PHYSICAL SCIENCES

Grade 12
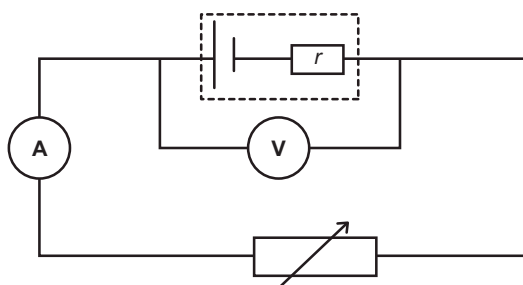
TERM 3

RESOURCE PACK

Contents

WORKSHEETS

TOPIC 10: Electric Circuits

WORKSHEET QUESTIONS

TOTAL: 62 MARKS

1. Learners conduct an investigation to determine the emf and internal resistance (r) of the battery. They set up a circuit as shown in the diagram below and measure the potential difference using the voltmeter for different currents in the circuit.

The results obtained are shown in the graph below.

Graph of potential difference versus current
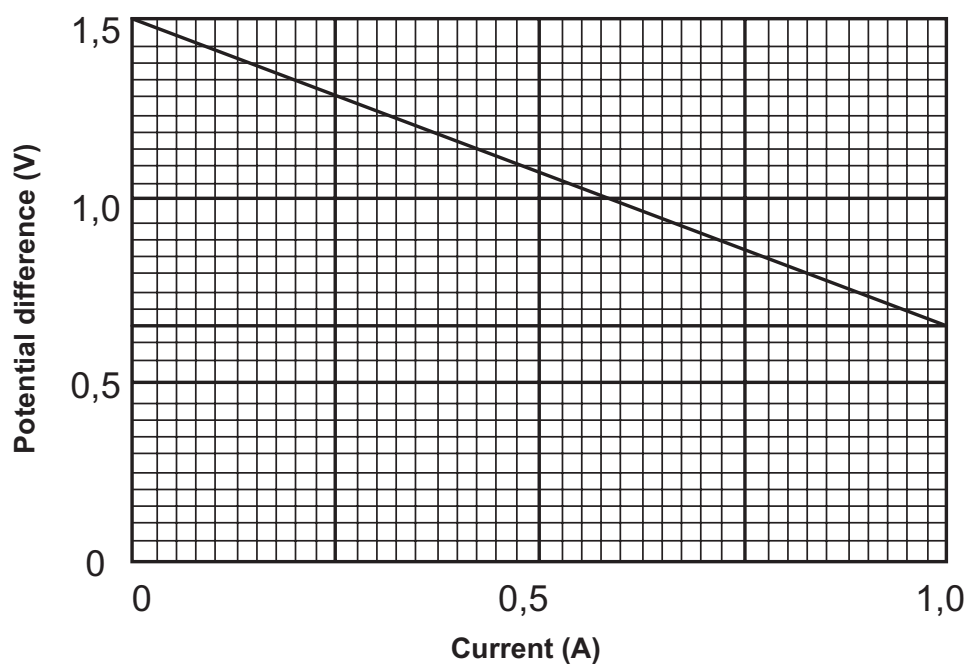
1.1 Use the graph to determine the emf of the battery. (1)

1.2 Calculate the gradient of the graph. (3)

1.3 What physical property is represented by the magnitude of the gradient of the graph? (2)

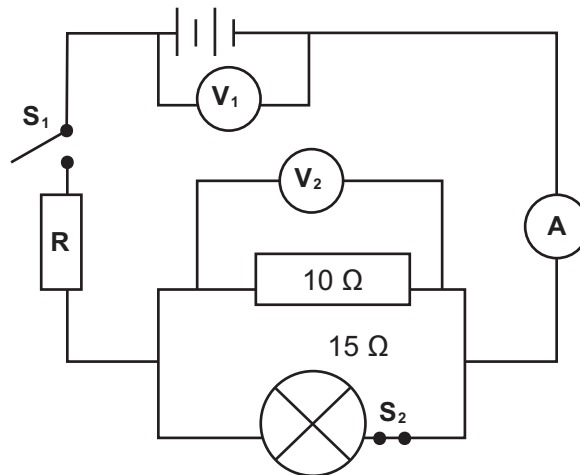**1.4** How does the voltmeter reading change as the ammeter reading increases? Write down INCREASES, DECREASES or REMAINS UNCHANGED. Use the formula *emf = I(R + r)* to explain the answer. (3)

2. The battery in the following circuit has an emf of 24 V and an internal resistance of 1,5 Ω.

R is a resistor with an unknown resistance. The light bulb has a resistance of 15 Ω. The resistance of the switches, S_1 and S_2, ammeter and conducting wires can be ignored.

2.1 State Ohm's law in words. (3)

2.2 What is meant by the internal resistance of the battery? (2)

2.3 Calculate the effective resistance of the 10 Ω resistor and light bulb. (3)

When the switch S_1 is closed, the bulb converts 576 J of energy per minute.

2.4 Calculate the reading on the voltmeter V_2 when the switch is closed. (4)

2.5 Calculate the reading on the ammeter. (3)

2.6 Determine the resistance of resistor R. (4)

2.7 Briefly explain what will happen to the reading on voltmeter V_1 when switch S_2 is opened. (4)

3. Learners conduct an investigation to verify Ohm's law. They measure the current through a conducting wire for different potential differences across its ends. The results obtained are shown in the graph below.
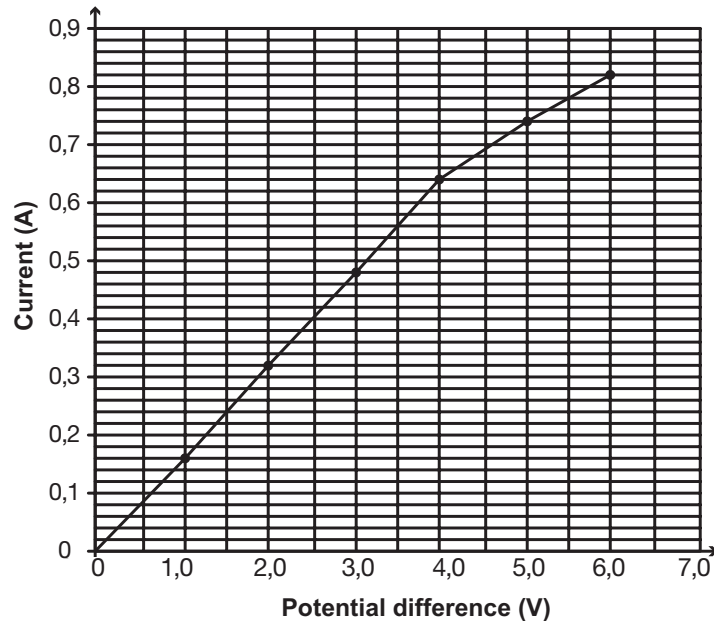
3.1 Which one of the measured quantities is the dependent variable? (1)

3.2 The graph deviates from Ohm's law at some point.

    3.2.1 Write down the coordinates of the plotted point on the graph beyond which Ohm's law is not obeyed (2)

    3.2.2 Give a possible reason for the deviation from Ohm's law as shown in the graph. Assume that all measurements are correct. (2)

3.3 Calculate the gradient of the graph for the section where Ohm's law is obeyed. Use this to calculate the resistance of the conducting wire. (4)

4. Three resistors, R_1, R_2 and R_3, are connected to a battery, as shown in the circuit diagram below. The internal resistance of the battery is 0,3 Ω. The resistance of R_2 and R_3 is equal. The resistance of R_1 is half that of R_2. When both switches are open, the voltmeter across the battery reads 9 V.
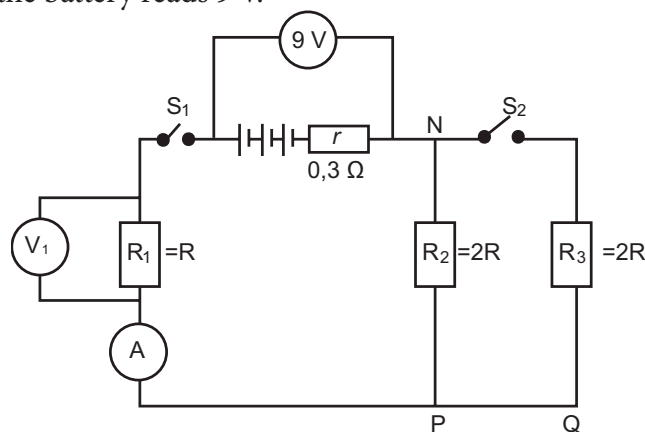
4.1 What is the emf of the battery? Give reason for the answer. (2)

4.2 When switches S_1 and S_2 are closed, the reading on the ammeter is 3 A. Calculate the resistance of R_1. (5)

4.3 Switch S_1 is now opened.

4.3.1 How will the resistance of the circuit change? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1)

4.3.2 What effect will this have on the "lost volts"? Explain the answer. (3)

5. The battery in the circuit below has an emf of 12 V and an internal resistance of 0,2 Ω. The resistance of the connecting wires can be ignored.
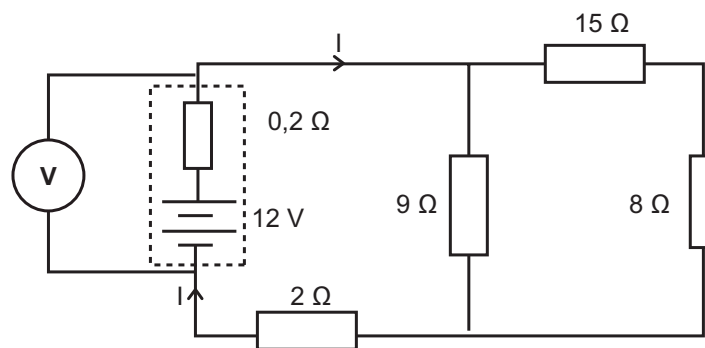
5.1 Calculate the current through the battery. (6)

5.2 How will the reading on the voltmeter be affected if the 9 Ω resistor is removed and replaced with a conducting wire of negligible resistance? Explain the answer. (4)

CONSOLIDATION QUESTIONS   TOTAL: 52 MARKS

1. **1.1** In an experiment, learners use the circuit below to determine the internal resistance of a cell.
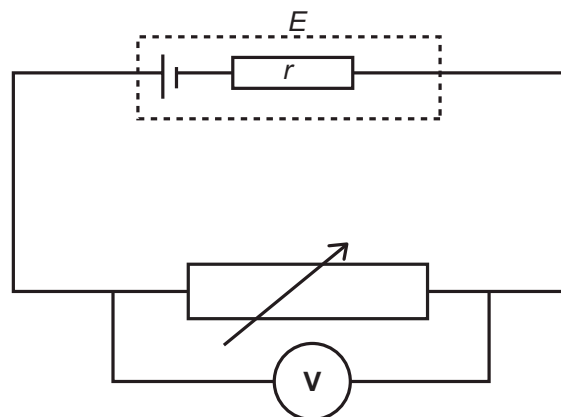
The circuit consists of a cell of emf E and internal resistance r. A voltmeter is placed across a variable resistor which can be set to known values R.

The equation used by the learners is:

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

They obtain the graph below.
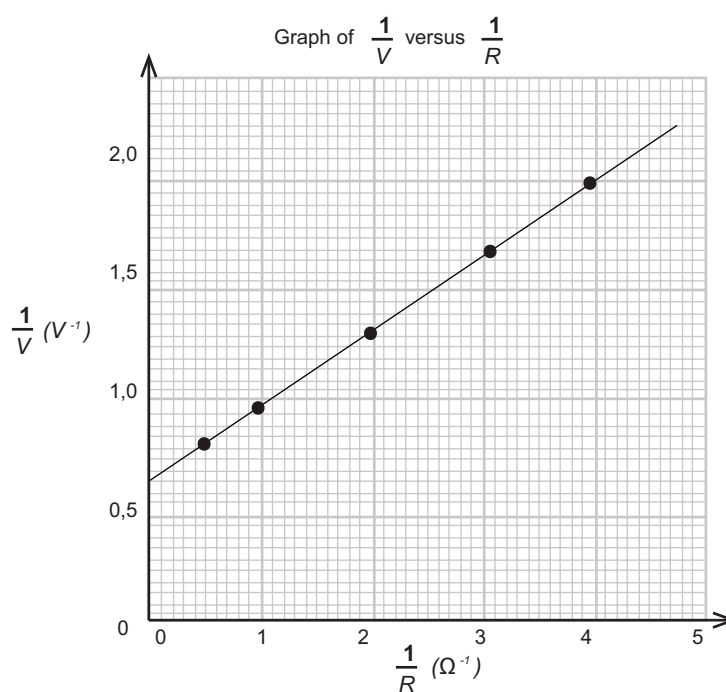
1.1.1   Write down a mathematical relationship for the slope of the graph.   (1)

Use the information in the graph and calculate the:

1.1.2   emf of the cell.   (2)

1.1.3   internal resistance of the cell.   (3)

1.2 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.
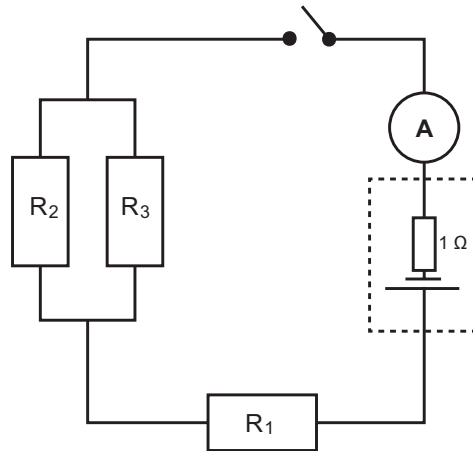
1.2.1 Calculate the current in R_1 when the switch is closed. (3)

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. ($R_3 = 4R_2$).

1.2.2 Calculate the resistance of resistor R_2. (5)

1.3 A hair dryer operates at a potential difference 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 hairdryer for the 12 minutes.

(1unit = 1kWh). (4)

2. Study the circuit diagram shown below. The battery has an emf of 17 V and an unknown internal resistance, r. The ammeter has negligible resistance.
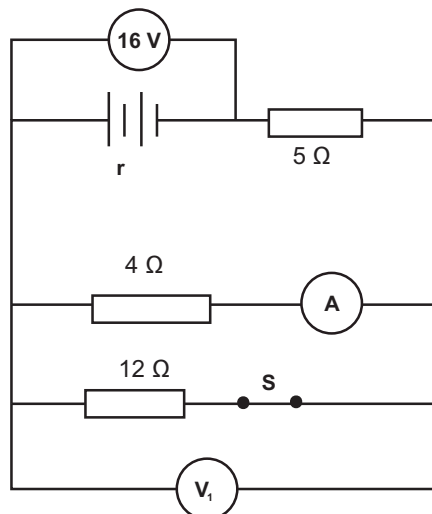
Switch S is CLOSED. Energy is dissipated in the 4 Ω resistor at a rate of $9\,\text{J·s}^{-1}$.

2.1 Calculate the reading on ammeter A. (4)

2.2 Calculate the reading on voltmeter V_1. (3)

2.3 Calculate the current in the 5 Ω resistor. (3)

2.4 Calculate the internal resistance r. (4)

Switch S is now OPENED.

2.5 What will happen to the reading on the voltmeter connected across the battery? Briefly explain. (4)

3. A learner wants to use a 12 V battery with an internal resistance of 1 Ω to operate an electrical device. He uses the circuit below to obtain the desired potential difference for the electrical device to function. The resistance of the device is 5 Ω. When the switch S is closed as shown, the device functions at its maximum power of 5 W.
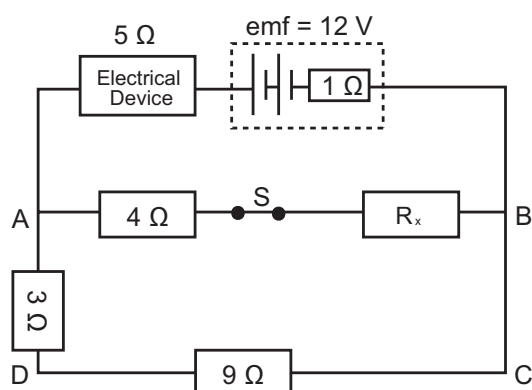
3.1 Explain, in words, the meaning of an *emf* of 12 V. (2)

3.2 Calculate the current that passes through the electrical device. (3)

3.3 Calculate the resistance of resistor R_x. (7)

3.4 Switch S is now opened. Will the device still function at maximum power? Write down YES or NO. Explain the answer without doing any calculations. (4)

MARKING GUIDELINES

WORKSHEET QUESTIONS   **TOTAL: 62 MARKS**

1.1 The voltmeter will read the emf of the battery when the current in the circuit is zero (the circuit is open).

When $I = 0$, $V = 1,5$ V

emf $= 1,5$ V $\checkmark$ (1)

1.2 gradient $= \dfrac{\Delta y}{\Delta x} = \dfrac{0,65 - 1,5\checkmark}{10\checkmark} = \dfrac{-0,85}{1} = -0,85\checkmark$ (3)

1.3 emf $= I(R + r)$

emf $= IR + Ir$

emf $= V + Ir$

$V = $ emf $- Ir$

$V = -rI + $ emf $\checkmark$

$y = mx + c$

gradient $= -r$

Magnitude of the gradient represents the internal resistance of the battery (r). $\checkmark$ (2)

1.4 DECREASES. $\checkmark$

emf $= I(R + r)$

emf $= IR + Ir$

emf $= V + Ir$

$V = $ emf $- Ir$

As current increases, the volts lost across the internal resistance will increase. $\checkmark$
$V_{internal\ resistance} = Ir$

This will decrease the volts available to the external circuit $V = $ emf $- Ir$. $\checkmark$ (3)

2.1 The current through a conductor is directly proportional $\checkmark$ to the potential difference across the conductor $\checkmark$ provided the temperature remains constant. $\checkmark$

                                                                 (3)

2.2 The battery itself has resistance which opposes the flow of charge. $\checkmark$ $\checkmark$ (2)

2.3 $\dfrac{1}{R_p} = \dfrac{1}{10} + \dfrac{1}{15}\checkmark = \dfrac{1}{6}$ $\checkmark$

$R_p = 6\ \Omega$ $\checkmark$ (3)

2.4 $W = \dfrac{V^2}{R}t$

$576\checkmark = \dfrac{V^2}{15\checkmark}(60\checkmark)$

$V^2 = \dfrac{(576)(15)}{60} = 144$

$V_{bulb} = 12\text{ V }\checkmark$

therefore, $V_2 = 12\text{ V}$ (4)

2.5 $I = \dfrac{V_p}{R_p} = \dfrac{12\checkmark}{6\checkmark} = 2\text{ A}\checkmark\checkmark$ (3)

2.6 $emf = I(R + r)$

$24\checkmark = 2\checkmark(R + 6 + 1,5)\checkmark$

$12 = R + 6 + 1,5$

$R = 4,5\,\Omega\;\checkmark$ (4)

2.7 The resistance in the external circuit will increase. ✓

The current through the battery will decrease. ✓

The volts lost across the internal resistance will decrease. ✓

There are more volts available across the external circuit.

V_1 will increase. ✓   (4)

3.1 Current. ✓ (The variable on the vertical axis).   (1)

   3.2.1 $(4,0\checkmark; 6,4\checkmark)$ (2)

   3.2.2 The temperature of the conductor increases ✓ at high currents, increasing resistance. ✓   (2)

3.3 $gradient = \dfrac{\Delta y}{\Delta x} = \dfrac{6,4 - 0\checkmark}{4 - 0\checkmark} = 1,6\;\checkmark$

$gradient = \dfrac{I}{V} = \dfrac{1}{R}$

$\dfrac{1}{R} = 1,6$

$R = 0,63\,\Omega\;\checkmark$ (4)

4.1 $emf = 9\text{ V }\checkmark$

There is no current through the battery. ✓   (2)

4.2 $emf = I(R + r)$

$9\checkmark = 3\checkmark(3R_1\checkmark + 0,3\checkmark)$

$3 = 3R_1 + 0,3$

$2,7 = 3R_1$

$R_1 = 0,9\,\Omega\;\checkmark$ (5)

4.3.1 Decrease. ✓ (1)

4.3.2 Resistance in the circuit will increase. ✓

Current through the battery will decrease. ✓

There will be less volts lost across the internal resistance of the battery. ✓

$V_{\text{internal resistance}} = Ir$ (3)

5.1 $\dfrac{1}{R_p} = \dfrac{1}{9} + \dfrac{1}{23}$ ✓ $= \dfrac{32}{207}$ ✓

$R_p = \dfrac{207}{32} = 6{,}47\,\Omega$ ✓

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

12✓ $= I(2 + 6{,}47 + 0{,}2)$ ✓

$12 = I(8{,}67)$

$I = 1{,}38\text{ A}$ ✓ (6)

5.2 The parallel network has been short-circuited by the conducting wire.

Resistance in the circuit has decreases. ✓

Current through the battery will increase. ✓

There will be more volts lost across the internal resistance of the battery. ✓

There are less volts available across the external circuit.

The voltmeter reading will decrease. ✓ (4)

CONSOLIDATION QUESTIONS   **TOTAL: 52 MARKS**

1.1.1 $\dfrac{1}{V} = \dfrac{r}{ER} + \dfrac{1}{E}$

$\dfrac{1}{V} = \dfrac{r}{E}(\dfrac{1}{R}) + \dfrac{1}{E}$

$y = mx + c$

$slope = \dfrac{r}{E}$ ✓   (1)

1.1.2 $y\ intercept = \dfrac{1}{E}$

$0,65✓ = \dfrac{1}{E}$

$E = \dfrac{1}{0,65} = 1,54\ V$ ✓   (2)

1.1.3 $slope = \dfrac{\Delta y}{\Delta x} = \dfrac{2,25 - 0,65✓}{4,8 - 0✓} = \dfrac{1,6}{4,8} = \dfrac{1}{3}$

$slope = \dfrac{r}{E}$

$\dfrac{1}{3} = \dfrac{r}{1,54}$

$3r = 1,54$

$r = 0,51\Omega$ ✓   (3)

1.2.1 $emf = I(R + r)$

$6✓ = I(9 + 1)$ ✓

$I = \dfrac{6}{10} = 0,6\ A$ ✓   (3)

1.2.2 $P = I^2R$

$R_1 = \dfrac{P}{I^2} = \dfrac{1,8✓}{(0,6)^2} = 5\ \Omega$ ✓

$R_p = 9 - 5 = 4\ \Omega$ ✓

$\dfrac{1}{R_p} = \dfrac{1}{R_2} + \dfrac{1}{R_3}$

$\dfrac{1}{4} = \dfrac{1}{R_2} + \dfrac{1}{4R_2}$ ✓

$\dfrac{1}{4} = \dfrac{1}{R_2}(1 + \dfrac{1}{4})$

$\dfrac{1}{4} = \dfrac{1}{R_2}(\dfrac{5}{4})$

$20 = 4R_2$

$R_2 = 5\ \Omega$ ✓   (5)

1.3 $P = VI$

$P = (240)(9,5) = 2\ 280\ W$ ✓

$Cost = kWh \times price$

$Cost = 2,280\ kW✓ \times \dfrac{12}{60}\ h✓ \times R\ 1,47$

$Cost = R\ 0,67$ ✓   (4)

2.1 $P = I^2R$

$9\checkmark = I^2(4)\checkmark$

$I^2 = \dfrac{9}{4}\checkmark$

$I_{4\Omega} = 1,5\,A\checkmark$ (4)

2.2 $V_1 = RI = (4\checkmark)(1,5\checkmark) = 6\,V\ \checkmark$ (3)

2.3 $I_{12\Omega} = \dfrac{V_1}{R} = \dfrac{6\checkmark}{12\checkmark} = 0,5\,A\ \checkmark$ (3)

2.4 $I = 1,5 + 0,5 = 2\,A$

$emf = V_{load} + Ir$

$17\checkmark = 16\checkmark + (2\checkmark)r$

$r = 0,5\,\Omega\ \checkmark$ (4)

2.5 Total resistance increases. $\checkmark$

Current I through the battery decreases. $\checkmark$

Lost volts will decrease. $\checkmark$ $V_{internal\,resistance} = Ir$

$V_{load} = emf - V_{internal\,resistance}$

V_{load} will increase. $\checkmark$ (4)

3.1 12 J of energy is supplied by the battery $\checkmark$ per coulomb of charge $\checkmark$ passing through it. (2)

3.2 $P = I^2R$

$I^2 = \dfrac{P}{R} = \dfrac{5\checkmark}{5\checkmark} = 1$

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

3.3 $emf = I(R + r)$

$12\checkmark = 1\checkmark\,(R + 1\checkmark)$

$R = 11\,\Omega\ \checkmark$

$R_p = 11 - 5 = 6\,\Omega\ \checkmark$

$\dfrac{1}{R_p} = \dfrac{1}{12} + \dfrac{1}{(4 + R_X)}\ \ \checkmark$

$\dfrac{1}{6} = \dfrac{1}{12} + \dfrac{1}{(4 + R_X)}$

$\dfrac{1}{6} - \dfrac{1}{12} = \dfrac{1}{(4 + R_X)}$

$\dfrac{1}{12} = \dfrac{1}{(4 + R_X)}$

$12 = 4 + R_X$

$R_X = 8\,\Omega\ \checkmark$ (7)

3.4 No. ✓

Resistance in the circuit has increased. ✓

Current through device will decrease. ✓

$P = I^2R$

Power is directly proportional to I^2 at constant resistance R. ✓ (4)

Topic 11: Electrodynamics

WORKSHEET QUESTIONS

TOTAL: 78 MARKS

1. The diagram below illustrates how electricity generated at a power station is transmitted to a substation.
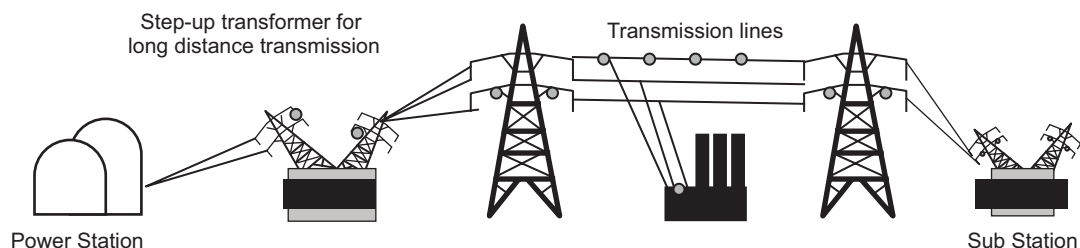
1.1 Does the power station use an AC or DC generator? (1)

1.2 Sketch a graph of the potential difference generated at the power station versus time. (2)

2. The diagrams A to D show four positions in sequence during the anti-clockwise rotation of the coil of a simple AC generator.
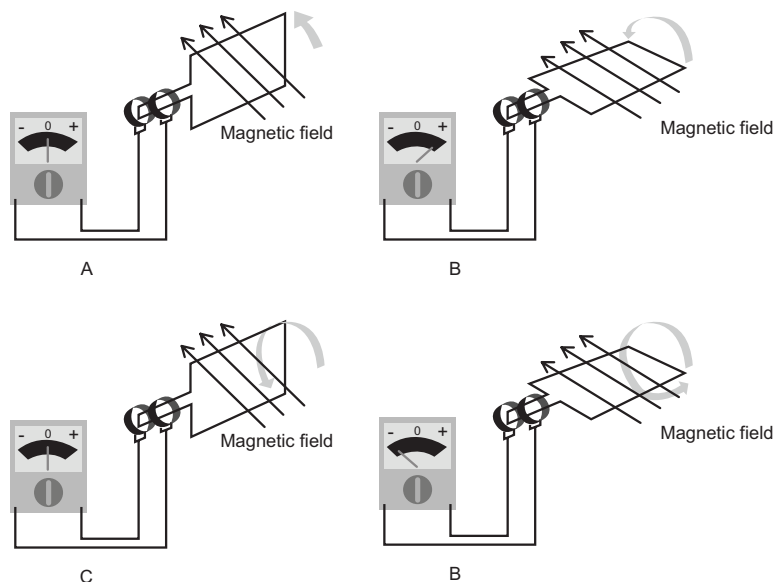
2.1 Name the fundamental principle on which generators work. (1)

2.2 What is the purpose of the slip rings in an AC generator? (1)

2.3 By referring to the relative positions of the coil in positions A to D, draw the corresponding graph of potential difference versus time for one full rotation (A to D to A). Indicate the positions of the coil (by using the letters A to D) on your graph. (3)

2.4 Name one way in which the induced emf of a specific generator can be increased.

(1)

2.5 Which component in a DC generator makes it different from an AC generator? (1)

3. The diagram below shows a dynamo attached to the wheel of a bicycle. When riding a bicycle, the wheel rotates a magnet near a coil.

Explain how a current is induced in the coil. (3)

4. A coil is rotated anti-clockwise in a uniform magnetic field. The diagram below shows the position at the instant the coil lies parallel to the magnetic field.
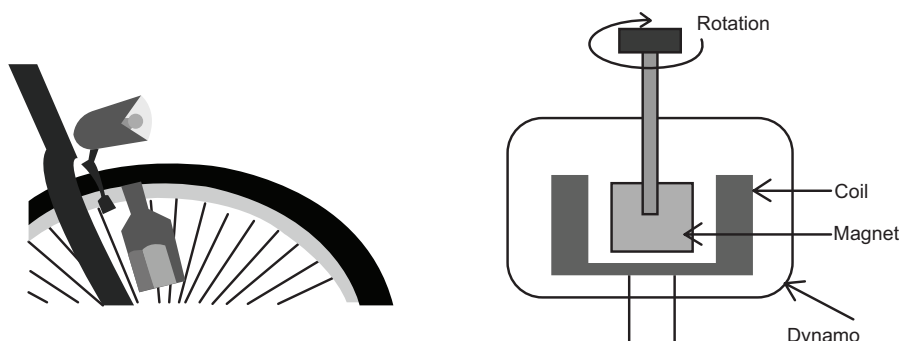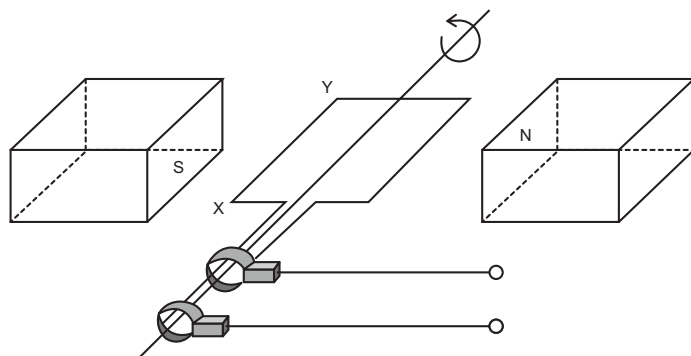

4.1 What type of generator is illustrated in the diagram? Give a reason for your answer.

(2)

4.2 Determine the direction of the current in segment XY when the coil is in the position shown above. Only write down X to Y or Y to X. (2)

4.3 Assume that the speed and direction of rotation are constant. Draw a sketch graph of potential difference against time that represents the output of this device. Start with the coil in the horizontal position. (3)

5.

5.1 The table below compares a motor and a generator in terms of the type of energy conversions and the underlying principle on which each operates. Complete the table by writing down only the question number (5.1.1 – 5.1.4) and next to each number the answer.

	TYPE OF ENERGY CONVERSION	PRINCIPLE OF OPERATION
Motor	5.1.1	5.1.3
Generator	5.1.2	5.1.4

(4)

The simplified diagram below represents an electric motor.
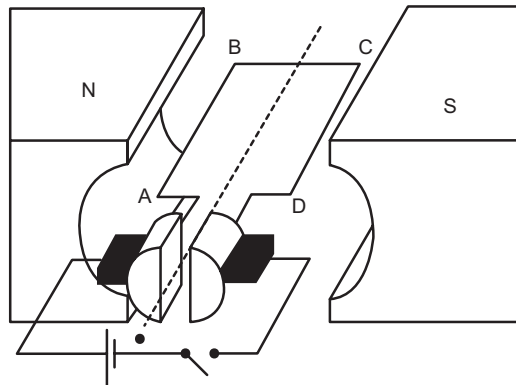
5.2 Give a reason why the section of the coil labelled BC in the above diagram does not experience a magnetic force whilst the coil is in the position as shown. (2)

6. Electric motors are used in pumps, fans and compressors. Electric motors can be either AC or DC. The diagram below illustrates one of these types of electric motors.
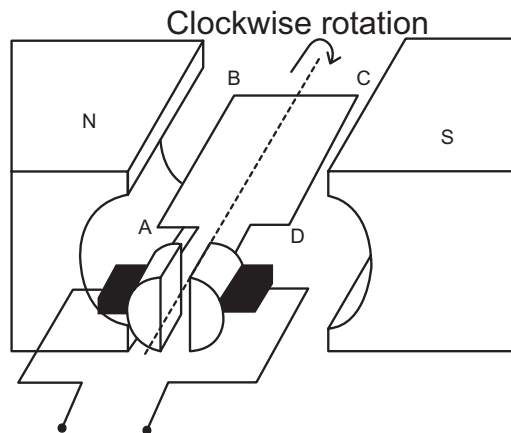
6.1 What type of electric motor (AC or DC) is illustrated in the diagram? Give a reason for your answer. (2)

6.2 If the loop turns in a clockwise direction, in what direction is the current in section AB of the loop flowing in the above diagram? Write down A to B, or from B to A only. (1)

The motor in the diagram is now changed to operate as a generator.

6.3 On what principle does a generator operate? (1)

6.4 Draw a sketch graph of the induced emf versus time for one revolution of the coil of this generator. Start with the coil in the horizontal position. (3)

7.

7.1 The average power produced at the power station is $4,45 \times 10^9 \, \text{W}$. Calculate the rms current in the transmission lines if the power is transmitted at a maximum voltage of 30 000 V. (5)

7.2 Give a reason why electricity should be transmitted at a high voltage and low current. (1)

8. Graphs of the current and potential difference outputs of an AC generator are shown below.
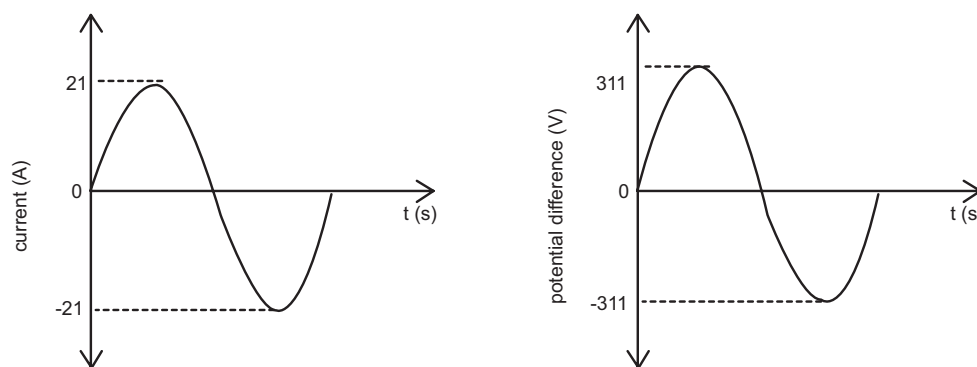
Calculate the average power output of this generator. (6)

9. A source provides a rms potential difference of 36 V to a 4 Ω and an 8 Ω speaker connected in series, as shown in the diagram below.
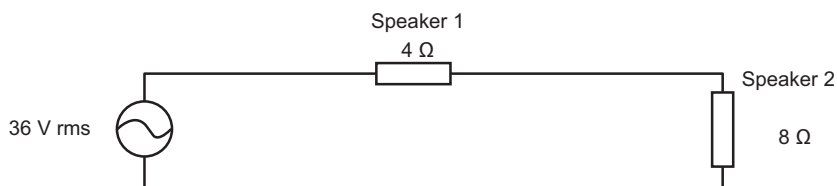
9.1 Calculate the following:

9.1.1 rms current through the 4 Ω speaker. (3)

9.1.2 peak current through each speaker. (3)

9.1.3 average power dissipated by the 4 Ω speaker. (3)

9.2 Without using a calculation, state how the average power dissipated by the 4 Ω speaker compares to the average power dissipated by the 8 Ω speaker.
Give a reason for your answer. (3)

10.

10.1 In the circuit diagram shown below the AC source delivers alternating voltages at audio frequency to the speaker.

10.1.1 What is the peak voltage that the source can deliver? (2)

10.1.2 Calculate the average power delivered to the speaker. (6)

10.2 Alternating current is generated at power stations. Name two advantages of AC transmission over long distances. (2)

11. The municipality of Dinaledin implements a power cutback in the town. As a result of the cutback the rms voltage drops from 220 V rms to 200 V rms.

11.1 Calculate the peak voltage during the cutback. (3)

11.2 A certain electrical appliance dissipates 1 200 W when it is operated at 220 V rms. Calculate the power at which it will operate during the cutback. (4)

11.3 It is common practice to connect many appliances to a multi-plug. Modern types of multi-plugs have a cut-off switch built in. Using principles in Physics, explain clearly why this cut-off switch is important. (4)

CONSOLIDATION QUESTIONS   TOTAL: 44 MARKS

1. A simplified diagram of a DC generator and a graph of its output potential difference for one cycle is shown below.
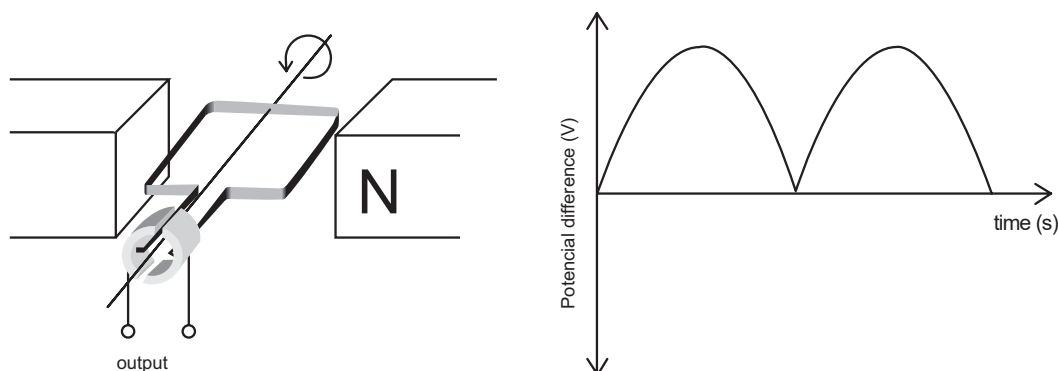
1.1 Write down ONE way in which the output of this generator can be increased.   (1)

A specific change is made to the structure of the DC generator in question 1.1. The output potential difference obtained as a result of this change is shown below.
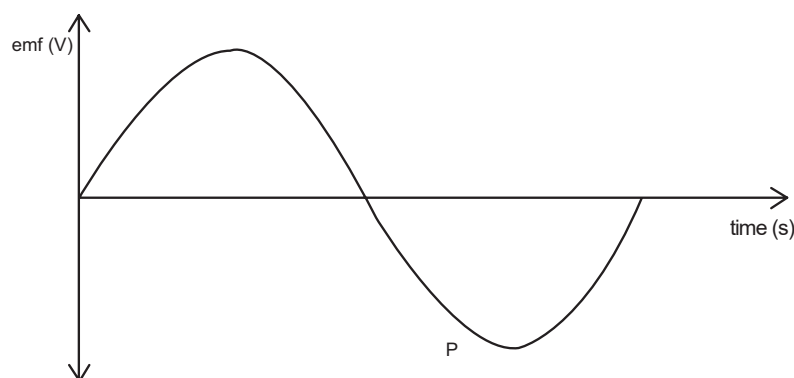
1.2 Write down the change that was made to the DC generator.   (1)

1.3 Copy graph P into your ANSWER BOOK. On the same set of 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)

1.4 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)

2. A simplified sketch represents an AC generator. The main components are labelled A, B, C and D.
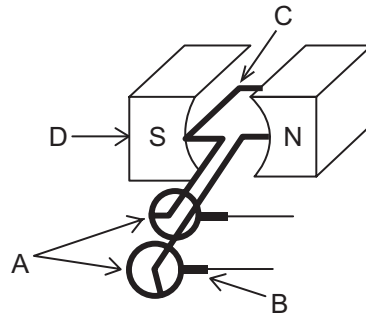
2.1 Write down the name of component:

    2.1.1 A (1)

    2.1.2 B (1)

2.2 Write down the function of component B. (1)

2.3 State the energy conversion which takes place in an AC generator. (1)

A similar coil is rotated in a magnetic field. The graph below shows how the alternating current produced by the AC generator varies with time.
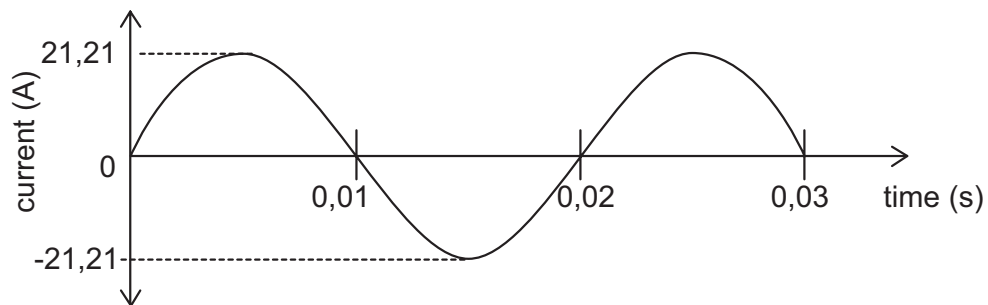
2.4 How many rotations are made by the coil in 0,03 s? (1)

2.5 Calculate the frequency of the alternating current. (3)

2.6 Will the plane of the coil be perpendicular to or parallel to the magnetic field at $t = 0,015\,s$? (1)

2.7 If the generator produces a maximum potential difference of 311 V, calculate its average power output. (5)

3. AC generators and DC generators differ in their construction and the type of current they deliver. The simplified sketch below represents a DC generator.
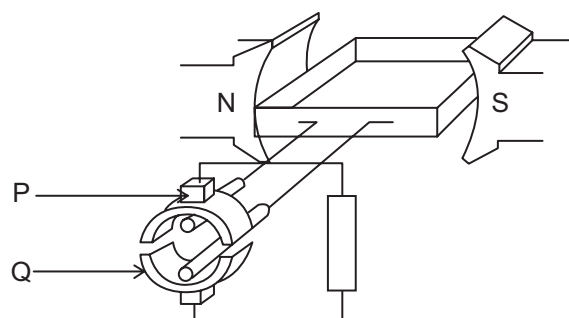
3.1 Which component (P or Q) enables this generator to produce DC? (1)

3.2 What structural change must be made to this generator to change it to an AC generator? (1)

3.3 Briefly explain why Eskom prefers using AC instead of DC for the long-distance transmission of electricity. (2)

3.4 An AC generator delivers 240 V rms to a 60 W light bulb. The peak current in the light bulb is 0,35 A.

3.4.1 Calculate the rms current in the light bulb. (3)

3.4.2 Calculate the resistance of the light bulb. (3)

4.

4.1 The essential components of a simplified DC motor are shown below.
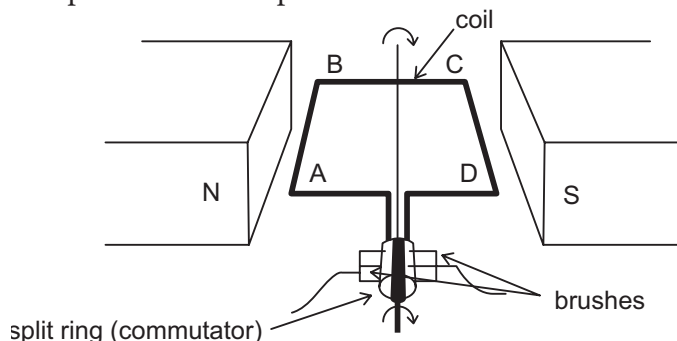
When the motor is functioning, the coil rotates in a clockwise direction, as shown.

4.1.1 Write down the function of each of the following components:

(a) split ring (commutator). (1)

(b) brushes. (1)

4.1.2 What is the direction of the conventional current in the part of the coil labelled AB? Write down only from A to B or from B to A. (1)

4.1.3 Will the coil experience a maximum or minimum turning effect (torque) if the coil is in the position as shown in the diagram above? (1)

4.1.4 State one way in which this turning effect (torque) can be increased. (1)

4.2 Alternating current (AC) is used for long-distance transmission of electricity.

4.2.1 Give a reason why AC is preferred over DC for long-distance transmission of electricity. (1)

4.2.2 An electric appliance with a power rating of 2 000 W is connected to a 230 V rms household mains supply.

Calculate the:

(a) peak (maximum) voltage. (3)

(b) rms current passing through the appliance. (3)

MARKING GUIDELINES

WORKSHEET QUESTIONS   TOTAL: 78 MARKS

1.1 AC generator. ✓   (1)

1.2
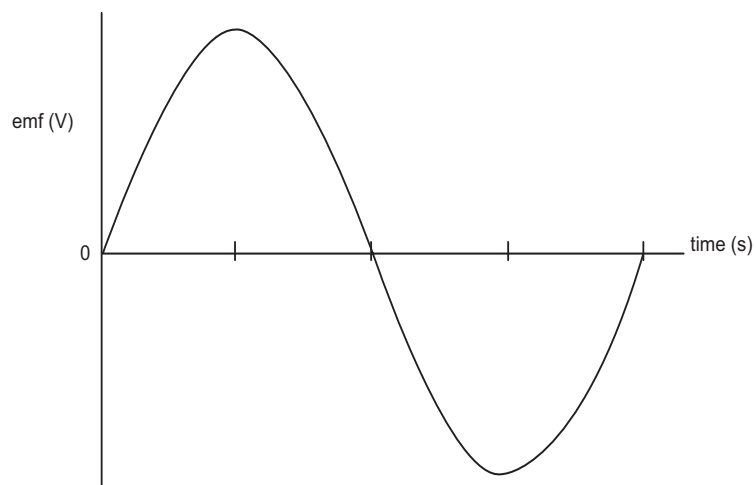
(2)

2.1 Electromagnetic induction. ✓   (1)

2.2 To ensure that there is AC in the external circuit. ✓   (1)
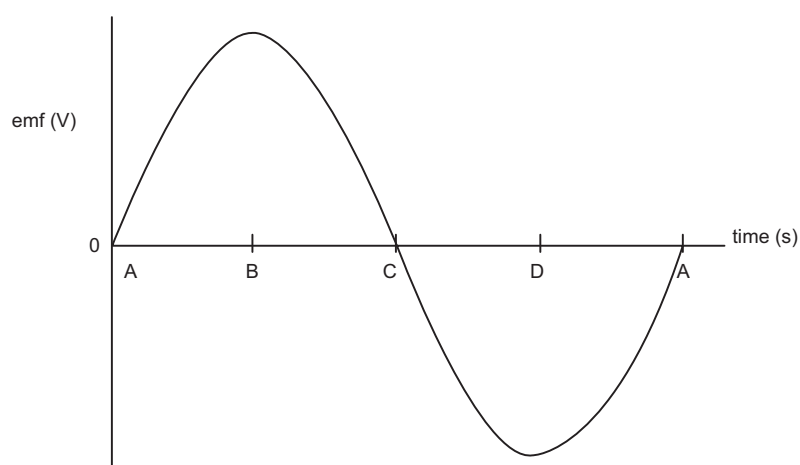
(3)

2.4 Rotate the coil faster (increase the frequency of rotation). ✓

Increase the number of turns in the coil.

Use stronger magnets.

Increase the surface area of the coil.   (1)

2.5 Split ring or commutator ✓ instead of slip rings.   (1)

3. When the magnet rotates, the magnetic flux passing through the coil is changing. ✓ An emf is induced in the coil.✓ The induced emf causes a current to flow in the coil. ✓ (3)

4.1 AC generator. ✓
It uses slip rings. ✓ (2)

4.2 X to Y. ✓ ✓ (2)

4.3
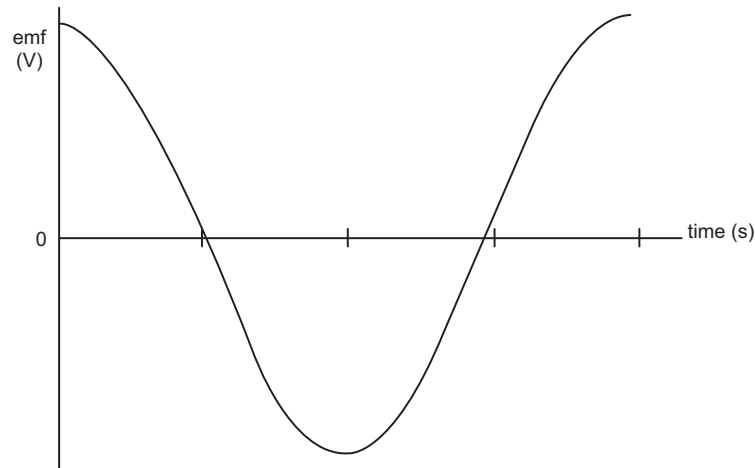
(3)

5.1.1 Electrical to mechanical energy. ✓ (1)

5.1.2 Mechanical to electrical energy. ✓ (1)

5.1.3 Motor effect. ✓ (1)

5.1.4 Electromagnetic induction. ✓ (1)

5.2 BC carries a current parallel ✓ to the magnetic field. ✓ (2)

6.1 DC electric motor ✓ split ring (commutator). ✓ (2)

6.2 BA. ✓ (1)

6.3 Electromagnetic induction. ✓ (1)

6.4
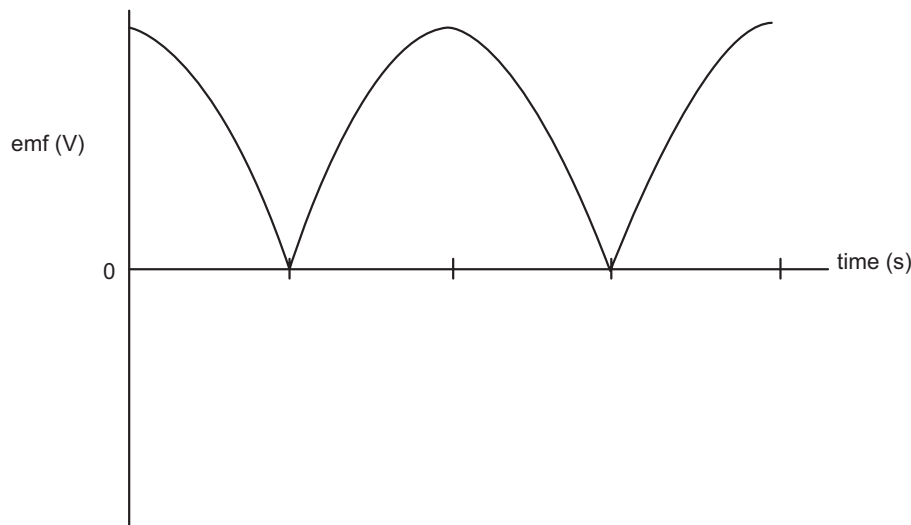
(3)

7.1 $V_{rms} = \dfrac{V_{max}}{\sqrt{2}}\checkmark = \dfrac{30\,000\checkmark}{\sqrt{2}} = 21213,20\text{ V }\checkmark$

$P_{av} = V_{rms}I_{rms}$

$I_{rms} = \dfrac{P_{av}}{V_{rms}} = \dfrac{4,45\times10^{9}\checkmark}{21213,20} = 2,10\times10^{5}\text{ A }\checkmark$ (5)

7.2 Low current minimises the power dissipated (energy lost as heat) in the long power lines. $\checkmark$ (1)

8. $V_{rms} = \dfrac{V_{max}}{\sqrt{2}} = \dfrac{311\checkmark}{\sqrt{2}} = 219,91\text{ V }\checkmark$

$I_{rms} = \dfrac{I_{max}}{\sqrt{2}} = \dfrac{21\checkmark}{\sqrt{2}} = 14,85\text{ V }\checkmark$

$P_{av} = V_{rms}I_{rms}\checkmark = (219,91)(14,85) = 3\,265,50\text{ W }\checkmark$ (6)

9.1.1 $I_{rms} = \dfrac{V_{rms}}{R} = \dfrac{36\checkmark}{12\checkmark} = 3\text{ A }\checkmark$ (3)

9.1.2 $I_{max} = \sqrt{2}\,I_{rms}\checkmark = \sqrt{2}\,(3\checkmark) = 4,24\text{ A }\checkmark$ (3)

9.1.3 $P_{av} = I_{rms}^{2}R = (3\checkmark)^{2}(4\checkmark) = 36\text{ W }\checkmark$ (3)

9.2 Power dissipated in 8 Ω resistor is double $\checkmark$ the power dissipated in the 4 Ω resistor

The current is the same through both resistors. $\checkmark$

Therefore, at constant current, power is directly proportional to resistance. $\checkmark$ (3)

10.1.1 $V_{max} = \sqrt{2}\,V_{rms} = \sqrt{2}\,(15\checkmark) = 21,21\text{ V }\checkmark$ (2)

10.1.2 $I_{rms} = \dfrac{V_{rms}}{R} = \dfrac{15\checkmark}{18,6\checkmark} = 0,8065\text{ A }\checkmark$

$P_{av} = I_{rms}^{2}R = (0,8065\checkmark)^{2}(10,4\checkmark) = 6,76\text{ W }\checkmark$ (6)

10.2 AC voltages can be stepped up using a transformer. $\checkmark$

Current is then stepped down.

The power dissipated in long power lines is minimised at low current. $\checkmark$ (2)

11.1 $V_{max} = \sqrt{2}\, V_{rms} \checkmark = \sqrt{2}\, (200\checkmark) = 282,84$ V $\checkmark$ (3)

11.2 $R = \dfrac{V_{rms}^2}{P_{av}} = \dfrac{(220)^2}{1200}\checkmark = 40,33\ \Omega\ \checkmark$

         $P_{av} = \dfrac{V_{rms}^2}{R} = \dfrac{(200\checkmark)^2}{40,33} = 991,74$ W $\checkmark$ (4)

11.3   Appliances are connected in parallel when plugged into a multi-plug. $\checkmark$
         The more appliances connected to the multi-plug, the less resistance there is in the circuit. $\checkmark$
         Less resistance means higher current. $\checkmark$
         High current can cause overheating of wires and a fire. $\checkmark$ (4)

CONSOLIDATION QUESTIONS   TOTAL: 44 MARKS

1.1 Rotate the coil faster (increase the frequency of rotation). ✓
Increase the number of turns in the coil.
Use stronger magnets.
Increase the surface area of the coil.   (1)

1.2 The split ring or commutator was replaced by slip rings. ✓   (1)

1.3
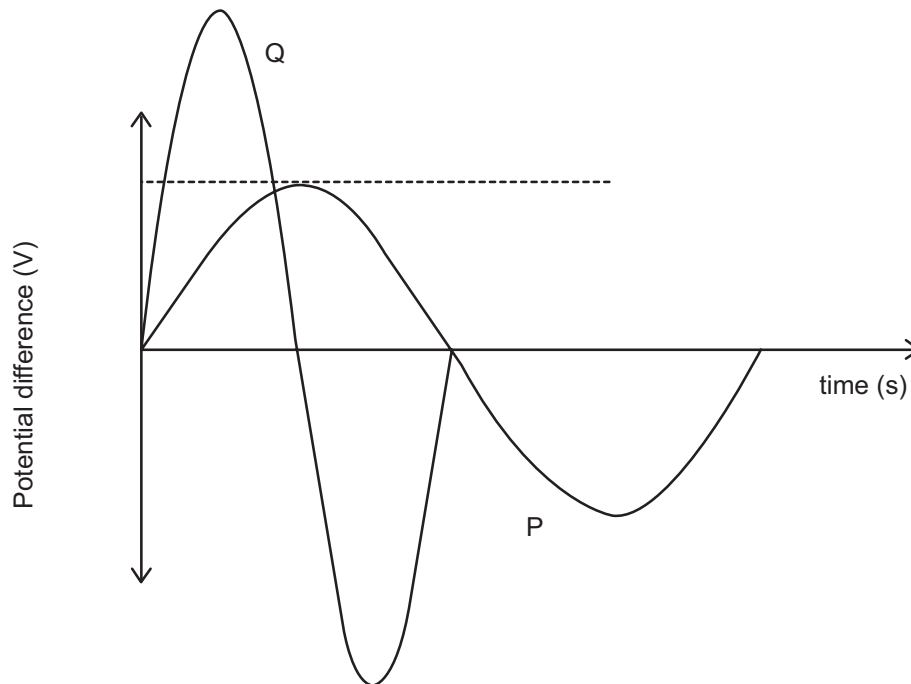
(2)

1.4 $V_{rms} = \dfrac{V_{max}}{\sqrt{2}} = \dfrac{340✓}{\sqrt{2}} = 240{,}42\,V$ ✓

$R = \dfrac{V_{rms}^2}{P_{av}} = \dfrac{(240{,}42)^2}{120✓} = 481{,}67\,W$ ✓   (4)

2.1.1   Slip rings ✓   (1)
2.1.2   Carbon brushes ✓   (1)

2.2 The carbon brushes connect the external circuit to the generator.   (1)

2.3 Mechanical to electrical energy. ✓   (1)

2.4 1,5 rotations. ✓   (1)

2.5 $f = \dfrac{1}{T}✓ = \dfrac{1}{0{,}02✓} = 50\,Hz$. ✓   (3)

2.6 perpendicular. ✓   (1)

2.7 $V_{rms} = \dfrac{V_{max}}{\sqrt{2}} = \dfrac{311\checkmark}{\sqrt{2}} = 219,91\,V\;\checkmark$

$\quad\;\; I_{rms} = \dfrac{I_{max}}{\sqrt{2}} = \dfrac{21,21\checkmark}{\sqrt{2}} = 15\,A\;\checkmark$

$\quad\;\; P_{av} = V_{rms}I_{rms} = (219,91)(15) = 3\,298,65\,W\;\checkmark$ (5)

3.1 Q $\checkmark$ (1)

3.2 Replace the split ring (commutator) with slip rings. $\checkmark$ (1)

3.3 AC can be used in transformers to step the voltage up. $\checkmark$
Stepping the voltage up steps the current down.
A lower current dissipates less power in long distance power lines. $\checkmark$ (2)

3.4.1 $\quad I_{rms} = \dfrac{I_{max}}{\sqrt{2}}\checkmark = \dfrac{0,35\checkmark}{\sqrt{2}} = 0,25\,A\;\checkmark$ (3)

3.4.2 $\quad R = \dfrac{V_{rms}^2}{P_{av}} = \dfrac{(240\checkmark)^2}{60\checkmark} = 960\,\Omega\;\checkmark$ (3)

4.1.1

   (a) To reverse the direction of the current in the coil every half revolution, so that it keeps spinning in the same direction. $\checkmark$ (1)

   (b) To connect the DC power source to the electric motor. $\checkmark$ (1)

4.1.2 B to A. $\checkmark$ (1)

4.1.3 Maximum. $\checkmark$ (1)

4.1.4 Increase the number of turns in the coil. $\checkmark$
Use curved magnets.
Increase the current in the coil.
Wind the coil onto an iron core.
Wind the coil on the iron core at different angles. (1)

4.2.1 AC is used in transformers to step up the voltage. $\checkmark$ (1)

4.2.2

   (a) $V_{max} = \sqrt{2}\,V_{rms}\checkmark = \sqrt{2}\,(230\checkmark) = 325,27\,V\;\checkmark$ (3)

   (b) $I_{rms} = \dfrac{P_{av}}{V_{rms}} = \dfrac{2\,000\checkmark}{230\checkmark} = 8,70\,A\;\checkmark$ (3)

WORKSHEETS

TOPIC 11

TOPIC 12: Optical Phenomena and Properties of Matter

WORKSHEET QUESTIONS

TOTAL: 54 MARKS

1. A metal surface is illuminated with ultraviolet light of wavelength 330 nm. Electrons are emitted from the metal surface. The minimum amount of energy required to emit an electron from the surface of this metal is $3,5 \times 10^{-19}$ J.
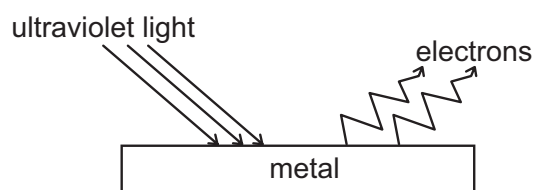
1.1 Name the phenomenon illustrated above. (1)

1.2 Calculate the frequency of the ultraviolet light. (3)

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

1.4 The intensity of the ultraviolet light incident on the metal surface is now increased. What effect will this change have on the following?

1.4.1 The maximum kinetic energy of the emitted photoelectrons. Write INCREASES, DECREASES or REMAINS THE SAME. (1)

1.4.2 The number of photoelectrons emitted per second. Write INCREASES, DECREASES or REMAINS THE SAME. (1)

2. The diagram below shows a metal plate that emits electrons when a certain frequency of electromagnetic radiation is incident on it. The plate is connected to a voltage source and an ammeter as shown in the circuit below.
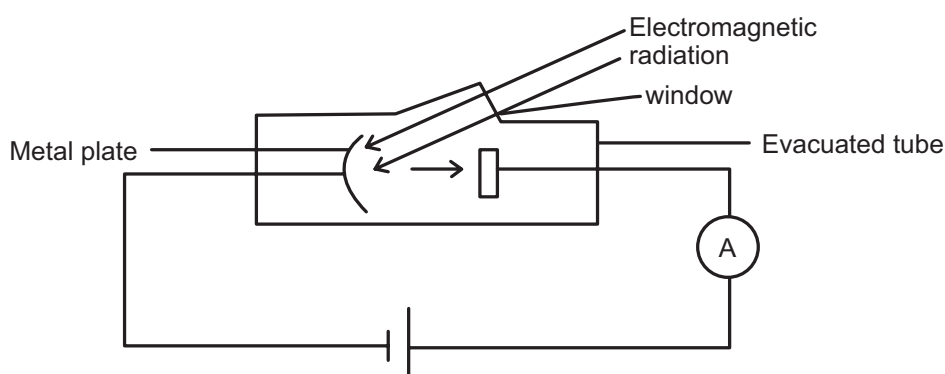
2.1 Name the phenomenon described above. (1)

When radiation of wavelength 555 nm is incident on the metal plate, electrons are released with zero kinetic energy.

2.2 Define the term "work function of a metal". (2)

2.3 Calculate the work function of the metal. (5)

2.4 How will the reading on the ammeter change if the intensity of the electromagnetic radiation is increased? Write INCREASES, DECREASES or REMAINS THE SAME. Give a reason for the answer. (3)

2.5 Incident radiation with a longer wavelength is now used. How will the reading on the ammeter change? Write INCREASES, DECREASES or REMAINS THE SAME. Explain the answer. (3)

3. The work function of three metals is shown in the table below.

METAL	WORK FUNCTION (W_0) IN J
Aluminium	$6{,}54 \times 10^{-19}$
Zinc	$6{,}89 \times 10^{-19}$
Silver	$7{,}58 \times 10^{-19}$

3.1 Give a reason why different metals have different work functions. (1)

3.2 Light of wavelength $2{,}3 \times 10^{-7}$ m is shone onto a metal X. The maximum speed of the emitted electrons is $4{,}78 \times 10^{5}$ m·s^{-1}. Identify metal X by performing a relevant calculation. (6)

3.3 What conclusion about the nature of light is drawn from the photoelectric effect? (1)

4. Some energy levels of an atom of a gas are shown in **Figure 1**.
Relative to energy level D, energy level A represents -2×10^{-18} J of energy.

energy level   energy/$\times 10^{-18}$ J

D ——————————————————— 0,0

C ———————————————

B ———————————————
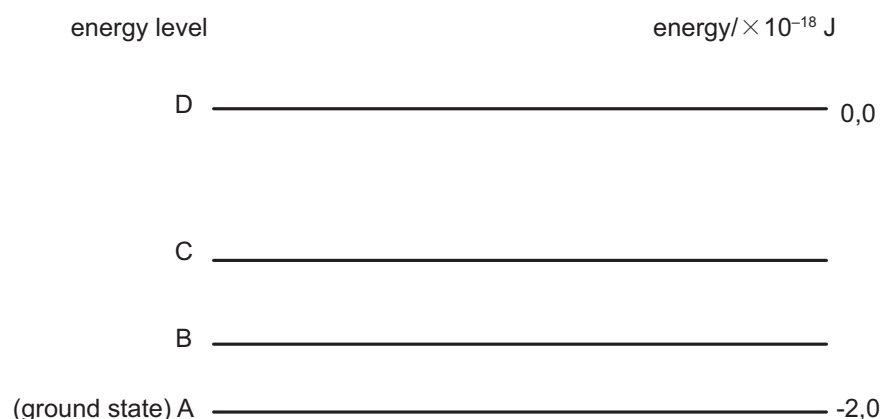
(ground state) A ——————————————— -2,0

Figure 1

When current is passed through the gas at low pressure, a line spectrum is produced. Two of these lines, which correspond to transitions from levels B and C respectively to the ground state, are shown in **Figure 2**.

5.

Intensity

0,0 1,0 2,0 3,0 4,0 5,0
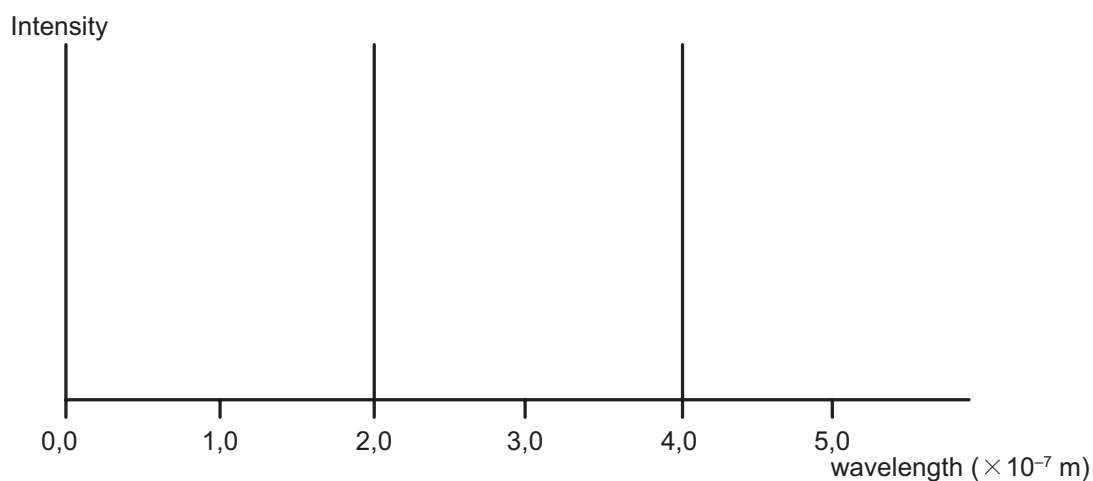
wavelength ($\times 10^{-7}$ m)

Figure 2

4.1 Describe what happens to an electron in an atom in the ground state in order for the atom to emit light of a specific wavelength. (4)

4.2 Calculate the energy of the photons responsible for each of the two lines shown in **Figure 2**. (5)

4.3 Determine the energy represented by levels B and C in **Figure 1**. (4)

5. An energy level diagram for a particular element is drawn to scale below. The only positions that the outer electron can occupy are the energy levels E_1, E_2 and E_3.

E_3

E_2

E_1
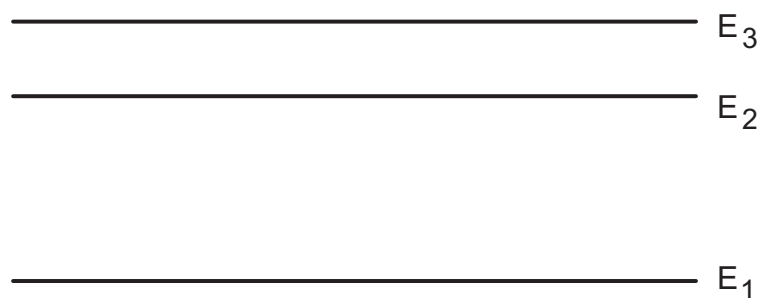
5.1 State two facts about atomic structure that have been deduced by observing the line spectra of elements. (2)

For this energy level diagram, the longest wavelength of light released is 628 nm.

5.2 Which transition would be responsible for releasing this wavelength of light? Explain your answer. (4)

5.3 Calculate the energy that corresponds to this wavelength of light. (3)

CONSOLIDATION QUESTIONS   **TOTAL: 50 MARKS**

1. 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
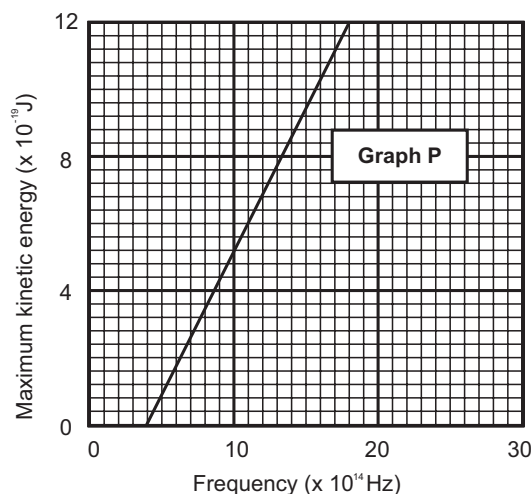
1.1 Define the term "work function".   (2)

1.2 Calculate the:

    1.2.1 work function of the metal used as the cathode in the photocell.   (3)

    1.2.2 velocity of the photoelectrons emitted when the frequency of the incident light is 8×10^{14} Hz.   (5)

1.3 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.

    1.3.1 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)

    1.3.2 What will the value of the x-intercept of graph Q be? Explain how you arrived at the answer.   (2)

2.

   2.1 In the simplified diagram below, light is incident on the emitter of a photocell. The emitted photoelectrons move towards the collector and the ammeter registers a reading.
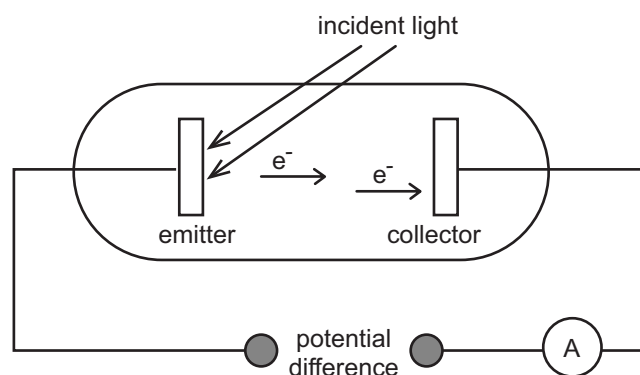
      2.1.1 Name the phenomenon illustrated above. (1)

      2.1.2 The work function of the metal used as emitter is 8×10^{-19} J. The incident light has a wavelength of 200 nm. Calculate the maximum speed at which an electron can be emitted. (5)

      2.1.3 Incident light of a higher frequency is now used. How will this change affect the maximum kinetic energy of the electrons emitted in question 2.1.2? Write down INCREASES, DECREASES or REMAINS THE SAME. (1)

      2.1.4 The intensity of the incident light is now increased. How will this change affect the speed of the electron calculated in question 2.1.2? Write down INCREASES, DECREASES or REMAINS THE SAME. Give a reason for the answer. (2)

   2.2 A metal worker places two iron rods, A and B, in a furnace. After a while he observes that A glows deep red while B glows orange. Which one of the rods (A or B) radiates more energy? Give a reason for the answer. (2)

   2.3 Neon signs illuminate many buildings. What type of spectrum is produced by neon signs? (1)

3. Light shines onto the cathode of a photocell as shown below. The ammeter registers a reading.

Light

A
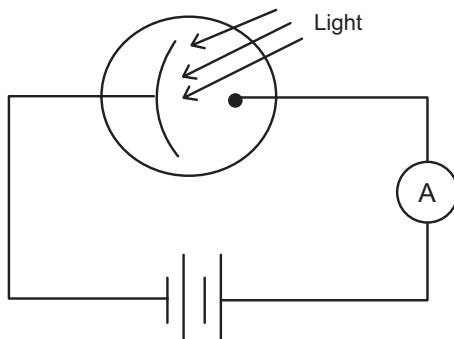
3.1 Define the term "photon". (2)

3.2 Each photon of light has an energy of $6,9 \times 10^{-19}$ J. The cathode has a work function of $6,4 \times 10^{-19}$ J.

Calculate the:

3.2.1 wavelength of the light. (5)

3.3.2 kinetic energy of an electron emitted from the cathode. (3)

3.3 How will the reading on the ammeter change if:

3.3.1 light of the same frequency, but of higher intensity, is used. Write down INCREASES, DECREASES or REMAINS THE SAME. Explain the answer.

(3)

3.3.2 light of the same intensity, but higher frequency, is used. Write down INCREASES, DECREASES or REMAINS THE SAME. Explain the answer.

(3)

4. The diagram shows some of the energy levels of an isolated hydrogen atom. The arrows, labelled A and B, represent transitions of electrons between the energy levels.
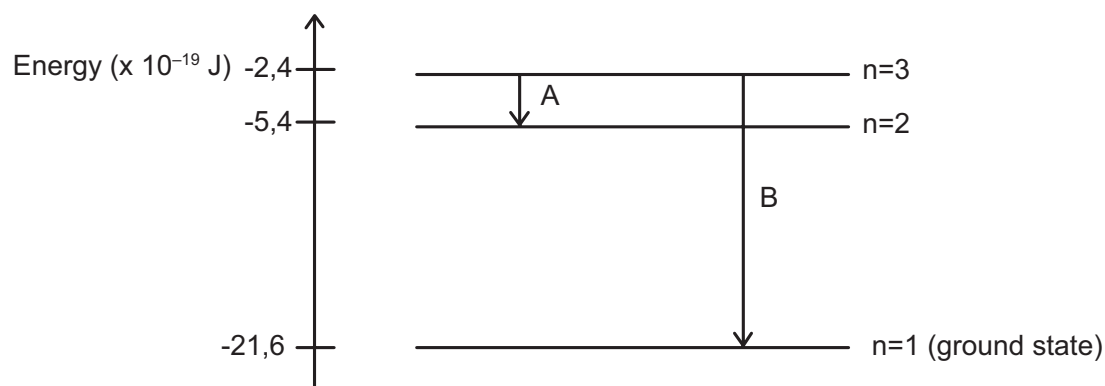
4.1 Calculate the frequency of the photon emitted when an excited electron falls from energy level n = 3 to n = 2. (4)

4.2 Compare the wavelength of the photon emitted in transition A to the wavelength of the photon emitted in transition B. Use the words GREATER THAN or LESS THAN or EQUAL TO in your comparison. (1)

4.3 Explain your answer to question 4.2, making reference to one or more suitable formulae. No further calculations are required. (3)

MARKING GUIDELINES

WORKSHEET QUESTIONS   **TOTAL: 54 MARKS**

1.1 Photoelectric effect ✓   (1)

1.2 $f = \dfrac{c}{\lambda} = \dfrac{3 \times 10^8 ✓}{330 \times 10^{-9} ✓} = 9,09 \times 10^{14}\,\text{Hz}$ ✓   (3)

1.3 $E = W_o + E_{k(max)}$

    $E_{k(max)} = E - W_o$

    $E_{k(max)} = hf - W_o$

    $E_{k(max)} = (6,63 \times 10^{-34} ✓)(9,09 \times 10^{14} ✓) - 3,5 \times 10^{-19}$ ✓

    $E_{k(max)} = 2,53 \times 10^{-19}\,\text{J}$ ✓   (4)

1.4.1   Remains the same. ✓   (1)

1.4.2   Increase. ✓   (1)

2.1 Photoelectric effect. ✓   (1)

2.2 The minimum energy needed for an electron to be emitted from the surface of a metal.
✓ ✓   (2)

2.3 $W_o = \dfrac{hc}{\lambda} ✓ = \dfrac{(6,63 \times 10^{-34})(3 \times 10^8 ✓)}{555 \times 10^{-9} ✓}$

    $W_o = 3,58 \times 10^{-19}\,\text{J}$ ✓   (5)

2.4 Increases. ✓
More photons are arriving at the metal surface per second. ✓
More electrons are ejected per second.
More charge is arriving at the anode per unit time. ✓   (3)

2.5 Decreases. ✓
Increasing the wavelength will decrease the energy of the photons. ✓
The photons now have less energy than the work function of the metal. ✓
No electrons are emitted from the metal surface.   (3)

3.1 The more protons in the nucleus of an atom, the stronger its attraction on the electrons in the outermost energy level. ✓   (1)

3.2 $E = W_o + E_{k(max)}$

    $W_o = E - E_{k(max)}$

    $W_o = \dfrac{hc}{\lambda} - \dfrac{1}{2}mv_{max}^2$

    $W_o = \dfrac{(6,63 \times 10^{-34})(3 \times 10^8 ✓)}{2,3 \times 10^{-7} ✓} - \dfrac{1}{2}(9,11 \times 10^{-31})(4,78 \times 10^5 ✓)^2$

    $W_o = 7,61 \times 10^{-19}\,\text{J}$ ✓

    Silver. ✓   (6)

3.3 Light has a particle nature. ✓ (1)

4.1 The electron is excited (gains energy) and makes a transition to a higher energy level. ✓ The electron then falls to a lower energy level ✓ and emits a photon of light ✓ which corresponds to a particular wavelength of light. ✓ (4)

4.2 $E = \dfrac{hc}{\lambda} = \dfrac{(6,63 \times 10^{-34})(3 \times 10^{8}\checkmark)}{2 \times 10^{-7}\checkmark}$

$E = 9,95 \times 10^{-19}$ J ✓

$E = \dfrac{hc}{\lambda} = \dfrac{(6,63 \times 10^{-34})(3 \times 10^{8})}{4 \times 10^{-7}\checkmark}$

$E = 4,97 \times 10^{-19}$ J ✓ (5)

4.3 Transition C to A will emit the photon with higher energy.

$E = E_C - E_A$

$9,95 \times 10^{-19} = E_C - (-2 \times 10^{-18})$ ✓

$E_C = -1,01 \times 10^{-18}$ J ✓

Transition B to A will emit the photon with lower energy.

$E = E_B - E_A$

$4,97 \times 10^{-19} = E_B - (-2 \times 10^{-18})$ ✓

$E_B = -1,50 \times 10^{-18}$ J ✓ (4)

5.1 There are different energy levels within an atom. ✓
In order to occupy a certain energy level, an electron must have a specific energy. ✓ (2)

5.2 E_3 to E_2 ✓

This represents the smallest energy difference ✓ , which corresponds to the emitted photon which has the lowest energy ✓ and light of the longest wavelength. ✓ (4)

5.3 $E = \dfrac{hc}{\lambda} = \dfrac{(6,63 \times 10^{-34})(3 \times 10^{8}\checkmark)}{628 \times 10^{-9}\checkmark}$

$E = 3,17 \times 10^{-19}$ J ✓ (3)

CONSOLIDATION QUESTIONS   **TOTAL: 50 MARKS**

1.1 The minimum amount of energy needed to emit an electron from the surface of a metal. ✓ ✓ (2)

1.2.1 $f_o = 4 \times 10^{14}\,Hz$ (x-intercept on graph)

$W_o = hf_o = (6{,}63 \times 10^{-34}\,\checkmark)(4 \times 10^{14}\,\checkmark) = 2{,}65 \times 10^{-19}\,J\ \checkmark$ (3)

1.2.2 $E = W_o + E_{k(max)}$

$hf = W_o + \frac{1}{2}mv_{max}^2\ \ \checkmark$

$(6{,}63 \times 10^{-34})(8 \times 10^{14})\checkmark = 2{,}65 \times 10^{-19}\checkmark + \frac{1}{2}(9{,}11 \times 10^{-31})v_{max}^2\ \ \checkmark$

$5{,}304 \times 10^{-19} = 2{,}65 \times 10^{-19} + 4{,}555 \times 10^{-31}v_{max}^2$

$2{,}654 \times 10^{-19} = 4{,}555 \times 10^{-31}v_{max}^2$

$v_{max}^2 = 5{,}8266 \times 10^{11}$

$v_{max} = 7{,}63 \times 10^5\,m{\cdot}s^{-1}\ \ \checkmark$ (5)

1.3.1   Equal to. ✓

$E = W_o + E_{k(max)}$

$E_{k(max)} = E - W_o$

$E_{k(max)} = hf - W_o$

$y = mx + c$

$gradient = m = h\ \checkmark$ (2)

1.3.2 $x\text{-intercept} = f_o = 2(4 \times 10^{14}) = 8 \times 10^{14}\,Hz\ \ \checkmark$

$f_o = \dfrac{W_o}{h}$

If the work function has doubled then the threshold frequency will also double. ✓

(2)

2.1.1   Photoelectric effect ✓ (1)

2.1.2 $E = W_o + E_{k(max)}$

$\dfrac{hc}{\lambda} = W_o + E_{k(max)}$

$\dfrac{(6{,}63 \times 10^{-34})(3 \times 10^8\,\checkmark)}{200 \times 10^{-9}\,\checkmark} = 8 \times 10^{-19}\checkmark + \frac{1}{2}mv_{max}^2$

$9{,}945 \times 10^{-19} = 8 \times 10^{-19} + \frac{1}{2}(9{,}11 \times 10^{-31}\,\checkmark)v_{max}^2$

$1{,}945 \times 10^{-19} = 4{,}555 \times 10^{-31}v_{max}^2$

$v_{max}^2 = 4{,}275 \times 10^{11}$

$v_{max} = 6{,}54 \times 10^5\,m{\cdot}s^{-1}\ \ \checkmark$ (5)

2.1.3   Increases. ✓ (1)

2.1.4 Remains the same. ✓

There is no change in the energy of the incident photons. ✓ (2)

2.2 Orange light has a greater frequency than red light. ✓

The energy of the photons is directly proportional to the frequency.

B radiates more energy. ✓ (2)

2.3 Line emission spectrum. ✓ (1)

3.1 A particle representing a quantum of light. ✓ ✓ (2)

3.2.1 $E = \dfrac{hc}{\lambda}$ ✓

$\lambda = \dfrac{hc}{E} = \dfrac{(6{,}63 \times 10^{-34}\checkmark)(3 \times 10^{8}\checkmark)}{6{,}9 \times 10^{-19}\checkmark} = 2{,}88 \times 10^{-7}\,\text{m}$ ✓ (5)

3.2.2 $E_{k(max)} = E - W_o$

$E_{k(max)} = 6{,}9 \times 10^{-19}\checkmark - 6{,}4 \times 10^{-19}\checkmark = 5 \times 10^{-20}\,\text{J}$ ✓ (3)

3.3.1 Increases. ✓

More photons are arriving per second, ✓ therefore more electrons are ejected per second. ✓ (3)

3.3.2 Stays the same. ✓

Electrons are emitted with higher kinetic energy (move faster). ✓

The number of electrons emitted per unit time stays the same (same current), they are just emitted with more energy. ✓ (3)

4.1 $E = E_3 - E_2$

$E = -2{,}4 \times 10^{-19}\checkmark - (-5{,}4 \times 10^{-19})$ ✓

$E = 3 \times 10^{-19}\,\text{J}$ ✓

$E = hf$

$f = \dfrac{E}{h} = \dfrac{3 \times 10^{-19}}{6{,}63 \times 10^{-34}}$

$f = 4{,}53 \times 10^{14}\,\text{Hz}$ ✓ (4)

4.2 Wavelength of A is greater than B. ✓ (1)

4.3 $E = \dfrac{hc}{\lambda}$ ✓

The energy of the emitted photon for transition A is less than that of B. ✓

Energy of photon is inversely proportional to the wavelength of light. ✓ (3)

TOPIC 13: Electrochemistry

WORKSHEET QUESTIONS

TOTAL: 95 MARKS

MULTIPLE CHOICE

1. Consider the reaction represented by the balanced equation below:

$$Cu\,(s) + 2Ag^+\,(aq) \longrightarrow Cu^{2+}\,(aq) + 2Ag\,(s)$$
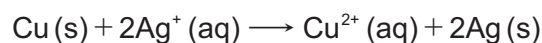
In the above reaction, Cu(s) is the ...

   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)

2. Which one of the following correctly describes the process taking place at the cathode of an electrochemical cell and the electron transfer involved?

	PROCESS	ELECTRON TRANSFER
A	Oxidation	Loss of electrons
B	Reduction	Loss of electrons
C	Oxidation	Gain of electrons
D	Reduction	Gain of electrons

(2)

3. Four tin (Sn) cans are each filled with a different solution as shown by the labels on the cans in the diagrams below. Each solution has a concentration of $1\,mol\cdot dm^{-3}$ at $25\,°C$. Which one of the tin cans will undergo reduction?

A	B	C	D
$Fe(NO_3)_{2\,(aq)}$	$Zn(NO_3)_{2\,(aq)}$	$Cu(NO_3)_{2\,(aq)}$	$Ba(NO_3)_{2\,(aq)}$

(2)
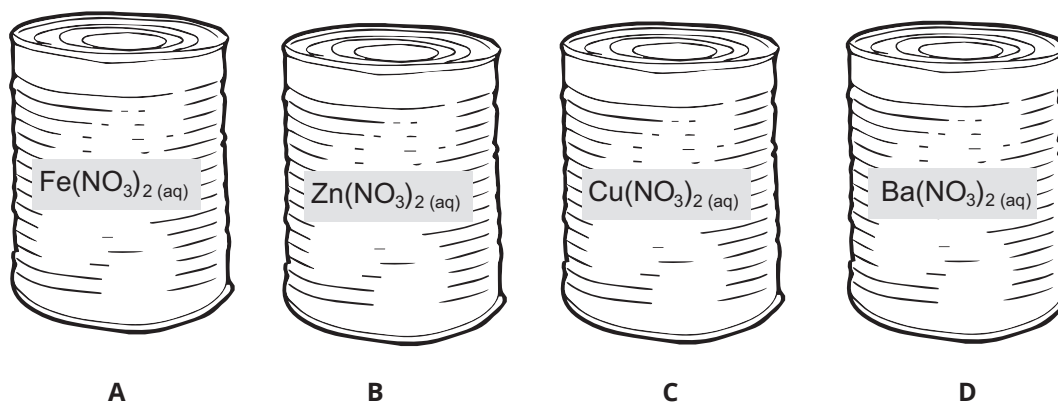
4. The following half reactions are used in a galvanic cell:

$$Co^{2+} + 2e^- \rightleftharpoons Co$$

$$Al^{3+} + 3e^- \rightleftharpoons Al$$

Which ONE of the following represents the correct cell notation for this cell?

A $Al/Al^{3+} \parallel Co^{2+}/Co$

B $Al/Al^{3+} \parallel Co^{2+}/Co^{2+}$

C $Co/Co^{2+} \parallel Al^{3+}/Al$

D $Co^{2+}/Co \parallel Al^{3+}/Al$ (2)

5. One of the functions of the salt bridge in a galvanic cell in operation is to …

A   allow anions to travel to the cathode.

B   maintain electrical neutrality in the half-cells.

C   allow electrons to flow through it.

D   provide ions to react at the anode and cathode.   (2)

6. 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 $Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$

B $Fe(s) \longrightarrow Fe^{2+}(aq) + 2e^-$

C $Ni^{2+}(aq) + 2e^- \longrightarrow Ni(s)$

D $Ni(s) \longrightarrow Ni^{2+}(aq) + 2e^-$ (2)

7. The major product formed at the ANODE in a membrane cell is …

A   hydrogen.

B   oxygen.

C   chlorine.

D   hydroxide ions.   (2)

LONG QUESTIONS

8. Learners are given the following two unknown half-cells:

Half-cell 1: Q^{2+} (aq)/Q (s)

Half-cell 2: (Pt)/R_2 (g)/R^- (aq)
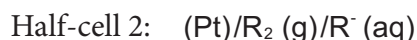
During an investigation to identify the two half-cells, the learners connect each half-cell alternately to a Cd^{2+} (aq) | Cd (s) half-cell under standard conditions. For each combination of two half-cells, they write down the net cell reaction and measure the cell potential.

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

COMBINATION	NET CELL REACTION	CELL POTENTIAL
I	Q^{2+} (aq) + Cd (s) $\longrightarrow$ Cd^{2+} (aq) + Q (s)	0,13 V
II	R_2 (g) + Cd (s) $\longrightarrow$ Cd^{2+} (aq) + $2R^-$ (aq)	1,76 V

8.1 Write down THREE conditions needed for these cells to function as standard cells.

(3)

8.2 For Combination I, identify:

    8.2.1 the anode of the cell. (1)

    8.2.2 Q by using a calculation. (5)

8.3 For Combination II, write down the:

    8.3.1 oxidation half reaction. (2)

    8.3.2 NAME or give the FORMULA of the metal used in the cathode compartment. (1)

8.4 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)

9. 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.
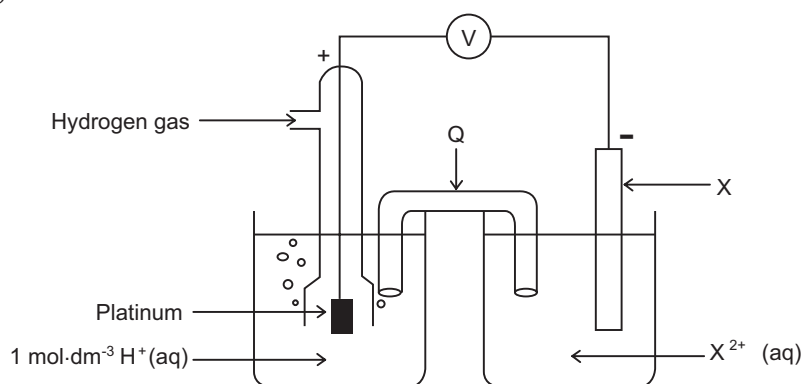
9.1 Besides concentration, write down TWO conditions needed for the hydrogen half-cell to function under standard conditions. (2)

9.2 Give TWO reasons, besides being a solid, why platinum is suitable to be used as the electrode in the above half-cell. (2)

9.3 Write down the:

    9.3.1 NAME of component Q. (1)

    9.3.2 standard reduction potential of the $X \mid X^{2+}$ half-cell. (1)

    9.3.3 half reaction that takes place at the cathode of this cell. (2)

9.4 The hydrogen half-cell is now replaced by a $M \mid M^{2+}$ half-cell. The cell notation of this cell is:

$$M(s) \mid M^{2+}(aq) \parallel X^{2+}(aq) \mid X(s)$$
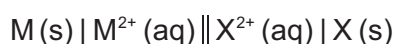
The initial reading on the voltmeter is now 2,05 V.

    9.4.1 Identify metal M. Show how you arrived at the answer. (5)

    9.4.2 Is the cell reaction EXOTHERMIC or ENDOTHERMIC? Explain your answer. (2)

9.5 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)

10. The simplified diagram below represents an electrochemical cell used for the purification of copper.
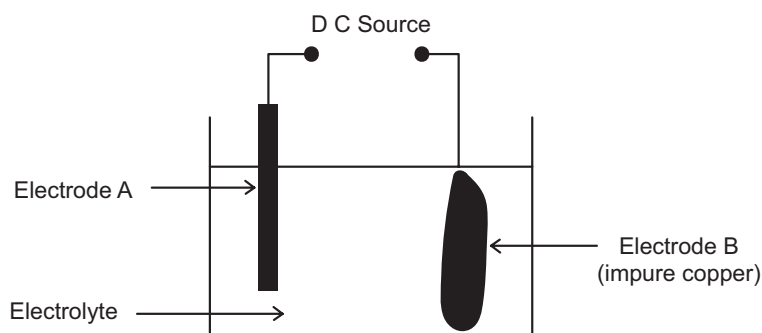
10.1 Define the term "electrolysis". (2)

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

10.3 What metal must electrode A be made out of in this electrochemical cell? (1)

10.4 Write down the half reaction which takes place at electrode A. (2)

10.5 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)

11. The diagram below shows a galvanic cell operating under standard conditions. The cell reaction taking place when the cell is functioning is:

$$6Cl^- \, (aq) + 2Au^{3+} \, (aq) \longrightarrow 3Cl_2 \, (g) + 2Au \, (s)$$
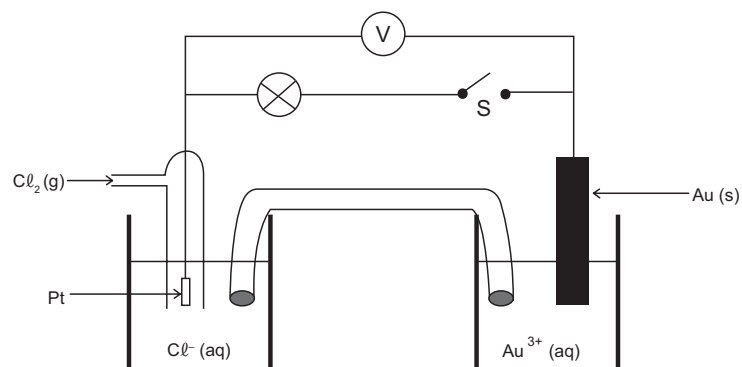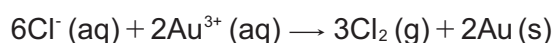
With switch S OPEN, the initial reading on the voltmeter is 0,14 V.

11.1 Write down the:

    11.1.1 NAME or FORMULA of the oxidising agent. (1)

    11.1.2 half reaction which takes place at the anode. (2)

    11.1.3 cell notation for this cell. (3)

11.2 Calculate the standard reduction potential of Au. (4)

Switch S is now closed and the bulb lights up.

11.3 How will the reading on the voltmeter now compare to the INITIAL reading of 0,14 V? Write down only LARGER THAN, SMALLER THAN or EQUAL TO. Give a reason for the answer. (2)

12. The diagram below represents a simplified electrolytic cell used to electroplate a spanner with chromium. The spanner is continuously rotated during the process of electroplating.
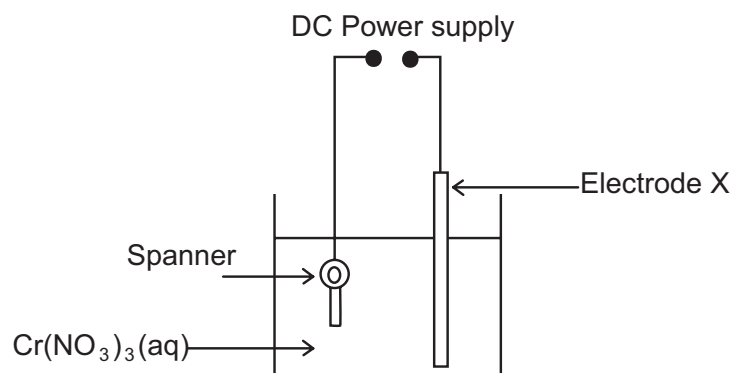
A constant current passes through the solution and the concentration of $Cr(NO_3)_3 \, (aq)$ remains constant during the process.

12.1 Define the term "electrolysis". (2)

12.2 Write down the:

12.2.1 half reaction that occurs at the spanner. (2)

12.2.2 NAME or give the FORMULA of the metal of which electrode X is made. (1)

12.3 Will electrode X be the anode or the cathode? Explain why this metal must be used as this electrode. (3)

12.4 NAME or give the FORMULA of the oxidising agent. (1)

13. The electrolysis of brine is the basis of the Chlor-Alkali process, a major industrial process producing hydrogen, chlorine and sodium hydroxide.

DIAGRAM OF A MEMBRANE CELL
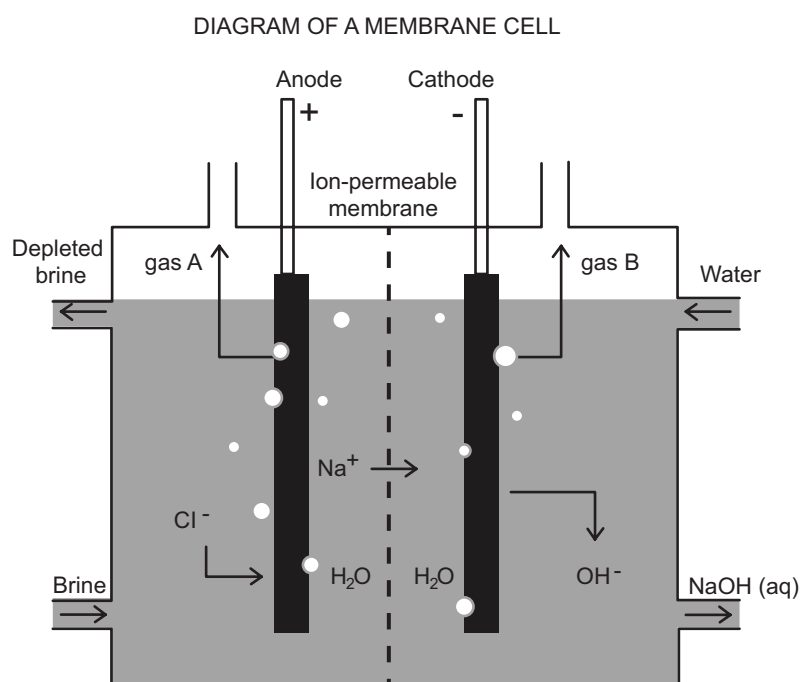
13.1 What is meant by the term 'brine'? (2)

13.2 Explain how the ion permeable membrane functions in this cell. (2)

13.3 Sodium cations (Na^+) are found in the cathodic compartment of the membrane cell, yet they do not undergo reduction to form sodium metal; instead hydrogen gas is produced. Using half reactions, explain why this occurs. (3)

13.4 Chlorine and sodium hydroxide are two of the major products formed in this cell. Give ONE possible use of each of these products in modern society. (4)

14. Impure aluminium (bauxite) ore is imported into South Africa from Australia and contains approximately 65 % aluminium oxide. The extraction of aluminium is done through an electrolytic technique which involves a three step process:

   I   Extraction of the aluminium oxide from the mineral bauxite.

  II   Mixing the molten aluminium oxide with a substance called cryolite.

 III   Electrolysing the molten aluminium oxide/cryolite mixture to extract aluminium.
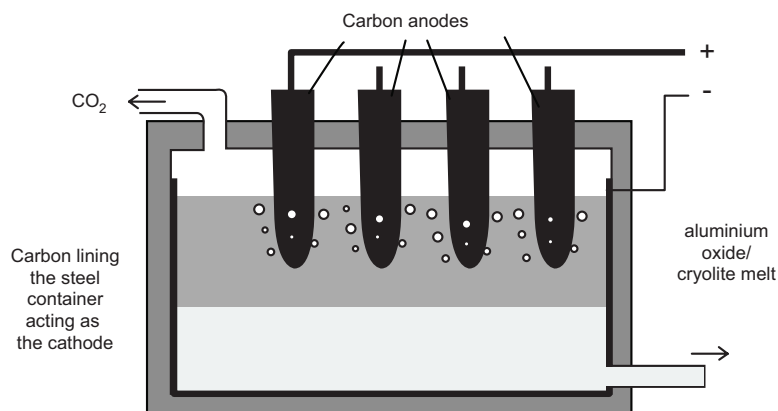
South Africa has four aluminium smelters situated in the coastal cities of Port Elizabeth and Richards Bay. The smelters contain giant electrolytic cells where carbon electrodes (anodes) are placed directly into the cell, while carbon lining the steel casing of the cell acts as the cathode.

14.1 What alternate name is given to the aluminium oxide present in the bauxite?   (1)

14.2 What is the importance of mixing the aluminium oxide with cryolite and how is this beneficial to the environment?   (3)

14.3 Write down an equation for the half reaction taking place at the cathode.   (2)

14.4 Carbon dioxide is one of the waste products produced by this process. How is carbon dioxide formed during this process?   (2)

CONSOLIDATION QUESTIONS   **TOTAL: 99 MARKS**

MULTIPLE CHOICE

1. Consider an electrochemical cell based on the following reaction:

$$Sn^{4+}(aq) + Sn(s) \longrightarrow 2Sn^{2+}(aq)$$
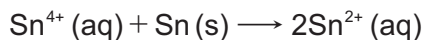
Which ONE of the following statements regarding this cell is CORRECT?

A   Sn is the anode of the cell.

B   Sn is the cathode of the cell.

C $Sn^{4+}(aq)$ is the reducing agent.

D   Sn is the oxidising agent.   (2)

2. Consider the galvanic cell represented below.

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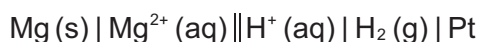
Which ONE of the following half reactions takes place at the cathode?

A $H_2(g) \longrightarrow 2H^+(aq) + 2e^-$

B $Mg^{2+}(aq) + 2e^- \longrightarrow Mg(s)$

C $Mg(s) \longrightarrow Mg^{2+}(aq) + 2e^-$

D $2H^+(aq) + 2e^- \longrightarrow H_2(g)$ (2)

3. In the electrochemical cell below the letters X and Y represent two metal electrodes.
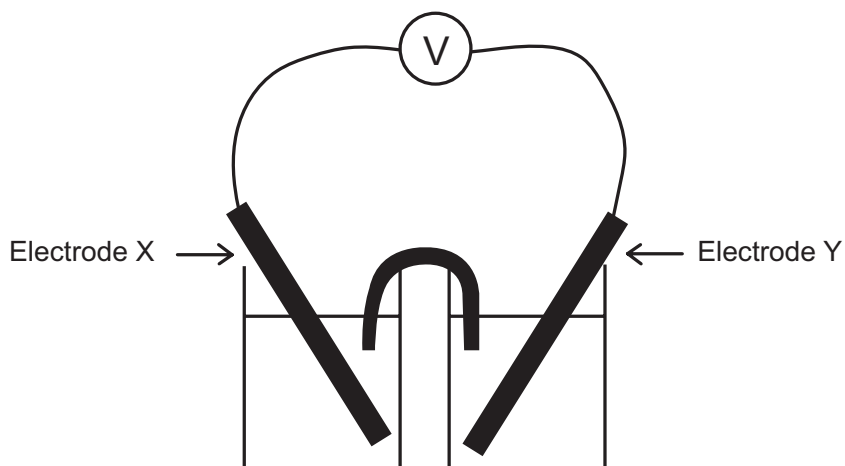
If the cell reaction is: $Y^{2+} + X \longrightarrow X^+ + Y$

Then the cell notation will be:

A $Y(s) | Y^{2+}(aq) \| X^+(aq) | X(s)$

B $X(s) | X^+(aq) \| Y^{2+}(aq) | Y(s)$

C $X^+(aq) | X(s) \| Y(s) | Y^{2+}(aq)$

D $Y^{2+}(aq) | Y(s) \| X(s) | X^+(aq)$ (2)

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

    A   An electric current causes a chemical change to occur.

    B   Reduction occurs at the anode.

    C   A spontaneous chemical reaction produces an electric current.

    D   Electrons flow to the electrode where oxidation occurs.   (2)

5. A learner wants to electroplate a copper ring with nickel. He uses the experimental set-up shown in the simplified diagram below.
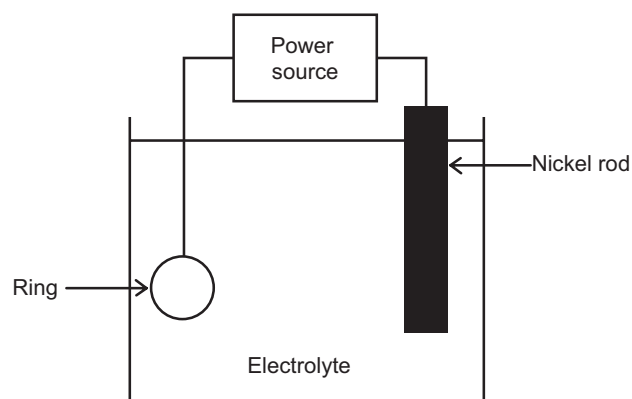
Which ONE of the following is CORRECT?

	ANODE	CATHODE	ELECTROLYTE
A	Copper ring	Nickel rod	Copper sulfate
B	Nickel rod	Copper ring	Copper sulfate
C	Copper ring	Nickel rod	Nickel sulfate
D	Nickel rod	Copper ring	Nickel sulfate

(2)

6. Which ONE of the following is formed at the cathode in a membrane cell?

    A   Chlorine.

    B   Hydrogen.

    C   Sodium chloride.

    D   Oxygen.   (2)

7. The Chlor-Alkali process leads to the production of two gases. Which ONE of the following CORRECTLY shows the gases produced at the anode and cathode of this cell?

	ANODE	CATHODE
A	Oxygen gas	Chlorine gas
B	Hydrogen gas	Chlorine gas
C	Chlorine gas	Hydrogen gas
D	Chlorine gas	Water vapour

(2)

8. A typical membrane cell which is used in the Chlor-Alkali industry in South Africa is illustrated below.
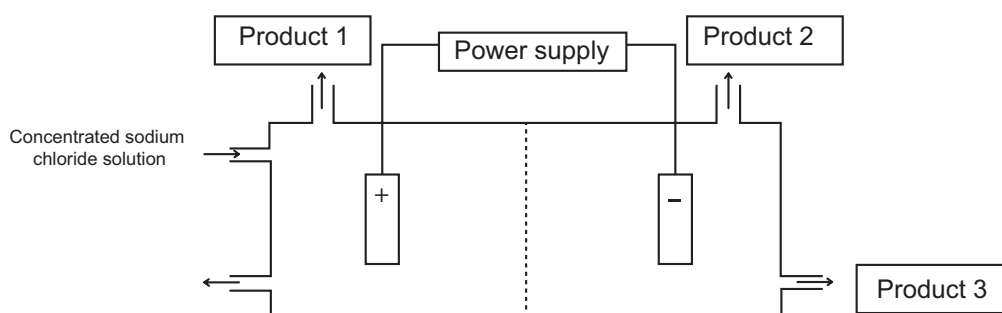
	PRODUCT 1	PRODUCT 2	PRODUCT 3
A	H_2	Cl	NaOH
B	Cl_2	H_2	Na
C	Cl_2	H_2	NaCl
D	Cl_2	H_2	NaOH

(2)

LONG QUESTIONS

9. The diagram below represents a galvanic cell operating under standard conditions.
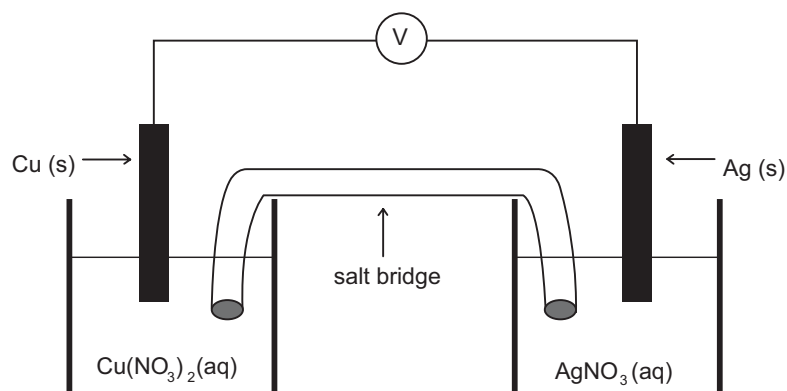
9.1 Write down:

    9.1.1 the energy conversion which takes place in this cell.   (1)

    9.1.2 the oxidation and reduction half reactions for this cell.   (4)

    9.1.3 a balanced equation for the overall cell reaction.   (3)

    9.1.4 the cell notation for this cell.   (3)

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

9.3 In which direction will electrons flow? Write down only 'from Ag to Cu' or 'from Cu to Ag'.   (1)

9.4 The silver half-cell is now replaced with the standard hydrogen half-cell.

    9.4.1 Is the copper electrode the POSITIVE or the NEGATIVE electrode? Refer to the relative strength of reducing agents to explain the answer.   (4)

    9.4.2 Write down the emf of this cell.   (1)

10. A learner conducts two experiments to investigate the reaction between copper (Cu) and a silver nitrate solution, $AgNO_3 (aq)$.

EXPERIMENT 1

The learner adds a small amount of copper (Cu) powder to a test tube containing silver nitrate solution, $AgNO_3 (aq)$. The solution changes from colourless to blue after a while.

Before addition of Cu (s)

After addition of Cu (s)

Colourless $AgNO_3$ (aq)

Blue $Cu(NO_3)_2$ (aq)

10.1 Define the term "oxidising agent".   (2)

10.2 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.
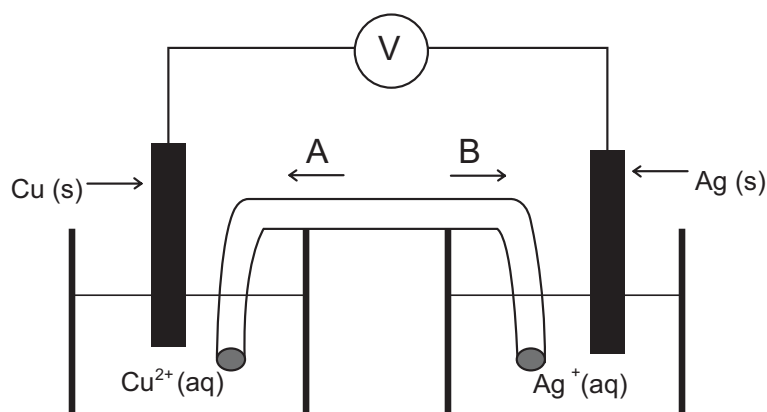
10.3 Write down the energy conversion that takes place in this cell. (1)

10.4 In which direction (A or B) will ANIONS move in the salt bridge?
Explain your answer. (3)

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

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

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

11. The electrochemical cell represented below consists of a hydrogen half-cell and a magnesium half-cell at standard conditions. The reading on the voltmeter is 2,36 V.
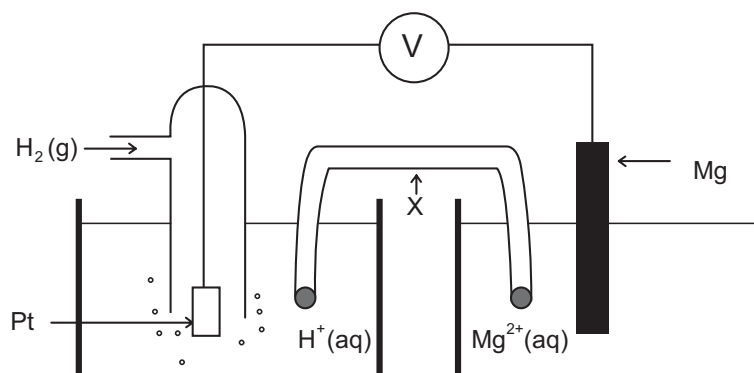
11.1 Apart from concentration, write down TWO other conditions needed for the hydrogen half-cell to function at standard conditions. (2)

11.2 Write down the name of the item of apparatus labelled X. (1)

11.3 Is magnesium the ANODE or CATHODE in the cell above? Refer to the relative strengths of reducing agents to explain the answer. (4)

11.4 Write down the cell notation for this cell. (3)

11.5 Calculate the standard reduction potential of the magnesium half-cell. Show ALL your working. (4)

11.6 Write down the balanced NET (overall) cell reaction that takes place in this cell. (3)

12. The diagram below represents the apparatus used in the electrolysis of a concentrated $CuCl_2$ solution. A and B are two carbon electrodes connected to a power supply.
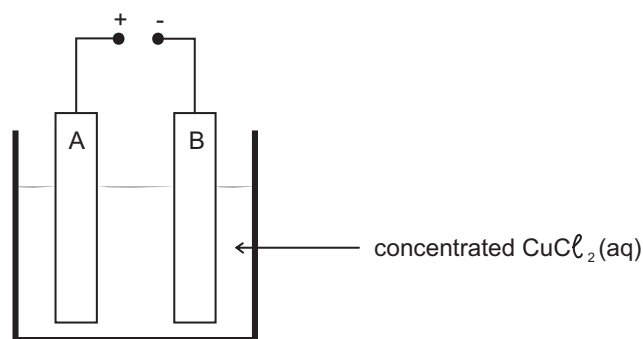
12.1 Which electrode (A or B) is the anode? Explain. (2)

12.2 Is the electrolytic process endothermic or exothermic? Explain. (2)

12.3 Write down THREE observations that can be made during this process. (3)

12.4 Write down the overall cell reaction. (3)

12.5 Give ONE reason why the salt needs to be in solution in this process. (1)

13. Aluminium is prepared on a large scale in industry by the electrolysis of molten aluminium oxide that is dissolved in molten cryolite at $950\,°C$. The electrolytic cell used in this process is shown in the diagram below.
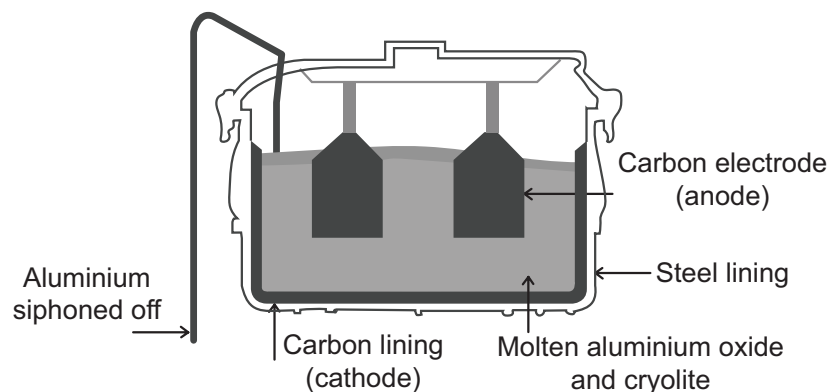
13.1 State the energy conversion that takes place in this electrolytic cell. (1)

13.2 Write down the equation for the half reaction that takes place at the cathode. (2)

13.3 Write down the equation for the half reaction that takes place at the anode. (2)

13.4 The carbon electrodes in this cell constantly corrode and need to be replaced. Explain why they corrode and write down a balanced chemical equation to support your answer. (4)

Cryolite lowers the melting point of aluminium oxide from $2\,000\,°C$ to $950\,°C$.

13.5 State one way in which the use of cryolite is a potential risk to the environment. (1)

13.6 Despite the use of cryolite, this process still consumes large quantities of electricity in order to achieve the required temperature of $950\,°C$.

Thuli makes the following energy saving suggestion:

"They should use the electrolysis of a concentrated aqueous solution of aluminium chloride at room temperature rather than molten aluminium oxide at $950\,°C$."

Consider the reaction taking place at the cathode in order to explain why Thuli's suggestion will not work. Write down the equation for a suitable half reaction that supports your answer. (4)

MARKING GUIDELINES

WORKSHEET QUESTIONS **TOTAL: 95 MARKS**

MULTIPLE CHOICE

1. D ✓✓ (2)

2. D ✓✓ (2)

3. C ✓✓ (2)

4. A ✓✓ (2)

5. B ✓✓ (2)

6. D ✓✓ (2)

7. C ✓✓ (2)

LONG QUESTIONS

8.1 Concentration of electrolyte is $1 mol \cdot dm^{-3}$. ✓
Temperature of the electrolyte is $25\,°C$. ✓
Pressure of a gas is 1 atmosphere. ✓ (3)

8.2.1 Cd. ✓ (1)

8.2.2 $E^o_{cell} = E^o_{cathode} - E^o_{anode}$ ✓

$0,13 = E^o_{cathode} - (-0,40)$ ✓

$0,13 - 0,40 = E^o_{cathode}$

$E^o_{cathode} = -0,27\,V$ ✓✓

Thus Q is Ni. ✓ (5)

8.3.1 $Cd \longrightarrow Cd^{2+} + 2e^-$ ✓✓ (2)

8.3.2 Platinum. (Pt). ✓ (1)

8.4 Q^{2+} Cd^{2+} R_2 ✓✓

Q^{2+} is being reduced in combination 1 thus has to be a stronger oxidising agent compared to Cd^{2+}. ✓

R_2 is being reduced in combination 2 where Cd^{2+} is not thus making R_2 a stronger oxidising agent that Cd^{2+}.✓ (4)

9.1 Hydrogen gas must be at a pressure of 1 atmosphere. ✓
Temperature of the cell must be at $25\,°C$. ✓ (2)

9.2 Platinum is very unreactive ✓ and thus will not become part of the electrochemistry of the cell. ✓ (2)

9.3.1 Salt bridge. ✓ (1)

9.3.2 - 0,31 V ✓ 1)

9.3.3 $2H^+ + 2e^- \longrightarrow H_2$ ✓ ✓ (2)

9.4.1 $E^o_{cell} = E^o_{cathode} - E^o_{anode}$ ✓

$2,05 = -0,31 - E^o_{anode}$ ✓

$2,05 + 0,31 = -E^o_{anode}$

$E^o_{anode} = -2,36\,V$ ✓ ✓

Thus metal M is magnesium (Mg). ✓ (5)

9.4.2 Exothermic. ✓ It is a galvanic cell thus chemical energy is converted into electrical energy which make the cell exothermic . ✓ (2)

9.5 The cell reaction will reach a state of dynamic chemical equilibrium. ✓ (1)

10.1 The electrochemical technique whereby electrical energy is used to create a chemical reaction whereby anions and cations are separated out of solution. ✓ ✓

(2)

10.2 The electrodes must carry a consistent charge, that is, remain either positive or negative to be either a cathode or an anode throughout the process. ✓ (1)

10.3 Copper. ✓ (1)

10.4 $Cu^{2+} + 2e^- \longrightarrow Cu$ ✓ ✓ (2)

10.5 Zn^{2+} is a weaker oxidising agent compared to Cu^{2+}, ✓ ✓ thus it will not undergo reduction in the cell. Cu^{2+}, being a stronger oxidising agent, will be reduced to Cu. ✓ (3)

11.1.1 Au (gold) as it is being reduced. ✓ (1)

11.1.2 $2Cl^- \longrightarrow Cl_2 + 2e^-$ ✓ ✓ (2)

11.1.3 $(Pt)/Cl^-(1\,mol\cdot dm^{-3})/Cl_2 // Au^{3+}(1\,mol\cdot dm^{-3})/Au$

✓ ✓ ✓ (3)

11.2 $E^o_{cell} = E^o_{cathode} - E^o_{anode}$ ✓

$0,14 = E^o_{cathode} - 1,36$

$E^o_{cathode} = 0,14 + 1,36$ ✓

$E^o_{cathode} = 1,50\,V$ ✓ ✓

The standard reduction potential for Au = 1,50 V. (4)

11.3 SMALLER THAN. ✓

Closing the switch to light up the bulb will increase the resistance of the circuit. The greater the resistance, the smaller the current. The smaller the current, the less the potential difference. ✓ (2)

12.1 The chemical process in which electrical energy is converted to chemical energy. ✓ ✓ (2)

12.2.1 $Cr^{3+} + 3e^- \longrightarrow Cr$ ✓ ✓ (2)

12.2.2 Chromium. (Cr). ✓ (1)

12.2.3 Electrode X must act as the anode which will undergo oxidation. ✓ As Cr^{3+} ions are being reduced at the cathode, Cr^{3+} ions must be replaced in the electrolyte. ✓

Thus oxidation of Cr must take place at the anode $Cr \longrightarrow Cr^{3+} + 3e^-$. ✓ (3)

12.2.4 Cr^{3+} ✓ (1)

13.1 A concentrated solution ✓ of sodium chloride. ✓ (2)

13.2 It is an ion selective membrane that only permits selected ions to pass through ✓ Na^+ ions can now pass through it. ✓ (2)

13.3 $Na^+ + e^- \rightleftharpoons Na$

$H_2O + 2e^- \rightleftharpoons H_2 + 2OH^-$
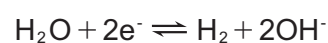
H_2O is a stronger oxidising agent that Na^+ ions. ✓ ✓

H_2O will thus be reduced in preference to Na^+. ✓ (3)

13.4

Chlorine	NaOH
• Water purification (kills bacteria)	• Soap and detergents
• Bleach	• Drain cleaner
• Production of PVC	• Household kitchen cleaners (Handy Andy)

✓ ✓   ✓ ✓ (4)

14.1 Alumina. ✓ (1)

14.2 Lowers the melting point. ✓

Less energy consumed. ✓

Less demand on power grid hence less coal burned (less pollutants in atmosphere). ✓ (3)

14.3 Cathode: $Al^{3+} + 3e^- \longrightarrow Al$ ✓ ✓ (2)

14.4 O_2 reacts with the carbon electrodes to form CO_2. ✓ ✓

$(C + O_2 \longrightarrow CO_2)$ (2)

CONSOLIDATION QUESTIONS   **TOTAL: 99 MARKS**

MULTIPLE CHOICE

1. A   ✓ ✓   (2)

2. D   ✓ ✓   (2)

3. B   ✓ ✓   (2)

4. A   ✓ ✓   (2)

5. D   ✓ ✓   (2)

6. B   ✓ ✓   (2)

7. C   ✓ ✓   (2)

8. D   ✓ ✓   (2)

LONG QUESTIONS

9.1.1 Chemical energy to electrical energy. ✓   (1)

9.1.2 OX: $Cu \longrightarrow Cu^{2+} + 2e^-$ ✓ ✓

RED: $Ag^+ + e^- \longrightarrow Ag$ ✓ ✓   (4)

9.1.3 $Cu + 2Ag^+ \longrightarrow Cu^{2+} + 2Ag$ ✓ ✓ ✓   (3)

9.1.4 $Cu/Cu^{2+}(1\,mol\cdot dm^{-3})//Ag^+(1\,mol\cdot dm^{-3})/Ag$ ✓ ✓ ✓ (3)

9.2 $E^o{}_{cell} = E^o{}_{cathode} - E^o{}_{anode}$ ✓

$= 0,80 - 0,34$ ✓   ✓   (4)

$E^o{}_{cell} = 0,46\ V$ ✓✓

9.3 Cu to Ag. ✓   (1)

9.4.1 Positive. ✓

H_2 is a stronger reducing agent than Cu ✓ thus the standard hydrogen electrode will be the anode as oxidation will take place in the electrode. ✓ and Cu will be the cathode. ✓   (4)

9.4.2 $E^o{}_{cell} = + 0,34\ V$ ✓   (1)

10.1 Substance that will undergo reduction✓ by gaining electrons. ✓   (2)

10.2 Cu is a stronger reducing agent than Ag ✓ thus Cu will oxidise in the presence of Ag^+ ions ✓ causing the Ag^+ ions to reduce.✓ Cu^{2+} will be formed which is blue in colour in solution.✓   (4)

10.3 Chemical energy to electrical energy. ✓   (1)

10.4 A ✓ : At the anode Cu is oxidised to Cu^{2+} which increases the concentration of Cu^{2+} ions in solution. ✓ To maintain half-cell neutrality, anions must be pumped from the salt bridge to balance out the positive cations in solution. ✓   (3)

10.5 $E^o_{cell} = E^o_{cathode} - E^o_{anode}$ ✓

$= 0,80 - 0,34$ ✓

$E^o_{cell} = 0,46\,V$ ✓ ✓   (4)

10.6 $Cu + 2Ag^+ \longrightarrow Cu^{2+} + 2Ag$ ✓ ✓ ✓   (3)

10.7 Remains the same. ✓

Although extra silver nitrate has been added, the concentration of the solution is the same at $1\,mol.dm^{-3}$. ✓ This means that the concentration of the solution will not change and thus will not affect the cell emf. ✓   (3)

11.1 Temperature of the cell is $25\,°C$. ✓

Pressure of the gas is 1 atmosphere. ✓   (2)

11.2 Salt bridge. ✓   (1)

11.3 Anode. ✓ Mg is a stronger reducing agent than H_2 ✓ thus will oxidise more readily. ✓ Oxidation always occurs at the anode. ✓   (4)

11.4 $(Pt)H_2(g)/H^+(1mol·dm^{-3})///Mg^{2+}(1mol·dm^{-3})/Mg(s)$

     ✓   ✓   ✓   (3)

11.5 $E^o_{cell} = E^o_{cathode} - E^o_{anode}$ ✓

$2,36 = 0,00 - E^o_{anode}$ ✓

$E^o_{anode} = -2,36\,V$ ✓ ✓   (4)

11.6 $Mg + 2H^+ \longrightarrow Mg^{2+} + H_2$ ✓ ✓ ✓   (3)
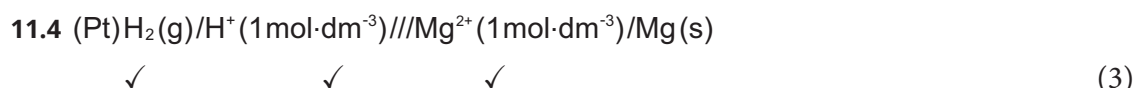
12.1 Electrode A. ✓ It is the positive electrode in the cell. ✓   (2)

12.2 Endothermic. ✓ Energy has to supplied from a source in an electrolytic cell. ✓   (2)

12.3 Cu (observed as a reddish-brown solid) will plate at the cathode. ✓

Cl_2 gas will bubble off at the anode. ✓

Blue colour of the $CuCl_2$ solution will fade. ✓   (3)

12.4 $Cu + Cu^{2+} \longrightarrow Cu^{2+} + Cu$

OR

$CuCl_2 \longrightarrow Cu + Cl_2$

   ✓   ✓   ✓   (3)

12.5 Ions must be free to move so that they can move creating a conducting medium. ✓   (1)

13.1 Electrical energy to chemical energy. ✓ (1)

13.2 $Al^{3+} + 3e^- \longrightarrow Al$ ✓ ✓ (2)

13.3 $2O^{2-} \longrightarrow O_2 + 4e^-$ ✓ ✓ (2)

13.4 With O_2 being produced at the anode, carbon from these electrodes will react ✓ to produce carbon dioxide ✓ according to the following equation:

$C + O_2 \longrightarrow CO_2$ ✓
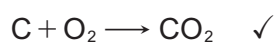
This will cause the electrode to slowly disintegrate ✓ which means it will have to be replaced after a period of time. (4)

13.5 Cryolite contains fluorine in its structure and there is the risk of toxic fluorine emissions. ✓ (1)

13.6 If an aqueous solution of aluminium oxide was used, the Al^{3+} ions would be weaker oxidising agents ✓ ✓ compared to water in the solution. Water would then reduce at the cathode ✓ and there would be hydrogen gas produced instead of aluminium metal.

$2H_2O + 2e^- \longrightarrow H_2 + 2OH^-$ ✓ (4)

TOPIC 14: The Chemical Industry

WORKSHEET QUESTIONS

TOTAL: 45 MARKS

1.

1.1 A farmer wants to produce the following fruit and vegetables for the market: spinach; potatoes; apples.

Write down the NAME of the most important primary nutrient required to enhance:

1.1.1 root growth of potato plants. (1)

1.1.2 leaf growth of spinach. (1)

1.1.3 flower and fruit production of apple trees. (1)

1.2 Ammonia must be produced in large quantities to produce nitrogen-based fertilisers.

1.2.1 Write down the name of the process used in the industrial preparation of ammonia. (1)

1.2.2 Write down a balanced chemical equation for the reaction that takes place in the process named in question 1.2.1. (3)

1.3 Ammonium hydrogen phosphate, $(NH_4)_2HPO_4$, is a type of fertiliser used in agriculture. Refer to the type of elements of which this fertiliser is composed to give a reason why it will be advantageous for a farmer to use this fertiliser instead of a fertiliser such as ammonium nitrate, NH_4NO_3. (2)

1.4 Describe ONE negative impact on humans when fertiliser runs off into dams and rivers. (2)

2.

2.1 The flow diagram below shows the processes involved in the industrial preparation of fertiliser Q.
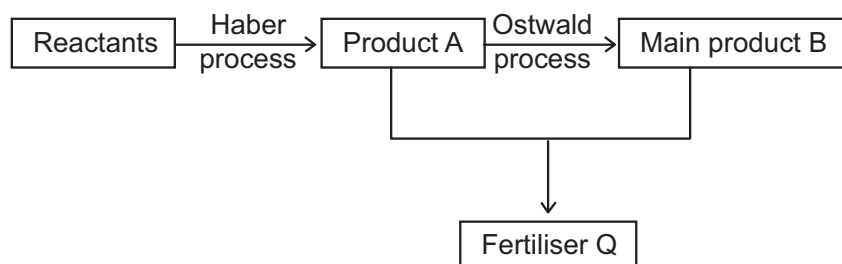
Write down the:

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

2.1.2 balanced equation for the formation of fertiliser Q. (3)

2.2 The diagram below shows a bag of NPK fertiliser.
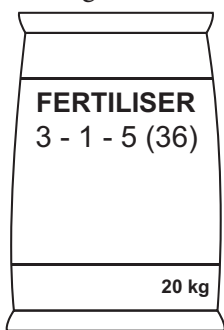
Calculate the mass of nitrogen in the bag. (4)

3. Reactions A, B, C and D in the flow diagram below represent the manufacturing of Fertiliser X.
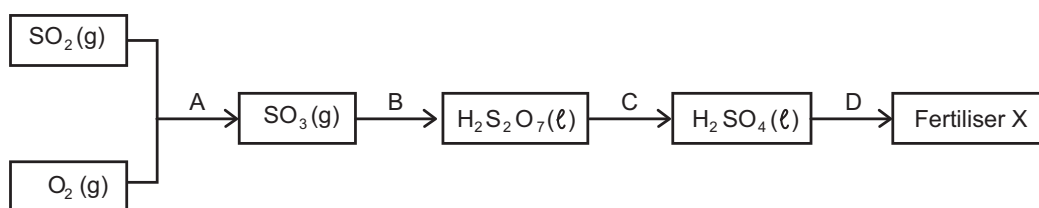
3.1 Write down the name of the industrial preparation of sulfuric acid. (1)

3.2 Write down the:

  3.2.1 NAME or FORMULA of the catalyst used in reaction A. (1)

  3.2.2 balanced equation for reaction C. (3)

3.3 Ammonia is one of the reactants used in reaction D to make Fertiliser X.
Write down:

  3.3.1 a balanced equation for reaction D. (3)

  3.3.2 the NAME of Fertiliser X. (1)

3.4 Two 50 kg bags, containing fertilisers P and Q respectively, are labelled as follows:

Fertiliser P: 5 : 2 : 3 (25)

Fertiliser Q: 1 : 3 : 4 (20)

  3.4.1 What do the numbers (25) and (20) on the labels represent? (1)

  3.4.2 Using calculations, determine which fertiliser (P or Q) contains the greater mass of potassium. (4)

4. 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.

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

4.2 The catalytic oxidation of ammonia is one of the steps in the process named in question 4.1. Write down the NAMES or FORMULAE of the TWO products formed in this step. (2)

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

4.4 Calculate the mass, in kg, of ammonium nitrate that can be made from $6,8 \times 10^7 \, \text{kg}$ of ammonia and excess nitric acid.
(One mole of ammonia produces one mole of ammonium nitrate.) (4)

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

CONSOLIDATION QUESTIONS   **TOTAL: 50 MARKS**

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

    1.1 For the industrial preparation of ammonia, write down:

    1.1.1 the name of the process used.   (1)

    1.1.2 a balanced equation for the reaction that occurs.   (3)

    1.1.3 the source of nitrogen.   (1)

    1.2 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 as it leaves the reaction vessel varies under different conditions.

GRAPHS OF THE PERCENTAGE OF AMMONIA IN THE REACTION MIXTURE VERSUS PRESSURE
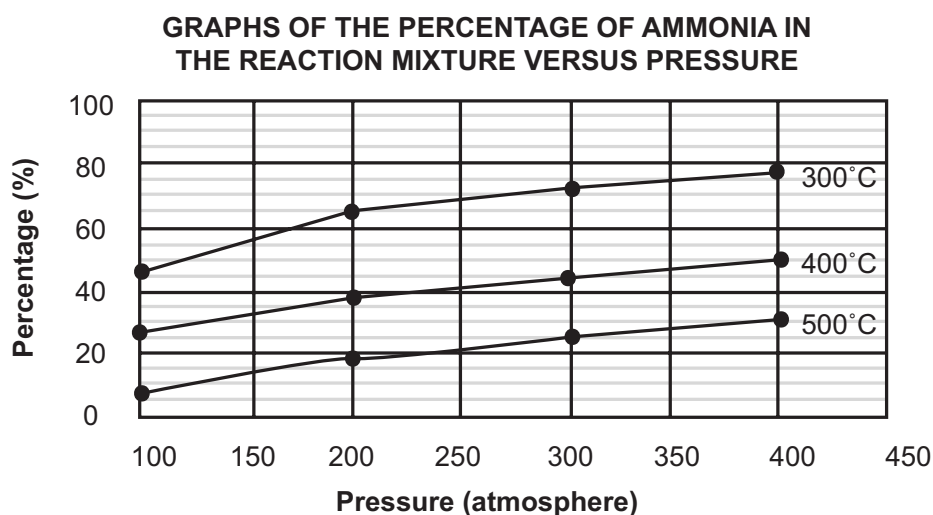
    1.2.1 Use the appropriate graph to estimate the percentage of ammonia present in the reaction mixture at 240 atmosphere and $400\,°C$.   (1)

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

    1.2.3 The advantage of using a low temperature is the large percentage of ammonia formed. What is the disadvantage of using a low temperature?   (1)

    1.3 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)

2. Different processes used in the preparation of fertilisers C and F are represented in the flow diagram below.
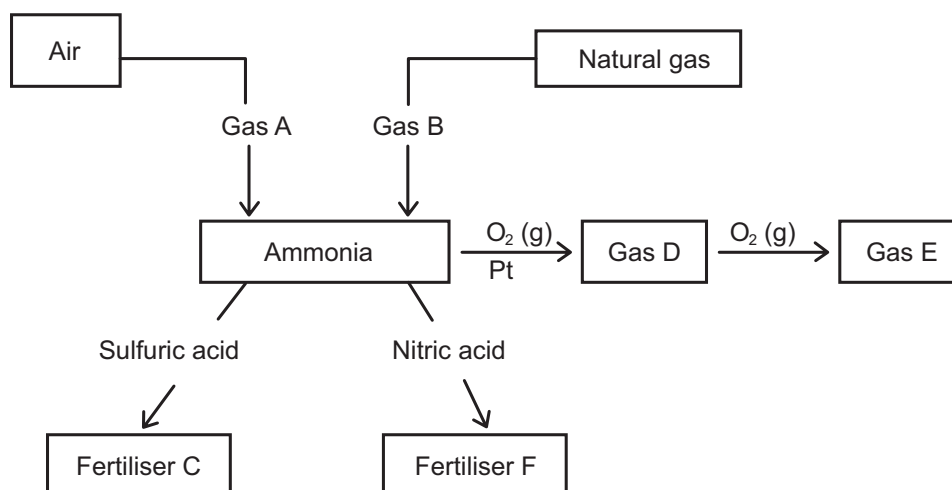
2.1 Write down the NAME or FORMULA of:

    2.1.1 gas A. (1)

    2.1.2 gas B. (1)

    2.1.3 fertiliser F. (1)

2.2 Sulfuric acid is used to prepare fertiliser C. Write down:

    2.2.1 the name of the industrial process used to prepare sulfuric acid. (1)

    2.2.2 a balanced equation for the preparation of fertiliser C. (3)

2.3 Gases D and E are prepared during the Ostwald process. Write down the:

    2.3.1 name given to the preparation of gas D from ammonia. (1)

    2.3.2 balanced equation for the preparation of gas D. (3)

    2.3.3 NAME or FORMULA of gas E. (1)

3. Sulfuric acid is produced by the Contact process and is used in the production of fertilisers such as ammonium sulphate.

    3.1 In one of the steps in this process, sulfur trioxide is dissolved in sulfuric acid rather than in water to produce oleum.

        3.1.1 Write down a balanced equation showing how oleum is produced. (3)

        3.1.2 Give a reason why sulfur trioxide is not dissolved in water to produce sulfuric acid. (1)

3.2 A farmer wants to use a fertiliser which promotes root growth in his vegetable garden. He must choose between ammonium sulfate, ammonium nitrate and ammonium phosphate. The percentage of the elements in each of the fertilisers is given in the table below.

ELEMENT	AMMONIUM SULFATE	AMMONIUM NITRATE	AMMONIUM PHOSPHATE
Nitrogen	21,21	35	28,19
Sulfur	24,24	0	0
Phosphorus	0	0	20,8

3.2.1 Which ONE of the above fertilisers will be the best choice? Refer to the data in the table to give a reason for the answer. (2)

3.2.2 Write down TWO negative impacts of the overuse of fertiliser on the environment. (4)

4. The flow diagram below shows the processes involved in the industrial preparation of fertiliser Q.
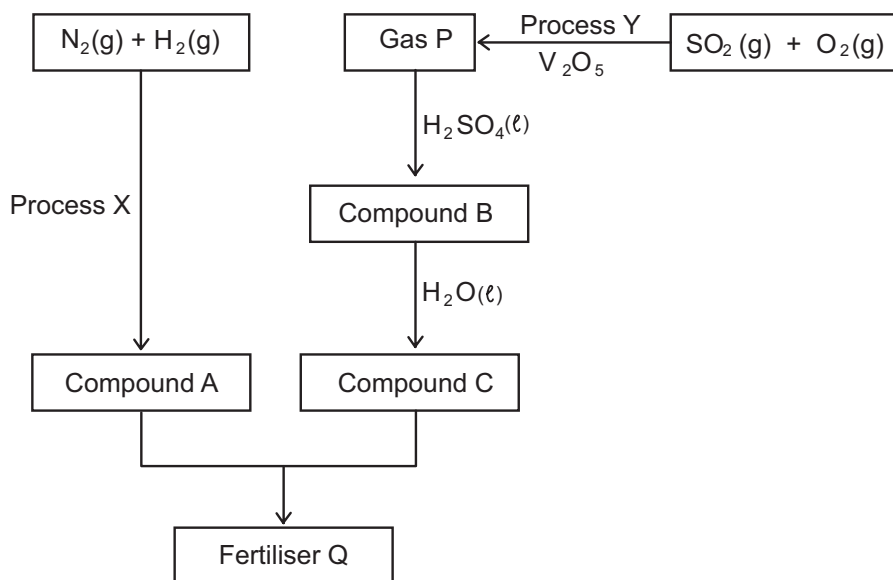
5.

5.1 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.

x - y - z (36)

20 kg
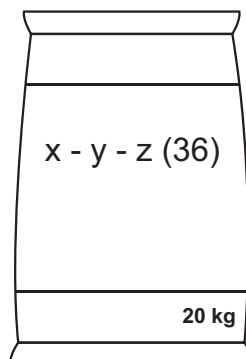
(6)

MARKING GUIDELINES

WORKSHEET QUESTIONS **TOTAL: 45 MARKS**

1.1.1 Phosphorus (P). ✓ (1)

1.1.2 Nitrogen (N). ✓ (1)

1.1.3 Potassium (K). ✓ (1)

1.2.1 Haber Process. ✓ (1)

1.2.2 $N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$

        ✓   ✓ balancing (3)

1.3 The fertilizer contains two primary nutrients, nitrogen (N) and phosphorus (P) ✓ whereas the ammonium nitrate contains only nitrogen (N). ✓ (2)

1.4 Fertilizers cause eutrophication in dams leading to algal bloom and oxygen deprivation in the water. Fish and plants will die; this removes a food source from humans.

OR

Remove drinking water.

OR

Excess nitrates and other heavy metals which can cause cancer.

OR

Reproductive problems or birth defects.

(Any ONE of the above) ✓ ✓ (2)

2.1.1 Nitrogen. (N_2). ✓
Hydrogen. (H_2). ✓ (2)

2.1.2 $NH_3 + HNO_3 \longrightarrow NH_4NO_3$
    ✓   ✓   ✓ balancing (3)

2.2 % N in bag $= \dfrac{3}{9}$ ✓ $\times 36$ ✓ $= 12$ %

Thus, in a 20 kg bag: $\dfrac{12}{100} \times 20$ ✓ $= 2,4\,kg$ ✓ (4)

3.1 The Contact Process. ✓ (1)

3.2.1 Vanadium pentoxide. (V_2O_5). ✓ (1)

3.2.2 $H_2S_2O_7(l) + H_2O(l) \longrightarrow 2H_2SO_4(l)$
     ✓   ✓   ✓ balancing (3)

3.3.1 $H_2SO_4 + 2NH_3 \longrightarrow (NH_4)_2SO_4$
     ✓   ✓   ✓ balancing (3)

3.3.2 ammonium sulfate. ✓ (1)

3.4.1 Total percentage of fertilizer in the bag. ✓ (1)

3.4.2 Fertilizer P: There is 25 % of fertilizer in a 50 kg bag

Thus mass of fertilizer in bag is $\frac{25}{100} \times 50 = 12,5$ kg

Therefore mass of K in bag is $\frac{3}{10} \times 12,5 = 3,75$ kg ✓

Fertilizer Q: There is 20 % of fertilizer in a 50 kg bag

Thus mass of fertilizer is $\frac{20}{100} \times 50 = 10$ kg ✓

Therefore mass of K is $\frac{4}{8} \times 10 = 5$ kg ✓

Thus fertilizer bag Q has more potassium(K) by mass than fertilizer bag P. ✓ (4)

4.1 Ostwald process. ✓ (1)

4.2 Ammonia (NH_3) ✓ and water (H_2O). ✓ (2)

4.3 $NH_3 + HNO_3 \longrightarrow NH_4NO_3$.

      ✓   ✓   ✓ balancing (3)

4.4 $n = \dfrac{m}{M} = \dfrac{6,8 \times 10^7}{17} = 4 \times 10^6$ mol ✓

$NH_4NO_3 : NH_3 = 1 : 1$

Mass of $NH_4NO_3 = nM$

$= 4 \times 10^6$ ✓ $\times 80$ ✓

$= 3,2 \times 10^8$ g $(3,2 \times 10^5$ kg$)$ ✓ (4)

4.5 To make an NPK fertilizer that has all three primary nutrients. ✓ (1)

CONSOLIDATION QUESTIONS   **50 MARKS**

1.1.1 Haber Process. ✓   (1)

1.1.2 $N_2 + 3H_2 \longrightarrow 2NH_3$

      ✓   ✓   ✓ balancing   (3)

1.1.3 Air. ✓   (1)

1.2.1 40 % ✓   (1)

1.2.2 High yield or high percentage. ✓
High rate due to higher concentration. ✓   (2)

1.2.3 Low reaction rate. ✓   (1)

1.3 Firstly, calculate the percentage composition of N in NH_4NO_3.

%N in $NH_4NO_3 = \dfrac{28}{80}$ ✓ $\times 100 = 35$ %

Now, from this percentage composition, determine the mass of N in the 50 kg bag.

Therefore mass of nitrogen in 50 kg is $\dfrac{35}{100} \times 50$ ✓ $= 17,5$ kg ✓   (3)

2.1.1 Nitrogen(N_2). ✓   (1)

2.1.2 Hydrogen(H_2). ✓   (1)

2.1.3 Ammonium nitrate. ✓   (1)

2.2.1 Contact Process. ✓   (1)

2.2.2 $2NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$

      ✓   ✓   ✓ balancing   (3)

2.3.1 Catalytic oxidation of ammonia. ✓   (1)

2.3.2 $4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$

        ✓   ✓   ✓ balancing   (3)

2.3.3 Nitrogen dioxide. (NO_2). ✓   (1)

3.1.1 $SO_3 + H_2SO_4 \longrightarrow H_2S_2O_7$

      ✓   ✓   ✓ balancing   (3)

3.1.2 The reaction is highly exothermic. It produces toxic fumes. ✓   (1)

3.2.1 Ammonium phosphate. ✓
Highest percentage phosphorus. ✓ (2)

3.2.2 Excess fertilizer runs into the water resources causing
contamination of the water ✓ ✓ resulting in high concentration of
nitrates / Eutrophication which causes plant and fish life to die. ✓ ✓
Change in acidity of the soil. ✓ ✓
(Any TWO answers) (4)

4.1.1 Haber process. ✓ (1)

4.1.2 Contact process. ✓ (1)

4.1.3 Sulfur trioxide. (SO_3). ✓ (1)

4.1.4 $SO_3 + H_2SO_4 \longrightarrow H_2S_2O_7$

          ✓   ✓   ✓ balancing (3)

4.1.5 H_2SO_4✓ $+ 2NH_3$✓ $\longrightarrow (NH_4)_2SO_4$ ✓   ✓ balancing (4)

4.2 First, calculate the mass of fertilizer.

$$mass\,(m) = \frac{36}{100} \times 20 = 7,2\,kg \quad ✓$$

Now calculate the percentage NPK.

$$\%N = \frac{4,11}{7,2} \times 100 = 57,08\,\% \quad ✓$$

$$\%P = \frac{0,51}{7,2} \times 100 = 7,08\,\% \quad ✓$$

$$\%K = 100 - 57,08 - 7,08 = 35,84\,\% \quad ✓$$

Now determine the ratio by percent.

$$N{:}P{:}K = \frac{57,08}{7,08} : \frac{7,08}{7,08} : \frac{35,84}{7,08}✓ = 8{:}1{:}5 \quad ✓ \tag{6}$$

FORMAL EXPERIMENT

FORMAL EXPERIMENT A

GRADE 12 TERM 3:
PHYSICS PRACTICAL
Electric Circuits
67 MARKS

This section provides guidance and assessment of the learner's knowledge and understanding when carrying out a virtual experiment using the NECT video of the same name.

If your class is carrying out the experiment using laboratory apparatus and taking down their own results, you must set up your classroom appropriately and give the learners the relevant instructions. You may find it useful to refer to the Technical Instructions which precede the Learner's Instructions while preparing for this experiment.

If the learners are proceeding with the virtual experiment, then continue with the NECT programme by using the information, handouts and marking guidelines contained in this section of this Resource Book.

FORMAL EXPERIMENT

TECHNICAL INSTRUCTIONS

PART 1: DETERMINE THE INTERNAL RESISTANCE OF A BATTERY

INSTRUCTION: Conduct an experiment as per instructions and submit the scientific report using the template provided on Page 5.   39 marks
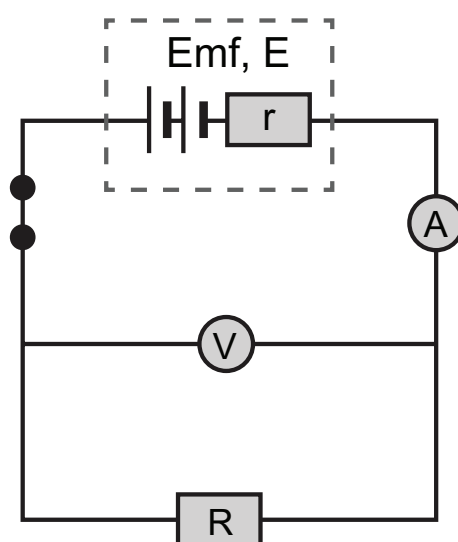
Apparatus

Voltmeter

Ammeter

Battery of two 1,5 V cells in series

Three 10 Ω resistors

12 connecting leads

PART 2: DETERMINE THE EQUIVALENT RESISTANCE OF A SERIES-PARALLEL NETWORK OF KNOWN RESISTORS, AND MEASURE ITS EFFECTIVE RESISTANCE USING AN AMMETER AND A VOLTMETER. COMPARE THIS MEASURED VALUE WITH ITS THEORETICAL VALUE.
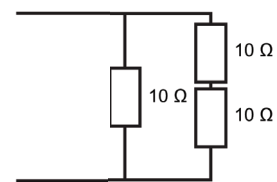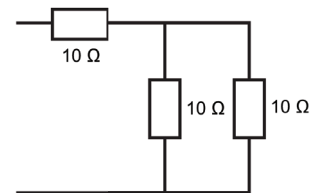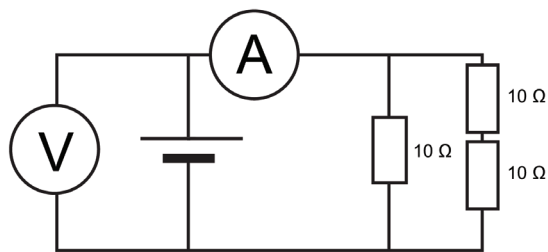
28 MARKS

Voltmeter

Ammeter

Battery of two 1,5 V cells in series

Three 10 Ω resistors

12 connecting leads

NAME: _____ GRADE:_____

Formal Experiment
ELECTRIC CIRCUITS

PART 1: DETERMINE THE INTERNAL RESISTANCE OF A BATTERY

INSTRUCTION: Conduct an experiment as per instructions and submit the scientific report using the template provided on Page 5. **39 marks**

AIM:

_____

_____

(2)

APPARATUS

Voltmeter

Ammeter

Battery of two 1,5 V cells in series

Three 10 Ω resistors

12 connecting leads

1. The minimum resistance of a combination of three 10 Ω resistors is 3,33 Ω, and the maximum resistance of a different combination of three 10 Ω resistors is 30 Ω.

   1.1 Draw the two arrangements of three 10 Ω resistors with effective resistance of 3,33 Ω and 30 Ω respectively. (4)

   1.2 Draw three other arrangements of 10 Ω resistors with three other values of effective resistance ranging between 3,33 Ω and 30 Ω. Try to spread out the values so that they are relatively evenly spaced. You can use one or two or three resistors to achieve the desired spread of value of effective resistance. Calculate the effective resistance of each of these three arrangements. (5)

METHOD

1. Connect two 1,5 V cells in series to form a battery.

2. Connect the battery to an ammeter, a switch and the combination of resistors (R).

3. Connect a voltmeter across the terminals of the external circuit as shown in the circuit diagram alongside.

4. Close the switch and take the readings on the voltmeter and the ammeter.

5. Adjust the effective resistance of the combination of resistors.

6. Repeat step 4 and 5 until you have taken and recorded five sets of readings for five different combinations of the resistors.
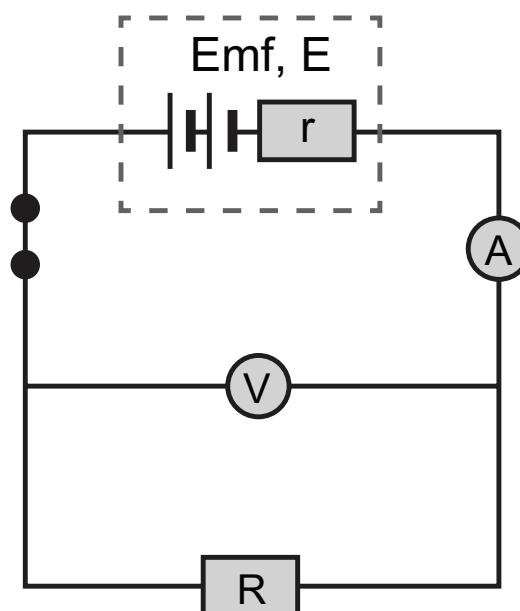
RESULTS

1. Table of results:_____

_____

Experiment Number	R (Ω)	V_T (V)	I (A)
1	3,33		
2			
3			
4			
5	30		

(8)

INTERPRETATION:

2. Plot a graph of voltage (V_T) across the external circuit against current through the battery. (7)
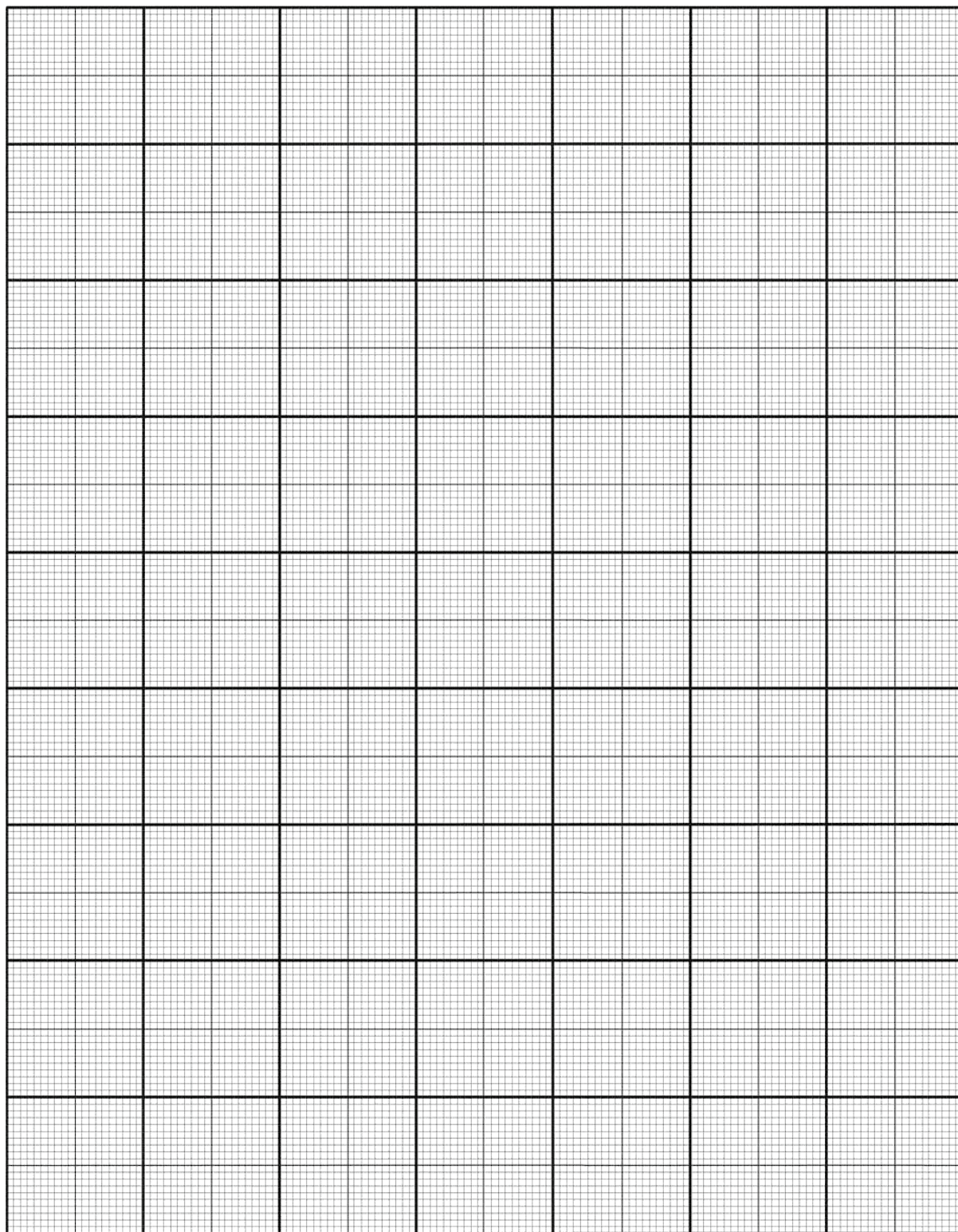
3. Comment on the shape of the graph. (2)

_____

_____

_____

_____

_____

_____

4. Extend the graph back so that it cuts the y-axis.
   Take the reading on the y-axis. _____ (2)

5. Calculate the gradient of the graph. Show the coordinates that you use for this
   calculation on the graph as well as in your calculation. (4)

_____

_____

_____

_____

_____

_____

6. Using the formula $emf = VT + Ir$ and the equation for a straight-line graph $y = mx + c$,
   show that

   a. the emf of the battery = the y-intercept   and

   b. the internal resistance of the battery = negative value of the gradient. (3)

_____

_____

_____

_____

_____

_____

7. Write down the values of the emf of the battery _____

   and the internal resistance of the battery. _____ (2)

PART 2: DETERMINE THE EQUIVALENT RESISTANCE OF A SERIES-PARALLEL NETWORK OF KNOWN RESISTORS, AND MEASURE ITS EFFECTIVE RESISTANCE USING AN AMMETER AND A VOLTMETER. COMPARE THIS MEASURED VALUE WITH ITS THEORETICAL VALUE. **(28)**

1. There are two possible combinations of three resistors in series and in parallel. Draw these two possible combinations, and label the combination with the lower effective resistance as Combination A and the other one as Combination B. (5)

2. Draw the circuit diagram for Combination A showing where the ammeter and voltmeter are connected in the circuit so that the effective resistance of this combination can be measured. (2)

3. Set up the circuits for Combination A and Combination B and take the appropriate readings. Record the readings in a table below. (11)

   Table of results: _____

   _____

4. Calculated values of the effective resistance of Combination A and Combination B.

Combination A (4)

_____

_____

_____

_____

_____

_____

Combination B (4)

_____

_____

_____

_____

_____

_____

Conclusion: (2)

_____

_____

_____

_____

_____

_____

MARKING GUIDELINES

67 MARKS

PART 1:   **39 MARKS**

AIM:

To verify/test/proof/determine/ ✓ the internal resistance of the battery. ✓   (2)

PRACTICAL

1. The minimum resistance of a combination of three 10 Ω resistors is 3,33 Ω, and the maximum resistance of a different combination of three 10 Ω resistors is 30 Ω.

    1.1 Draw the two arrangements of three 10 Ω resistors with effective resistance of 3,33 Ω and 30 Ω respectively.

3,33 Ω ✓✓   30 Ω ✓✓

10 Ω   10 Ω   10 Ω   (4)
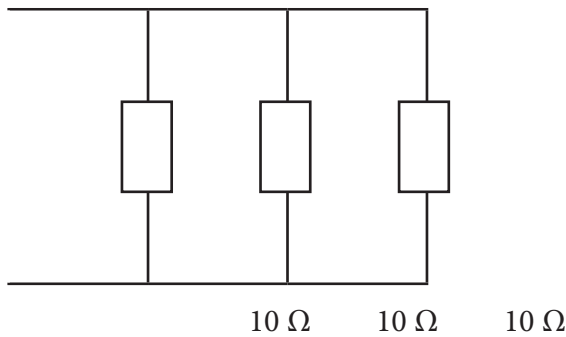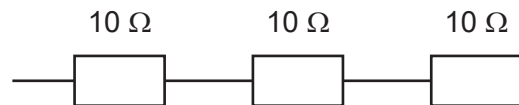
    1.2 Draw three other arrangements of the resistors with three other values of effective resistance ranging between 3,33 Ω and 30 Ω. Try to spread out the values so that they are not all very similar. You can use one or two or three resistors to achieve the desired spread of value of effective resistance.
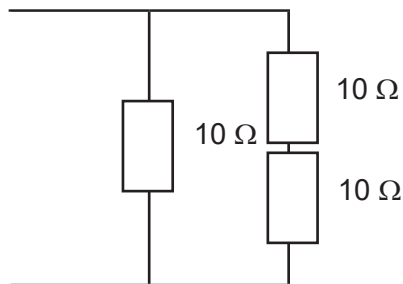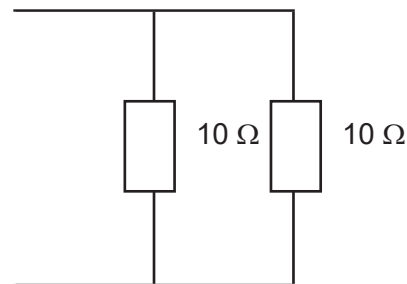
10 Ω   ✓   20 Ω   ✓✓   15 Ω ✓✓
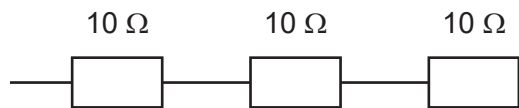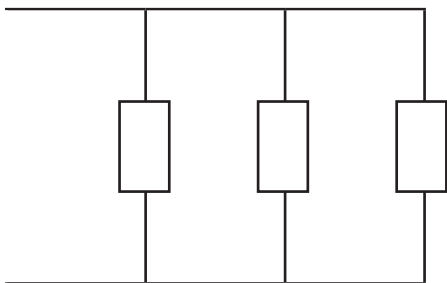
OR   5 Ω   OR   6,67 Ω

(5)

Method

1. Connect two 1,5 V cells in series to form a battery.

2. Connect the battery to an ammeter, a switch and the combination of resistors (R).

3. Connect a voltmeter across the terminals of the external circuit.

4. Close the switch and take the readings on the voltmeter and the ammeter.

5. Adjust the effective resistance of the combination of resistors.

6. Repeat step 4 and 5 until you have taken and recorded five sets of readings for five different combinations of the resistors.

Results

1. Table of results: (Terminal) voltage vs Current for a battery (with internal resistance)✔

Experiment Number	R (Ω)✔	V_T (V)	I (A)✔
1	3,33	2,61	0,766✔
2	10	2,81	0,251✔
3	15	2,85	0,191✔
4	20	2,87	0,145✔
5	30	2,89	0,096✔
✔Mark for the title of the Table ✔✔ for correct SI units as shown ✔✔✔✔ for correct values for each row of results			

(8)

2. Plot a graph of voltage across the external circuit against current through the battery.
   - ✔ Appropriate title (heading) e.g. Terminal voltage vs Current (for a battery with internal resistance.)
   - ✔ Correct choice of axes: Independent variable on x-axis (Current)
   - ✔ Appropriate scale on x-axis with label and SI units
   - ✔ Appropriate scale on y-axis with label and SI units
   - ✔ Points plotted correctly.
   - ✔ Best fit straight-line graph.
   - ✔ Graph extended back to cut the y-axis

      (Extension of graph must be the same straight-line as the best fit line)   (7)

INTERPRETATION

Terminal voltage vs Current
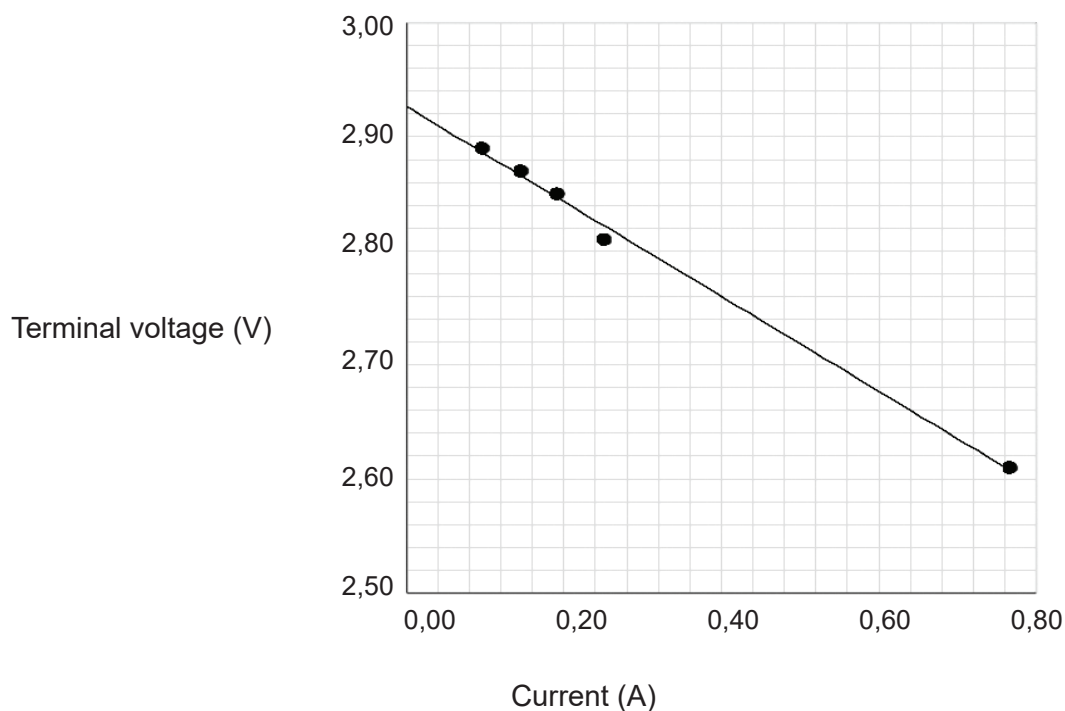
3. Comment on the shape of the graph.
   Straight-line graph ✓ *with negative gradient (slope)* ✓ (2)

4. Extend the graph back so that it cuts the y-axis.
   Take the reading on the y-axis. (2,92 V)   Accuracy, ✓ SI units ✓ (2)

5. Calculate the gradient of the graph. Show the coordinates that you use for this
   calculation on the graph as well as in your working out. (4)
   (0,00; 2,925) (0,40; 2,76) ✓   (Matches points on graph.) ✓
   gradient =   =   = 0,41✓   (or 0,42 depending on co-ordinates)

6. Using the formula *emf* = V_T + *Ir* and the equation for a straight-line graph *y* = *mx* + *c*,
   determine   a. the emf of the battery: 2,925 V (y-intercept✓ + SI units✓) (2)
   and   b. the internal resistance of the battery: 0,41✓ Ω

                                                         (Abs. value gradient) (1)

7. emf = 2,925 V (y-intercept) ✓
   internal resistance = 0,41 Ω ✓

   Justification:
   V_T = *emf* – *Ir* ✓
   V_T = - *rI* + *emf* ✓
   But *y* = *mx* + *c*
   Therefore *c* = *emf* (y-intercept)
   r = internal resistance (Take the positive value of the gradient as the internal resistance.)

PART 2: DETERMINE THE EQUIVALENT RESISTANCE OF A SERIES-PARALLEL NETWORK OF KNOWN RESISTORS, AND MEASURE ITS EFFECTIVE RESISTANCE USING AN AMMETER AND A VOLTMETER. COMPARE THIS MEASURED VALUE WITH ITS THEORETICAL VALUE.   **28 MARKS**

1. There are two possible combinations of three resistors in series and in parallel. Draw these two possible combinations, and label the combination with the lower effective resistance as Combination A and the other one Combination B. (5)
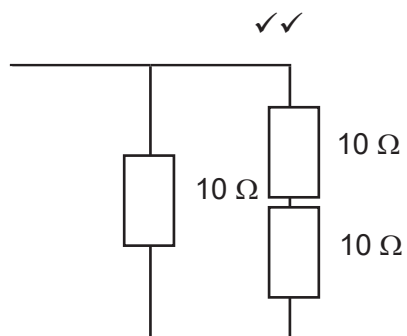
COMBINATION A✓   COMBINATION B✓✓
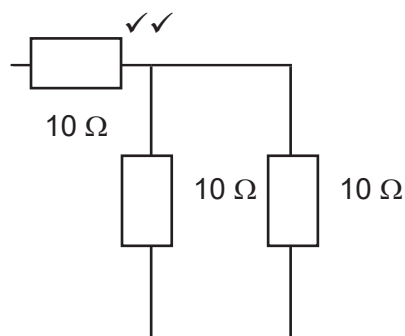
2. Draw the circuit diagram for Combination A showing where the ammeter and voltmeter are connected in the circuit so that the effective resistance of this combination can be measured. (2)
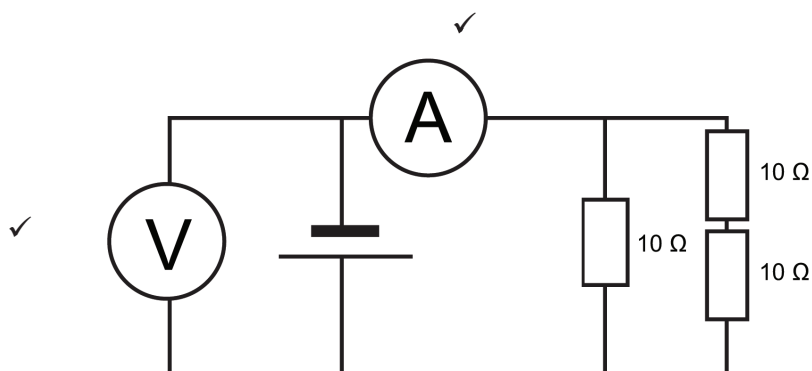
3. Table of results: Voltage (Potential difference) and Current readings for Combinations A and B (series and parallel circuits). ✔

Combination	VT (V) ✔	I (A)✔	R (Ω)
A Average	2,74	0,412	6,65✔
	2,75	0,411	6,69✔
	2,76	0,411	6,72✔
	6,69 ✔		
B Average	2,85	0,190	15,00✔
	2,84	0,190	14,95✔
	2,84	0,191	14,87✔
	14,94 ✔		

<div align="right">

(11)
</div>

4. Calculated values of the effective resistance of Combination A and Combination B.

Combination A:

$\dfrac{1}{R_T} = \dfrac{1}{R_T} + \dfrac{1}{R_2 + R_3}$ ✔   (Method or method implied)

$= \dfrac{1}{10} + \dfrac{1}{20}$ ✔   (Correct substitutions or implied)

$= \dfrac{3}{20}$

$R_T = \dfrac{20}{3}$ ✔   (Inverting the reciprocal)

$= 6,67\ \Omega$ ✔   (Accuracy; SI units)   (4)

Combination B:

$R_{/\!/} = \dfrac{\text{product}}{\text{sum}}$ ✔   (Method or using the reciprocal formula)

$= \dfrac{10 \times 10}{10 + 10}$ (Accuracy; SI units)

$= 5\Omega$ ✔

$R_T = R_1 + R_{/\!/}$ ✔   (Method)

$= 10 + 5$

$= 15\ \Omega$ ✔   (Accuracy; SI units)   (4)

5. Conclusion:

6. The measured results are very close to the calculated results. ✔ Therefore, the method of calculating the effective resistance is correct. ✔   (2)

PRACTICAL

ASSESSMENTS

Topic 10: Electric Circuits

QUESTIONS

MULTIPLE CHOICE QUESTIONS

1. In the circuit diagram below, the resistance of resistor R_2 is TWICE the resistance of resistor R_1. The two resistors are connected in series and identical high-resistance voltmeters are connected across each resistor. The readings on the voltmeters are V_1 and V_2 respectively.
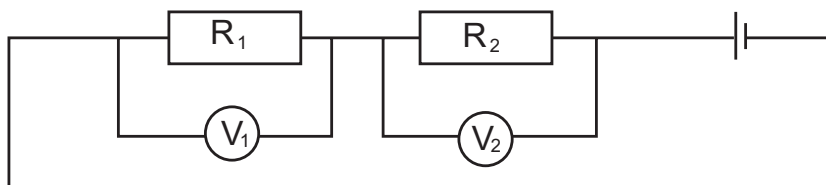
    A $V_1 = 2\,V_2$

    B $V_1 = \dfrac{1}{4}V_2$

    C $V_1 = V_2$

    D $V_1 = \dfrac{1}{2}V_2$ (2)

2. 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.
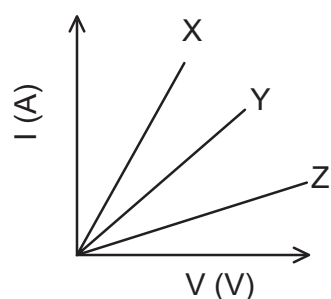
    The resistances of X, Y and Z are R_X, R_Y and R_Z respectively. Which ONE of the following conclusions regarding the resistances of the resistors is CORRECT?

    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)

3. 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.
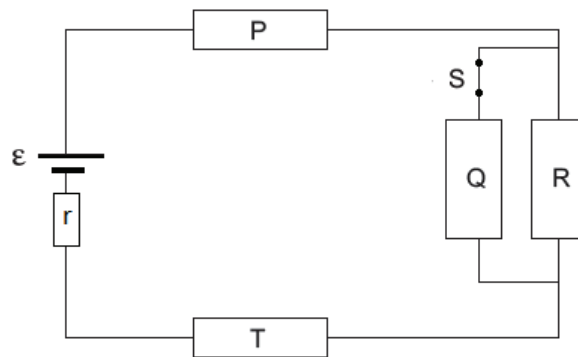
Switch S is now OPENED. Which ONE of the following combinations of changes will occur in P, R and T?

	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)

4. 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.
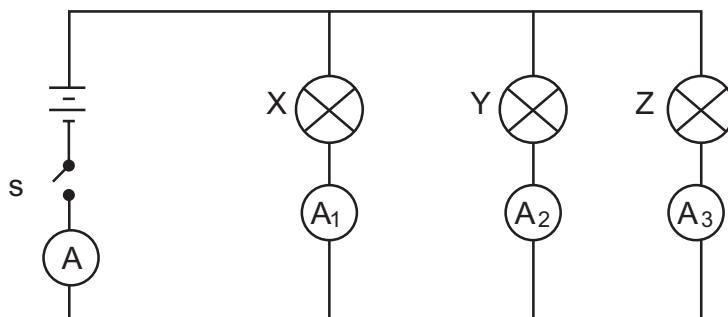
Which ONE of the following correctly describes the readings on the ammeters (in amperes) when bulb Z burns out?

	A_1	A_2	A_3	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)

ASSESSMENTS

5. 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)

6. Consider the circuit diagram below.
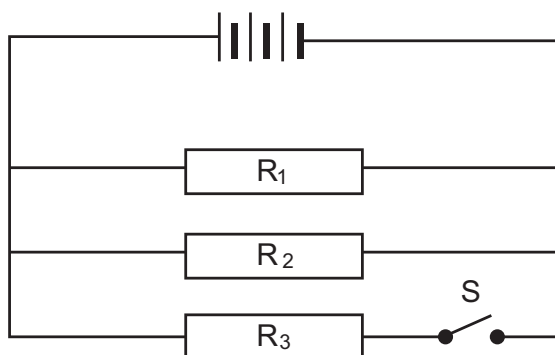
Which ONE of the following correctly describes the change in total resistance and total current when switch S is closed?

	Total Resistance	Total Current
A	Decreases	Increases
B	Increases	Increases
C	Decreases	Decreases
D	Increases	Decreases

(2)

7. In the circuit given below the battery has negligible internal resistance. What will happen to the current through resistor R_1 if the resistance of the variable resistor, R_2, is increased?
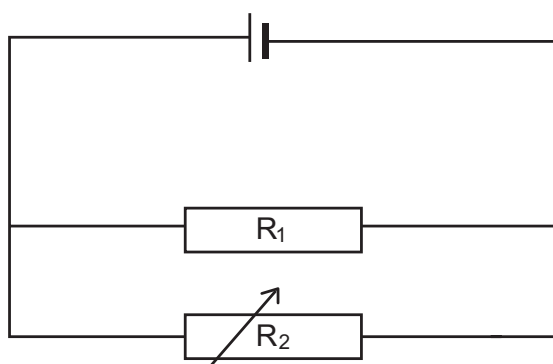
A   It will decrease.
B   It will increase.
C   It will remain unchanged.
D   It will decrease to a minimum value and then remain constant.   (2)

8.   Which one of the following graphs best represents the relationship between the electrical power and the current in a given ohmic conductor?

A

B

C

D
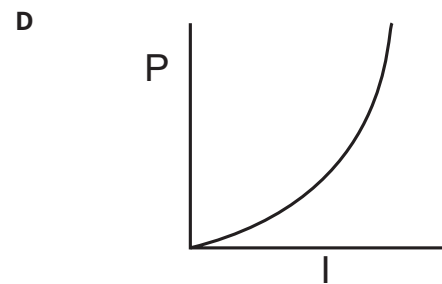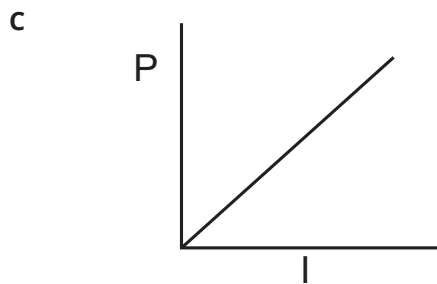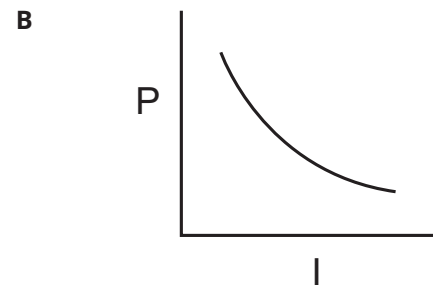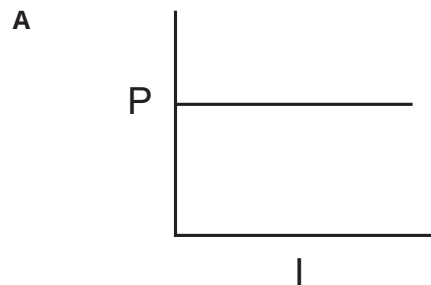
(2)

LONG QUESTIONS

9.

9.1   In Circuit 1 below three identical light bulbs, P, Q and R, with the same resistance, are connected to a battery with emf ε and negligible internal resistance.

Circuit 1
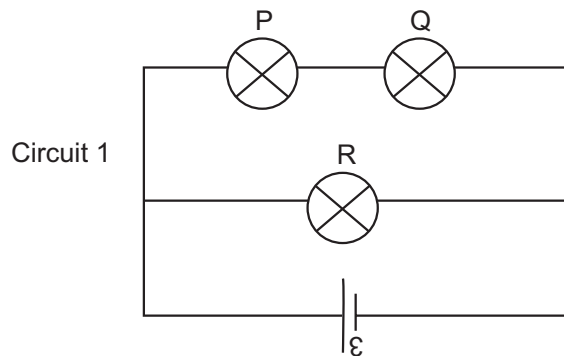
9.1.1   How does the brightness of bulb P compare with that of bulb Q? Give a reason for the answer.   (2)

9.1.2   How does the brightness of bulb P compare with that of bulb R? Give a reason for the answer.   (2)

A fourth, identical bulb T, with the same resistance as the other three, is connected to the circuit by means of an ordinary wire of negligible resistance, as shown in Circuit 2 below.
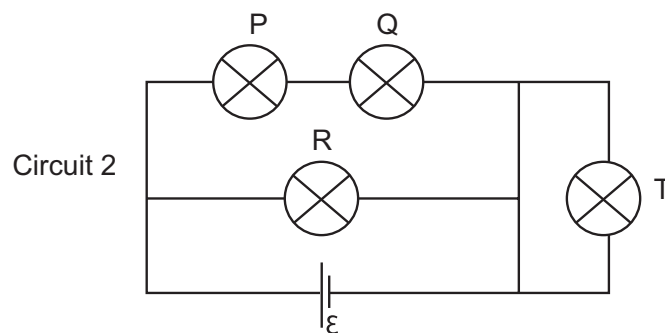
Circuit 2

9.1.3 How does the brightness of bulb T compare with that of bulb R? Give a reason for the answer. (2)

9.2 A battery with an emf of 20 V and an internal resistance of 1 Ω is connected to three resistors, as shown in the circuit below.
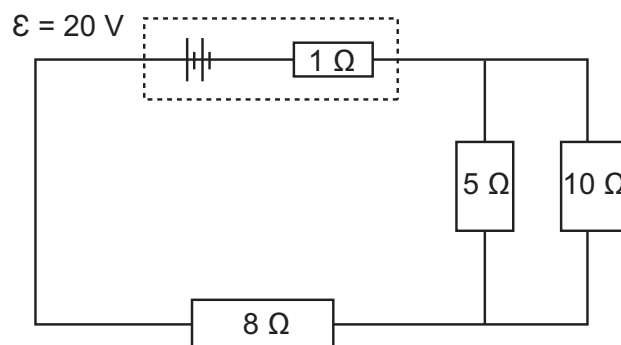
Calculate the:

9.2.1 current in the 8 Ω resistor. (6)

9.2.2 potential difference across the 5 Ω resistor. (4)

9.2.3 total power supplied by the battery. (3)

10. The battery in the circuit represented below has an emf of 12 V and an internal resistance r. Voltmeter V_1 is connected across the battery. The resistance of the connecting wires is negligible.
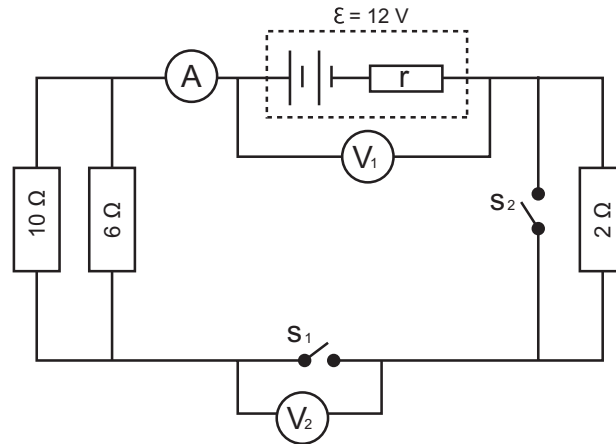
Switches S_1 and S_2 are both open.

10.1 Write down the reading on voltmeter V_2. (1)

10.2 Switch S_1 is now closed. Switch S_2 remains open. The reading on V_1 is now 10 V.

Calculate the:

    10.2.1 total external resistance of the circuit. (4)

    10.2.2 internal resistance of the battery. (5)

10.3 Both switches S_1 and S_2 are now closed. How will the reading on the ammeter be affected? Choose from INCREASES, DECREASES or REMAINS THE SAME. Explain the answer. (3)

11. A learner sets up the circuit shown below to measure the internal resistance of a battery.
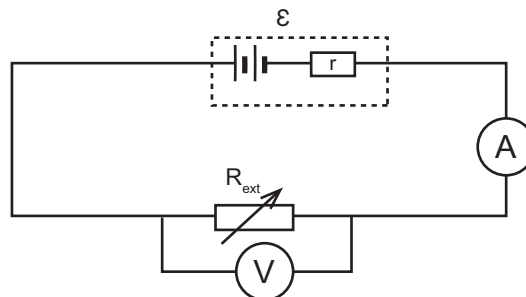
She records the readings on the voltmeter and ammeter for different resistances of the rheostat. The graph below was obtained from the results.

Graph of inverse of current versus external resistance
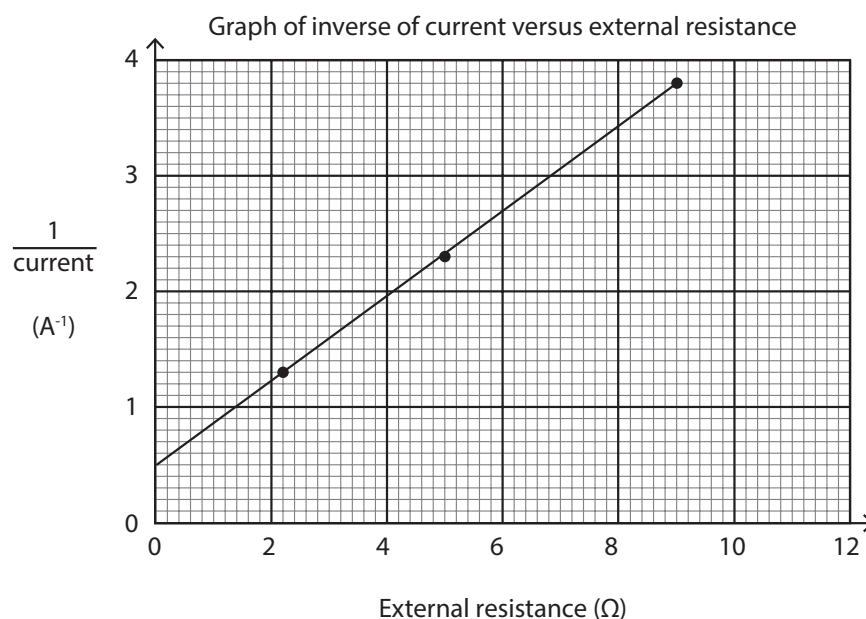
11.1 Define the term "emf". (2)

11.2 Calculate the gradient of the above graph. (3)

11.3 What is represented by the gradient in question 11.2? (3)

11.4 Use the information on the graph to calculate the:

    11.4.1 emf of the battery. (2)

    11.4.2 internal resistance of the battery. (3)

12.1 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.
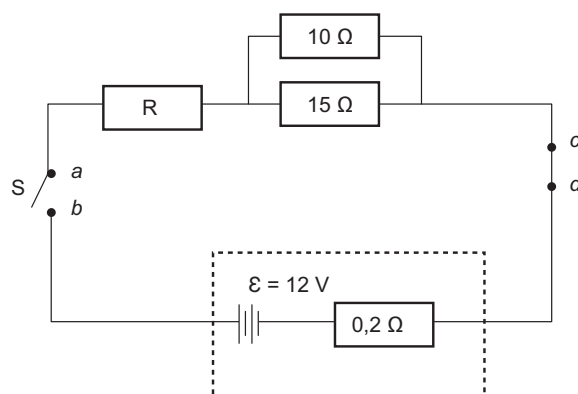
    12.1.1 Define the term emf of a battery. (2)

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

    12.1.3 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.

12.1.4 Calculate the current in the battery. (3)

12.1.5 Calculate the effective resistance of the parallel branch. (2)

12.1.6 Calculate the resistance of resistor R. (4)

12.2 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.
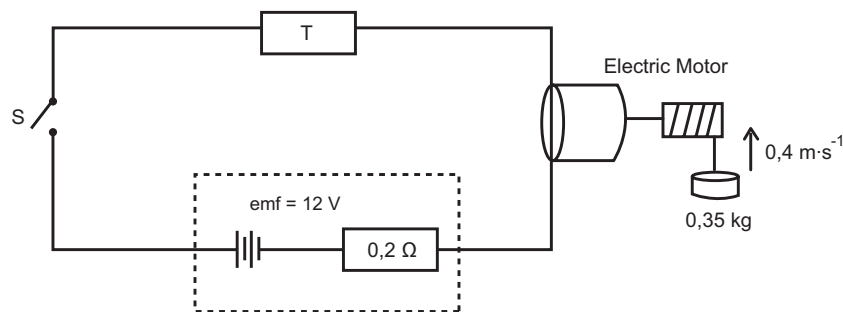
When switch S is closed, the motor lifts a 0,35 kg mass vertically upwards at a constant speed of 0,4 m·s⁻¹. Assume that there is no energy conversion into heat and sound. Calculate the value of:

12.2.1 X. (3)
12.2.2 the resistance of resistor T. (5)

13. A battery with an internal resistance of 1 Ω and an unknown emf (ε) is connected in a circuit, as shown below. A high-resistance voltmeter (V) is connected across the battery. A_1 and A_2 represent ammeters of negligible resistance.
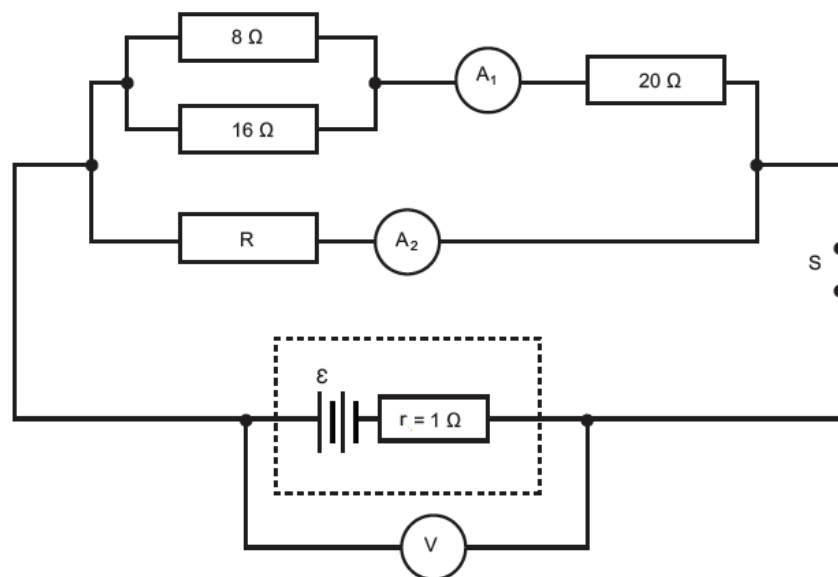
With switch S closed, the current passing through the 8 Ω resistor is 0,5 A.

13.1 State Ohm's law in words. (2)

13.2 Calculate the reading on ammeter A_1. (4)

13.3 If device R delivers power of 12 W, calculate the reading on ammeter A_2. (5)

13.4 Calculate the reading on the voltmeter when switch S is open. (3)

14.

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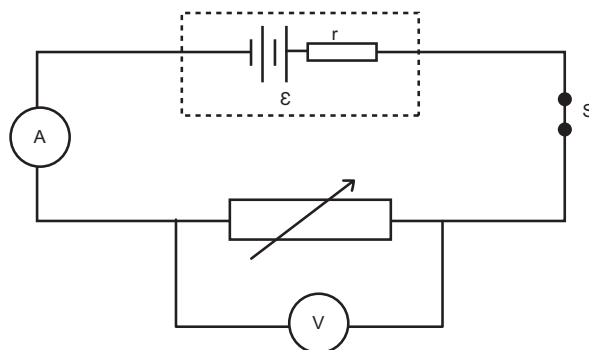
The data obtained from the experiment is displayed in the table below.

Reading on Voltmeter (V)	Reading on Ammeter (A)
2	0,58
3	0,46
4	0,36
5	0,24
6	0,14

14.1.1 State ONE factor which must be kept constant during the experiment. (1)

14.1.2 Using the information in the table above, plot the points and draw the line of best fit on graph paper. (6)

Use the graph drawn in question 14.1.2 to determine the following:

14.1.3 emf (ε) of the battery. (1)

14.1.4 internal resistance of the battery, WITHOUT USING ANY FORM OF THE EQUATION ε = I(R + r). (3)

14.2 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 ratings of each of the devices X and Y are indicated in the diagram.
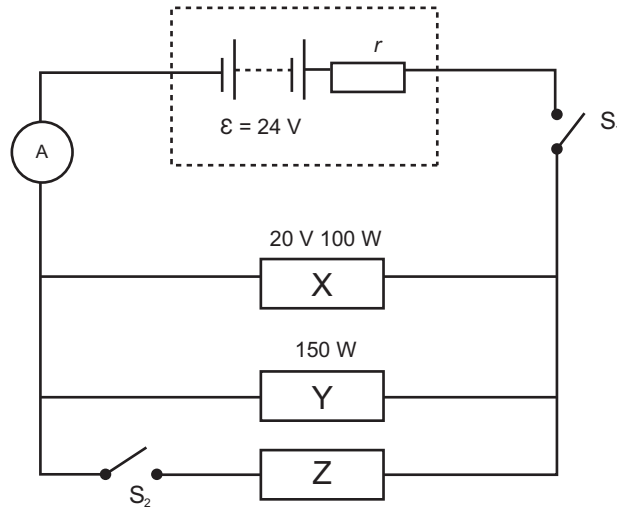
With switch S_1 closed and S_2 open, the devices function as rated. Calculate the:

14.2.1 current in X. (3)

14.2.2 resistance of Y. (3)

14.2.3 internal resistance of the battery. (5)

Now switch S_2 is also closed.

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

14.2.5 Explain how you arrived at the answer to question 14.2.4. (2)

MARKING GUIDELINES

ANSWERS TO MULTIPLE CHOICE QUESTIONS

1. D ✓ ✓ R_1 : R_2
                  1   :   2
                  $V = IR$
                  I is the same through each resistor, therefore V is directly
                  proportional to R.
                  V_1 : V_2
                  1   :   2   [CL2] (2)

2. A ✓ ✓   gradient $= \dfrac{I}{V} = R^{-1}$
                  Therefore, as the gradient increases, resistance decreases.   [CL3] (2)

3. D ✓ ✓   Total resistance increases, circuit current decreases.
                  R doesn't share the current now.   [CL2] (2)

4. D ✓ ✓   [CL2] (2)

5. D ✓ ✓   In series: $R_T = R + R = 2R$
                  In parallel: $R_T = \dfrac{1}{2}R$
                  Resistance is four times LESS when the same resistors are connected
                  in parallel. Current will therefore four times GREATER. Current is
                  inversely proportional to resistance at constant emf.   [CL3] (2)

6. A ✓ ✓   Connecting more resistors in parallel decreases the total resistance as
                  there are more pathways for the charge to flow.
                  Current is inversely proportional to resistance at constant emf.   [CL2] (2)

7. C ✓ ✓   Same potential difference across R_1.
                  Resistance of R_1 does not change.
                  $I_1 = \dfrac{emf}{R_1} = constant$.   [CL3] (2)

8. D ✓ ✓   Power is directly proportional to I^2 at constant resistance.
                  $P = I^2 R$ [CL3] (2)

ANSWERS TO LONG QUESTIONS

9. 9.1   9.1.1   Same brightness. ✓
                  $P = VI$
                  Both bulbs have the same potential difference across them and they
                  have the same current in them. ✓   [CL2] (2)

9.1.2 Bulb R is brighter than P. ✓

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

The bulbs have the same resistance.

The potential difference across each branch is the same.

This potential difference is divided among P and Q.

The potential difference across R is double that across P. ✓   [CL3] (2)

9.1.3 R is brighter than T. ✓

T has been short-circuited by a pathway of zero resistance. ✓   [CL3] (2)

9.2.1 $\dfrac{1}{R_p} = \dfrac{1}{5} + \dfrac{1}{10}$ ✓ $= \dfrac{3}{10}$ ✓

$R_p = \dfrac{10}{3} = 3,33\,\Omega$ ✓

$R_T = 8 + 1 + 3,33 = 12,33\,\Omega$ ✓

$I_{total} = \dfrac{emf}{R_{total}} = \dfrac{20✓}{12,33} = 1,62\,A$ ✓   [CL3] (6)

9.2.2 $V_p = I.R_p = (1,62✓)(3,33✓) = 5,40\,V$ ✓

$V_{5\,\Omega} = 5,40\,V$ ✓   [CL3] (4)

9.2.3 $P = VI = (20✓)(1,62✓) = 32,4\,W$ ✓   [CL3] (3)

10.   **10.1** 12 V ✓   [CL2] (1)

10.2.1 $\dfrac{1}{R_p} = \dfrac{1}{10} + \dfrac{1}{6}$ ✓ $= \dfrac{4}{15}$ ✓

$R_p = \dfrac{15}{4} = 3,75\,\Omega$ ✓

$R_{ext} = 3,75 + 2 = 5,75\,\Omega$ ✓   [CL3] (4)

10.2.2 $V_{ext} = 10\,V$

$V_{ext} = IR_{ext}$

$I = \dfrac{V_{ext}}{R_{ext}} = \dfrac{10✓}{5,75✓} = 1,74\,A$ ✓

$V_{lost} = emf - V_{ext} = 12 - 10 = 2\,V$

$V_{lost} = Ir$

$2✓ = (1,74)r$

$r = 1,15\,\Omega$ ✓   [CL3] (5)

10.3 INCREASES. ✓

The 2 Ω resistor has been short-circuited. ✓

The total resistance in the circuit has decreased. ✓   [CL3] (3)

11.   **11.1** The energy supplied by the battery per coulomb of charge. ✓ ✓   [CL1] (2)

11.2 $gradient = \dfrac{\Delta y}{\Delta x} = \dfrac{(3,80 - 0,5)✓}{(9 - 0)✓} = \dfrac{3,3}{9} = 0,37\,A^{-1}\Omega^{-1}$ ✓   [CL2] (3)

ASSESSMENTS

11.3 $emf = I(R_{ext} + r)$

$I = \dfrac{emf}{(R_{ext} + r)}$

$I^{-1} = \dfrac{(R_{ext} + r)}{emf}$

$I^{-1} = \dfrac{1}{emf} R_{ext} \checkmark + \dfrac{r}{emf}$ $\checkmark$

$y = mx + c$

$m = \text{gradient} = \dfrac{1}{emf} = emf^{-1}$ $\checkmark$ [CL3] (3)

11.4.1 $\dfrac{1}{emf} = 0{,}37$ $\checkmark$

$emf = 2{,}70 \text{ V}$ $\checkmark$ [CL3] (2)

11.4.2 $\text{y-intercept} = \dfrac{r}{emf} = 0{,}5$ $\checkmark$

$\dfrac{r}{2{,}70\checkmark} = 0{,}5$

$r = 1{,}35 \text{ Ω}$ $\checkmark$ [CL4] (3)

12.   **12.1** **12.1.1** The energy supplied by the battery per coulomb of charge. $\checkmark\ \checkmark$ [CL1] (2)

           12.1.2 12 V $\checkmark$ [CL2] (1)

           12.1.3 0 V $\checkmark$ [CL2] (1)

           12.1.4 $V_{\text{internal resistance}} = emf - V_{\text{load}} = 12 - 11{,}7 = 0{,}3 \text{ V}$ $\checkmark$

                  $V_{\text{internal resistance}} = Ir$

                  $0{,}3 = I(0{,}2\checkmark)$

                  $I = 1{,}5 \text{ A}$ $\checkmark$ [CL3] (3)

           12.1.5 $\dfrac{1}{R_p} = \dfrac{1}{10} + \dfrac{1}{15} = \dfrac{1}{6}$ $\checkmark$

                  $R_p = 6 \text{ Ω}$ $\checkmark$ [CL2] (2)

           12.1.6 $R_{ext} = \dfrac{V_{\text{load}}}{I} = \dfrac{11{,}7}{1{,}5}\checkmark = 7{,}8 \text{ Ω}$ $\checkmark$

                  $R = R_{ext} - 6 = 7{,}8 - 6\checkmark = 1{,}8 \text{ Ω}$ $\checkmark$ [CL3] (4)

           12.2.1 $W = mg = (0{,}35)(9{,}8) = 3{,}43 \text{ N}$ $\checkmark$

                  $P = Fv = (3{,}43)(0{,}4\checkmark) = 1{,}37 \text{ W}$ $\checkmark$ [CL3] (3)

           12.2.2 $P = VI$

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

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

                  $P = I^2 R$

                  $1{,}37 = (0{,}46)^2 R$

                  $R = 6{,}47 \text{ Ω}$ $\checkmark$

                  $emf = I(R_{ext} + r)$

                  $12 = 0{,}46(R_{ext} + 0{,}2)$

                  $R_{ext} = 25{,}89 \text{ Ω}$ $\checkmark$

                  $R_T = R_{ext} - 6{,}47 = 25{,}89 - 6{,}47 = 19{,}42 \text{ Ω}$ $\checkmark$ [CL3] (5)

13. **13.1** Current is directly proportional to potential difference ✓ at constant temperature. ✓ [CL1] (2)

13.2 Ratio of resistances

8 Ω : 16 Ω

1 : 2 ✓

Current divides in the inverse ratio to resistance

2 : 1 ✓

0,5 A : 0,25 A ✓

$I_1 = 0,5 + 0,25 = 0,75\,A$ ✓ [CL2] (4)

13.3 Resistance in top branch:

$\dfrac{1}{R_p} = \dfrac{1}{8} + \dfrac{1}{16} = \dfrac{3}{16}$

$R_p = 5,33\,\Omega$ ✓

$R_{top} = 20 + 5,33 = 25,33\,\Omega$ ✓

$V_{top} = R_{top}I = (25,33)(0,75) = 19\,V$ ✓

$V_R = 19\,V$

$P = VI$

$12\checkmark = (19)I$

$I_2 = 0,63\,A$ ✓ [CL3] (5)

13.4 $I = 0,75 + 0,63 = 1,38\,A$

$emf = V_{load} + V_{internalresitance}$

$emf = 19 + Ir$

$emf = 19 + (1,38\checkmark)(1\checkmark)$

$emf = 19 + 1,38 = 20,38\,V$ ✓ [CL3] (3)

14. **14.1** **14.1.1** Battery is at constant temperature. ✓ [CL2] (1)

14.1.2

Line graph to show the relationship between the voltmeter and ammeter readings
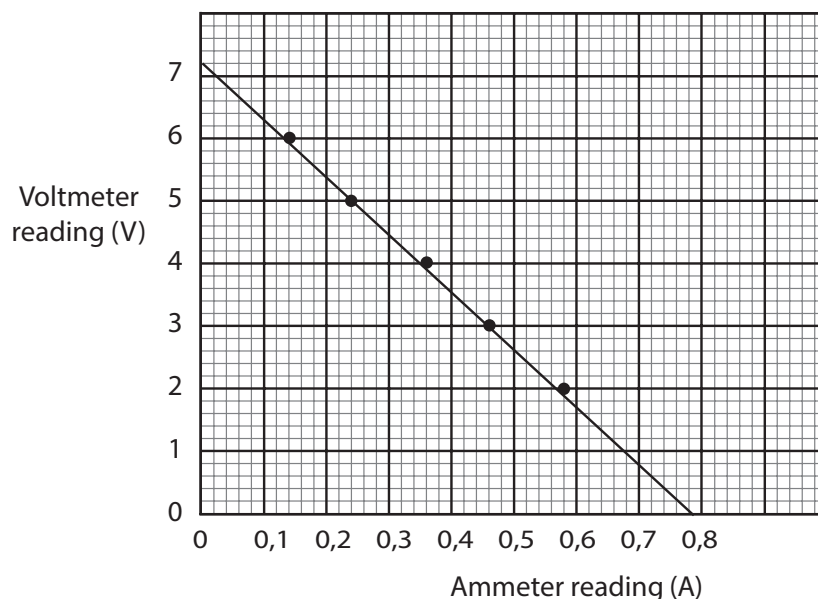
Heading. ✓
Both axes labelled with units. ✓ ✓
Good scales. ✓
Points plotted. ✓
Line of best fit. ✓ [CL2] (6)

14.1.3 $emf = V_{load} + V_{internal\ resistance}$

$V_{load} = emf - V_{internal\ resistance}$

$V_{load} = emf - Ir$

$V_{load} = Ir + emf$

$V = rI + emf$

$y = mx + c$

$y\ intercept = emf = 7,2\ V$ ✓ [CL3] (1)

14.1.4 $m = gradient = -r$

$r = \dfrac{\Delta y}{\Delta x} = \dfrac{0 - 7,2✓}{7,8 - 0✓} = \dfrac{-7,2}{7,8} = -0,92$

$r = 0,92\ \Omega$ ✓ [CL3] (3)

14.2.1 $P = VI$

$100✓ = (20✓)I$

$I_X = 5\ A$ ✓ [CL2] (3)

14.2.2 $P = \dfrac{V^2}{R}$

$R_Y = \dfrac{V^2}{P} = \dfrac{(20)^2✓}{150✓} = 2,67\ \Omega$ ✓ [CL3] (3)

14.2.3 $P = VI$

$I_Y = \dfrac{P}{V} = \dfrac{150}{20} = 7,5\,A$ ✓

$I = 5 + 7,5 = 12,5\,A$ ✓

$emf = V_{load} + V_{internal\,resitance}$

$emf = 20$✓$ + Ir$

24✓$ = 20 + (12,5)r$

$r = 0,32\,\Omega$ ✓   [CL3] (5)

14.2.4 Z is a voltmeter. ✓   [CL2] (1)

14.2.5 A voltmeter has a very high resistance ✓ and does not affect the circuit current. ✓   [CL4] (2)

ASSESSMENTS

Topic 11: Electrodynamics

QUESTIONS

MULTIPLE CHOICE QUESTIONS

1. In a DC generator the current to the external circuit is delivered through the …
    A   coils.
    B   battery.
    C   slip rings.
    D   split rings (commutators).   (2)

2. Which ONE of the following will NOT increase the output current of a generator?
    A   Increase the number of turns in the coil.
    B   Wind the armature coil around an aluminium core.
    C   Increase the speed of rotation of the armature coil.
    D   Increase the strength of the magnet.   (2)

3. 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.   (2)

4. A DC current passes through a rectangular wire loop OPQR placed between two
    pole pieces of a magnet, as shown below.
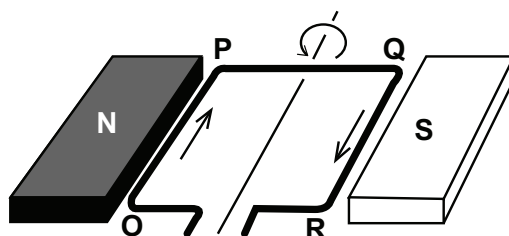
Which TWO segments of the loop will experience an electromagnetic force when
    the loop is in the position as shown in the diagram?
    A   OP and PQ.
    B   QR and RO.
    C   OP and QR.
    D   RO and OP.   (2)

5, The coils of an AC generator make one complete rotation. The resulting graph for the output emf is shown below.
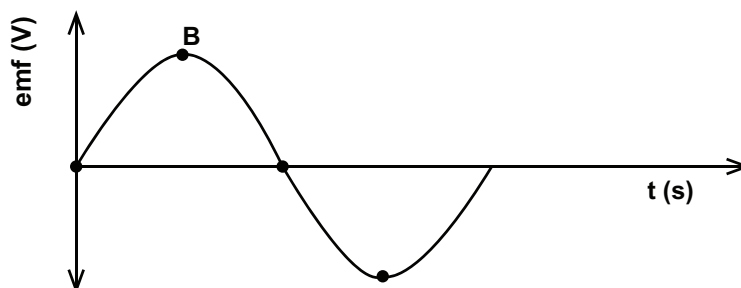
The position B on the graph is obtained when the plane of the coil is at an angle of … to the magnetic field

A 0º

B 60º

C 90º

D 120º (2)

6, In the diagram below, a conductor placed between two magnets is carrying current out of the page.
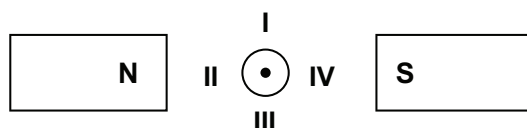
The direction of the force exerted on the conductor is towards:

A I

B II

C III

D IV (2)

7, The diagram below shows the cross-section of a conductor with conventional current flowing into the page. The conductor is placed between two magnets as shown.
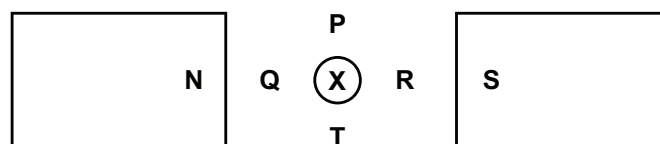
In which direction will the conductor experience a force?

A Towards P.

B Towards Q.

C Towards R.

D Towards T. (2)

8. In the sketch below, a conductor carrying current I, is placed in a magnetic field.
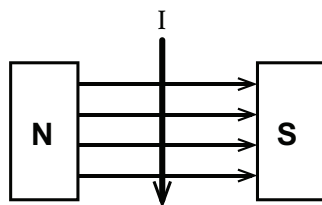
Which one of the following best describes the direction of the magnetic force experienced by the conductor?

A   Parallel to the direction of the magnetic field.

B   Opposite to the direction of the magnetic field.

C   Into the page perpendicular to the direction of the magnetic field.

D   Out of the page perpendicular to the direction of the magnetic field.   (2)

LONG QUESTIONS

9. A simplified diagram of an AC generator is shown below.
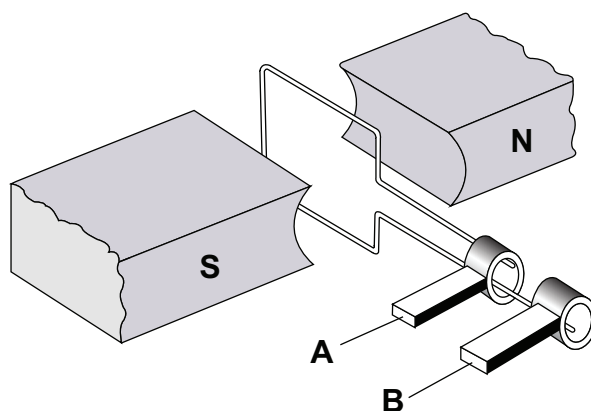
9.1   Name the component in this arrangement that makes it different from a DC generator.   (1)

9.2   Sketch a graph of induced emf versus time for one complete rotation in the coil. Start your graph with the coil in the position shown above.   (3)

A practical version of the generator above has a large number of turns of the coil and it produces an rms potential difference of 240 V.

9.3   State TWO ways in which the induced emf can be increased.   (2)

9.4   Define the term "root mean square (rms) value of an AC potential difference".   (2)

9.5   The practical version of the generator is connected across an appliance rated at 1 500 W. Calculate the rms current passing through the appliance.   (3)

10. The diagram below shows the essential parts of a generator.
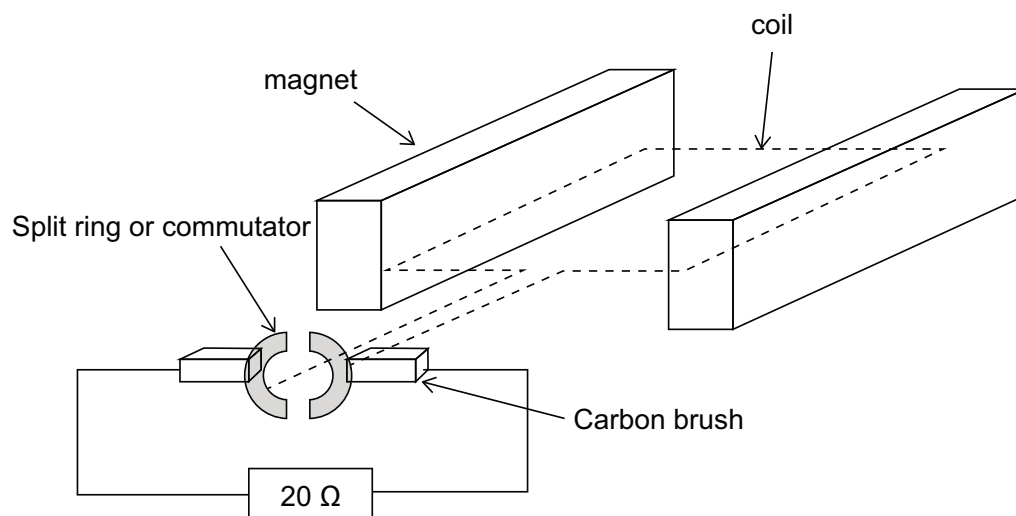
10.1 The coil rotates within the magnetic field. Write down the type of current (AC or DC):

    10.1.1 induced in the coil. (1)

    10.1.2 passing through the 20 Ω resistor. Give a reason for the answer. (2)

10.2 An AC generator is used in the commercial production of electricity.

    10.2.1 State ONE fundamental difference in construction between an AC generator and a DC generator. (2)

    10.2.2 Fully explain why AC is preferred to DC for transmission of electricity over long distances. (3)

10.3 The diagram below shows the output of the above AC generator. A 20 Ω resistor is connected in the circuit.
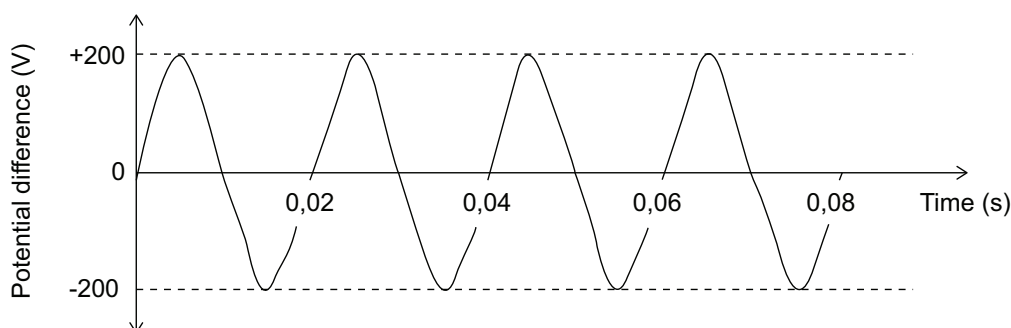
Calculate the:

    10.3.1 frequency of the power source. (2)

    10.3.2 average power dissipated in the resistor. (5)

11. A simplified diagram of a generator is shown below. Assume that the coil is in a vertical position.
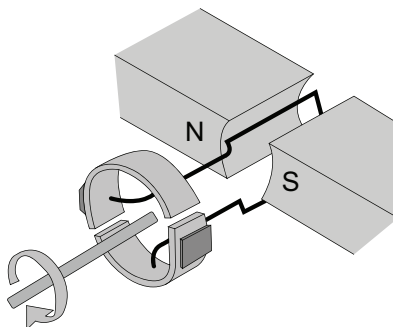
     11.1.1 Is this an AC or a DC generator? Give a reason for the answer. (2)

     11.1.2 Sketch an induced emf versus time graph for ONE complete rotation of the coil. (The coil starts turning from the vertical position.) (3)

    11.2 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.
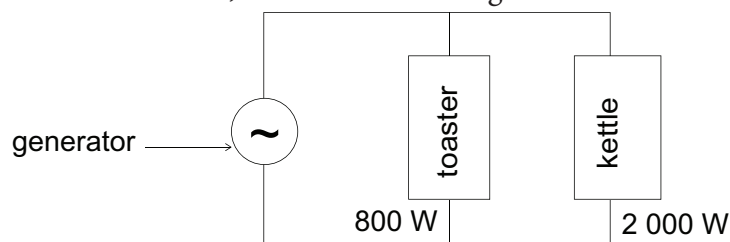
The toaster is rated at 800 W, while the kettle is rated at 2 000 W. Both are working under optimal conditions.

Calculate the:

     11.2.1 rms current passing through the toaster. (4)

     11.2.2 total rms current delivered by the generator. (3)

12.1 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, in and out of the coil as shown by the arrow in the diagram below.
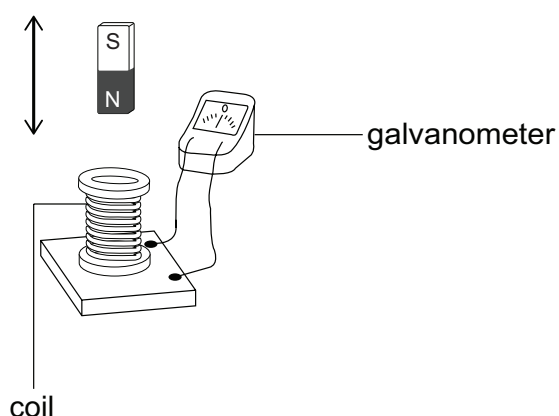
     12.1.1 Briefly describe how the magnet must be moved in order to obtain a LARGE deflection on the galvanometer. (2)

The two devices, A and B, below operate on the same principle as that which produced the deflection on the galvanometer in **12.1.1** above.
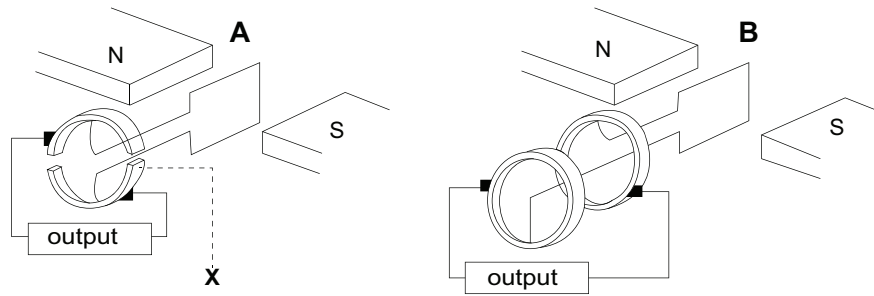
12.1.2 Write down the name of the principle. (1)

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

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

12.2.1 electrical energy consumed by the kettle per second. (4)

12.2.2 maximum (peak) current through the kettle. (3)

13. The diagram below represents a simplified version of an electrical machine used to light up a bulb.
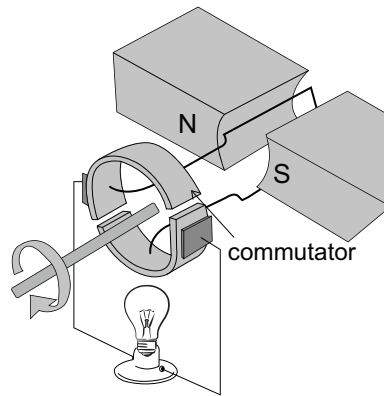
13.1 Name the principle on which the machine operates. (1)

13.2 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.
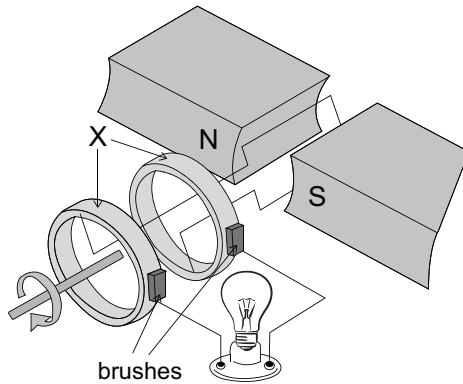
13.3 Name part X in the new device. (1)

13.4 The graph of output emf versus time obtained using the new device in question 13.3 is shown below.
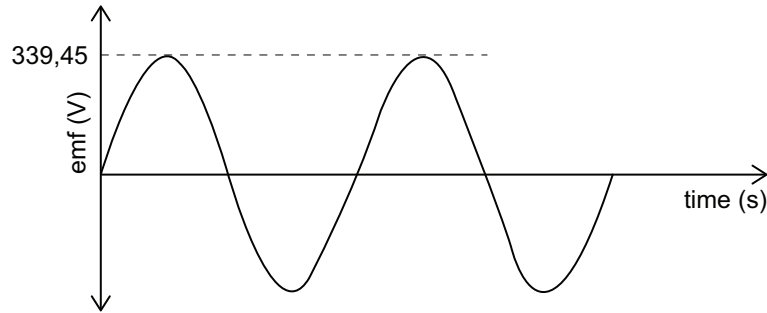
13.4.1 Define the term "root mean square value of an AC voltage". (2)

13.4.2 Calculate the rms voltage. (3)

14.

14.1 A simplified diagram of an electric motor is shown below.
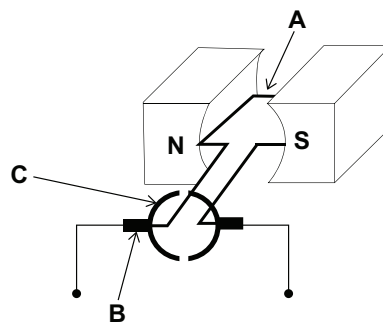
14.1.1 Name the components labelled A, B and C. Write down only the name of the component next to the letter (A–C). (3)

14.1.2 Write down the function of the component labelled B. (1)

14.1.3 Is this motor an AC motor or a DC motor? (1)

14.1.4 Give a reason why component A experiences a magnetic force when a current passes through it. (2)

14.2 A coil is rotated in a magnetic field. The varying induced emf obtained is shown in the graph below.
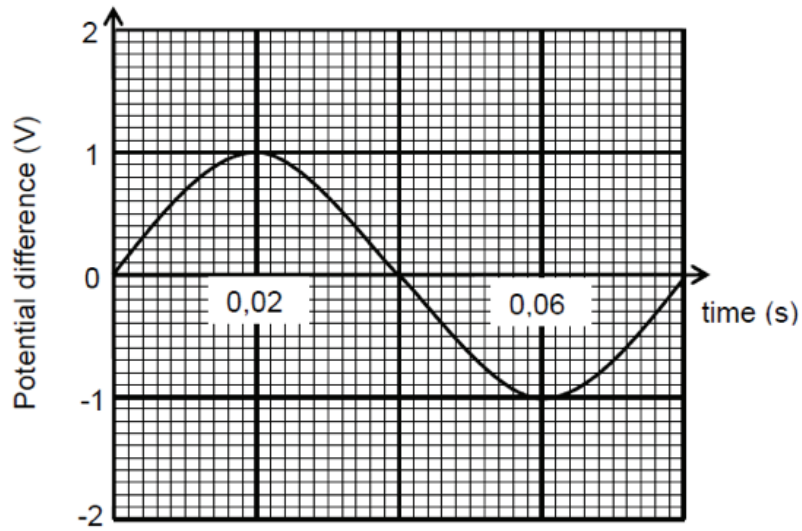
14.2.1 Calculate the induced rms potential difference. (3)

14.2.2 Calculate the average power generated if the generator produces a maximum current of 2 A. (4)

14.2.3 The coil is now rotated at TWICE the original speed. Write down the period of the new wave. (2)

MARKING GUIDELINES

ANSWERS TO MULTIPLE CHOICE QUESTIONS

1. D✓ ✓   A split ring converts the AC in the coil into DC in the external circuit.

[CL2] (2)

2. B✓ ✓   An iron core should be used as it is easily magnetised.   [CL2] (2)

3. B✓ ✓   Increasing the area of coil increases the magnetic flux passing through the coil. When it is rotated, there will be a greater change in magnetic flux passing through the surface area bounded by the coil, leading to a greater induced emf in the coil.   [CL3] (2)

4. C✓ ✓   The current is perpendicular to the magnetic field.   [CL2] (2)

5. A✓ ✓   The greatest rate of change of magnetic flux through the coil occurs when the plane of the coil is parallel to the magnetic field. The induced emf in the coil is a maximum at this point.   [CL3] (2)

6. A✓ ✓   Fleming's left hand motor rule.   [CL2] (2)

7. D✓ ✓   Fleming's left hand motor rule.   [CL2] (2)

8. D✓ ✓   Fleming's left hand motor rule.   [CL2] (2)

ANSWERS TO LONG QUESTIONS

9.   **9.1**   The slip rings. ✓   [CL2] (1)

9.2
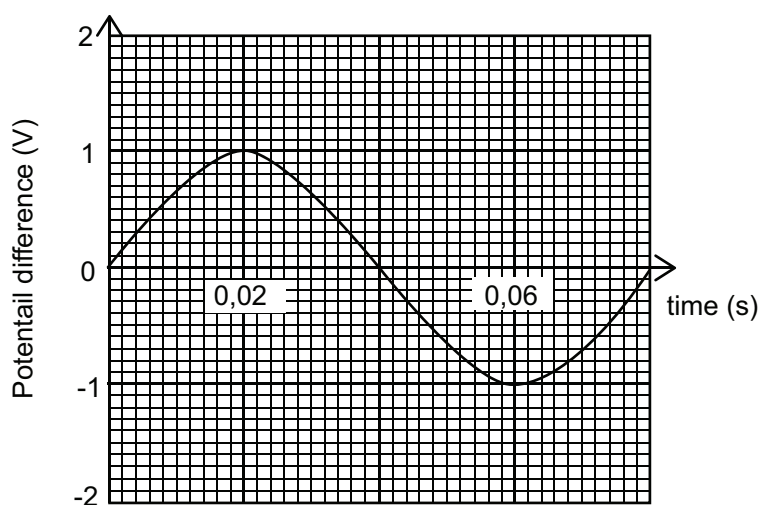
[CL2] (3)

9.3   Rotate the coil faster (increase the frequency of rotation). ✓
Increase the number of turns in the coil. ✓
Use stronger magnets.
Increase the surface area of the coil.   [CL1] (2)

9.4 The equivalent DC voltage necessary to deliver the same power
as the AC voltage. ✓ ✓ [CL1] (2)

9.5 $P_{av} = V_{rms} I_{rms}$

$I_{rms} = \dfrac{P_{av}}{V_{rms}} = \dfrac{1500✓}{240✓} = 6,25 \text{ A} ✓$ [CL2] (3)

10. **10.2** **10.1.1** AC. ✓ [CL1] (1)

10.1.2 DC. ✓

The split ring commutator changes the AC in the coil to DC in the
external circuit. ✓ [CL2] (2)

10.2.1 The AC generator has slip rings instead of a split ring or commutator.
✓ ✓ [CL2] (2)

10.2.2 AC voltages can be stepped up using a transformer. ✓
Stepping up the voltage steps down the current. ✓
Lower current in power lines means less power is dissipated over long
distances. ✓ [CL3] (3)

10.3 **10.3.1** $f = \dfrac{1}{T} = \dfrac{1}{0,02✓} = 50 \text{ Hz} ✓$ [CL1] (2)

10.3.2 $V_{rms} = \dfrac{V_{max}}{\sqrt{2}} = \dfrac{200✓}{\sqrt{2}} = 141,42 \text{ V} ✓$

$P_{av} = \dfrac{V_{rms}^2}{R}✓ = \dfrac{(141,42)^2}{20✓} = 1000 \text{ W} ✓$ [CL3] (5)

11. **11.1** **11.1.1** DC. ✓

A split ring or commutator is used. ✓ [CL2] (2)

11.1.2
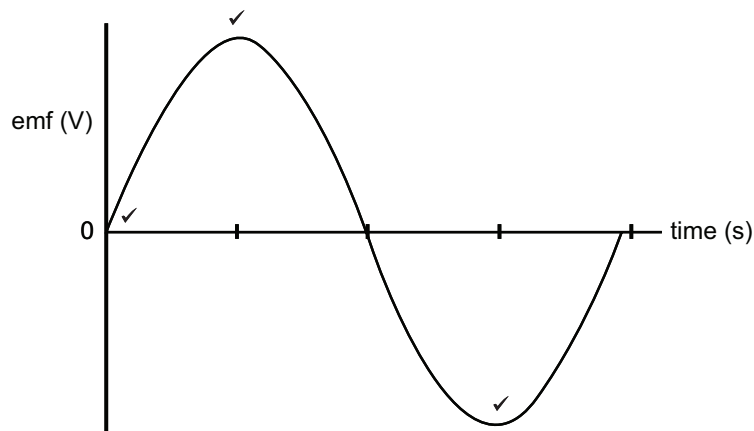
[CL2] (3)

11.2.1 $V_{rms} = \dfrac{V_{max}}{\sqrt{2}} = \dfrac{340✓}{\sqrt{2}} = 240,42 \text{ V} ✓$

$P_{av} = V_{rms} I_{rms}$

$I_{rms} = \dfrac{P_{av}}{V_{rms}} = \dfrac{800✓}{240,42} = 3,33 \text{ A} ✓$ [CL3] (4)

11.2.2 $I_{rms} = \dfrac{P_{av}}{V_{rms}} = \dfrac{2\,000✓}{240,42} = 8,32 \text{ A} ✓$

$I_{total\,rms} = 3,33 + 8,32 = 11,65 \text{ A} ✓$ [CL3] (3)

12. **12.1** **12.1.1** Move the magnet faster. ✓ ✓

Move the magnet closer to the coil. [CL2] (2)

12.1.2 Electromagnetic induction. ✓ [CL1] (1)

12.1.3 Split ring or commutator. ✓ [CL1] (1)

12.2.1 $P_{av} = \dfrac{V_{rms}^2}{R}✓ = \dfrac{(240✓)^2}{40,33✓} = 1428,22\,W$ ✓ [CL3] (4)

12.2.2 $P_{av} = V_{rms}I_{rms}$

$I_{rms} = \dfrac{P_{av}}{I_{rms}} = \dfrac{1428,22}{240}✓ = 5,95\,A$ ✓

$I_{rms} = \dfrac{I_{max}}{\sqrt{2}}$

$I_{max} = \sqrt{2}\,I_{rms} = \sqrt{2}\,(5,95) = 8,42\,A$ ✓ [CL3] (3)

13. **13.1** Electromagnetic induction. ✓ [CL1] (1)

13.2 Rotate the coil faster (increase the frequency of rotation). ✓

Increase the number of turns in the coil.

Use stronger magnets.

Increase the surface area of the coil. [CL1] (1)

13.3 Slip rings. ✓ [CL1] (1)

13.4.1 The equivalent DC voltage necessary to deliver the same power

as the AC voltage. ✓ ✓ [CL1] (2)

13.4.2 $V_{rms} = \dfrac{V_{max}}{\sqrt{2}} = \dfrac{339,45✓}{\sqrt{2}} = 240,03\,V$ ✓ [CL2] (3)

14. **14.1** **14.1.1** A Coil. ✓

B Carbon brush. ✓

C Split ring or commutator. ✓ [CL1] (3)

14.1.2 Makes contact with the split ring commutator so that there is DC in

the coil. ✓ [CL2] (1)

14.1.3 DC motor. ✓ [CL2] (1)

14.1.4 There is a current in the coil.

The magnetic field around the current carrying coil ✓ interacts with

the magnetic field between the permanent magnets, ✓ producing a

magnetic force on the coil. [CL3] (2)

14.2.1 $V_{rms} = \dfrac{V_{max}}{\sqrt{2}}✓ = \dfrac{1✓}{\sqrt{2}} = 0,71V$ ✓ [CL2] (3)

14.2.2 $I_{rms} = \dfrac{I_{max}}{\sqrt{2}} = \dfrac{2✓}{\sqrt{2}} = 1,41A$ ✓

$P_{av} = V_{rms}I_{rms}✓ = (0,71)(1,41) = 1,00\,W$ ✓ [CL3] (4)

14.2.3 $T = \dfrac{0,08\,s}{2}✓ = 0,04\,s$ ✓ [CL3] (2)

Topic 12: Optical phenomena and properties of matter

QUESTIONS

MULTIPLE CHOICE QUESTIONS

1. In an experiment investigating the photoelectric effect, the frequency of the incident light is high enough to cause the removal of electrons from the surface of the metal. The number of electrons ejected from the metal surface is proportional to the …

    A kinetic energy of the electrons.

    B number of incident photons.

    C work function of the metal.

    D frequency of the incident light. (2)

2. A metallic surface emits photoelectrons when irradiated with green light. When the green light is replaced by ultraviolet light, the kinetic energy (E_k) of the emitted photoelectrons will …

    A increase.

    B decrease.

    C drop to zero.

    D remain the same. (2)

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 … the energy 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)

4. 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)

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

    A   Increase the intensity of the light.

    B   Use light with a much shorter wavelength.

    C   Use metal with a larger work function.

    D   Increase the surface area of the metal.   (2)

6. The diagram below shows the electron transitions P, Q, R and S between different energy levels in an atom.
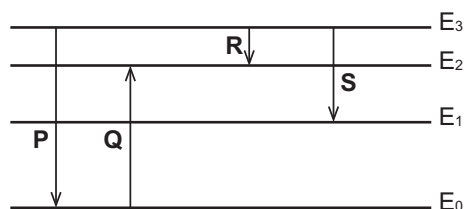
    Which ONE of the transitions will result in an emission of a radiation with the longest wavelength?

    A   P

    B   Q

    C   R

    D   S   (2)

7. A learner makes the observations below after conducting an experiment using a photocell with frequencies of the incident light being above the threshold frequency (cut-off frequency).

    (i)   The photocurrent increases as the intensity of the incident light increases.

    (ii)   The ammeter in the circuit registers a current immediately after the incident light is radiated on the cathode.

    (iii)   The photocurrent increases as the frequency of the incident light increases.

    Which of the observation(s) is/are CORRECT?

    A   (i) only.

    B   (ii) only.

    C   (i) and (ii) only.

    D   (i), (ii) and (iii).   (2)

8. Light spectra help to identify elements. White light is passed through a cold gas and then through a prism as shown in the sketch below.
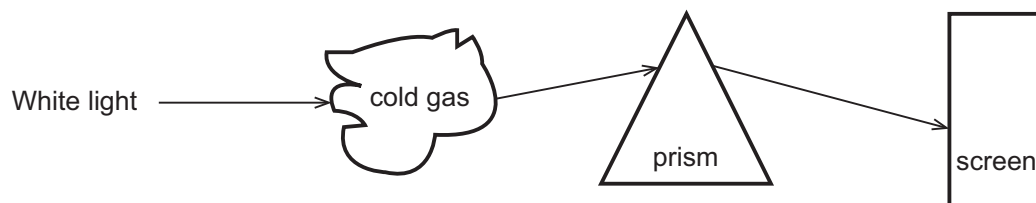
What type of spectrum is observed on the screen?
A Line absorption spectrum.
B Line emission spectrum.
C Continuous absorption spectrum.
D Continuous emission spectrum. (2)

LONG QUESTIONS

9. The graph below is obtained for an experiment investigating the photoelectric effect using different frequencies of light and a given metal plate.
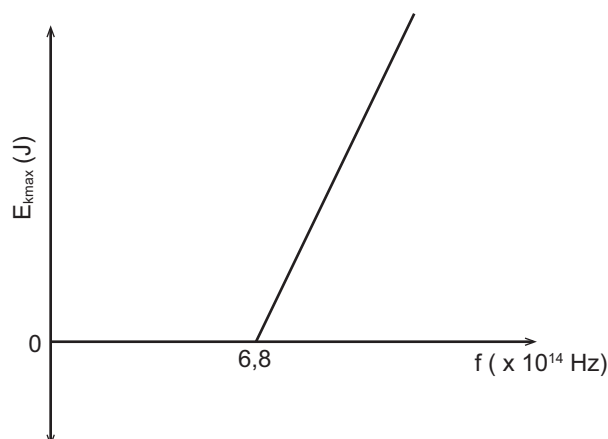
The threshold frequency for the metal is $6,8 \times 10^{14}\,\text{Hz}$.

9.1 Define the term "threshold frequency". (2)

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

9.2 State how this change influences the speed of the photoelectrons emitted. Choose from INCREASES, DECREASES or REMAINS UNCHANGED. (1)

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

One of the radiations used in this experiment has a frequency of $7,8 \times 10^{14}\,\text{Hz}$.

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

10. Incident light of different wavelengths was shone on a metal cathode in an evacuated tube as shown in the diagram below.
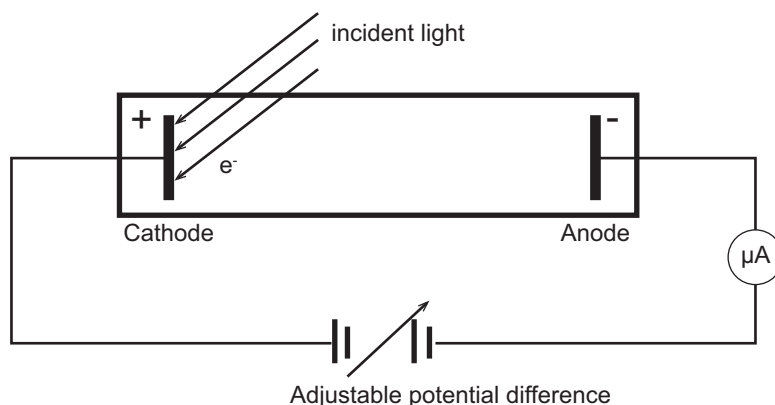
It was found that light of 500 nm releases electrons with zero kinetic energy. The micro-ammeter gives a zero reading.

10.1 Define the term "work function". (2)

10.2 Calculate the work function of the metal used as cathode. (3)

10.3 How will each of the following changes, implemented separately, affect the reading on the micro-ammeter? Choose from INCREASES, DECREASES or REMAINS THE SAME.

    10.3.1 The intensity of the light is increased. (1)

    10.3.2 Light of a wavelength 550 nm is used. (1)

10.4 The metal cathode is now irradiated with light of wavelength 400 nm. Calculate the maximum kinetic energy of an emitted photoelectron. (5)

11. 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.
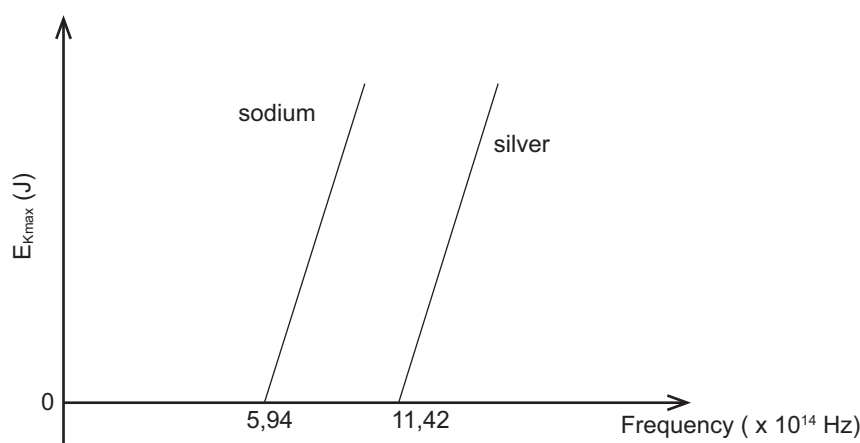
    11.1.1 Define the term "threshold frequency". (2)

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

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

11.1.4 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)

11.2 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.

11.2.1 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)

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

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

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

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

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

12.3 USE THE GRAPH to determine:

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

12.3.2 Planck's constant. (5)

ASSESSMENTS

13. Ultraviolet light is incident onto a photocell with a potassium cathode as shown in the diagram below. The threshold frequency of potassium is $5,548 \times 10^{14}\,\text{Hz}$.
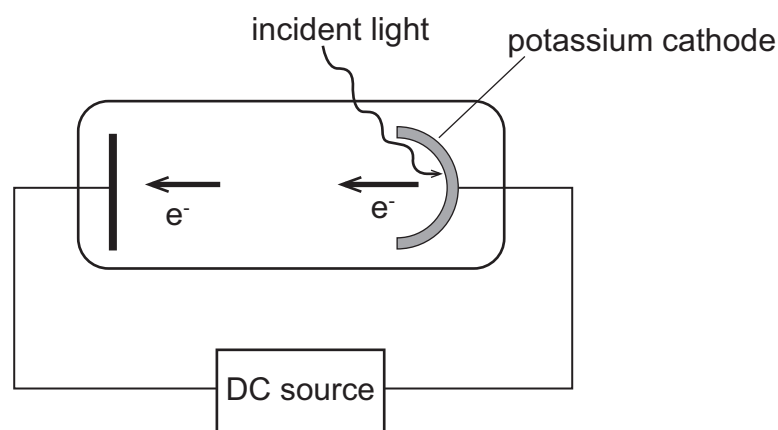
13.1 Define the term "threshold frequency" ("cut-off frequency"). (2)

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

13.2 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 $6,10 \times 10^{5}\,\text{m·s}^{-1}$ when the same ultraviolet light source is used.

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

13.4 Explain the answer to question 13.3. (3)

14. **14.1** The apparatus below is used to demonstrate the photoelectric effect.
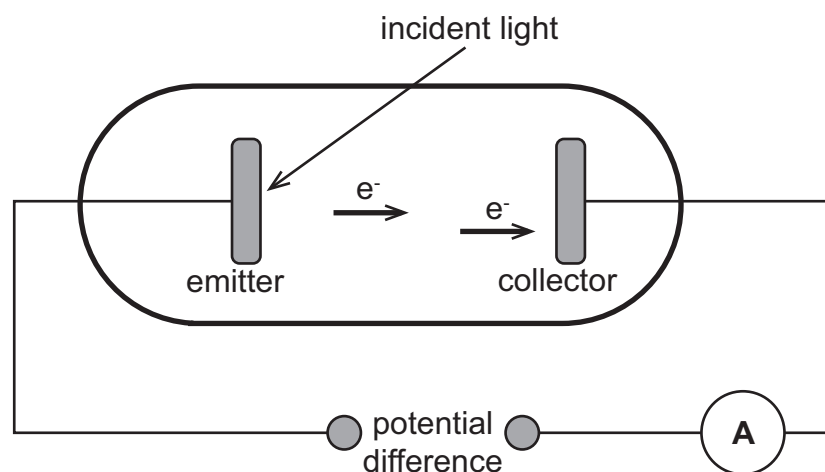
      14.1.1 Define, in words, the "photoelectric effect". (2)

The incident monochromatic light transfers $1,8 \times 10^{-9}$ J of energy in one second to a certain area of the emitter. The wavelength of a photon in the incident light is 260 nm. If one photon releases one electron, calculate the:

14.1.2 number of electrons released from the surface of that area of the emitter in one second. (5)

14.1.3 current produced, in amperes. (4)

14.2 The sketch below shows an example of a line emission spectrum.

14.2.1 Briefly explain how this type of spectrum is formed by referring to electron transitions in atoms. (2)

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

MARKING GUIDELINES

ANSWERS TO MULTIPLE CHOICE QUESTIONS

1. B✓ ✓   The more photons arriving per second, the more electrons are ejected per second. [CL2] (2)

2. A✓ ✓ $E = W_o + E_{k(max)}$
    $E_{k(max)} = E - W_o$
    $E_{k(max)} = hf - W_o$
    The frequency of UV light is greater than green light.
    The energy of the incoming photon is greater $E = hf$.
    The work function of the metal is a constant.
    $E_{k(max)}$ will increase. [CL3] (2)

3. B✓ ✓ $E_Q = \dfrac{hc}{\lambda_Q}$
    $E_P = \dfrac{hc}{\lambda_P} = 2\dfrac{hc}{\lambda_Q} = \dfrac{1}{2}E_Q$ [CL2] (2)

4. A✓ ✓ [CL2] (2)

5. B✓ ✓ $E = \dfrac{hc}{\lambda}$
    The energy of a photon is inversely proportional to the wavelength of light. A shorter wavelength will result in a photon of higher energy.
    [CL3] (2)

6. C✓ ✓ $E = E_3 - E_2$
    $E = \dfrac{hc}{\lambda}$
    The energy of a photon is inversely proportional to the wavelength of light. A longer wavelength corresponds to a photon of lower energy.
    $E_3 - E_2$ represents the smallest energy difference. [CL3] (2)

7. C✓ ✓   Increasing the intensity of the light, increases the number of electrons being ejected per second. More electrons will be arriving at the other electrode per second, leading to a higher current.
    The photoelectric effect happens immediately when the light is shone on the metal surface (if the frequency is higher than the threshold frequency).
    Increasing the frequency will increase the energy of the photon and the kinetic energy of the ejected electron. However, the same charge would arrive at the anode per unit time, ie the current will remain the same. [CL4] (2)

8. A✓ ✓   Certain wavelengths of light are absorbed by the cold gas and are missing in the spectrum. [CL1] (2)

ANSWERS TO LONG QUESTIONS

9.   9.1   The minimum frequency of incident radiation at which electrons will be
              emitted from a particular metal. ✓ ✓   [CL2] (2)

      9.2   Remains unchanged. ✓
             Increasing the brightness (intensity) of the light has no effect on kinetic
             energy.   [CL2] (1)

      9.3 $c = f\lambda$

             $f = \dfrac{c}{\lambda} = \dfrac{3 \times 10^8 \checkmark}{6 \times 10^{-7} \checkmark} = 5 \times 10^{14}$ Hz ✓

             NO photoelectric emission ✓ , the incident frequency is less than ✓ the
             threshold frequency $f_0 = 6{,}8 \times 10^{14}$ Hz .   [CL3] (5)

      9.4 $E = W_o + E_{k(max)}$

             $hf = hf_0 + \dfrac{1}{2}mv_{max}^2$ ✓

             $(6{,}63 \times 10^{-34})(7{,}8 \times 10^{14})\checkmark = (6{,}63 \times 10^{-34})(6{,}8 \times 10^{14})\checkmark + \dfrac{1}{2}(9{,}11 \times 10^{-31})v_{max}^2$ ✓

             $5{,}1714 \times 10^{-19} = 4{,}5084 \times 10^{-19} + 4{,}555 \times 10^{-31}v_{max}^2$

             $6{,}63 \times 10^{-20} = 4{,}555 \times 10^{-31}v_{max}^2$

             $v_{max}^2 = 1{,}455543 \times 10^{11}$

             $v_{max} = 3{,}82 \times 10^5$ m·s^{-1} ✓   [CL3] (5)

10.   10.1   The minimum amount of energy needed to emit an electron from the
             surface of a metal. ✓ ✓   [CL1] (2)

      10.2 $W_o = hf_0 = \dfrac{hc}{\lambda} = \dfrac{(6{,}63 \times 10^{-34})(3 \times 10^8 \checkmark)}{500 \times 10^{-9}\checkmark} = 3{,}98 \times 10^{-19}$ J ✓   [CL3] (3)

      10.3   10.3.1 Increases. ✓
                     Higher intensity means more photons are arriving per second,
                     therefore more electrons are ejected per second.   [CL2] (1)

             10.3.2 Decreases. ✓
                     A longer wavelength results in a decrease in frequency.
                     Now the light has a frequency less than the threshold frequency, no
                     electrons are ejected, no reading on the micro-ammeter.   [CL2] (1)

      10.4 $E = W_o + E_{k(max)}$

             $\dfrac{hc}{\lambda} = W_o + E_{k(max)}$ ✓

             $\dfrac{(6{,}63 \times 10^{-34})(3 \times 10^8 \checkmark)}{400 \times 10^{-9}} = 3{,}98 \times 10^{-19} + E_{k(max)}$

             $4{,}9725 \times 10^{-19} = 3{,}98 \times 10^{-19} + E_{k(max)}$

             $E_{k(max)} = 9{,}93 \times 10^{-20}$ J ✓   [CL3] (5)

ASSESSMENTS

11. **11.1** **11.1.1** The minimum frequency of incident radiation at which electrons will be emitted from a particular metal. ✓ ✓ [CL1] (2)

11.1.2 Silver. ✓

Silver has the larger threshold frequency ✓ and $W_o = hf_o$.

Work function is directly proportional to the threshold frequency. ✓

[CL2] (3)

11.1.3 Plank's constant h. ✓

$E = W_o + E_{k(max)}$

$E_{k(max)} = E - W_o$

$E_{k(max)} = hf - W_o$

$y = mx + c$

gradient $= m = h$ [CL3] (1)

11.1.4 Sodium. ✓ [CL2] (1)

11.2 **11.2.1** $P = \dfrac{W}{t} = \dfrac{\text{Energy transferred}}{t}$

$P = \dfrac{5}{100} \times (60 \times 10^{-3}\ \text{W}) = 0{,}003\ \text{W} = 0{,}003\ \text{J·s}^{-1}$ ✓

In 1 second 0,003 J of energy is incident on the metal surface.

Each photon has an energy of:

$E = \dfrac{hc}{\lambda} = \dfrac{(6{,}63 \times 10^{-34})(3 \times 10^{8})}{470 \times 10^{-9}} = 4{,}23192 \times 10^{-19}\ \text{J}$ ✓

number of photons arriving per second $= \dfrac{0{,}003\text{J} ✓}{4{,}23192 \times 10^{-19}} = 7{,}09 \times 10^{15}$ ✓

[CL4] (5)

11.2.2 $7{,}09 \times 10^{15}$ ✓ electrons are emitted per second.

One photon per electron. [CL2] (1)

12. **12.1** The process that occurs when light shines on a metal and electrons are ejected. ✓ ✓ [CL1] (2)

12.2

Line graph to show the relationship between the
maximum kinetic energy of the ejected electrons and
the inverse of the wavelength of incident light.
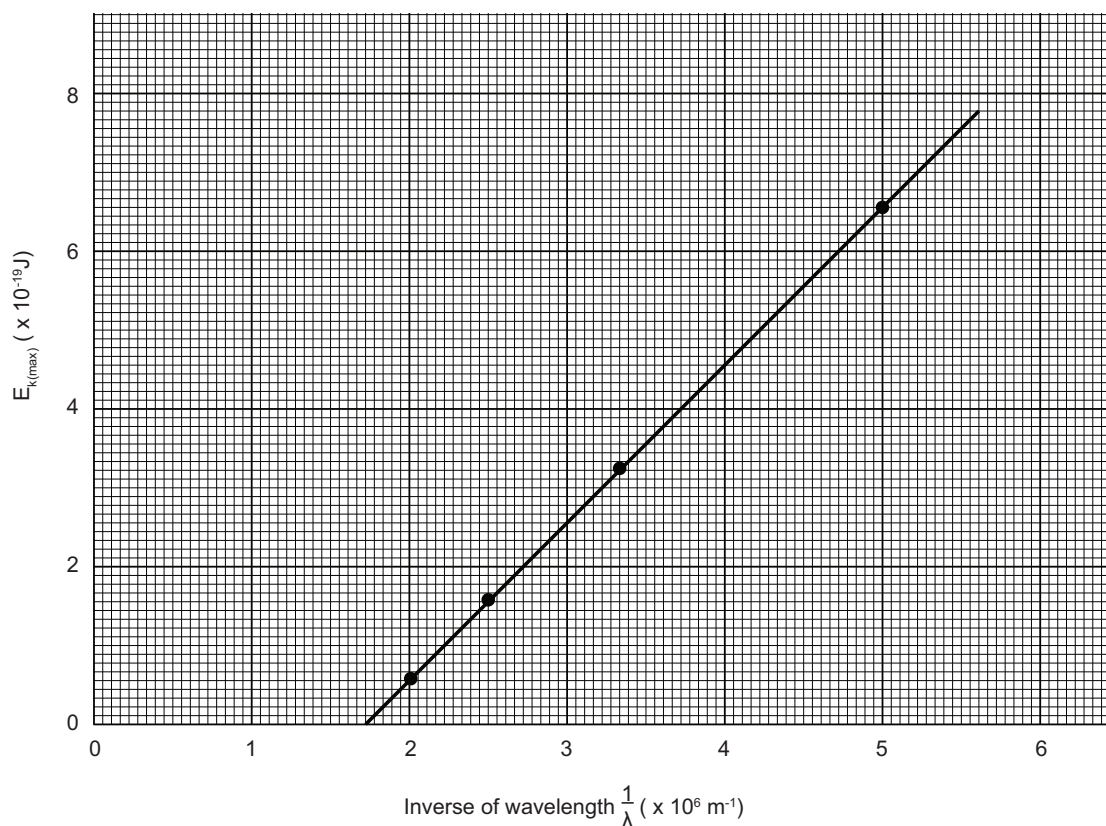
✓ Plotted points   ✓ Line of best fit   ✓ Labels on axes with units

[CL2] (3)

12.3.1 $x \text{ intercept} = \dfrac{1}{\lambda} = 1{,}65 \times 10^{6}$ ✓

$f_{o} = \dfrac{c}{\lambda}$ ✓ $= c\dfrac{1}{\lambda} = (3 \times 10^{8}$ ✓$)(1{,}65 \times 10^{6}) = 4{,}95 \times 10^{14} \text{ Hz}$ ✓   [CL3] (4)

12.3.2 $E = W_{o} + E_{k(max)}$

$E_{k(max)} = E - W_{o}$

$E_{k(max)} = \dfrac{hc}{\lambda} - W_{o}$

$E_{k(max)} = hc\left(\dfrac{1}{\lambda}\right) - W_{o}$

$y = mx + c$

$\text{gradient} = m = hc$

$\text{gradient} = \dfrac{\Delta y}{\Delta x} = \dfrac{(6{,}60 - 0{,}70) \times 10^{-19}\,✓}{(5 - 2) \times 10^{6}\,✓} = 1{,}96667 \times 10^{-25}$ ✓

$hc = 1{,}96667 \times 10^{-25}$

$h = \dfrac{1{,}96667 \times 10^{-25}}{3 \times 10^{8}\,✓} = 6{,}56 \times 10^{-34}$ ✓   [CL3] (5)

ASSESSMENTS

13. **13.1** The minimum frequency of incident radiation at which electrons will be emitted from a particular metal. ✓ ✓ [CL1] (2)

13.2 $E = W_o + E_{k\,(max)}$

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

$$\frac{(6,63 \times 10^{-34})(3 \times 10^8)\checkmark}{\lambda} = (6,63 \times 10^{-34})(5,548 \times 10^{14})\checkmark + \frac{1}{2}(9,11 \times 10^{-31}\checkmark)(5,33 \times 10^5)^2\ \checkmark$$

$$\frac{1,989 \times 10^{-25}}{\lambda} = 3,6783 \times 10^{-19} + 1,2940 \times 10^{-19}$$

$$\frac{1,989 \times 10^{-25}}{\lambda} = 4,9723 \times 10^{-19}$$

$$4,9723 \times 10^{-19}\lambda = 1,989 \times 10^{-25}$$

$$\lambda = 4,00 \times 10^{-7}\,\text{m}\ \checkmark \qquad\qquad\qquad\qquad \text{[CL3] (5)}$$

13.3 **13.3.1** Smaller than. ✓ [CL2] (1)

13.3.2 The energy of the incoming photon is a constant.

$E_{k(max)} = E - W_o$ ✓

If the work function is smaller, then there will be more kinetic energy ✓ and a greater maximum speed ✓ of the ejected electron. [CL3] (3)

14. **14.1** **14.1.1** The process that occurs when light shines on a metal and electrons are ejected. ✓ ✓ [CL1] (2)

14.1.2 $E = \dfrac{hc}{\lambda} = \dfrac{(6,63 \times 10^{-34})(3 \times 10^8)\checkmark}{260 \times 10^{-9}\checkmark} = 7,65 \times 10^{-19}\,\text{J}\ \checkmark$

number of photons arriving per second $= \dfrac{1,8 \times 10^{-9}\,\text{J}\checkmark}{7,65 \times 10^{-19}\,\text{J}} = 2,35 \times 10^9$

number of electrons ejected per second $= 2,35 \times 10^9$ ✓ [CL3] (5)

14.1.3 $Q = ne = (2,35 \times 10^9)(1,6 \times 10^{-19}\checkmark) = 3,76 \times 10^{-10}\,\text{C}\ \checkmark$

$I = \dfrac{q}{\Delta t} = \dfrac{3,76 \times 10^{-10}}{1s\checkmark} = 3,76 \times 10^{-10}\ \text{A}\ \checkmark$ [CL4] (4)

14.2 **14.2.1** An electron falls from a higher energy level to a lower energy level within the atom. ✓

The electron must lose energy. The energy is emitted in the form of a photon of light of a particular wavelength. ✓ [CL2] (2)

14.2.2 To identify elements in a distant star. ✓ [CL2] (1)

TOPIC 13: Electrochemistry

QUESTIONS

MULTIPLE CHOICE QUESTIONS

1. Consider the redox reaction represented by the following equation:

    $2MnO_4^- + 3ClO_3^- + H_2O \longrightarrow 3ClO_4^- + 2MnO_2 + 2OH^-$
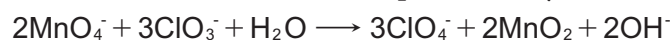
    Which substance is the oxidising agent is?

    A H_2O

    B ClO_3^-

    C MnO_2

    D MnO_4^- (2)

2. In the electrochemical cell represented in the diagram below, it is observed that electrons flow through the voltmeter from electrode X to electrode Y.
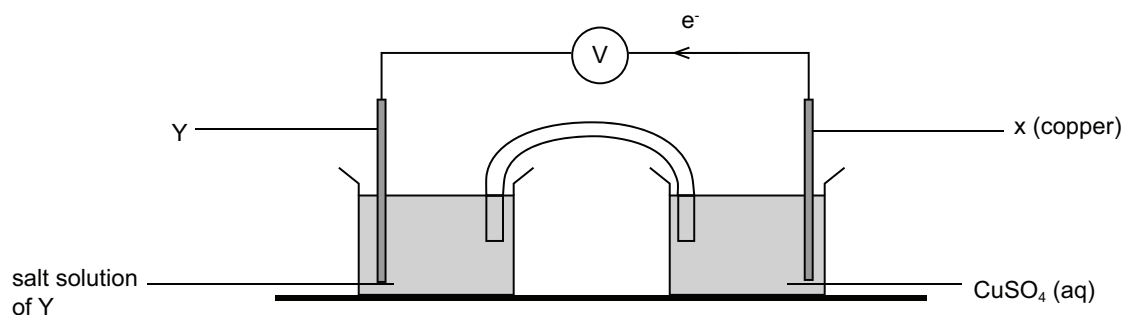
    Which one of the following metals is most likely to be electrode Y?

    A Sn

    B Ag

    C Pb

    D Zn (2)

3. A piece of tin metal is placed in each of the following four test tubes containing an aqueous solution as indicated below. In which test tube (A – D) will a metal deposit be seen on the surface of the tin metal?
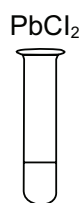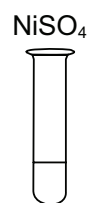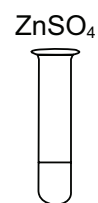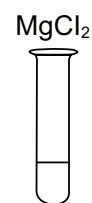
(2)

4. A standard galvanic electrochemical cell is based on the following half reactions of which the standard reduction potentials are given in brackets:

$Y^{2+} + 2e^- \rightleftharpoons Y$	$(E^\theta = +0,32 \text{ V})$
$X^{3+} + 3e^- \rightleftharpoons X$	$(E^\theta = +1,8 \text{ V})$

Which substance is the oxidising agent in this electrochemical cell?

A X

B Y

C Y^{2+}

D X^{3+} (2)

5. The diagram shows apparatus used in an attempt to electroplate a metal ring with copper.
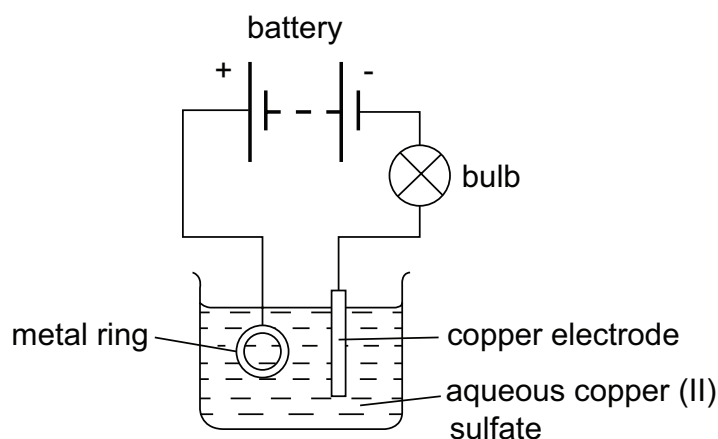
The experiment did not work. Which change is needed to make the experiment work?

A Add solid copper sulfate to the electrolyte.

B Increase the temperature of the electrolyte.

C Replace the copper electrode with a carbon electrode.

D Reverse the connection to the battery. (2)

6. Which one of the following statements about the extraction of aluminium is TRUE?

A The ore of aluminium oxide is called cryolite.

B When the cell is in operation, aluminium forms at the anode.

C Aluminium oxide is dissolved in cryolite.

D When the cell is in operation, carbon dioxide is formed at the cathode. (2)

LONG QUESTIONS

7. Pupils set up a galvanic cell, shown in the simplified diagram below, using magnesium and iron as electrodes. Magnesium nitrate and iron (III) nitrate solutions are used respectively as electrolytes in the half-cells.
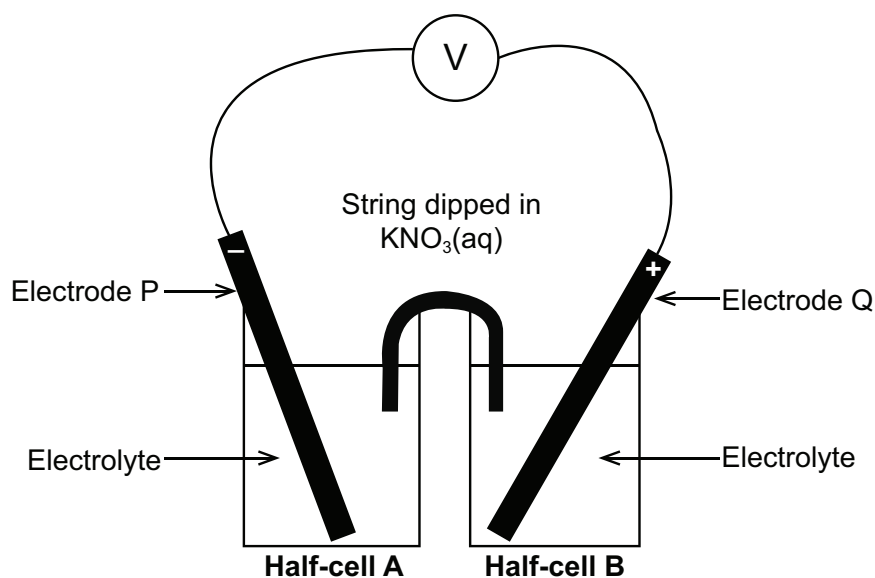
7.1 Which electrode, P or Q, is magnesium? Give a reason for the answer. (2)

7.2 Write down the cell notation for this cell. (3)

7.3. Define *oxidising agent*. (2)

7.4 Give the symbol of the oxidising agent in this cell. (2)

7.5 Calculate the initial emf of the cell above under standard conditions. (3)

7.6 Write down only INCREASES, DECREASES or REMAINS THE SAME when answering questions 7.6.1 and 7.6.2.
How will the voltmeter reading change if the:

    7.6.1 string used is wider and shorter? (1)

    7.6.2 electrolyte in half–cell B has sodium hydroxide (NaOH) added to it? (1)

7.7 After the cell has been operating for a period of time, the gain in mass at the cathode is 1,12 g.

    7.7.1 Calculate the number of moles of metal which have been deposited at the cathode. (2)

    7.7.2 Write down the net cell reaction for this cell. (3)

    7.7.3 Calculate the subsequent loss in mass at the anode. (4)

8. Aluminium is extracted from its mineral ore, bauxite, using electrolysis. The main production of aluminium in South Africa occurs at BHP Billiton, in Richard's Bay, KZN. The aluminium oxide (alumina) is dissolved in molten cryolite (Na_3AlF_6), and then electrolysed in huge carbon-lined tanks. The molten aluminium is then siphoned off, as shown in the diagram below:
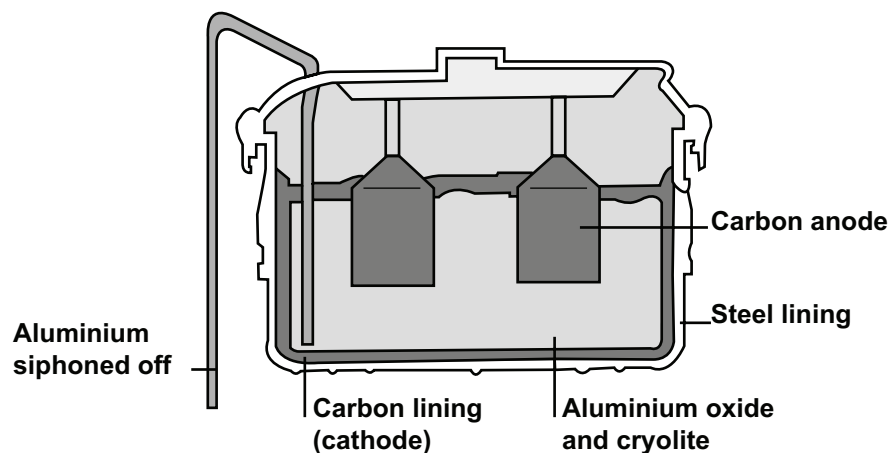
8.1 Write down the half reaction which occurs at the anode. (2)

8.2 Write down the half reaction which occurs at the cathode. (2)

8.3 What is the benefit of the alumina being dissolved in molten cryolite? (2)

8.4 How is CO_2 produced in the process? (2)

8.5 The melting point of aluminium is 660 °C. Why is the aluminium siphoned off in liquid form? (2)

9. Approximately 30 million tons of chlorine gas are used throughout the world annually. Chlorine gas is produced industrially by the electrolysis of a concentrated solution of NaCl. The diagram below represents a membrane cell used in the production of chlorine gas in the Chlor-Alkali industry.
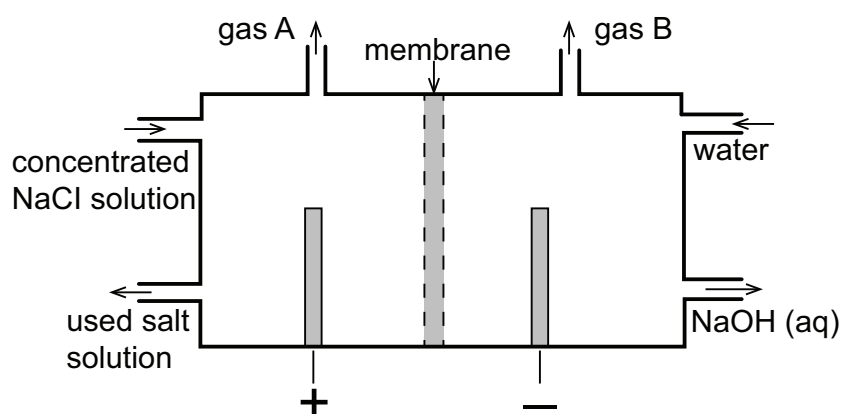
9.1 State the energy conversion in this cell. (2)

9.2 What is the common name for the saturated NaCl solution used in the Chlor-Alkali process? (1)

9.3 What is the function of the membrane in the membrane cell? (2)

9.4 Before chemical engineers designed the membrane cell the diaphragm cell was used. Explain, with reference to **quality of the product** and **cost** why the industry decided to convert to the membrane cell. (4)

9.5 Write down the formula of the gas released at the anode in this cell. (1)

9.6 Write down the half reaction occurring at the **cathode** in this cell. (2)

9.7 Refer to the Table of Standard Reduction Potentials to explain why sodium metal is NOT produced at the cathode in the membrane cell. (3)

10. Amy sets up a standard galvanic cell using chromium and palladium electrodes as shown in the diagram below. The electrode potential for palladium is shown below:

$$Pd^{2+} + 2e^- \rightleftharpoons Pd \qquad E^o = + 0,987 \text{ V}$$

Cr^{3+} ions are green and Pd^{2+} ions are colourless and each electrolyte has a constant volume of 500 cm^3.
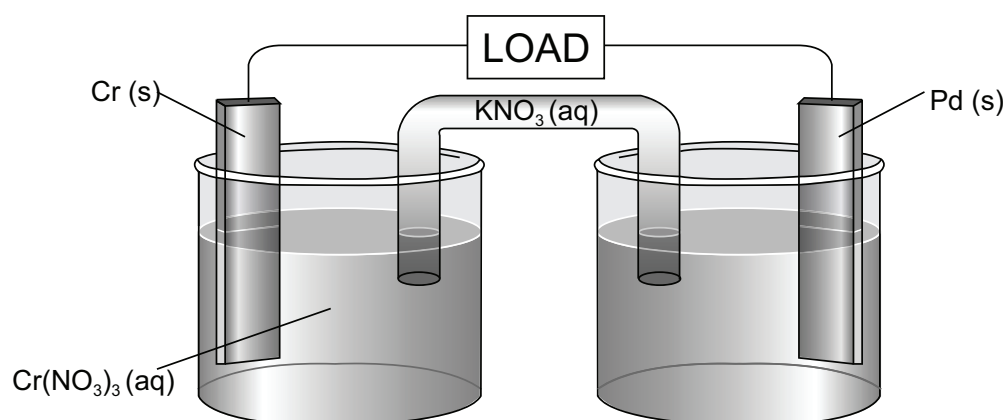
10.1 What energy conversion occurs in this cell? (2)

10.2 Write down the formula for a suitable electrolyte for the palladium half-cell. (1)

10.3 Explain how one would obtain the electrode potential of palladium. (3)

10.4 Write down the oxidation half reaction. (2)

10.5 Write down the reduction half reaction. (2)

10.6 Write down the overall ionic cell reaction equation. (2)

10.7 Write the cell notation for this cell. (3)

10.8 Calculate the standard cell emf. (3)

10.9 Concentrated sodium hydroxide solution is added to the palladium half-cell electrolyte. **(Note that palladium hydroxide is insoluble in water)**

10.9.1 State what happens to your answer to question 10.8 above. State only INCREASES, DECREASES, or REMAINS THE SAME. (1)

10.9.2 Explain your answer to question 10.9.1. above. (3)

11. An electrochemical cell is set up under standard conditions between magnesium and silver. The balanced chemical equation for the net cell reaction is given below:

$$Mg(s) + 2Ag^+(aq) \longrightarrow Mg^{2+}(aq) + 2Ag(s)$$

11.1 Write down the cell notation of this cell. Standard conditions need NOT be shown. (3)

11.2 Give the **NAME** of a possible electrolyte for use in the magnesium half-cell. (1)

11.3 Give the symbol of the oxidising agent in the above reaction. (1)

11.4 Calculate the initial emf of this cell under standard conditions. (2)

11.5 This cell (under standard conditions) is connected to a bulb marked, 3 V; 6 W. In theory the bulb should light up but in practice it does not. Suggest a possible reason for this. (1)

11.6 The volume of the electrolyte in a standard half-cell is $0,4 \, dm^3$. Calculate the maximum possible loss in mass that can occur at the anode. (4)

12. The apparatus below is used in the electro-refining of impure copper to obtain pure copper.
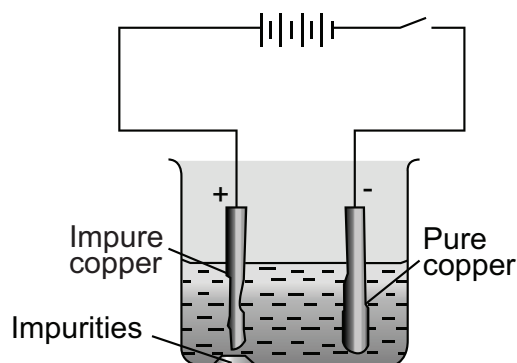
12.1 Define the term *anode*. (2)

12.2 The impurities present in the impure copper are silver, gold, iron and zinc. Which of these metal impurities would be present in the sludge that forms beneath the anode? Explain WHY these impurities are present in this sludge. (4)

12.3 Write down an equation to represent the half reaction taking place at the cathode. (2)

MARKING GUIDELINES

ANSWERS TO MULTIPLE CHOICE QUESTIONS

1.   D✓ ✓   Using oxidation numbers, the Mn in MnO_4^{1-} changes oxidation state from +7 to +2 which represents a gain of $5e^-$. This is a reduction process, therefore MnO_4^{1-} will be the oxidising agent, hence option D. [CL2] (2)

2.   B✓ ✓   Electrons flow from copper electrode making copper the anode. This means that the cathode must be a weaker reducing agent by comparison. The only metal which is a weaker reducing agent is Ag, hence option B. [CL3] (2)

3.   A✓ ✓   Sn is the weakest reducing agent out of all the metals except for Pb. This means that Sn will be able to oxidise in the presence of Pb^{2+} ions to form Sn^{2+} ions while Pb^{2+} will reduce to Pb metal. Thus option A is correct. [CL3] (2)

4.   D✓ ✓   Metal Y has the less positive electrode potential which makes it a stronger reducing agent compared to metal X. This means that Y will be the reducing agent in the cell which then makes X^{2+} the oxidising agent in the cell. Hence the correct option is D. [CL3] (2)

5.   D✓ ✓   The electrode where the metal ring is connected has to be the cathode (negative electrode) as reduction must take place to electroplate the ring. Thus the polarities of the power source need to be swapped around, hence option D is correct. [CL3] (2)

6.   C✓ ✓   To reduce the melting point of aluminium oxide, cryolite is added to the reaction mixture. This will save enormously on electricity costs. In the reaction cell, aluminium metal always forms at the cathode and oxygen, which then reacts with the carbon on the electrode, always forms at the anode. [CL2] (2)

ANSWERS TO LONG QUESTIONS

7.   **7.1**   P. ✓ [Magnesium is a stronger reducing agent than iron, so will be oxidised.] Electrode P is negative, ∴ it is the source of electrons from this oxidation. ✓ [CL2] (2)

   7.2 $Mg/Mg^{2+}(aq)(1mol \cdot dm^{-3})//Fe^{3+}(aq)(1mol \cdot dm^{-3})/Fe$
                ✓   ✓   ✓   [CL2] (3)

   7.3   A substance which accepts electrons. ✓ ✓   [CL1] (2)

   7.4 Fe^{3+} . ✓ ✓   [CL2] (2)

   7.5 $E°$ cell $= E^o$ cathode $- E^o$ anode
           $= -0,06 ✓ -(-2,36) ✓$
           $= +2,4 V ✓$ [CL2] (3)

ASSESSMENTS

7.6 **7.6.1** Remains the same. ✓   [CL2] (1)

        7.6.2 Decreases. ✓   [CL2] (1)

7.7 **7.7.1** $n = \dfrac{m}{M} = \dfrac{1,12}{56}$ ✓ $= 0,02\,\text{mol}$ ✓   [CL2] (2)

        7.7.2 $3Mg + 2Fe^{3+} \longrightarrow 3Mg^{2+} + 2Fe$

                              ✓   ✓   ✓ balancing   [CL2] (3)

        7.7.3 Mol ratio Mg : Fe

                              3 : 2 ✓

                              X : 0,02

                $\therefore n(\text{Fe}) = 0,03\,\text{mol}$ ✓

                      $m = n \times M$

                        $= 0,03 \times 24$ ✓

                      $m = 0,72\,\text{g}$ ✓   [CL3] (4)

8. **8.1** $2O^{2-} \longrightarrow O_2 + 4e^-$ ✓ ✓   [CL2] (2)

        8.2 $Al^{3+} + 3e^- \longrightarrow Al$ ✓ ✓   [CL2] (2)

        8.3 It reduces its melting point ✓ and $\therefore$ saves on energy costs. ✓   [CL2] (2)

        8.4 The oxygen gas ✓ produced at the anode reacts with the carbon ✓ which
the anode is made of.   [CL2] (2)

        8.5 The dissolving process takes place at 1 000ºC/at a higher temperature ✓
than the melting point of aluminum. ✓   [CL2] (2)

9. **9.1** Electrical ✓ $\longrightarrow$ Chemical. ✓   [CL1] (2)

        9.2 brine. ✓   [CL1] (1)

        9.3 Allows for the exchange of positive ions ✓ (Na^+) from anode compartment
to cathode compartment. ✓   [CL2] (2)

        9.4 The diaphragm cell produced <u>NaOH which was of a very low % purity</u> (or
concentration). The <u>membrane cell produces a better quality/purer</u> ✓ NaOH.
Diaphragm cell used a <u>lot of energy,</u> $\therefore$ <u>was very costly</u> ✓ , whereas the
<u>membrane cell uses significantly less energy</u> ✓ $\therefore$ cheaper to run.   [CL2] (4)

        9.5 Cl_2 ✓   [CL2] (1)

        9.6 $2H_2O + 2e^- \longrightarrow 2OH^- + H_2$ ✓ ✓   [CL2] (2)

        9.7 Water is a stronger oxidizing agent ✓ than Na^+ (or Na^+ is a weaker
oxidizing agent) $\therefore$ will have a greater tendency to be reduced ✓ / will be
selectively discharged. (NB DO NOT accept anything about reducing agents,
as there is no oxidation at the cathode).   [CL3] (3)

10 **10.1** Chemical energy ✓ to electrical energy. ✓   [CL1] (2)

      10.2 $Pd(NO_3)_2$ ✓   [CL2] (1)

      10.3 A galvanic cell is set up with a palladium half-cell together with a standard
hydrogen electrode in $1\,\text{mol·dm}^{-3}$ H^+ electrolyte. ✓
Electrode potential for hydrogen = 0V ✓ and thus the voltmeter reading
equals electrode potential of Pd. ✓   [CL2] (3)

10.4 $Cr \longrightarrow Cr^{3+} + 3e^-$ ✓ ✓ [CL2] (2)

10.5 $Pd^{2+} + 2e^- \longrightarrow Pd$ ✓ ✓ [CL2] (2)

10.6 $2Cr + 3Pd^{2+} \longrightarrow 2Cr^{3+} + 3Pd$ ✓ ✓ [CL2] (2)

10.7 $Cr(s)\,|\,Cr^{3+}(aq)(1mol\cdot dm^{-3})\,||\,Pd^{2+}(aq)(1mol\cdot dm^{-3)}\,|\,Pd(s)$

        ✓   ✓   ✓ [CL2] (3)

10.8 $E°cell = E°cathode − E°anode$ ✓

$E°cell = (0,987) − (−0,74)$ ✓

$E°cell = +1,73\,V$ ✓ [CL2] (3)

10.9 10.9.1 decrease. ✓ [CL3] (1)

    10.9.2 $[Pd^{2+}]$ decreases ✓ thus reverse reaction is favoured. ✓ Pd electrode

         (cathode) becomes less positive. ✓ [CL3] (3)

11. 11.1 $Mg/Mg^{2+}//Ag^+/Ag$ [CL2] (3)

11.2 Magnesium nitrate. ✓ (Any other suitable one). [CL1] (1)

11.3 Ag^+ ✓ [CL2] (1)

11.4 $E°cell = E°cathode − E°anode$

       $= 0,8 − (−2,36)$ ✓

       $= 3,6\,V$ ✓ [CL2] (2)

11.5 Internal resistance in the cell. ✓ [CL3] (1)

11.6 Mg is the anode.

     $n = cV = 1 \times 0,4$✓$= 0,4\,mol$ ✓

     $m = nM = 0,4 \times 24,3$✓$= 9,72\,g$ ✓ [CL3] (4)

12. 12.1 Anode is the electrode where oxidation takes place. ✓ ✓ [CL1] (2)

12.2 Ag✓ and Au ✓ are not oxidised ✓ as they are weaker reducing agents than

     Cu ✓ therefore will drop to the bottom of the cell. [CL3] (4)

12.3 $Cu^{2+} + 2e^- \longrightarrow Cu$ ✓ ✓ [CL2] (2)

TOPIC 14: The Chemical Industry

QUESTIONS

MULTIPLE CHOICE QUESTIONS

1. Which ONE of the following correctly describes the initial product(s) formed during the industrial fixation of nitrogen?
   A   Ammonia.
   B   Ammonium nitrate.
   C   Nitrogen dioxide.
   D   Nitrogen and hydrogen. (2)

2. Which ONE of the following is a primary nutrient needed by plants?
   A   Nitrogen.
   B   Carbon.
   C   Magnesium.
   D   Sodium. (2)

3. Which of the following processes are ALL involved in the preparation of ammonium sulphate?

A	Ostwald process	Contact process	Haber process
B	Fractional distillation of liquid air	Ostwald process	Contact process
C	Fractional distillation of liquid air	Haber process	Cracking
D	Fractional distillation of liquid air	Haber process	Contact process

(2)

LONG QUESTIONS

4. Nitric acid is used in the preparation of fertiliser. The flow diagram below shows the three steps (A, B and C) in the industrial preparation of nitric acid.

4.1 4.1.1   Name this industrial process used in the preparation of nitric acid. (1)

  4.1.2   Write a balanced equation for step B. (3)

4.2 $NH_3(g)$ reacts with $O_2(g)$ to form two products in step A. One of the products is nitrogen(II) oxide. Write down the NAME or FORMULA of the OTHER product. (1)

4.3 In step **C**, water is added to the reaction mixture. This step can be represented by the following incomplete equation:

$NO_2(g) + \underline{\quad} + H_2O(l) \longrightarrow HNO_3(l)$
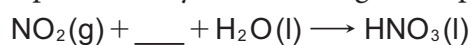
Copy the above incomplete equation and fill in the missing reactant and balance the equation. (2)

4.4 A 50 kg bag of fertiliser is labelled as shown in the diagram.
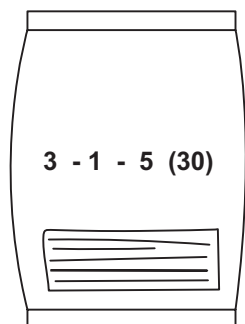
Calculate the mass of nitrogen present in this bag of fertiliser. (3)

4.5 Uncontrolled use of fertiliser may cause excess fertiliser to run down into streams and rivers, leading to eutrophication. State ONE negative impact that eutrophication in water may have on humans. (2)

5. The flow diagram below represents processes used in the fertiliser industry.
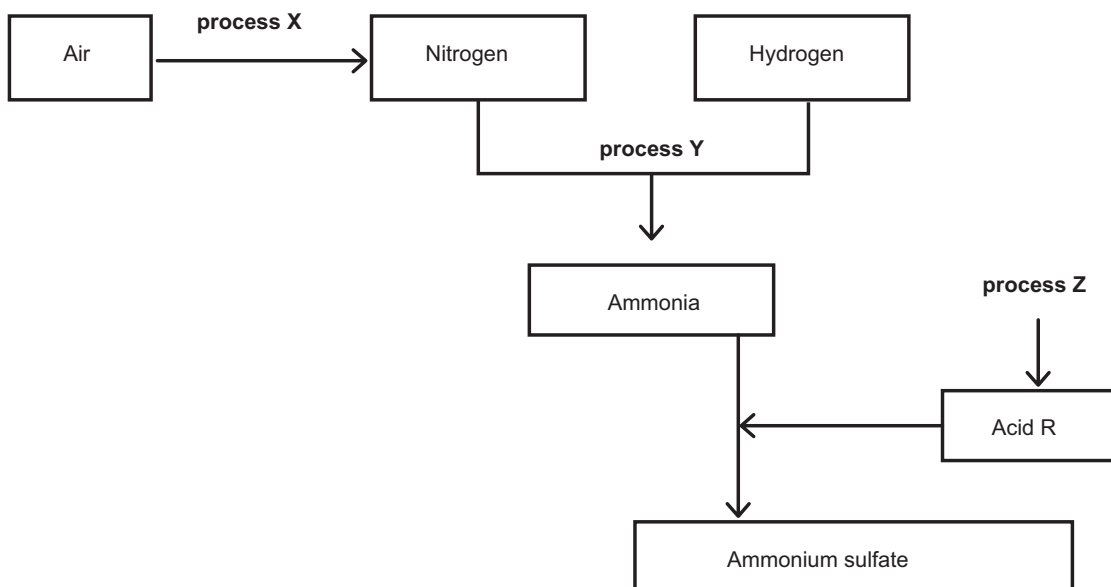
Write down:

5.1 the name of industrial process X. (1)

5.2 a balanced equation for process Y. (3)

5.3 the name of industrial process Z. (1)

5.4 a balanced equation for the preparation of ammonium sulfate using acid R. (3)

5.5 the name of the type of reaction taking place in question 5.4. (1)

Ammonium nitrate is one of the most common compounds used as fertiliser.

5.6 Write down the NAME or FORMULA of the acid needed to prepare
ammonium nitrate from ammonia. (1)

5.7 Write down TWO properties of ammonium nitrate that make it suitable for
use as a fertiliser. (2)

6. Sulfuric acid is used, amongst others, in the manufacturing of fertilisers. The flow
diagram below shows how fertiliser D can be prepared using sulfuric acid as one
of the reagents.
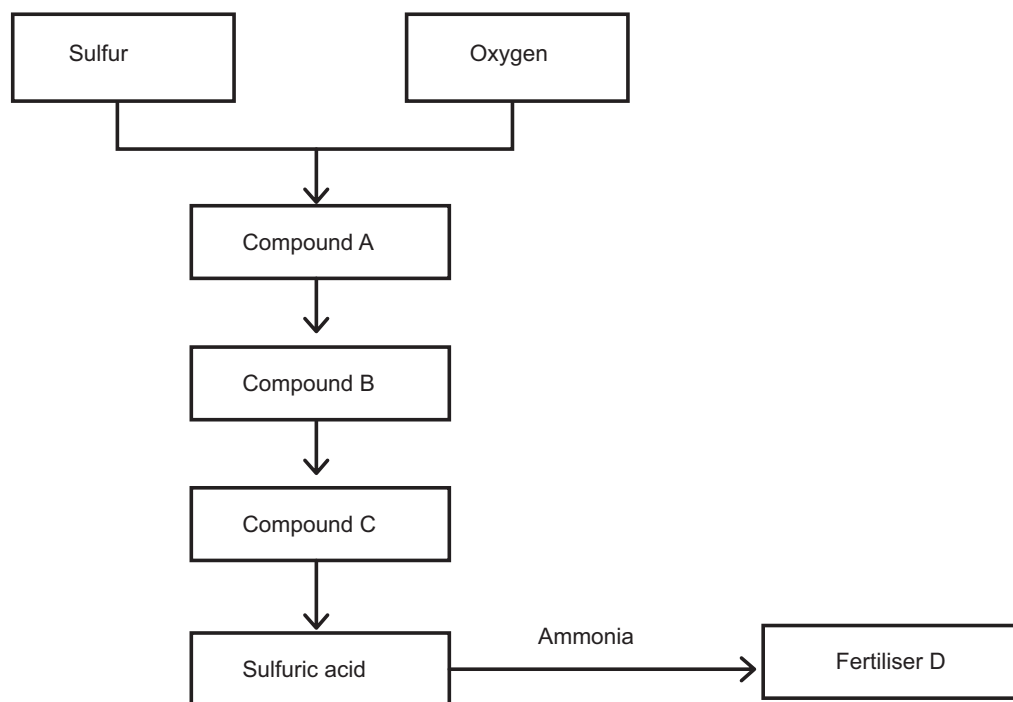
6.1 Write down the NAME of the industrial process for the preparation of
sulfuric acid. (1)

6.2 Compound A is formed when sulfur burns in oxygen. Write down the
NAME or FORMULA of compound A. (1)

6.3 Compound B is formed when compound A reacts with oxygen in the
presence of a catalyst. Write down the:

6.3.1 NAME or FORMULA of the catalyst. (1)

6.3.2 balanced equation for the reaction which takes place. (3)

6.4 Compound B is dissolved in concentrated sulfuric acid to form compound
C. Write down the:

6.4.1 NAME or FORMULA of compound C. (1)

6.4.2 reason why compound B is not dissolved in water to form sulfuric acid. (1)

6.5 Write down the NAME or FORMULA of fertiliser D. (1)

6.6 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. (1)

7. The letters A to F in the table below represent some fertilisers and raw materials used in the preparation of fertilisers.

A	Sulfur	B	Air
C	Methane	D	Potassium chloride
E	Ammonium sulfate	F	Ammonium nitrate

Write down the:

7.1 LETTERS representing TWO raw materials used in the preparation of compound E. (2)

7.2 NAME or FORMULA of the acid needed to prepare compound F (1)

7.3 LETTER representing the solid raw material used in the contact process (1)

7.4 balanced equation for the preparation of compound E. (3)

7.5 LETTER representing the raw material that supplies the primary nutrient needed for development of flowers. (1)

7.6 A 2 kg bag of fertiliser is labelled as follows:
2 : 3 : 2 (22)
Calculate the mass of the:
7.6.1 pohosphorus in the bag. (3)
7.6.2 filler in the bag. (3)

ASSESSMENTS

MARKING GUIDELINES

ANSWERS TO MULTIPLE CHOICE QUESTIONS

1. A✓ ✓   The first step in the production of nitrates is to convert nitrogen from the air into ammonia gas which is then used onwards in the Ostwald Process to produce nitric acid and ultimately nitrates, hence option A is correct. [CL2] (2)

2. A✓ ✓   There are three primary nutrients that are essential for plants, namely nitrogen, phosphorus and potassium, Thus option A is correct. [CL1] (2)

3. D✓ ✓   The three sequential steps that are performed to produce nitrates as described by option D, namely to distil nitrogen from the air, convert it into ammonia via the Haber Process and then into nitric acid via the Ostwald Process. [CL2] (2)

ANSWERS TO LONG QUESTIONS

4. 4.1 4.1.1 The Ostwald Process. ✓ [CL1] (1)

  4.1.2 $2NO + O_2 \longrightarrow 2NO_2$
  　　　　✓　　　　✓　　　✓ balancing [CL2] (3)

  4.2 H_2O (water) ✓ [CL1] (1)

  4.3 $4NO + \underline{O_2} + 2H_2O \longrightarrow 4HNO_3$
  　　　　✓　　　　　　✓ balancing [CL2] (2)

  4.4 30 % of a 50 kg bag $=$ 15 kg ✓
  NPK ratio is 3:1:5 which gives a total of 9
  Thus $\frac{3}{9} \times 15 = 5\,kg$ ✓ ✓ [CL2] (3)

  4.5 Any one of:
  - excess nitrates causes algal bloom which removes O_2 from water causing fish/aquatic life to die. ✓ ✓
  - Poor water quality unfit for drinking which poses a health risk. ✓ ✓
  - no water recreation activities which reduces visitors to the area. Hence loss of income to the surrounding community. ✓ ✓ [CL2] (2)

5. 5.1 Fractional distillation of air. ✓ [CL1] (1)

  5.2 $N_2 + 3H_2 \longrightarrow 2NH_3$
  　　　✓　　　　✓　　　　　✓ balancing [CL2] (3)

  5.3 Contact Process. ✓ [CL1] (1)

  5.4 $H_2SO_4 + 2NH_3 \longrightarrow (NH_4)_2SO_4$
  　　　　✓　　　　✓　　✓ balancing [CL2] (3)

  5.5 Neutralisation. ✓ [CL2] (1)

  5.6 Nitric acid (HNO_3). ✓ [CL2] (1)

  5.7 High percentage of nitrogen in its structure which is a primary nutrient. ✓
  Highly soluble for easy absorption by plants. ✓ [CL2] (2)

6. **6.1** Contact Process. ✓   [CL1] (1)

    6.2 Sulfur dioxide. (SO_2). ✓   [CL1] (1)

    6.3 **6.3.1** Vanadium pentoxide. (V_2O_5).   [CL1] (1)

        6.3.2 $2SO_2 + O_2 \longrightarrow 2SO_3$

                ✓   ✓   ✓ balancing   [CL2] (3)

    6.4 **6.4.1** Oleum. ($H_2S_2O_3$). ✓   [CL2] (1)

        6.4.2 Reaction is highly exothermic and forms a fine mist. ✓   [CL2] (1)

    6.5 Ammonium sulfate $(NH_4)_2SO_4$. ✓   [CL2] (1)

    6.6 Eutrophication leads to destruction of aquatic life. ✓   OR

        Causes loss of income to surrounding community due to poor recreation
facilities . ✓

                                                            [CL2] (1)

7. **7.1** B = air. ✓   A = sulfur. ✓   [CL2] (2)

    7.2 Nitric acid. (HNO_3). ✓   [CL1] (1)

    7.3 A = sulfur. ✓   [CL1] (1)

    7.4 $2NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$.

               ✓   ✓   ✓ balancing   [CL2] (3)

    7.5 D = potassium chloride. ✓   [CL2] (1)

    7.6 **7.6.1** NPK ratio is 2:3:2 which gives ratio total of 7

           % P $= \dfrac{3}{9} \times 7 = 9{,}43$ % ✓ ✓

           mass $= \dfrac{9{,}43}{100} \times 2 = 0{,}19\,kg$ ✓   [CL2] (3)

        7.6.2 Mass of fertilizer $= \dfrac{22}{100} \times 2 = 0{,}44\,kg$ ✓

                 Mass of filler $= 2 - 0{,}44$ ✓

                              $= 1{,}56\,kg$ ✓   [CL2] (3)

ASSESSMENTS