checkmark \quad I_{rms/wgk} = 11,65 \text{ A} \checkmark$	
<p>OPTION 4</p> $P_{ave/gemid} = V_{rms/wgk} I_{rms/wgk} \checkmark$ $2\ 800 \checkmark = \frac{340}{\sqrt{2}} I_{rms/wgk} \checkmark$ $I_{rms/wgk} = 11,65 \text{ A} \checkmark$	<p>OPTION 5</p> $P_T : P_K$ $800 : 2\ 000 \checkmark$ $1 : 2,5$ $I_T : I_K$ $3,33 : 8,325 \checkmark$ $I_{rms} = 3,33 + 8,325 \checkmark$ $= 11,66 \text{ A} \checkmark$

QUESTION 10

10.1

10.1.1 North pole

10.1.2 Q to P

10.2

10.2.1

OPTION 1	OPTION 2
$I_{rms} = \frac{I_{max}}{\sqrt{2}} \checkmark$ $I_{rms} = \frac{8}{\sqrt{2}} \checkmark$ $= 5,66 \text{ A}$ $V_{rms} = I_{rms} R \checkmark$ $220 = (5,66)R \checkmark$ $R = 38,87 \Omega \checkmark$	$V_{rms} = \frac{V_{max}}{\sqrt{2}} \checkmark$ $220 = \frac{V_{max}}{\sqrt{2}} \checkmark$ $V_{max} = 311,12 \text{ V}$ $V_{max} = I_{max} R \checkmark$ $311,12 = (8)R \checkmark$ $R = 38,89 \Omega \checkmark$

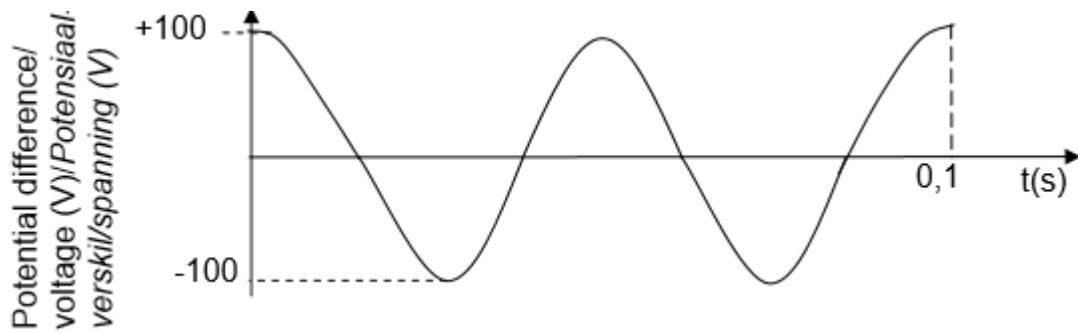
10.2.2

OPTION 1	OPTION 2	OPTION 3
$P_{average} = V_{rms} I_{rms} \checkmark$ $= (220)(5,66) \checkmark$ $= 1\,245,2 \text{ W}$ $P = \frac{W}{\Delta t} \checkmark$ $1245,2 = \frac{W}{7200} \checkmark$ $W = 8\,965\,440 \text{ J} \checkmark$	$P_{average} = I_{rms}^2 R$ $= (5,66)^2(38,89)$ $= 1245,86$ $E = Pt$ $= (1245,86)(7200)$ $= 8970192 \text{ J}$	$P_{average} = \frac{V_{rms}^2}{R} \checkmark$ $P_{average} = \frac{220^2}{38,87} \checkmark$ $= 1245,18 \text{ W}$ $P = \frac{W}{\Delta t} \checkmark$ $1245,18 = \frac{W}{7200} \checkmark$ $W = 8\,965\,296 \text{ J} \checkmark$

QUESTION 11

11.1 Anticlockwise

11.1.2



11.1.3 Decrease the frequency/ speed of rotation

11.2

$$P_{\text{average/gemiddeld}} = V_{\text{rms}} I_{\text{rms}} \checkmark$$

$$1\,500 = (220)(I_{\text{rms}}) \checkmark$$

$$I_{\text{rms}} = 6,82 \text{ A}$$

$$I_{\text{rms}} = \frac{I_{\text{max/maks}}}{\sqrt{2}} \checkmark$$

$$I_{\text{max/maks}} = (\sqrt{2})(6,82) \checkmark$$

$$= 9,65 \text{ A} \checkmark$$

3. PHOTO-ELECTRIC EFFECT

QUESTION 1

1.1 B 1.2 A 1.3 B 1.4 C 1.5 B

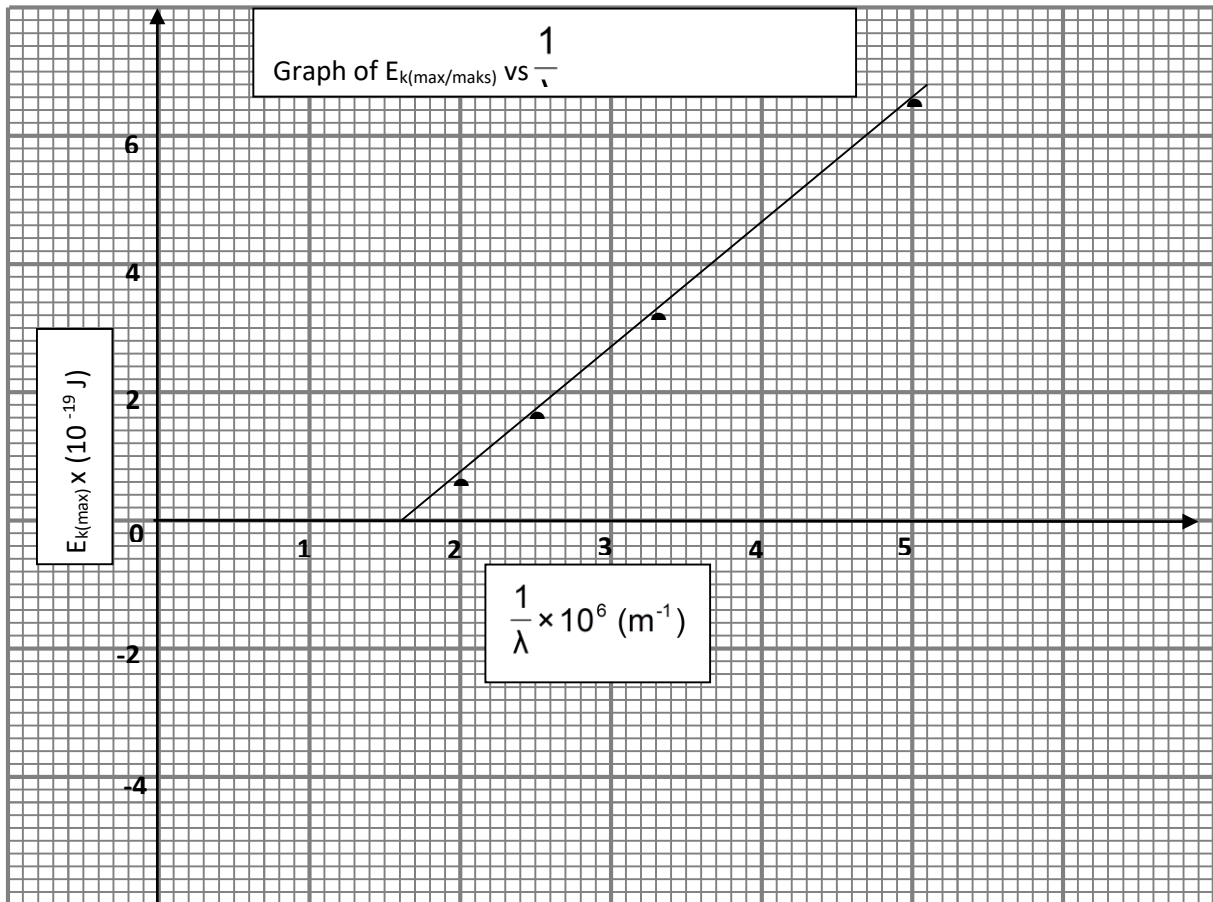
QUESTION 2

2.1 It is the process whereby electrons are ejected from a metal surface when light (of suitable frequency) is incident on it.

OR

It is the phenomenon that occurs when light of (suitable frequency), incident on a metal surface, ejects electrons (from the metal surface).

2.2



2.3.1

OPTION 1

$$\frac{1}{\lambda} = 1,6 \times 10^6 \text{ m}^{-1} \checkmark \quad (\text{Accept } 1,6 \times 10^6 \text{ m}^{-1} \text{ to/tot } 1,7 \times 10^6 \text{ m}^{-1})$$

$$f_0 = c \frac{1}{\lambda} \checkmark$$

$$= (3 \times 10^8)(1,6 \times 10^6) \checkmark$$

$$= 4,8 \times 10^{14} \text{ Hz} \checkmark \quad (\text{Accept } 4,8 \times 10^{14} \text{ Hz to/tot } 5,1 \times 10^{14} \text{ Hz})$$

(4)

OPTION 2

By extrapolation: y-intercept = $-W_0$

$$W_0 = hf_0 \checkmark$$

$$3,2 \times 10^{-19} \checkmark = (6,63 \times 10^{-34})f_0 \checkmark$$

$$f_0 = 4,8 \times 10^{14} \text{ Hz} \checkmark \quad (\text{Accept } 4,8 \times 10^{14} \text{ Hz to/tot } 4,83 \times 10^{14} \text{ Hz})$$

(4)

OPTION 3 (Points from the graph)

$$E = W_0 + E_{k(\text{max})}$$

$$\frac{hc}{\lambda_0} = hf_0 + E_{k(\text{max})} \checkmark$$

$$(6,63 \times 10^{-34})(3 \times 10^8)(1,6 \times 10^6) \checkmark = (6,63 \times 10^{-34})f_0 + 0 \checkmark$$

$$f_0 = 4,8 \times 10^{14} \text{ Hz} \checkmark$$

OR

$$(6,63 \times 10^{-34})(3 \times 10^8)(5 \times 10^6) = (6,63 \times 10^{-34})f_0 + 6,6 \times 10^{-19}$$

$$f_0 = 4,92 \times 10^{14} \text{ Hz}$$

OR

$$(6,63 \times 10^{-34})(3 \times 10^8)(3,3 \times 10^6) = (6,63 \times 10^{-34})f_0 + 3,3 \times 10^{-19}$$

$$f_0 = 4,8 \times 10^{14} \text{ Hz}$$

OR

$$(6,63 \times 10^{-34})(3 \times 10^8)(2,5 \times 10^6) = (6,63 \times 10^{-34})f_0 + 1,7 \times 10^{-19}$$

$$f_0 = 4,94 \times 10^{14} \text{ Hz}$$

OR

$$(6,63 \times 10^{-34})(3 \times 10^8)(2,2 \times 10^6) = (6,63 \times 10^{-34})f_0 + 0,7 \times 10^{-19}$$

$$f_0 = 5,54 \times 10^{14} \text{ Hz}$$

(4)

2.3.2

OPTION 1

$$hc = \text{Gradient} \quad \checkmark$$

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

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

$$= 1,941 \times 10^{-25} \text{ (J}\cdot\text{m)}$$

$$h = \frac{\text{gradien}}{c}$$

$$h = \frac{1,941 \times 10^{-25}}{3 \times 10^8} \checkmark$$

$$= 6,47 \times 10^{-34} \text{ J}\cdot\text{s} \checkmark$$

OPTION 2

$$W_0 = \text{y intercept} \quad \checkmark$$

$$= 3,2 \times 10^{-19} \text{ J} \quad \checkmark$$

Accept

$$3,2 \times 10^{-19} \text{ J to } 3,4 \times 10^{-19} \text{ J}$$

$$W_0 = hf_0$$

$$3,2 \times 10^{-19} \checkmark = h(4,8 \times 10^{14}) \checkmark$$

$$h = 6,66 \times 10^{-34} \text{ J}\cdot\text{s} \checkmark$$

Accept

$$6,66 \times 10^{-34} \text{ J}\cdot\text{s to } 7,08 \times 10^{-34} \text{ J}\cdot\text{s}$$

(4)

OPTION 3

(Points from the graph)

$$\frac{hc}{\lambda} = W_0 + K_{\max} = 3,2 \times 10^{-19} \text{ J} + 6,6 \times 10^{-19} \text{ J} \quad \checkmark$$

$$h = \frac{9,8 \times 10^{-19}}{(3 \times 10^8)(5 \times 10^6)} \text{ J} \cdot \text{s} \quad \checkmark$$

OR/OF

$$\frac{hc}{\lambda} = W_0 + K_{\max} = 3,2 \times 10^{-19} \text{ J} + 3,3 \times 10^{-19} \text{ J} \quad \checkmark$$

$$h = \frac{6,5 \times 10^{-19}}{(3 \times 10^8)(3,3 \times 10^6)} \text{ J} \cdot \text{s} \quad \checkmark$$

OR/OF

$$\frac{hc}{\lambda} = W_0 + K_{\max} = 3,2 \times 10^{-19} \text{ J} + 1,7 \times 10^{-19} \text{ J} \quad \checkmark$$

$$h = \frac{4,7 \times 10^{-19}}{(3 \times 10^8)(2,5 \times 10^6)} \text{ J} \cdot \text{s} \quad \checkmark$$

OR/OF

$$\frac{hc}{\lambda} = W_0 + K_{\max} = 3,2 \times 10^{-19} \text{ J} + 0,7 \times 10^{-19} \text{ J} \quad \checkmark$$

$$h = \frac{3,9 \times 10^{-19}}{(3 \times 10^8)(2 \times 10^6)} \text{ J} \cdot \text{s} \quad \checkmark$$

(4)

QUESTION 3

3.1.1 The minimum frequency (of a photon/light) needed ✓ to emit electrons from (the surface of) a metal. (substance) ✓

OR/OF

The frequency (of a photon/light) needed ✓ to emit electrons from (the surface of) a metal. (substance) with zero kinetic energy ✓

(2)

3.1.2 Silver ✓

⊖ Threshold/cutoff frequency (of Ag) is higher
 $W_0 \propto f_0 / W_0 = hf_0$ ✓

(3)

3.1.3 Planck's constant / *Planck se konstante* ✓

(1)

3.1.4 Sodium ✓

(1)

3.2.1 Energy radiated per second by the blue light = $(\frac{5}{100})(60 \times 10^{-3})$ ✓ = $3 \times 10^{-3} \text{ J} \cdot \text{s}^{-1}$

$$E_{\text{photon}} = \frac{hc}{\lambda} \checkmark$$

$$= \frac{(6,63 \times 10^{-34})(3 \times 10^8)}{470 \times 10^{-9}} \checkmark = 4,232 \times 10^{-19} \text{ J}$$

Total number of photons incident per second = $\frac{3 \times 10^{-3}}{4,232 \times 10^{-19}}$ ✓ = $7,09 \times 10^{15}$ ✓

(5)

3.2.2

$7,09 \times 10^{15}$ (electrons per second) ✓

OR

Same number as that calculated in Question 2.2.1 above

(1)

QUESTION 4

- 4.1 The minimum frequency (of a photon/light) needed to emit electrons ✓ from (the surface of) a metal. (substance) ✓ (2)

4.2 **OPTION 1/OPSIE 1**

$$E = W_o + E_{k(max)}$$

$$E = W_o + \frac{1}{2}mv_{max}^2$$

$$h\frac{c}{\lambda} = hf_o + \frac{1}{2}mv_{max}^2$$

✓ Any one / Enige een

$$\frac{(6,63 \times 10^{-34})(3 \times 10^8)}{\lambda} \checkmark = (6,63 \times 10^{-34})(5,548 \times 10^{14}) \checkmark + \frac{1}{2}(9,11 \times 10^{-31})(5,33 \times 10^5)^2 \checkmark$$

$$\lambda = 4 \times 10^{-7} \text{ m} \checkmark$$

OPTION 2

$$E = W_o + E_{k(max)}$$

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

$$E = W_o + \frac{1}{2}mv_{max}^2$$

✓ Any one

$$(6,63 \times 10^{-34})f = (6,63 \times 10^{-34})(5,548 \times 10^{14}) \checkmark + \frac{1}{2}(9,11 \times 10^{-31})(5,33 \times 10^5)^2 \checkmark$$

$$f = 7,5 \times 10^{14} \text{ Hz}$$

$$c = f\lambda$$

$$3 \times 10^8 = (7,5 \times 10^{14})\lambda \checkmark$$

$$\lambda = 4 \times 10^{-7} \text{ m} \checkmark$$

(5)

- 4.3 Smaller (less) than ✓

(1)

- 4.4 The wavelength/frequency/energy of the incident light (photon/hf) is constant ✓

Since the speed is larger, the kinetic energy is larger ✓ the work function/ W_o /threshold frequency smaller. ✓

QUESTION 5

- 5.1 The minimum energy needed to remove an electron ✓
from the surface of a metal. ✓ (2)
- 5.2
- 5.2.1 $W_0 = hf_0$ ✓
 $= (6,63 \times 10^{-34})(4 \times 10^{14})$ ✓
 $= 2,65 \times 10^{-19} \text{ J}$ ✓ (3)
- 5.2.2 $E = W_0 + E_k$ } ✓ Any one
 $hf = hf_0 + \frac{1}{2}mv^2$ }
 $(6,63 \times 10^{-34})(8 \times 10^{14})$ ✓ $= 2,65 \times 10^{-19}$ ✓ $+ \frac{1}{2}(9,11 \times 10^{-31})v^2$ ✓
 $\therefore v = 7,63 \times 10^5 \text{ m}\cdot\text{s}^{-1}$ ✓ (5)
- 5.3
- 5.3.1 Equal to ✓
The gradient is Planck's constant./ *Gradient is Planck se konstante* ✓ (2)
- 5.3.2 $8 \times 10^{14} \text{ Hz}$ ✓
 f_0 is directly proportional to W_0 . ✓ (2)
- [14]**

QUESTION 6

6.1.1 It tells us that light has a particle nature (1)

6.1.2 Remain the same. ✓



For the same colour/ frequency/wavelength the energy of the photons will be the same✓. (The brightness causes more electrons to be released, but they will have the same maximum kinetic energy.)

OR

Intensity only affects the number of ejected photo-electrons and not the maximum kinetic energy or maximum speed of the ejected photo-electrons

OR

Maximum kinetic energy of ejected photo-electrons is independent of intensity of radiation (2)

6.1.3

$$E = W_0 + E_k$$

$$hf = hf_0 + E_k$$

$$hf = hf_0 + \frac{1}{2} mv^2$$

$$E = W_0 + \frac{1}{2} mv^2$$

✓ Any one

$$\frac{(6,63 \times 10^{-34})(3 \times 10^8)}{420 \times 10^{-9}} = \frac{(6,63 \times 10^{-34})(3 \times 10^8)}{\lambda_0} + \frac{1}{2}(9,11 \times 10^{-31})(4,76 \times 10^5)^2$$

$$\lambda_0 = 5,37 \times 10^{-7} \text{ m}$$

∴ the metal is sodium ✓ (5)

6.2 **Q**✓ and/en **S** ✓



Emission spectra occur when excited atoms /electrons drop from higher energy levels to lower energy levels. ✓✓ (4)

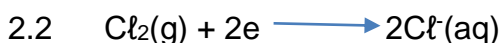
GALVANIC CELLS

QUESTION 1

- 1.1 A 1.2 C 1.3 D 1.4 D 1.5 D
 1.6 B 1.6 B 1.7 C 1.8 B 1.9 B 1.10 D

QUESTION 2

2.1 B



2.3 Cl_2 / Chlorine

2.4 $E^\circ_{\text{cell}} = E^\circ_{\text{Cathode}} - E^\circ_{\text{Anode}}$

$$= 1,36 - (-2,36)$$

$$= 3,72 \text{ V}$$

2.4 The Mg electrode becomes smaller./The mass of the Mg electrode decreases./Mg electrode being corroded



QUESTION 3

3.1 A substance that gains/accepts electrons

3.2 Ag^+ is a stronger oxidising agent than Cu^{2+} and will oxidise Cu to (blue) Cu^{2+} ions.

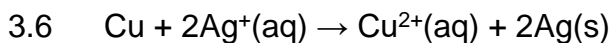
3.3 Chemical \rightarrow Electrical

3.4 A

3.5 $E^\circ_{\text{cell}} = E^\circ_{\text{Reduction}} - E^\circ_{\text{Oxidation}}$

$$= +0,80 - 0,34$$

$$= +0,46 \text{ V}$$



3.7 Remains the same

QUESTION 4

4.1 $1 \text{ mol} \cdot \text{dm}^{-3}$ ✓ (1)

4.2 Iodine is not a conductor. ✓ (1)

4.3 Graphite is a conductor ✓
Graphite is inert. ✓ (2)

4.4

4.4.1 Permanganate ion ✓ (1)

4.4.2 $2\text{MnO}_4^- (\text{aq}) + 16\text{H}^+ (\text{aq}) + 10\text{I}^- (\text{aq}) \checkmark \rightarrow 2\text{Mn}^{2+} (\text{aq}) + 5\text{I}_2 (\text{s}) + 8\text{H}_2\text{O} (\text{l}) \checkmark \text{ bal. } \checkmark$ (3)

4.4.3 $\text{C} (\text{s}) \mid \text{I}^- (\text{aq}) \mid \text{I}_2 (\text{s}) \parallel \text{H}^+ (\text{aq}), \text{MnO}_4^- (\text{aq}), \text{Mn}^{2+} (\text{aq}) \mid \text{C} (\text{s})$ (3)

4.5 $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}} \checkmark$
 $= 1,51 \checkmark - 0,54 \checkmark$
 $E^\circ_{\text{cell}} = 0,97 \text{ V} \checkmark$ (4)

4.6 Decreases ✓ (1)
[16]

QUESTION 5

5.1 • Pressure: 1 atmosphere (atm) / $1,013 \times 10^5 \text{ Pa}$

• Temperature $25 \text{ }^\circ\text{C} / 298 \text{ K}$
(2)

5.2 • Platinum is inert / does not react with the H^+ ions OR acid.
• Platinum is a conductor (of electricity). (2)

5.3

5.3.1 Salt bridge (1)

5.3.2 $-0,31 \text{ V}$ (1)

5.3.3 $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$

5.4.1 $E^\circ_{\text{cell}} = E^\circ_{\text{reduction}} - E^\circ_{\text{oxidation}} \checkmark$

$$2,05 \checkmark = -0,31 \checkmark - E_{M/M^{2+}}^{\circ}$$

$$E_{M/M^{2+}}^{\circ} = -2,36 \text{ (V)} \checkmark$$

M is magnesium/ Mg. \checkmark

Option 2



$$E^{\circ} = 2,05 \text{ V} \checkmark$$

Thus: $E_{\text{reduction}}^{\circ} = -2,36 \text{ (V)} \checkmark$

M is magnesium/ Mg. \checkmark

5.4.2 Exothermic

(1)

5.5 The cell reaction reaches equilibrium.

QUESTION 6

6.1 Temperature: 25 °C / 298 K \checkmark

Pressure 101,3 kPa / 1,013 x 10⁵ Pa / 1 atm / 100 kPa \checkmark

Concentration: 1 mol·dm⁻³ \checkmark

6.2.1 Cd(s) / Cadmium / Cd|Cd²⁺ / Cd²⁺

$$6.2.2 \quad E_{\text{cell}}^{\circ} = E_{\text{cathode}}^{\circ} - E_{\text{anode}}^{\circ} \checkmark$$

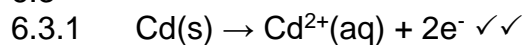
$$0,13 \checkmark = E_{\text{cathode}}^{\circ} - (-0,40) \checkmark$$

$$E_{\text{cathode}}^{\circ} = 0,13 - 0,40$$

$$= -0,27 \text{ (V)} \checkmark$$

Q is Ni/nickel \checkmark

6.3



6.3.2 Pt/Platinum

QUESTION 7

7.1

7.1.1 AgNO_3 / Silver nitrate ✓

(1)

7.1.2 $\text{Ni} \rightarrow \text{Ni}^{2+} + 2\text{e}^-$ ✓✓

7.1.3 $\text{Ni} + 2\text{Ag}^+ \rightarrow \text{Ni}^{2+} + 2\text{Ag}$ ✓ Bal ✓

OR/

$\text{Ni} + 2 \text{AgNO}_3 \rightarrow \text{Ni}(\text{NO}_3)_2 + 2\text{Ag}$

7.2

7.2.1 Ni ✓



Ni is a stronger reducing agent. / Ni has a higher reducing ability. / Ni is the anode. / Ni loses electrons. / Ni is oxidised. ✓

(2)

7.2.2 $\text{Ni}(\text{s}) \mid \text{Ni}^{2+}(\text{aq}) \parallel \text{Ag}^+(\text{aq}) \mid \text{Ag}(\text{s})$

OR/OF

$\text{Ni}(\text{s}) \mid \text{Ni}^{2+}(1 \text{ mol}\cdot\text{dm}^{-3}) \parallel \text{Ag}^+(1 \text{ mol}\cdot\text{dm}^{-3}) \mid \text{Ag}(\text{s})$

Accept

$\text{Ni} \mid \text{Ni}^{2+} \parallel \text{Ag}^+ \mid \text{Ag}$

(3)

7.2.3

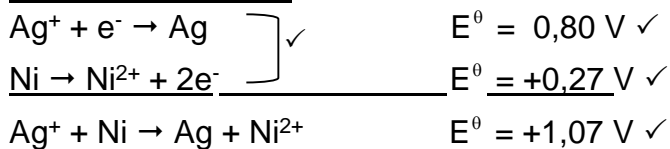
OPTION 1/OPSIE 1

$$E_{\text{cell}}^{\theta} = E_{\text{reduction}}^{\theta} - E_{\text{oxidation}}^{\theta} \checkmark$$

$$= 0,80 \checkmark - (-0,27) \checkmark$$

$$= 1,07 \text{ V} \checkmark$$

OPTION 2/OPSIE 2



7.2.4 Increases

QUESTION 8

8.1 Redox (reaction) (1)

8.2 P

Negative electrode/Mg is a stronger reducing agent/is oxidized/release electrons.
/Mass of Mg decreases.

(2)

8.3 8.3.1 (Temperature) 25 °C/298 K

(Concentration) 1 mol·dm⁻³ (2)

8.3.2 Mg(s) | Mg²⁺(aq) || Pb²⁺(aq) | Pb(s)

OR Mg | Mg²⁺ || Pb²⁺ | Pb (3)

8.3.3 Pb²⁺ / Pb(NO₃)₂ / lead(II) ions / lead(II) nitrate

8.4

OPYION 1	OPTION 2
$E_{\text{cell}}^{\ominus} = E_{\text{reduction}}^{\ominus} - E_{\text{oxidation}}^{\ominus} \checkmark$ $= -0,13 \checkmark - (-2,36) \cdot$ $= 2,23 \text{ V} \checkmark$	$\text{Pb}^{2+}(\text{aq}) + 2\text{e}^{-} \longrightarrow \text{Pb}(\text{s}) \quad E^{\ominus} = -0,13 \text{ V}$ $\text{Mg}(\text{s}) \longrightarrow \text{Mg}^{2+}(\text{aq}) + 2\text{e}^{-} \quad \underline{E^{\ominus} = +2,36 \text{ V}}$ $\text{Pb}^{2+}(\text{aq}) + \text{Mg}(\text{s}) \longrightarrow \text{Pb}(\text{s}) + \text{Mg}^{2+}(\text{aq}) \quad E^{\ominus} = +2,23 \text{ V}$

8.5

8.5.1 Remains the same

(1)

8.5.2 Increases

QUESTION 9

9.1 Electrons are transferred. OR The oxidation number of Mg/H changes. OR/OF Mg is oxidised / H⁺ is reduced.

9.2 H⁺ ions/HCl/H⁺(aq)/HCl(aq)

9.3 Ag is a weaker reducing agent (than H₂) and will not be oxidised to Ag⁺

9.4 Electrode/Conductor of electrons (in hydrogen half-cell)

9.5.1 Chemical energy to electrical energy

9.5.2 Provides path for movement of ions./Completes the circuit./Ensures electrical neutrality in cell.

9.5.3 $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$

8.5.4 $\text{Mg}(\text{s}) \mid \text{Mg}^{2+}(\text{aq}) \parallel \text{H}^+(\text{aq}) \mid \text{H}_2(\text{g}) \mid \text{Pt}$

OR $\text{Mg}(\text{s}) \mid \text{Mg}^{2+}(1 \text{ mol}\cdot\text{dm}^{-3}) \parallel \text{H}^+(1 \text{ mol}\cdot\text{dm}^{-3}) \mid \text{H}_2(\text{g}) \mid \text{Pt}$

Accept

$\text{Mg} \mid \text{Mg}^{2+} \parallel \text{H}^+ \mid \text{H}_2 \mid \text{Pt}$

9.6

$$\begin{aligned} E_{\text{cell}}^{\ominus} &= E_{\text{reduction}}^{\ominus} - E_{\text{oxidation}}^{\ominus} \\ &= 0,00 \checkmark - (-2,36) \\ &= 2,36 \text{ V } \checkmark \end{aligned}$$

9.7 Increases

5 . ELECTROLYTIC CELLS

QUESTION 1

1.1 C 1.2 D 1.3 C 1.4 B 1.5 D

QUESTION 2

2.1 Electrolytic cell

2.2 The substance/species which loses electrons

2.3 P

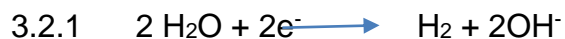
2.4 $\text{Cu}(\text{s}) \longrightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{e}^-$

2.5 A

Cl^- ions move to the positive electrode/anode where they are oxidised to Cl_2 .

QUESTION 3

3.1 A solution that conducts electricity (through the movement of ions).



3.2.2 Chlorine gas/ Cl_2

3.3 H_2O is a stronger oxidising agent (than Na^+) and will be reduced (to H_2).

OR The half-reaction that produces $\text{H}_2(\text{g})$ has a more positive reduction potential (-0,83 V) than the half-reaction that produces Na (-2,71 V).

QUESTION 4

4.1 A solution that conducts electricity through the movement of ions. (2)
✓✓

4.2 Bracelet ✓ (1)

4.3

4.3.1 Chromium ✓ (1)

4.3.2 $\text{Cr}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Cr}(\text{s})$ ✓✓ (2)

4.4

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

$$= \frac{0,86}{52} \checkmark$$

$$= 0,0165 \text{ mol}$$

$$n(\text{electrons}) = 3n(\text{Cr}) \checkmark = 4,96 \times 10^{-2} \text{ mol}$$

$$n = \frac{N}{N_A} \checkmark$$

$$4,96 \times 10^{-2} = \frac{N}{6,02 \times 10^{23}}$$

$$\therefore N = 2,99 \times 10^{22} \checkmark$$

(6)
[12]

QUESTION 5

5.1 Electrolytic ✓ (1)

5.2 Q & T



5.3

5.3.1 Cl_2 / chlorine (gas) ✓ (1)

5.3.2 Cu^{2+} (ions) / copper(II) ions / CuCl_2 / copper(II) chloride ✓ (1)

①

5.4 Cu is a stronger reducing agent ✓ than Cl^- (ions) ✓ and Cu will be oxidised ✓ (to Cu^{2+}).

OR

Cl^- (ions) is a weaker reducing agent ✓ than Cu ✓ and Cu will be oxidised ✓ (to Cu^{2+}).

(3)

QUESTION 6

6.1 The chemical process in which electrical energy is converted to chemical energy.

6.2 • To keep the polarity of the electrodes the same.

• To prevent the anode and cathode from swapping .

• DC provides a one way flow of electrons ensuring that the same chemical reaction occurs all the time at the electrodes.

• If you use AC the polarity of the electrodes will keep changing.

• Pure copper deposited on only one electrode.

6.3 $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$ ✓✓

6.4 Cu^{2+} is a stronger oxidising agent than Zn^{2+} .

• Cu^{2+} will be reduced to Cu

OR

• Zn is a stronger reducing agent than Cu.

•Cu²⁺ will be reduced to Cu.

OR

•The standard reduction potential of Cu²⁺|Cu is higher than that of Zn²⁺|Zn.

•Cu²⁺ will be reduced to Cu.

OR

•The standard reduction potential of Zn²⁺|Zn is lower than that of Cu²⁺|Cu.

•Cu²⁺ will be reduced to Cu. (3)

6.5

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

$$2,85 \times 10^{-2} = \frac{m}{63,5}$$

$$m = 1,81 \text{ g}$$

$$\% \text{ purity} = \frac{1,81}{2} \times 100$$

$$= 90,49 \%$$

QUESTION 7

7.1 Endothermic (1)

7.2 Anode ✓



Connected to the positive terminal of the battery. ✓

(2)

7.3

7.3.1 Chlorine (gas) / Cl₂ ✓ (1)

7.3.2 Hydrogen (gas) /H₂ ✓ (1)

7.3.3 2H₂O(l) + 2e⁻ → H₂(g) + 2OH⁻(aq) ✓✓

74 Basic/ Alkaline/ NaOH /strong base forms

QUESTION 8

8.1 Substance that dissolves in water to give a solution that conducts electricity./ A substance that forms ions in water / when melted.

8.2 Plastic is a non-conductor of electricity / Graphite is a conductor.

8.3.1 $\text{Ni}^{2+}(\text{aq}) + 2\text{e}^{-} \rightarrow \text{Ni}(\text{s})$

8.3.2 nickel

Ni is oxidised.

OR Ni loses electrons. OR Ni is the anode. OR Ni is the positive electrode.

OR Ni

$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^{-}$ (2)

8.4 Ring

Reduction takes place at the cathode.

OR Negative electrode. (2)

8.5 Decreases

Ni^{2+} ions from the electrolyte will be reduced (to Ni).

QUESTION 9

9.1

9.1.1 Electrolyte

9.1.2 Electrolytic (cell)

9.2 A to B

9.3

9.3.1 B

9.3.2 A

9.4 Decreases

Copper (Cu) is oxidised to Cu^{2+} /Oxidation takes place at A/Electrons are lost

6. FERTILIZERS

QUESTION 1

1.1 B 1.2 C 1.3 B 1.4 C 1.5 D 1.6 B

QUESTION 2

2.1 Contact process (1)

2.2 Sulphur dioxide / SO₂ (1)

2.3

2.3.1 Vanadium pentoxide / vanadium(V) oxide / V₂O₅ (1)

2.3.2 2SO₂(g) + O₂ ⇌ 2SO₃ (3)

2.4

2.4.1 Oleum / Pyrosulphuric acid / H₂S₂O₇ (1)

2.4.2 Reaction is highly exothermic and forms a mist. (1)

2.5 Ammonium sulphate / (NH₄)₂SO₄ (1)

2.6 Eutrophication leads to the destruction of aquatic life / dead zones.

This results in less income due to selling of food / recreation areas. (2)

QUESTION 3

3.1

3.1.1 Nitrogen / N₂
Hydrogen / H₂

(2)

3.1.2 NH₃ + HNO₃ → NH₄NO₃

3.2

<u>OPTION 1 / OPSIE 1:</u>	<u>OPTION 2 / OPSIE 2:</u>	<u>OPTION 3 / OPSIE 3:</u>
$\% \text{ N} = \frac{3}{9} \checkmark (\times 36) \checkmark$ $= 12 \%$ $\therefore m(\text{N}) : \frac{12}{100} (\times 20 \text{ kg})$ $= 2,4 \text{ kg} \checkmark$	$\frac{m(\text{nutrients})}{36} \checkmark (\times 20) = 7,2 \text{ kg}$ $\frac{3}{9} \checkmark \times 7,2$ $= 2,4 \text{ kg} \checkmark$	$m(\text{N}) :$ $\frac{3}{9} \checkmark \times (\times 20) (\times \frac{36}{100}) = 2,4 \text{ kg} \checkmark$

(4)

QUESTION 4

4.1

4.1.1 Haber (process)

4.1.2 $\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$

4.1.3 Air (1)

4.2

4.2.1 40% (1)

4.2.2 • High yield / percentage
• High rate due to higher concentration. (2)

4.2.3 Low reaction rate (1)

4.3

<u>OPTION 1</u>	<u>OPTION 2</u>
$\% \text{ N in } \text{NH}_4\text{NO}_3 = \frac{28}{80} \times 100$ $= 35\%$ <p>m(N) in 50 kg:</p> $\frac{35}{100} \times 50 \checkmark = 17,5 \text{ kg}$	$m(\text{N in } \text{NH}_4\text{NO}_3) = \frac{28}{80} \times 50$ $= 17,5 \text{ kg}$

(3)

QUESTION 5

5.1

5.1.1 Haber (process)

5.1.2 Contact process / Catalytic oxidation of SO_2

5.1.3 Sulphur trioxide / SO_3

5.1.4 $\text{SO}_3 + \text{H}_2\text{SO}_4 \longrightarrow \text{H}_2\text{S}_2\text{O}_7$

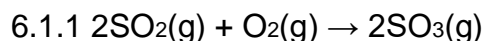
5.1.5 $\text{H}_2\text{SO}_4 + 2\text{NH}_3 \longrightarrow (\text{NH}_4)_2\text{SO}_4$

5.2

OPTION 1	OPTION 2
$m(\text{fertiliser}) = \frac{36}{100} \times 20 \quad \checkmark$ $= 7,2 \text{ kg}$ $\%N = \frac{4,11}{7,2} \times 100$ $= 57,08\%$ $\%P = \frac{0,51}{7,2} \times 100$ $= 7,08\%$ $\%K = \frac{100 - \checkmark (57,08 + 7,08)}{\quad} \checkmark$ $= 35,84\%$ $57,08 : 7,08 : 35,84$ $8 : 1 : 5 \checkmark$	$m(\text{fertiliser}) = \frac{36}{100} \times 20 \quad \checkmark$ $= 7,2 \text{ kg}$ $m(K) = \frac{7,2 - \checkmark (4,11 + 0,51)}{\quad} \checkmark$ $= 2,58 \text{ kg}$ $4,11 : 0,51 : 2,58$ $8 : 1 : 5 \checkmark$

QUESTION 6

6.1



6.1.2 Catalyst

OR

Increase the reaction rate

6.2 Exothermic

The temperature increases.

OR

Before the reaction the temperature was 450 °C and after the reaction it was 600 °C / 518 °C / 475 °C / 460 °C.

6.3 • An exothermic reaction is favoured by a decrease in temperature.

• The forward reaction is favoured.

Higher yield (of SO_3).

OR

- An endothermic reaction is favoured by an increase in temperature.
- The reverse reaction is favoured.

Lower yield (of SO_3).

6.4

6.4.1 $\text{H}_2\text{S}_2\text{O}_7$

6.4.2 A mist will form (which is difficult to collect).

OR

The reaction is too exothermic.

6.5 $\text{H}_2\text{SO}_4 + 2\text{NH}_3 \rightarrow (\text{NH}_4)_2\text{SO}_4$

QUESTION 7

7.1 Contact process

7.2.1 Vanadium pentoxide/ V_2O_5

7.2.2 $\text{H}_2\text{S}_2\text{O}_7(\ell) + \text{H}_2\text{O}(\ell) \rightarrow 2\text{H}_2\text{SO}_4(\ell)$

7.3.1 $\text{H}_2\text{SO}_4 + 2\text{NH}_3 \rightarrow (\text{NH}_4)_2\text{SO}_4$

7.3.2 Ammonium sulphate

QUESTION 8

8.1 Ostwald process

8.2 NO/nitrogen monoxide

Water/ H_2O

8.3 $\text{NH}_3 + \text{HNO}_3 \rightarrow \text{NH}_4\text{NO}_3$

8.4

<p><u>OPTION 1/OPTION 1</u></p> $n(\text{NH}_3) = \frac{m}{M}$ $= \frac{6,8 \times 10^7}{17\checkmark}$ $= 4 \times 10^6 \text{ mol}$ <p style="text-align: center;">↓</p> $n(\text{NH}_4\text{NO}_3) = n(\text{NH}_3)$ $= 4 \times 10^6 \text{ mol}$ $m(\text{NH}_4\text{NO}_3) = nM$ $= (4 \times 10^6)(80) \checkmark$ $= 3,2 \times 10^8 \text{ g}$ $= 3,2 \times 10^5 \text{ kg} \checkmark$	<p><u>OPTION 2/OPSIE 2</u></p> $m(\text{NH}_4\text{NO}_3) = \frac{6,8 \times 10^4}{17\checkmark} \times 80\checkmark \checkmark$ $= 3,2 \times 10^5 \text{ kg}\checkmark$ <hr/> <p><u>OPTION 3/OPSIE 3</u></p> <p>17 g ✓ NH₃ forms/vorm 80 g ✓ NH₄NO₃ 6,8 x 10⁴ kg forms/vorm x g NH₄NO₃</p> $x = 6,8 \times 10^4 \times \frac{80}{17}$ $= 3,2 \times 10^5 \text{ kg}\checkmark$
--	---

8.5 To make a NPK fertiliser/fertilisers which contain all three primary nutrients.

QUESTION 9

9.1.1 Sulphur dioxide/ SO_2

9.1.2 Catalytic oxidation of SO_2

9.1.3 Vanadium pentoxide (V_2O_5)

9.1.4 $\text{H}_2\text{S}_2\text{O}_7$

9.1.5 $\text{NH}_3 + \text{H}_2\text{SO}_4 \rightarrow (\text{NH}_4)_2\text{SO}_4$

9.2 **ANY ONE**

- Fertilisers in water leads to eutrophication which can result in less drinking water/starvation due to dying of fish/less water recreation areas.
- Fertilisers in water leads to excess of nitrates in water resulting in blue baby syndrome/cancer.

9.3.1 Nitrogen

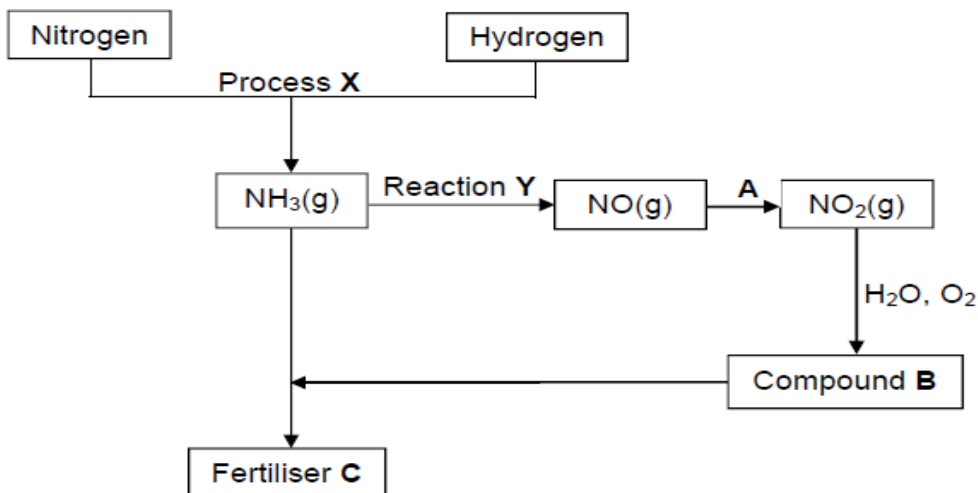
9.3.2 Potassium

9.4 Phosphorus

QUESTION 10

Different processes used in the preparation of fertiliser C are represented in the flow

diagram below



Use the above information and write down the:

- 10.1 NAME of the industrial preparation of nitrogen (1)
- 10.2 NAME of process X (1)
- 10.3 NAME of reaction Y (1)
- 10.4 NAME or FORMULA of compound A (1)
- 10.5 Balanced equation for the preparation of compound B from NO₂(g) (3)
- 10.6 Balanced equation for the preparation of fertiliser C (3)

SOLUTION

10.1 Fractional distillation (of liquid air) process

10.3 Catalytic oxidation (of ammonia)

10.4 O₂(g)/oxygen (gas)

10.5 $4\text{NO}_2(\text{g}) + \text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow 4\text{HNO}_3(\text{aq})$

10.6 $\text{NH}_3 + \text{HNO}_3 \rightarrow \text{NH}_4\text{NO}_3$