PHYSICAL SCIENCES

MATERIAL FOR GRADE 12

THIRD TERM

ELECTRIC CIRCUITS

QUESTIONS

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FORMULAE

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

TERMINOLOGY

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

1.1.1 Resistance

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

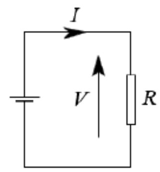
The resistance of the conductor depends on

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

1.1.2 Ohm's Law

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

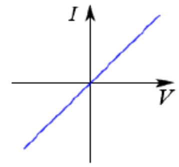
The value $\frac{V}{I}$ is the resistance R of the conductor and is a constant.



$V \propto I$

$V = I \times constant$

$V = I \times R$



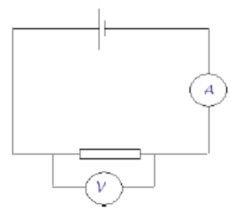
Resistance = $\frac{\text{potential difference}}{\text{current}}$ In symbols: $R = \frac{V}{I}$

1.2 Ohmic and non-ohmic conductors

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

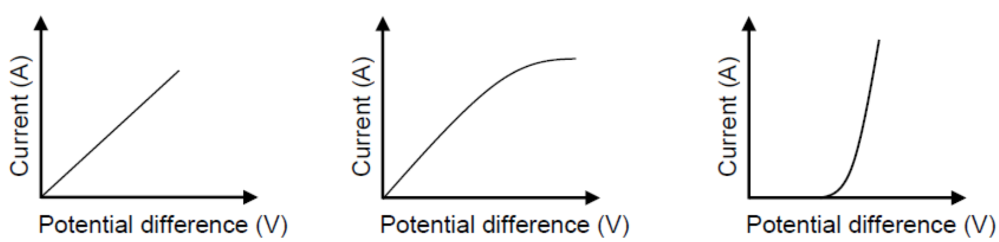
Metals and alloys obey Ohm's Law. Carbon is a non-metal that also obeys Ohm's Law. For most other materials the resistance is not a constant and changes with the applied potential difference (voltage). An example of a non-ohmic conductor is a tungsten light bulb.

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



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

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



Ohmic conductor Filament lamp Diode

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

2. Resistance, equivalent resistance

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

Series Circuits

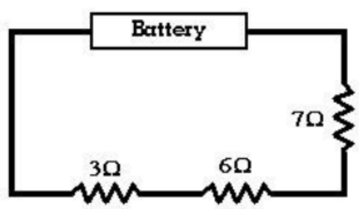
Resistances are arranged so that current must pass through each resistance, one after the other – current has no choice of path. There are no branches in the circuit, and hence the electricity can only travel in one route.

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

$$R_{total} = R_1 + R_2 + R_3 + \ldots.$$

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

Example



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

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

Effect of adding more resistors in serises

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

Parallel Circuits

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

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

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

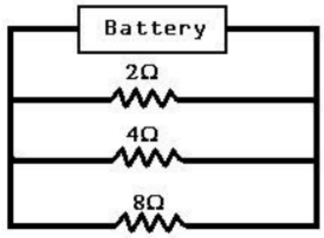
$$\frac{1}{R_{parallel}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

Effect of adding more resistors in parallel

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

Example

Calculate the total resistance for the given circuit



Answer:

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

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

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

Resistance

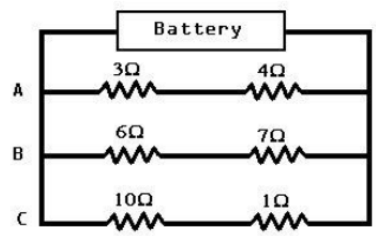
Step 1: For each individual series path, calculate the total resistance for that path using the series resistance formula.

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

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

Example

Calculate the total resistance for the given circuit.



Answer:

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

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

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

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

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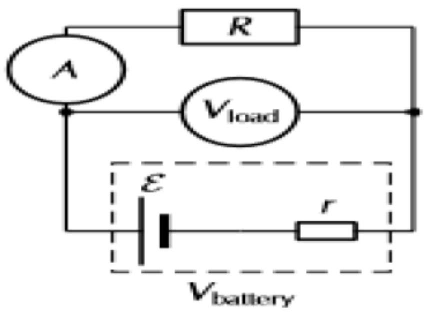
INTERNAL RESISTANCE AND EMF

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

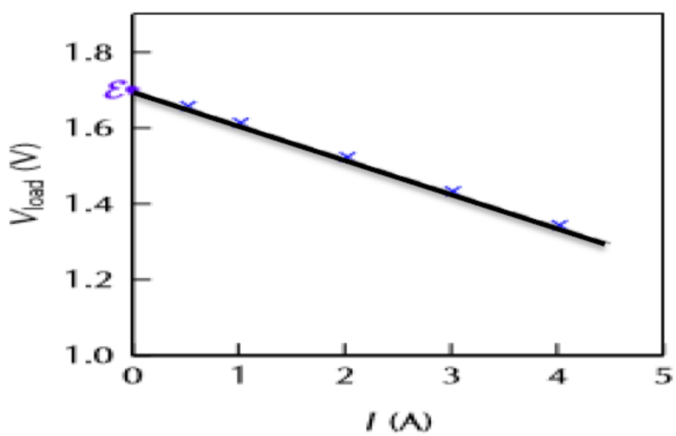
EMF is the total energy supplied per coloumb of charge that passes through the cell.

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



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

A graph of V versus I



slope = - r

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

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

POWER

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

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

P= V.I

Which can be developed to:

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$P = I^2R$

$P = VI$

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

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

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

Example: If an oven of power 3 000W was run for 4h, it uses 3 kW· 4h = 12 kW·h or 12 UNITS of energy.

If this were charged out at 50c per unit: cost = 12 kW· h x 50 c. kW· h^{-1}

= 600c

= R6

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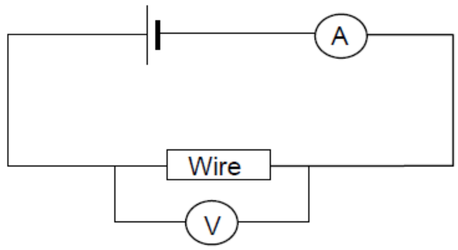
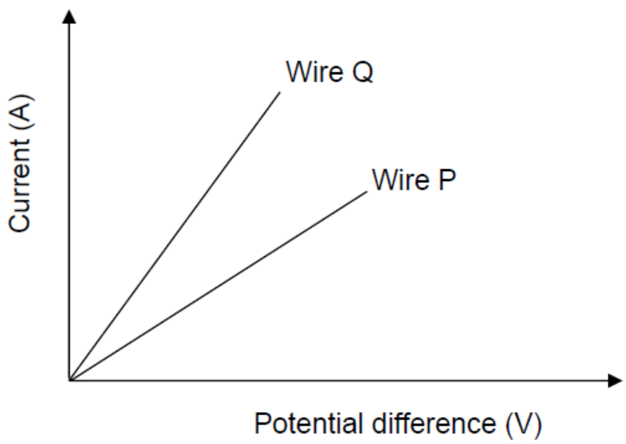
QUESTION 11

Learners investigate the conducting ability of two metal wires P and Q, made of different materials. They connect ONE wire at a time in a circuit as shown below.



The potential difference across each wire is increased in equal increments, and the resulting current through these wires is measured. Using the measurements, the learners obtained the following sketch graphs for each of the wires.



11.1 Name TWO variables that the learners would have controlled in each of the experiments. (2)

11.2 Which one (P or Q) is the better conductor? Explain your answer. (4)
[6]

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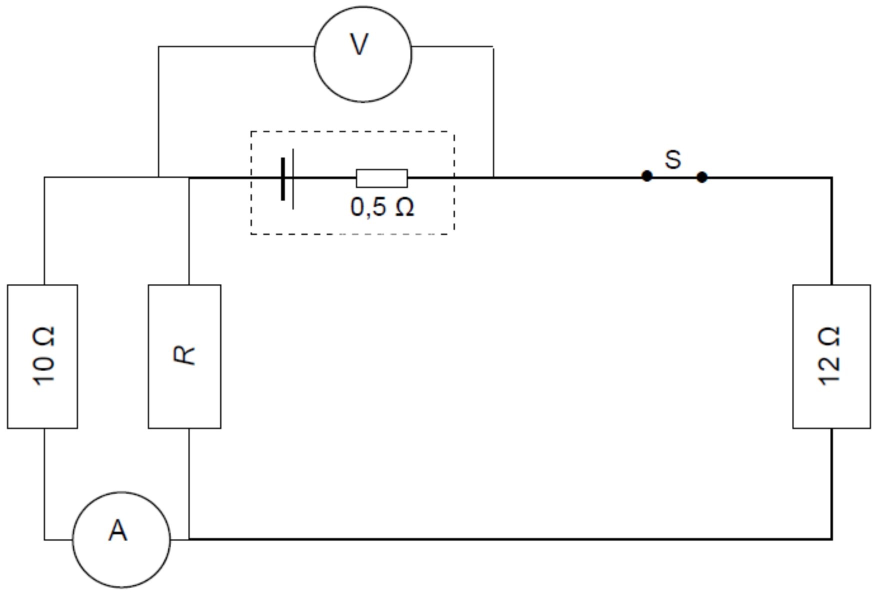
QUESTION 12

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



12.1 Calculate the reading on ammeter A. Show ALL your calculations. (8)

12.2 Determine the resistance of resistor *R*. (3)

12.3 How will the reading on voltmeter V change if resistor *R* burns out? Give a reason for your answer. (4)

[15]

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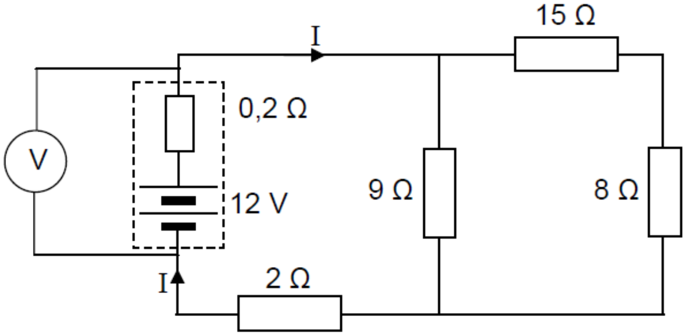
QUESTION 12

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.



12.1 Calculate the current, I, that flows through the battery. (6)

12.2 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 your answer. (4)

[10]

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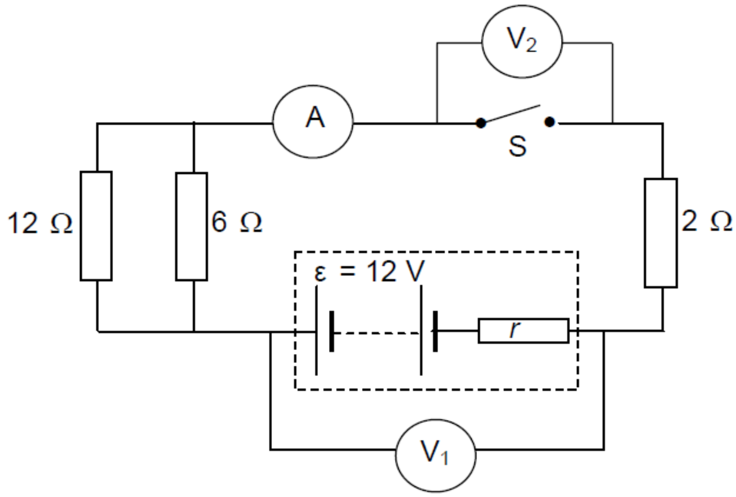
QUESTION 12 (Start on a new page.)

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



12.1.1 Write down the respective readings on voltmeters V_1 and V_2 when switch S is open. (2)

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

12.1.2 What will the new reading on V_2 be? (1)

12.1.3 Calculate the total **external** resistance of the circuit. (4)

12.1.4 Calculate the internal resistance, *r*, of the battery. (5)

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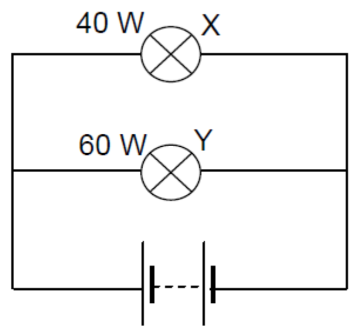
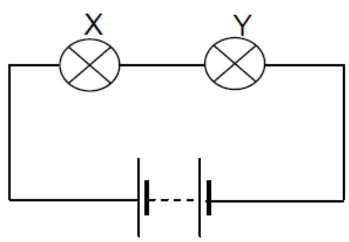
12.2 The circuit below shows two light bulbs, X and Y, connected in parallel to a battery with negligible internal resistance.



The bulbs are marked 40 W and 60 W respectively. Bulb Y glows brighter than bulb X.

12.2.1 How does the resistance of bulb Y compare to that of bulb X? Use an appropriate equation (or relationship) to explain your answer. (3)

During an experiment a learner connects these two bulbs in series to the same power supply as shown below. He observes that bulb X now glows brighter than bulb Y.



12.2.2 Use an appropriate equation (or relationship) to explain why bulb X now glows brighter than bulb Y. (3)

[18]

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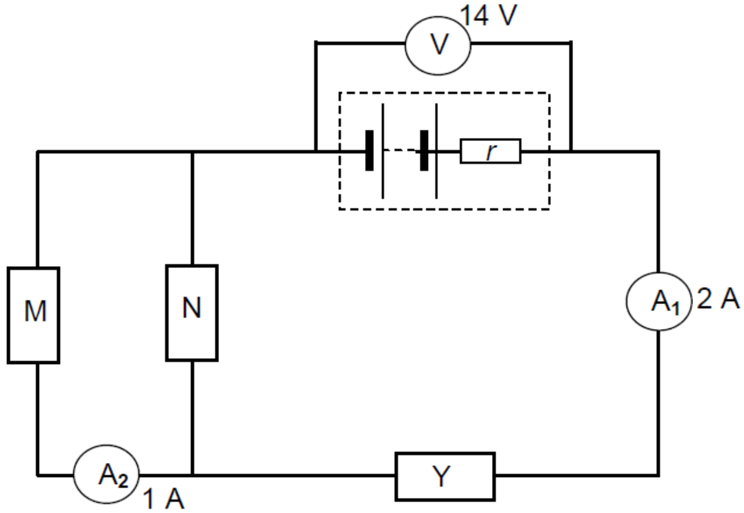
QUESTION 11 (Start on a new page.)

The circuit diagram below shows a battery, with an internal resistance *r*, connected to three resistors, M, N, and Y. The resistance of N is 2 Ω and the reading on voltmeter V is 14 V. The reading on ammeter A_1 is 2 A and the reading on ammeter A_2 is 1 A. (The resistance of the ammeters and the connecting wires may be ignored.)



11.1	State Ohm's law in words.	(2)
11.2	How does the resistance of M compare with that of N? Explain how you arrived at the answer.	(2)
11.3	If the emf of the battery is 17 V, calculate the internal resistance of the battery.	(5)
11.4	Calculate the potential difference across resistor N.	(3)
11.5	Calculate the resistance of Y.	(4)
		[16]

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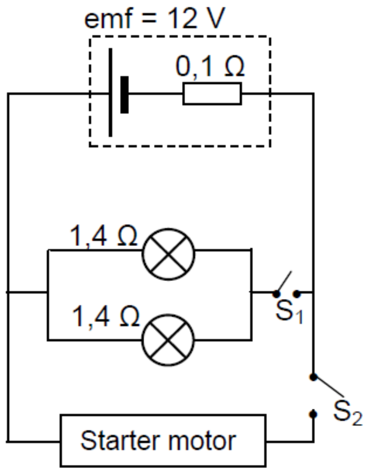
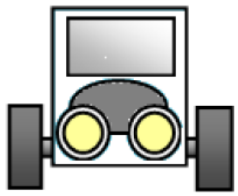
QUESTION 10 (Start on a new page.)

The headlights of a car are connected in parallel to a 12 V battery, as shown in the simplified circuit diagram below. The internal resistance of the battery is 0,1 Ω and each headlight has a resistance of 1,4 Ω. The starter motor is connected in parallel with the headlights and controlled by the ignition switch, $\mathbf{S_2}$. The resistance of the connecting wires may be ignored.





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

10.2 With only switch $\mathbf{S_1}$ closed, calculate the following:

10.2.1 Effective resistance of the two headlights (3)

10.2.2 Potential difference across the two headlights (4)

10.2.3 Power dissipated by one of the headlights (3)

10.3 Ignition switch $\mathbf{S_2}$ is now closed (whilst $\mathbf{S_1}$ is also closed) for a short time and the starter motor, with VERY LOW RESISTANCE, rotates.

How will the brightness of the headlights be affected while switch $\mathbf{S_2}$ is closed? Write down only INCREASES, DECREASES or REMAINS THE SAME.

Fully explain how you arrived at the answer. (4)

[16]

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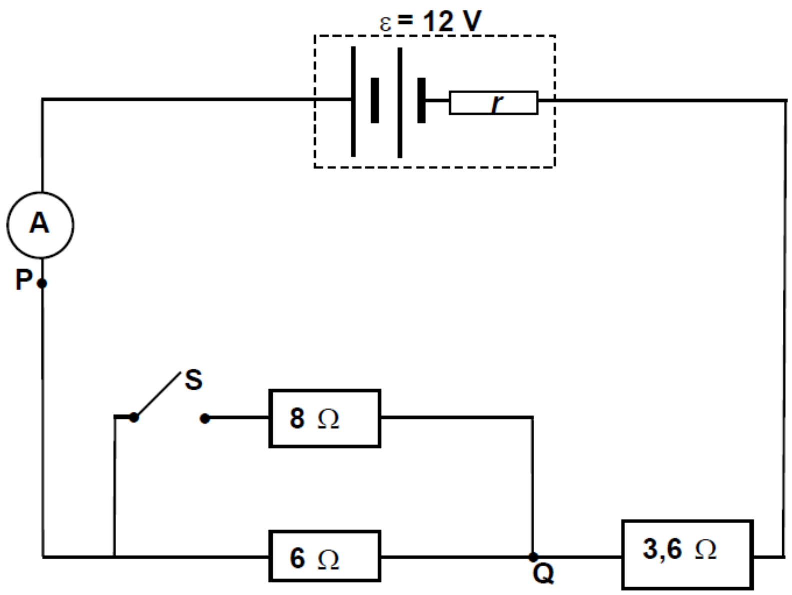
QUESTION 9 (Start on a new page.)

The circuit diagram below represents a combination of resistors in series and parallel. The battery has an emf of 12 V and an unknown internal resistance *r*.



With switch **S** OPEN, ammeter A gives a reading of 1,2 A.

9.1 Calculate the total resistance of the circuit. (3)

9.2 Calculate the internal resistance of the battery. (4)

9.3 Calculate the energy dissipated in the 6 Ω resistor in 3 minutes. (3)

Switch **S** is now CLOSED.

9.4 How will EACH of the following be affected? Write down only INCREASES, DECREASES or REMAINS THE SAME.

9.4.1 The total resistance of the circuit (1)

9.4.2 The reading on ammeter A (1)

9.5 A conducting wire of negligible resistance is now connected between points **P** and **Q**. What effect will this have on the temperature of the battery?

Write down only INCREASES, DECREASES or REMAINS THE SAME. Explain how you arrived at the answer. (4)

[16]

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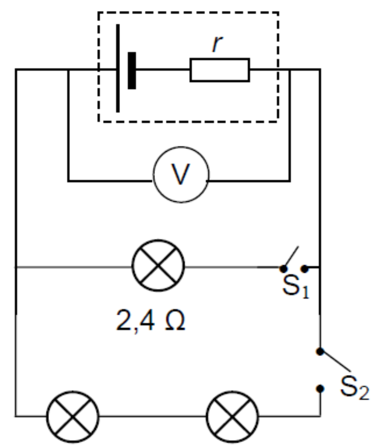
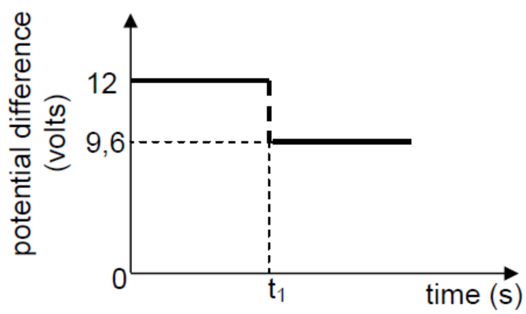
QUESTION 10 (Start on a new page.)

The headlamp and two IDENTICAL tail lamps of a scooter are connected in parallel to a battery with unknown internal resistance as shown in the simplified circuit diagram below. The headlamp has a resistance of 2,4 Ω and is controlled by switch **S_1**. The tail lamps are controlled by switch **S_2**. The resistance of the connecting wires may be ignored.

The graph alongside shows the potential difference across the terminals of the battery before and after switch **S_1** is closed (whilst switch **S_2** is open). Switch **S_1** is closed at time t_1.





10.1 Use the graph to determine the emf of the battery. (1)

10.2 WITH ONLY SWITCH **S_1** CLOSED, calculate the following:

10.2.1 Current through the headlamp (3)

10.2.2 Internal resistance, *r*, of the battery (3)

10.3 BOTH SWITCHES **S_1** AND **S_2** ARE NOW CLOSED. The battery delivers a current of 6 A during this period.

Calculate the resistance of each tail lamp. (5)

10.4 How will the reading on the voltmeter be affected if the headlamp burns out? (Both switches **S_1** and **S_2** are still closed.)

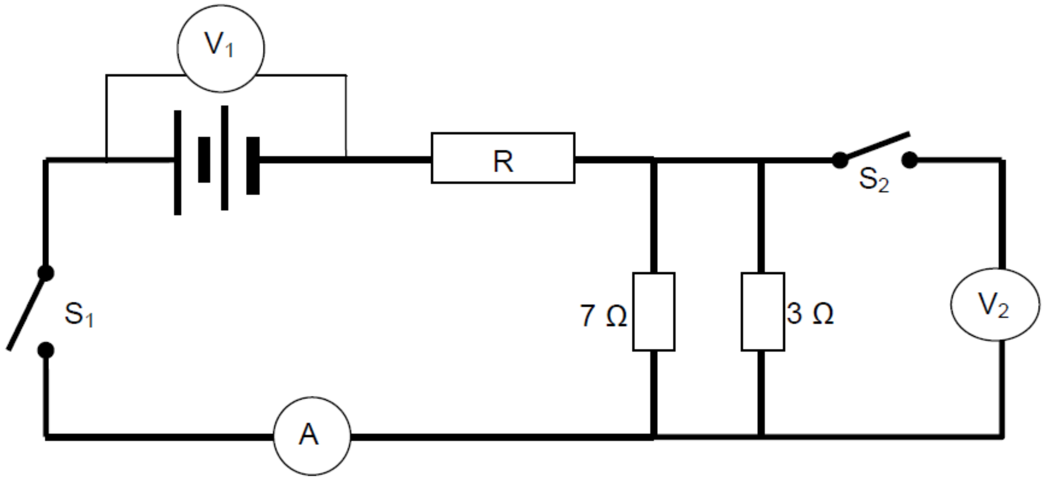
Write down only INCREASES, DECREASES or REMAINS THE SAME.

Give an explanation. (3)

[15]

QUESTION 11

In the circuit diagram below resistor R has an unknown resistance. When both switches are open the reading on V_1 is 30 V. When switch S_1 is closed, the reading on V_1 is 28,5 V and the reading on the ammeter is 3 A.



11.1 Define the term *emf*. (2)

11.2 Calculate the internal resistance of the battery. (4)

11.3 What is the reading on voltmeter V_2? (1)

Switch S_2 is now closed as well.

11.4 What will happen to the ammeter reading? (1)

11.5 Calculate the new reading on voltmeter V_2. (4)

11.6 Calculate the amount of heat energy dissipated in the battery in one minute as a result of its internal resistance. (3)

[15]

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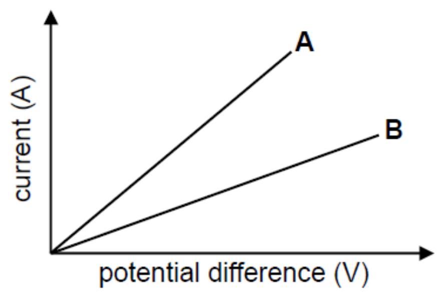
QUESTION 9 (Start on a new page.)

9.1 Learners use Ohm's law to determine which ONE of two resistors **A** and **B** has the greater resistance.

For each resistor, they measure the current through the resistor for different potential differences across its ends. The graph below shows the results obtained in their investigation.



9.1.1 The learners are supplied with the following apparatus:

6 V battery
Voltmeter
Ammeter
Rheostat
Resistors **A** and **B**
Conducting wires

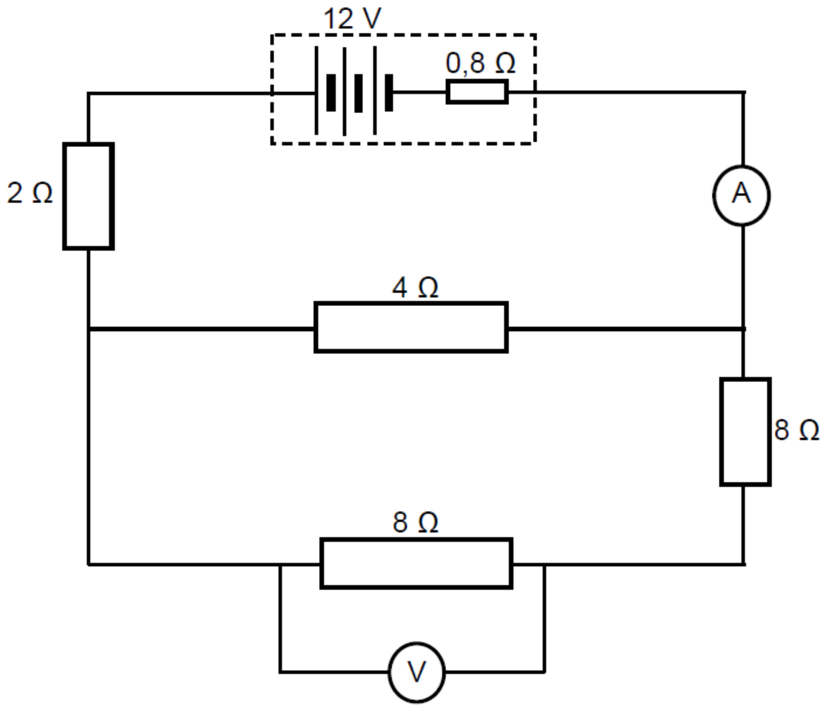
Draw a circuit diagram to show how the learners must use the above apparatus to obtain each of the graphs shown above. (4)

9.1.2 Write down ONE variable that must be kept constant during this investigation. (1)

9.1.3 Which ONE of **A** or **B** has the higher resistance?

Give an explanation for the answer. (3)

9.2 In the circuit diagram below, the battery has an emf of 12 V and an internal resistance of 0,8 Ω. The resistance of the ammeter and connecting wires may be ignored.



Calculate the:

9.2.1 Effective resistance of the circuit (4)

9.2.2 Reading on the ammeter (3)

9.2.3 Reading on the voltmeter (4)

[19]

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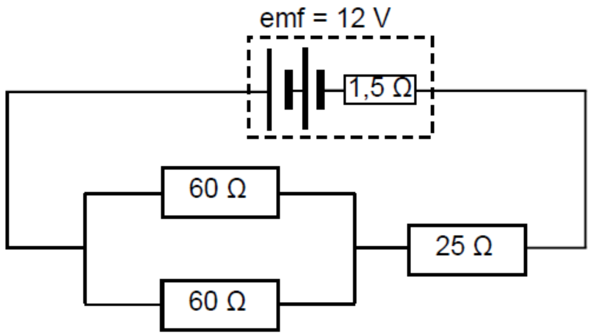
QUESTION 9 (Start on a new page.)

9.1 In the circuit represented below, two 60 Ω resistors connected in parallel are connected in series with a 25 Ω resistor. The battery has an emf of 12 V and an internal resistance of 1,5 Ω.



Calculate the:

9.1.1 Equivalent resistance of the parallel combination (3)

9.1.2 Total current in the circuit (5)

9.1.3 Potential difference across the parallel resistors (3)

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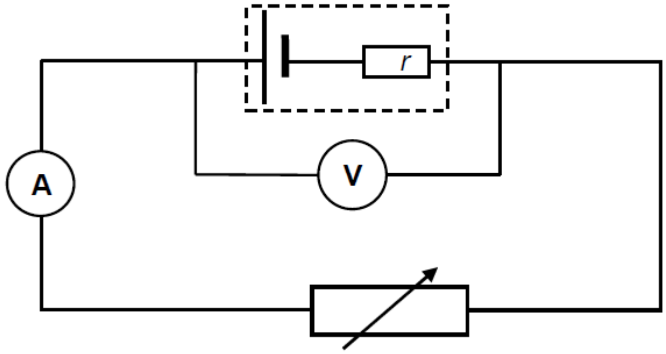
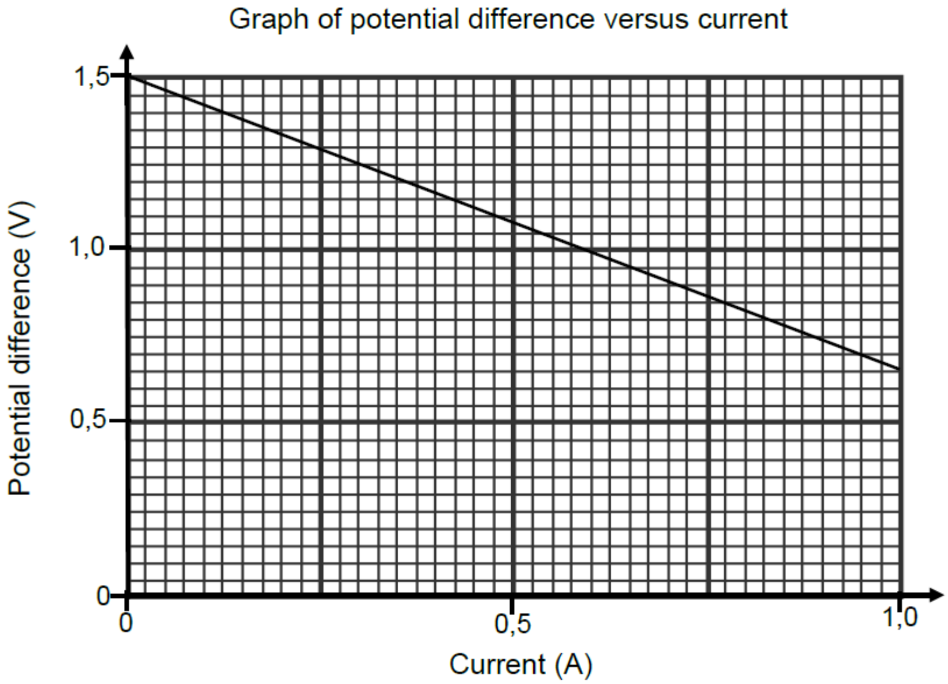
9.2 Learners conduct an investigation to determine the emf and internal resistance (*r*) of a battery.

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.



9.2.1 Use the graph to determine the emf of the battery. (1)

9.2.2 Calculate the gradient of the graph. (3)

9.2.3 Which physical quantity is represented by the magnitude of the gradient of the graph? (2)

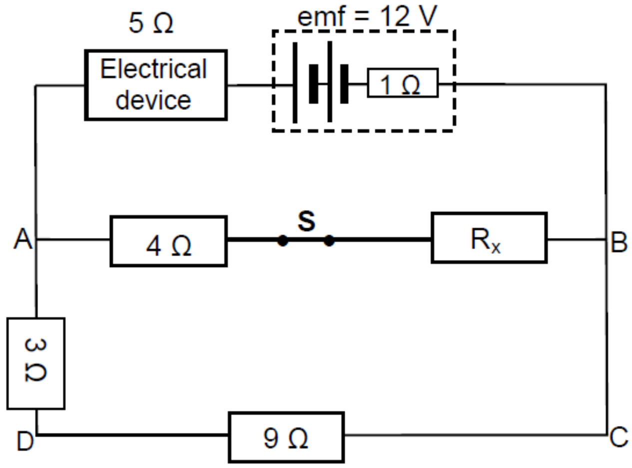
9.2.4 How does the voltmeter reading change as the ammeter reading increases? Write down INCREASES, DECREASES or REMAINS THE SAME. Use the formula emf = IR + Ir to explain the answer. (3)

[20]

QUESTION 9 (Start on a new page.)

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 device to function. The resistance of the device is 5 Ω.

When switch **S** is **closed** as shown, the device functions at its maximum power of 5 W.



9.1 Explain, in words, the meaning of *an emf of 12 V*. (2)

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

9.3 Calculate the resistance of resistor $\mathbf{R_x}$. (7)

9.4 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)

[16]

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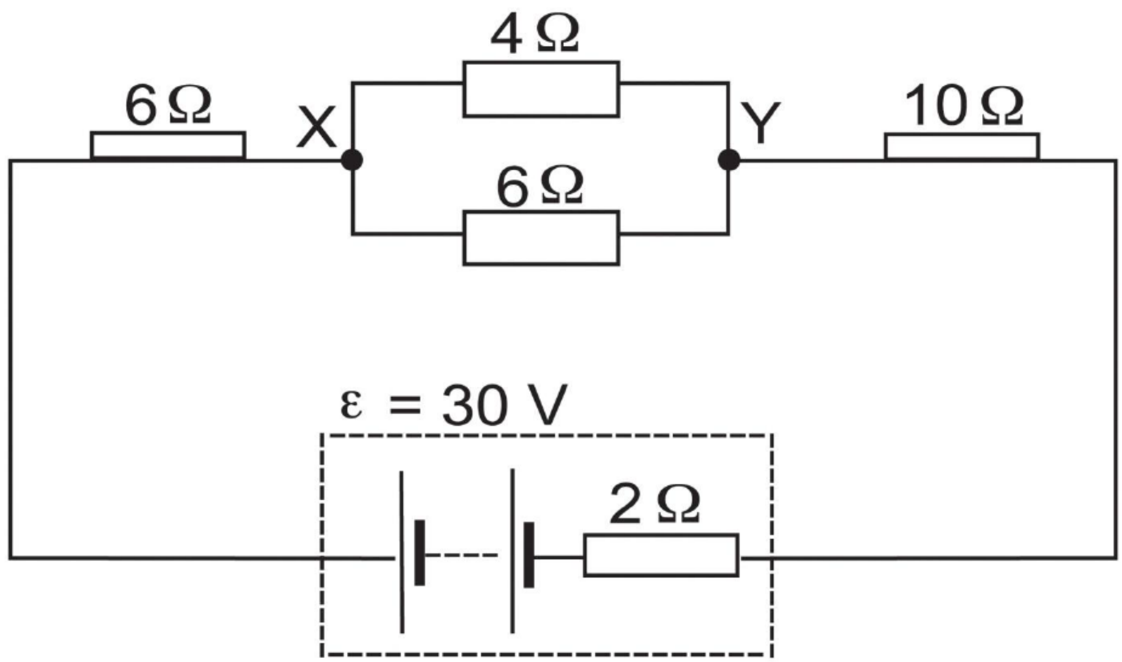
QUESTION 9 **(Start on a new page.)**

Four resistors of different resistances are connected in a circuit as shown below. The battery has an *emf* of 30 V and an internal resistance of 2 Ω. The resistance of the connecting wires is negligible.



9.1 Define the concept *emf* of a battery. (2)

9.2 Calculate the current through the battery. (6)

9.3 Calculate the potential difference between points X and Y. (3)
[11]

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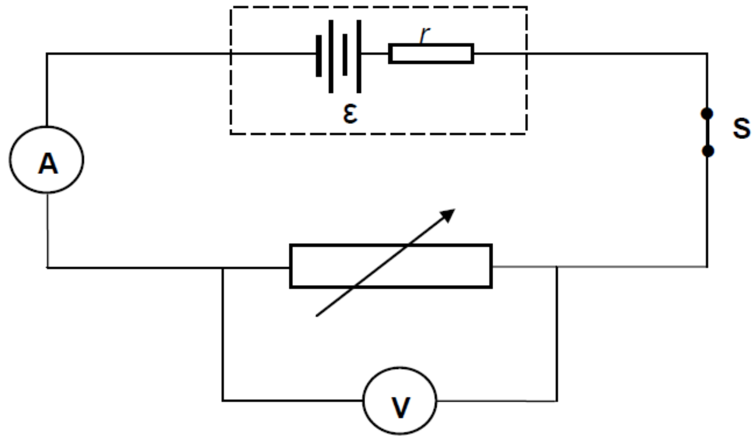
QUESTION 8 (Start on a new page.)

NOTE: The graph for QUESTION 8.1.2 must be drawn on the GRAPH SHEET attached at the end of the QUESTION PAPER.

8.1 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

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

8.1.2 Using the information in the table above, plot the points and draw the line of best fit on the attached GRAPH SHEET. (3)

Use the graph drawn in QUESTION 8.1.2 to determine the following:

8.1.3 Emf (ε) of the battery (1)

8.1.4 Internal resistance of the battery, WITHOUT USING ANY FORM OF THE EQUATION $\varepsilon = I(R + r)$ (3)

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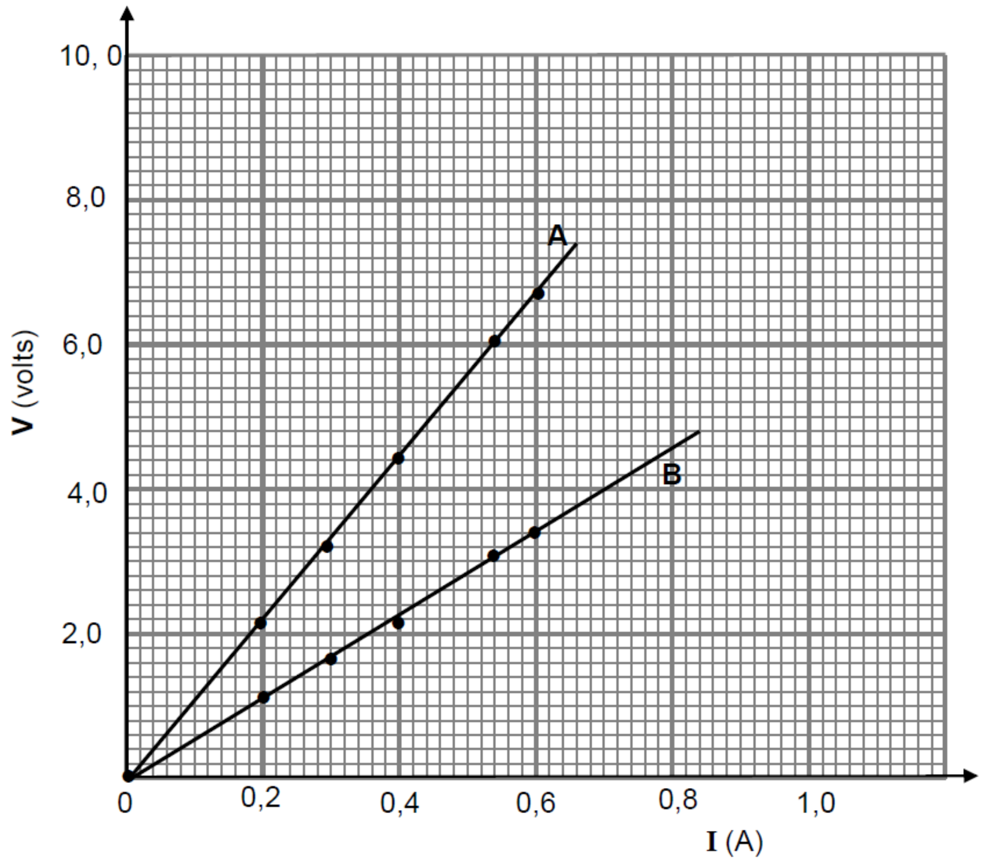
QUESTION 8 (Start on a new page.)

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

Graph of V versus I for resistors A and B

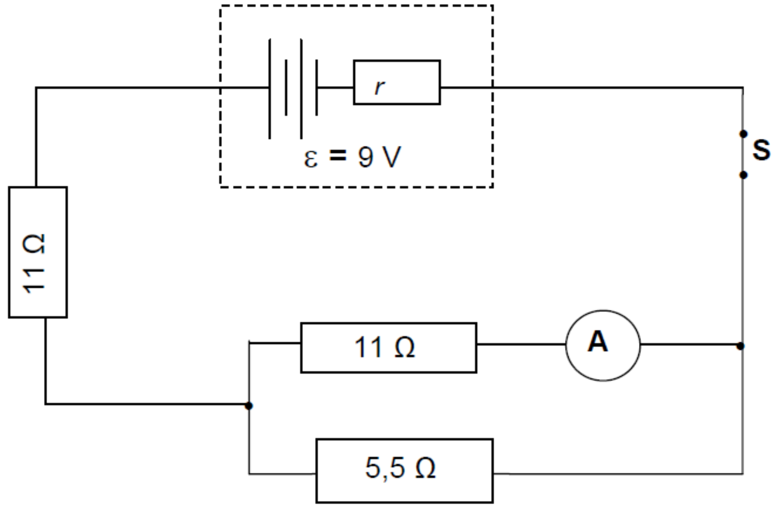


8.1.1 Apart from temperature, write down TWO other factors that the learners should consider to ensure a fair test when choosing which wire to use. (2)

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

Use suitable calculations to show clearly how you arrive at the answer. (8)

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



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

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

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

[22]

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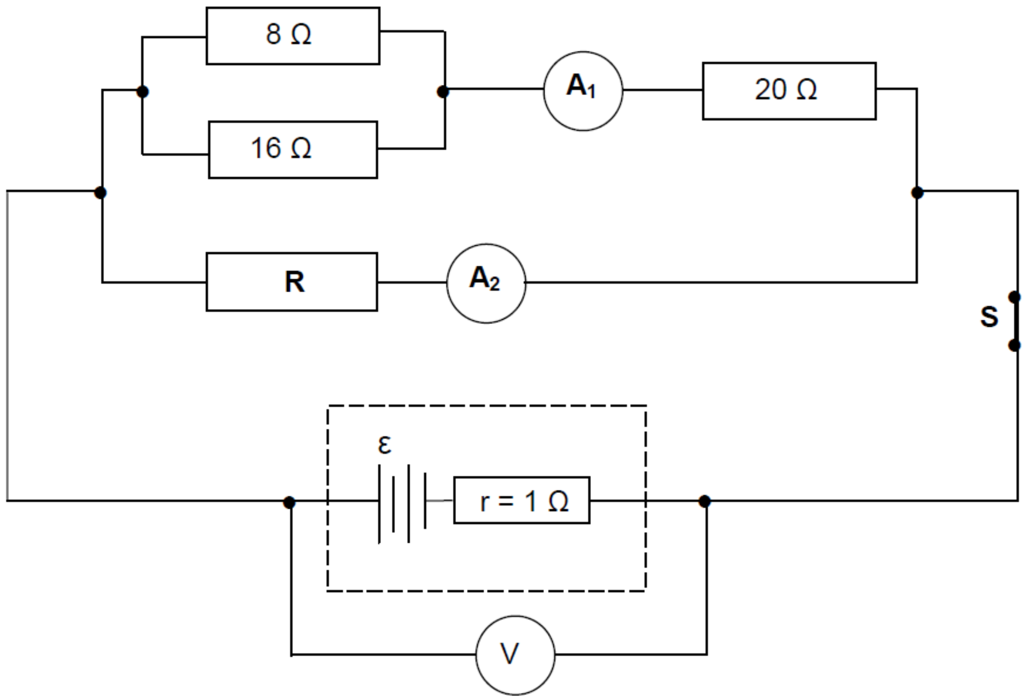
QUESTION 9 (Start on a new page.)

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.

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

9.2 Calculate the reading on ammeter **A_1**. (4)

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

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

[14]

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