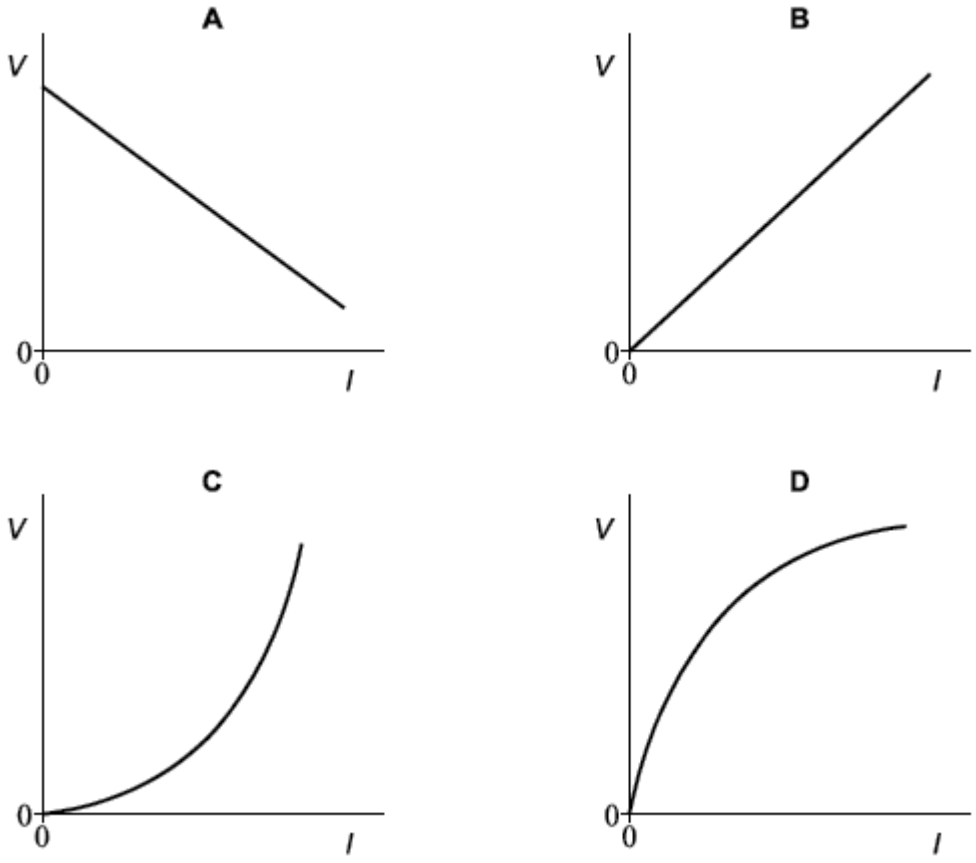
EMF and Internal Resistance Questions

Multiple Choice

Q1.

A student investigates how the potential difference *V* across the terminals of a cell varies with the current *I* in the cell.



Which graph correctly shows how *V* varies with *I*?

A ⬭

B ⬭

C ⬭

D ⬭

(Total 1 mark)

Q2.

The circuit in **Figure 1** is used to investigate how the potential difference V between the terminals of a cell varies as the current I in the circuit changes. **Figure 2** shows the graph of the results.

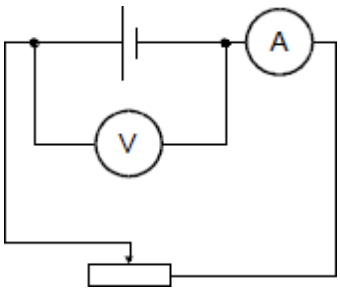


Figure 1

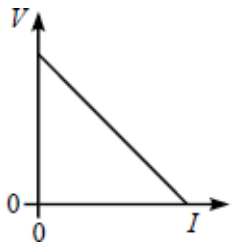


Figure 2

Which one of the following can be deduced from the gradient of the graph?

A The internal resistance of the cell ⬭

B The e.m.f. of the cell ⬭

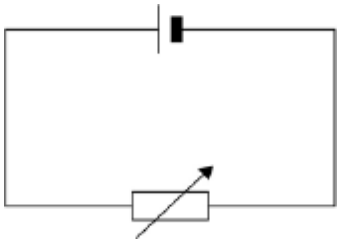
C The power dissipated by the cell ⬭

D The resistance of the variable resistor ⬭

(Total 1 mark)

Q3.

The cell in the circuit has an emf of 2.0 V. When the variable resistor has a resistance of 4.0 Ω, the potential difference (pd) across the terminals of the cell is 1.0 V.



What is the pd across the terminals of the cell when the resistance of the variable resistor is 12 Ω?

A 0.25 V ⬭

B 0.75 V ⬭

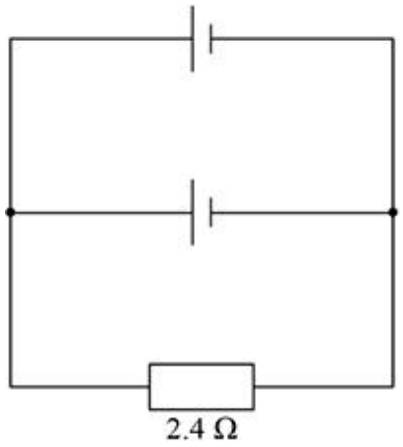
C 1.33 V ⬭

D 1.50 V ⬭

(Total 1 mark)

Q4.

Two identical batteries each of emf 1.5 V and internal resistance 1.6 Ω are connected in parallel. A 2.4 Ω resistor is connected in parallel with this combination.



What is the current in the 2.4 Ω resistor?

A 0.38 A ⬭

B 0.47 A ⬭

C 0.75 A ⬭

D 0.94 A ⬭

(Total 1 mark)

Q5.

A practical power supply provides a steady current I for a time t to an external circuit.

The emf of the power supply during t is equivalent to

A the energy dissipated in the external circuit. ⬭

B the energy dissipated in the whole circuit. ⬭

C the energy dissipated in the whole circuit, divided by the product It. ⬭

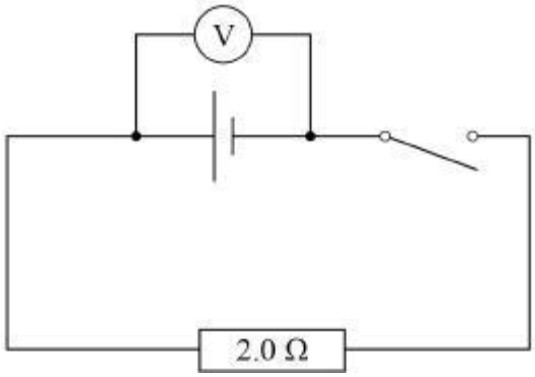
D the potential difference across the terminals of the power supply. ⬭

(Total 1 mark)

Q6.

In the circuit, the reading of the voltmeter is V.

When the switch is closed the reading becomes $\frac{V}{3}$.



What is the internal resistance of the cell?

A 0.33 Ω ⬭

B 0.67 Ω ⬭

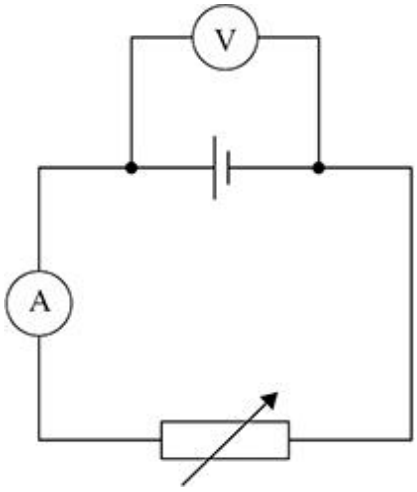
C 4.0 Ω ⬭

D 6.0 Ω ⬭

(Total 1 mark)

Q7.

In the circuit shown, the cell has an emf of 12 V and an internal resistance which is not negligible.



When the resistance of the variable resistor is 10 Ω the voltmeter reads 10 V and the ammeter reads 1.0 A.

The resistance of the variable resistor is changed to 5 Ω.

What is the new reading on the ammeter?

A 1.4 A ⬭

B 1.7 A ⬭

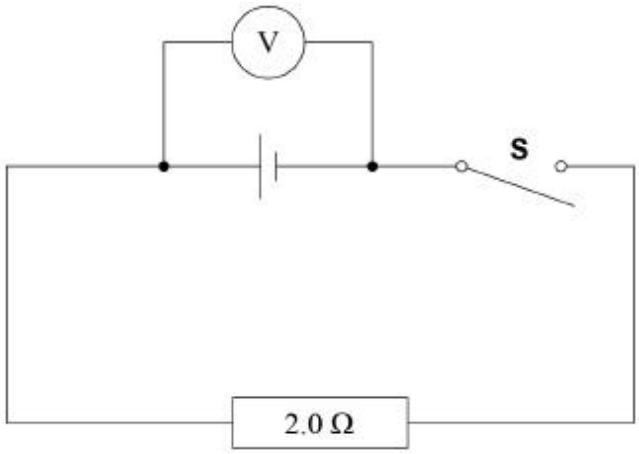
C 2.0 A ⬭

D 2.4 A ⬭

(Total 1 mark)

Q8.

The reading on the voltmeter halves when switch **S** is closed.



What is the internal resistance of the cell?

A 0.50 Ω ⬭

B 1.0 Ω ⬭

C 2.0 Ω ⬭

D 4.0 Ω ⬭

(Total 1 mark)

Q9.

A $12\ \Omega$ resistor is connected across the terminals of a cell that has an emf of $2.0\ \text{V}$ and an internal resistance of $4.0\ \Omega$.

What is the terminal pd?

A $0.50\ \text{V}$ ⬭

B $0.75\ \text{V}$ ⬭

C $1.30\ \text{V}$ ⬭

D $1.50\ \text{V}$ ⬭

(Total 1 mark)

Q10.

A battery is connected to a 10 Ω resistor and a switch in series. A voltmeter is connected across the battery. When the switch is open (off) the voltmeter reads 1.45 V. When the switch is closed the reading is 1.26 V.

What is the internal resistance of the battery?

A 0.66 Ω ⬭

B 0.76 Ω ⬭

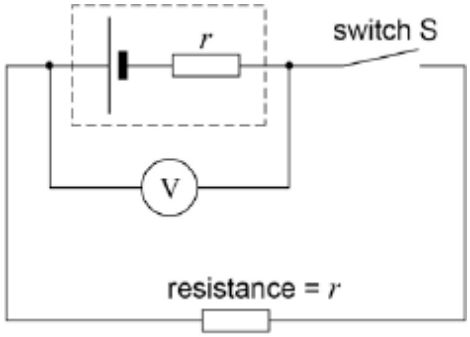
C 1.3 Ω ⬭

D 1.5 Ω ⬭

(Total 1 mark)

Q11.

In the circuit shown, V is a voltmeter with a very high resistance. The internal resistance of the cell, *r*, is equal to the external resistance in the circuit.



external resistance

Which of the following is not equal to the emf of the cell?

A the reading of the voltmeter when the Switch S is open ⬭

B the chemical energy changed to electrical energy when unit charge passes through the cell ⬭

C twice the reading of the voltmeter when the switch S is closed ⬭

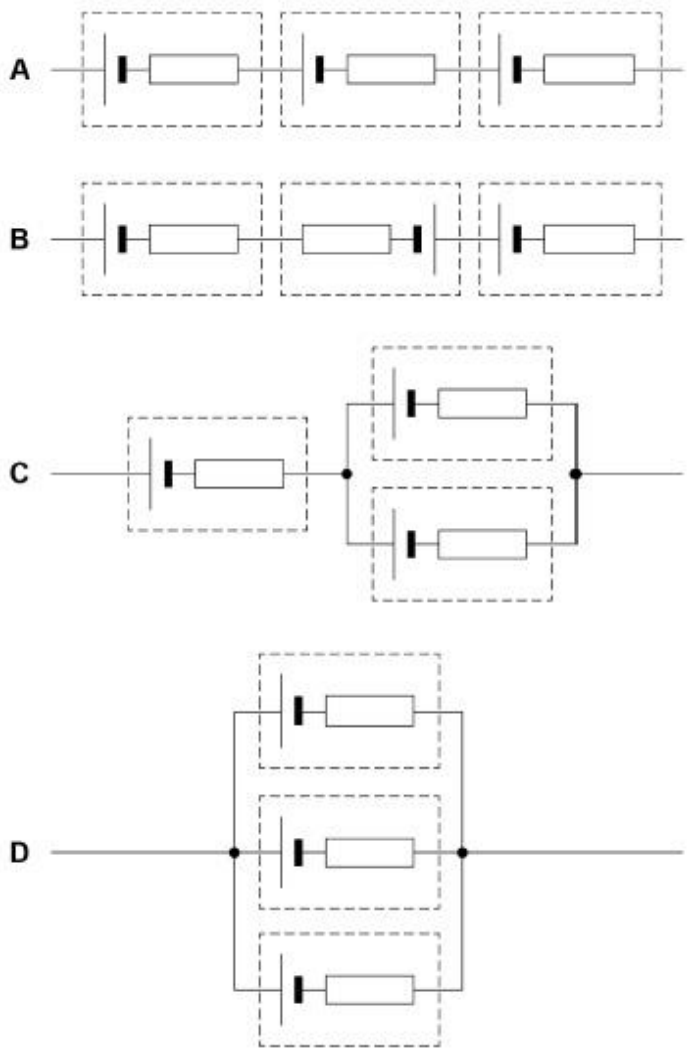
D the electrical energy produced when unit current passes through the cell ⬭

(Total 1 mark)

Q12.

Three cells each have an emf ε = 1.5 V and an internal resistance r = 0.6 Ω.

Which combination of these cells will deliver a total emf of 1.5 V and a maximum current of 7.5 A?



A ⬭

B ⬭

C ⬭

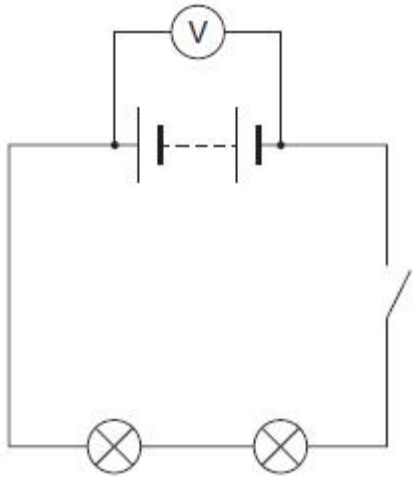
D ⬭

(Total 1 mark)

State/Explain/Describe

Q13.

The diagram shows an electrical circuit in a car. A voltmeter of very high resistance is used to measure the potential difference across the terminals of the battery.



(a) Define potential difference.

_____

_____

(1)

(b) Explain how and why the voltmeter reading changes when the switch is closed.

_____

_____

_____

_____

_____

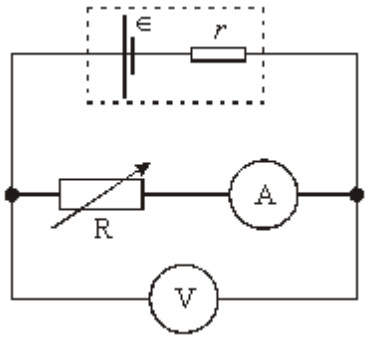
_____

(3)

(Total 4 marks)

Q14.

In the circuit shown, a battery of emf $\in$ and internal resistance *r* is connected to a variable resistor R. The current *I* and the voltage *V* are read by the ammeter and voltmeter respectively.



(a) The emf is related to *V*, *I* and *r* by the equation

$\in = V + Ir$

Rearrange the equation to give *V* in terms of $\in$, *I* and *r*.

_____

(1)

(b) In an experiment, the value of R is altered so that a series of values of *V* and the corresponding values of *I* are obtained. Using the axes, sketch the graph you would expect to obtain as R is changed.

(2)

(c) State how the values of $\in$ and *r* may be obtained from the graph.

$\in$ _____

r _____

(2)

(Total 5 marks)

Q15.

(a) Define the *electromotive force (emf)* of an electrical power supply.

_____

_____

_____

_____

_____

(2)

(b) Explain why, when a battery is supplying a current to a circuit, the voltage measured between its terminals is less than its emf.

_____

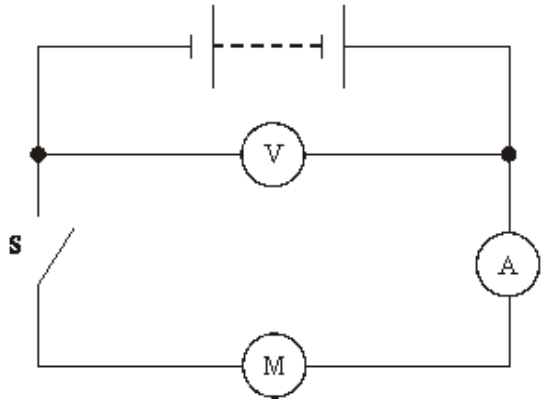
_____

_____

_____

(2)

(c) In the circuit shown in the figure below the voltmeter has a very high resistance and the resistance of the ammeter is negligible. The motor M is being tested using a battery with an emf of 9.00 V.



(i) State the reading on the voltmeter when the switch S is open.

voltmeter reading _____

(ii) When S is closed and the motor is allowed to run freely the voltmeter reading is 8.41 V and the ammeter reads 0.82 A. Calculate the internal resistance of the battery.

internal resistance _____

(iii) Explain why the ammeter reading is greater than 0.82 A when the motor does

work by lifting a load.

_____

_____

_____

(5)

(Total 9 marks)

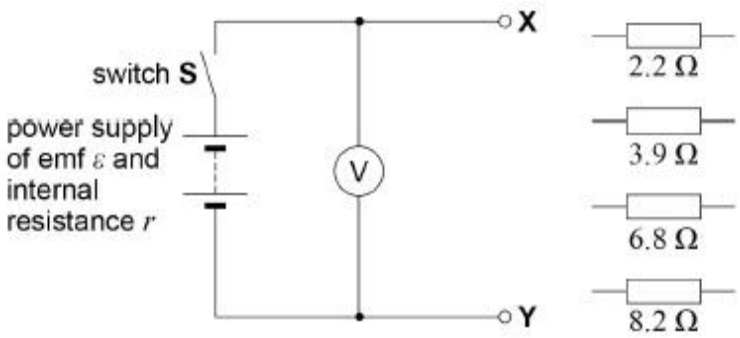
State/Explain/Numerical

Q16.

This question is about an experiment to determine the internal resistance of a power supply.

A student is given the circuit and the four resistors of known resistance shown in **Figure 1**.

Figure 1



The student can change the external resistance R of the circuit between terminals **X** and **Y**. This is done by connecting different combinations of **two** resistors in series or in parallel between **X** and **Y**.
This method can produce **12 different values** for R.

(a) Calculate the largest value of R that the student can obtain using **two** resistors.

largest value of R = _____ Ω

(1)

(b) Calculate the smallest value of R that the student can obtain using **two** resistors.

smallest value of R = _____ Ω

(2)

(c) With switch **S** closed (in the on position) and no resistors connected between **X** and **Y** the voltmeter reading V is 1.62 V.

The student concludes that this voltmeter reading equals the emf ε of the power supply.

State why the student's conclusion that ε = 1.62 V was correct.

_____

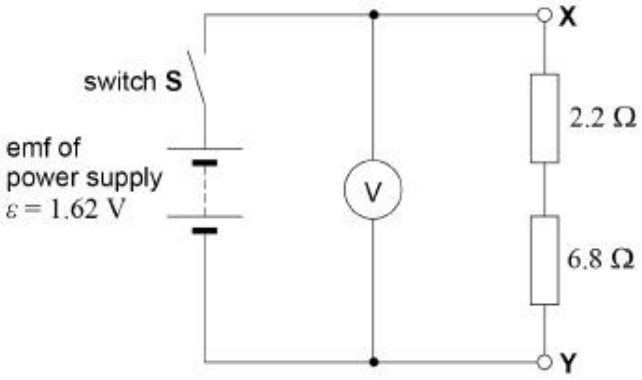
_____

_____

(1)

(d) **Figure 2** shows one particular combination and arrangement of two resistors that the student could use.

Figure 2



When **S** is closed the voltmeter reading V is 1.14 V.

Explain why V is less than 1.62 V when **S** is closed.

_____

_____

_____

(1)

(e) It can be shown that

$$\varepsilon - V = r \times \frac{V}{R}$$

where r is the internal resistance of the power supply.

Determine (ε – V) and $\frac{V}{R}$ for this circuit using the data given in part (d).

($\varepsilon - V$) = _____ V

$\frac{V}{R}$ = _____ V Ω^{-1}

(1)

(f) The student obtains values of V for five further different values of R.

These data were used to produce the graph of ($\varepsilon - V$) against $\frac{V}{R}$ in **Figure 3**.

Plot the point you determined in part (e) on **Figure 3** and add a suitable best-fit line.

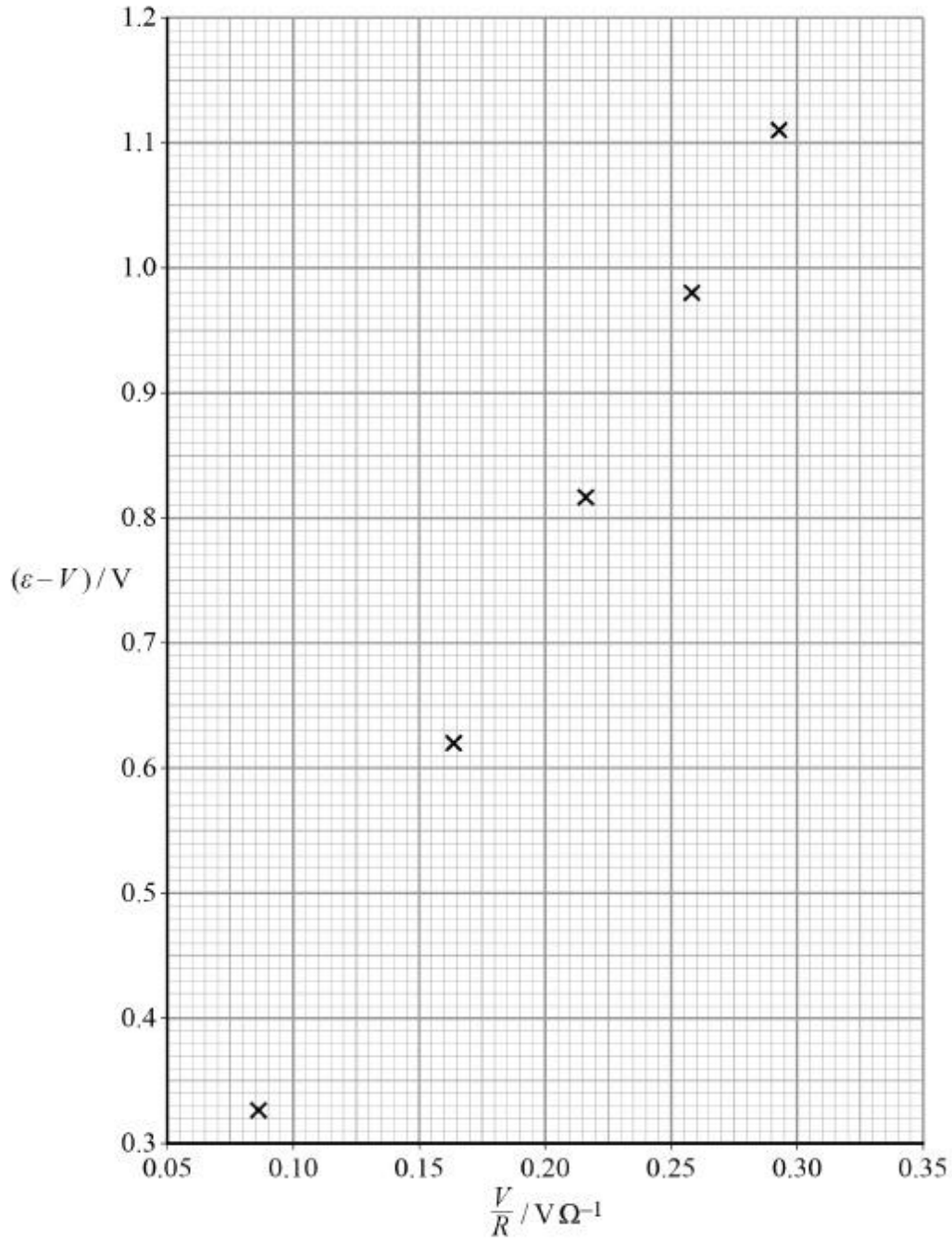
(1)

(g) Use **Figure 3** to determine r.

r = _____ Ω

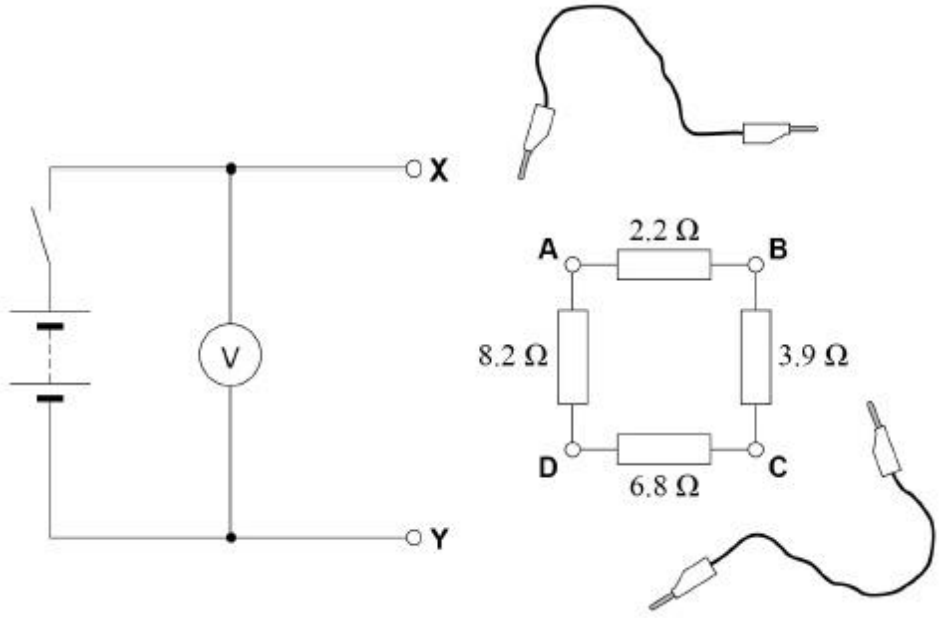
(2)

Figure 3



(h) **Figure 4** shows a different method for varying the resistance R described in part (a).

Figure 4



The four resistors are connected in a loop with sockets **A**, **B**, **C** and **D** at each junction. Two leads are used to connect the resistor loop to **X** and **Y**.

Discuss whether this method is an improvement over the method described in part (a). In your answer, you should refer to the number of different values that can be obtained for R.

_____

_____

_____

_____

_____

_____

(2)

(Total 11 marks)

Q17.

A very high resistance voltmeter reads 15.0 V when it is connected across the terminals of a power supply.

(a) Explain why the reading on the voltmeter is equal to the emf of the power supply.

_____

_____

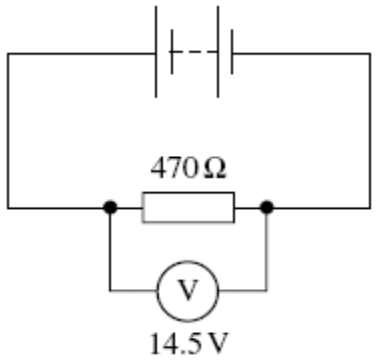
_____

_____

_____

(3)

(b) A resistor of value 470 Ω is connected across the terminals of the power supply in parallel with the voltmeter, as the figure below shows. The voltmeter reads 14.5 V.



(i) Calculate the current in the 470 Ω resistor.

_____

_____

_____

current _____ A

(2)

(ii) Calculate the internal resistance of the power supply.

_____

_____

_____

_____

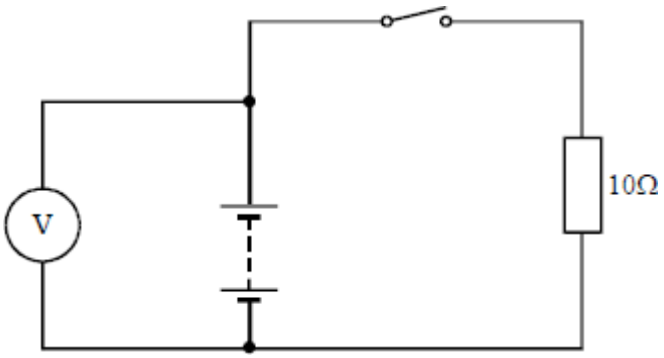
_____

internal resistance _____ Ω

(3)

(Total 8 marks)

Q18.



A battery is connected to a 10 Ω resistor as shown. The e.m.f. (electromotive force) of the battery is 12 V.

(a) (i) Explain what is meant by the e.m.f. of a battery.

_____

_____

_____

_____

(ii) When the switch is open the voltmeter reads 12.0 V and when it is closed it reads 11.5 V. Explain why the readings are different.

_____

_____

_____

(3)

(b) Calculate the internal resistance of the battery.

_____

_____

_____

(3)

(Total 6 marks)

Q19.

(a) (i) Define the term electromotive force (emf).

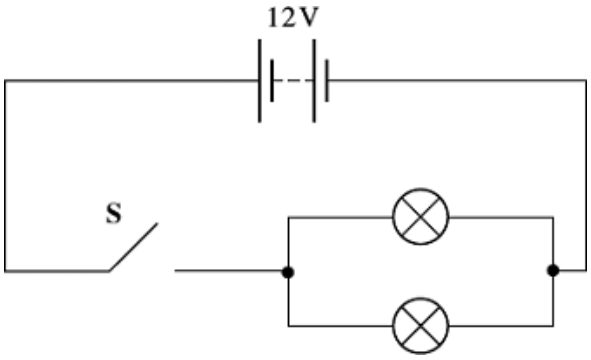
_____

_____

_____

(2)

(ii) The figure below is a circuit diagram illustrating how two of these headlamps are connected to a car battery.



The car battery has an emf of 12 V.

When the switch **S** is closed there is a current of 9.1 A through the battery and a potential difference of 11.9 V across the headlamps.
Calculate the internal resistance of the car battery.

internal resistance _____ Ω

(2)

(b) A fault develops in one of the headlamps in the figure above causing its resistance to decrease.
State and explain how this fault affects the brightness of the other headlamp.

_____

_____

_____

_____

_____

_____

(3)

(Total 7 marks)

Q20.

Figure 1 shows a circuit that includes an oscilloscope used to find the internal resistance *r* of a battery.

Figure 1

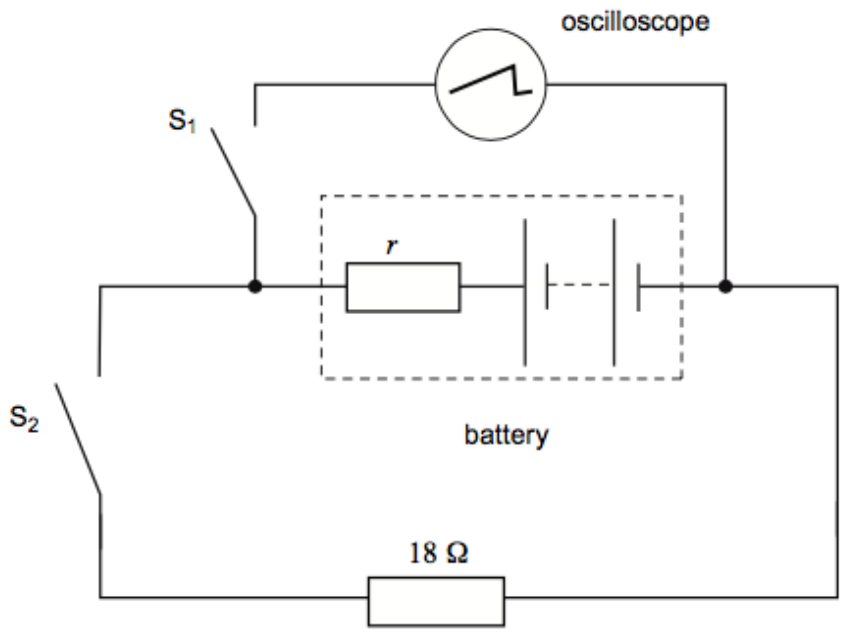
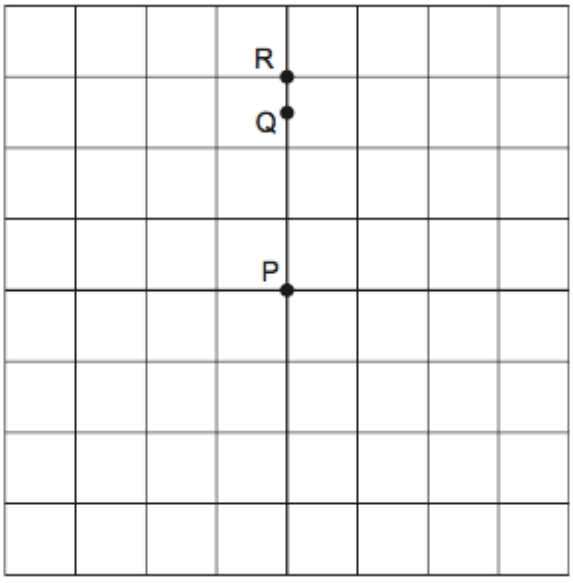


Figure 2 represents the screen of the oscilloscope. With switches S_1 and S_2 open, a bright spot is seen on the screen at P.

Figure 2



The vertical sensitivity of the oscilloscope is set at 2.0 V per division.

(a) Explain why the oscilloscope shows a bright spot rather than a horizontal line.

_____

_____

(1)

(b) When switch S_1 is closed, the spot moves to R.

(i) State the electrical property of the battery represented by the deflection PR.

_____

_____

(1)

(ii) Determine the value of the electrical quantity represented by the deflection PR.

electrical quantity = _____

(1)

(c) With switch S_1 kept closed, switch S_2 is also closed. The spot moves to Q.

Explain why the spot moves from R to Q.

_____

_____

_____

_____

_____

(3)

(d) Calculate the current in the battery when both switches are closed.

current = _____ A

(2)

(e) Calculate the internal resistance of the battery.

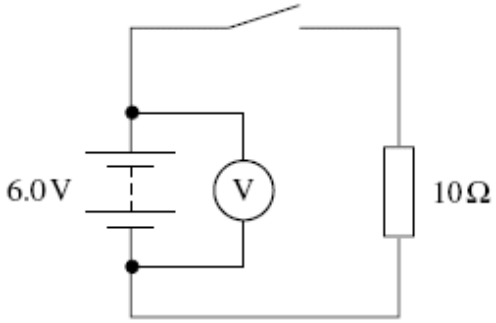
internal resistance = _____ Ω

(2)

(Total 10 marks)

Q21.

A battery is connected to a 10 Ω resistor as shown in the diagram below. The emf (electromotive force) of the battery is 6.0 V.



(a) (i) Define the emf of a battery.

_____

_____

(1)

(ii) When the switch is open the voltmeter reads 6.0 V and when it is closed it reads 5.8 V.
Explain why the readings are different.

_____

_____

_____

_____

_____

(2)

(b) Calculate the internal resistance of the battery.

answer = _____ Ω

(3)

(c) State and explain why it is important for car batteries to have a very low internal resistance.

_____

_____

_____

_____

_____

_____

(2)

(Total 8 marks)

Q22.

(a) **Figure 1** and **Figure 2** show two circuits in which a supply of e.m.f. 6.0 V and internal resistance 5.0 Ω is delivering power to a pair of resistors.

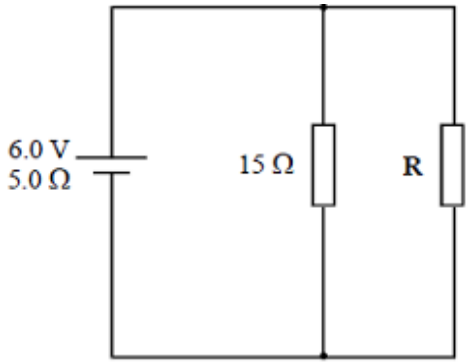


Figure 1

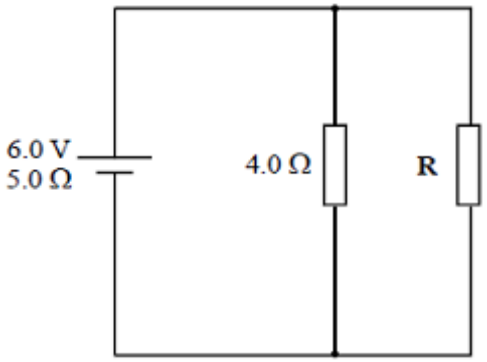


Figure 2

When maximum power is dissipated in an external circuit, the resistance of the external circuit is equal to the internal resistance of the supply.

(i) For the circuit in **Figure 1**, determine the value of **R** which results in the maximum power being delivered to the external circuit.

(3)

(ii) Calculate the terminal potential difference when the supply is delivering maximum power to the circuit in **Figure 1**.

(1)

(iii) Calculate the power that will be dissipated by the 15 Ω resistor when the supply is delivering maximum power to the external circuit.

(2)

(iv) For the circuit in **Figure 2**, explain why the supply cannot deliver maximum power in this circuit for any value of the resistor **R**.

_____

_____

_____

_____

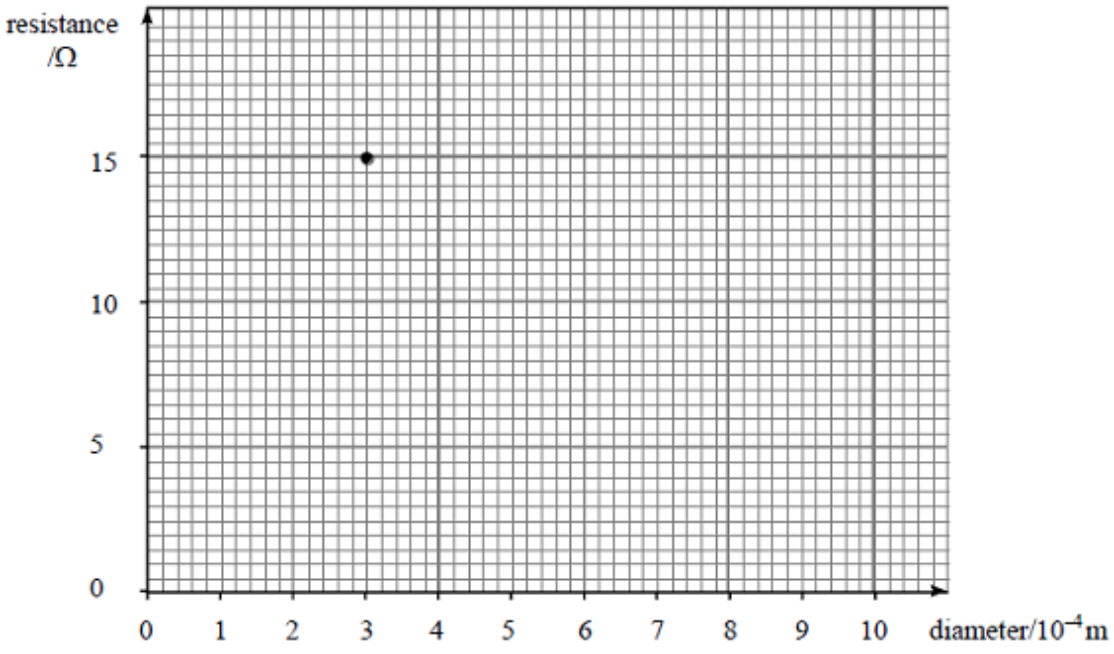
_____

(2)

(b) (i) The 15 Ω resistor is made from wire of length 2.3 m. The wire has a diameter of 3.0×10^{-4} m. Calculate the resistivity of the material from which the wire is made.

(3)

(ii) Sketch below a graph showing how the resistance of 2.3 m of wire made from this material varies with the diameter of the wire. The value for a wire of diameter 3.0×10^{-4} m has been plotted for you.



(2)

(Total 13 marks)

Q23.

A battery of e.m.f. ε and internal resistance r is connected in series with a variable resistor R as shown in **Figure 1**. A voltmeter is connected as shown.

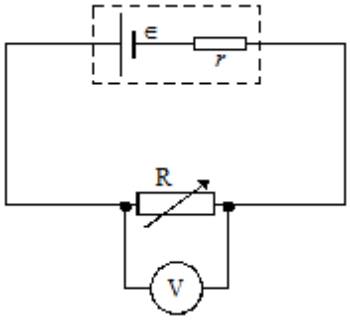


Figure 1

(a) (i) State what is meant by the e.m.f of a battery.

_____

_____

(ii) The reading V on the voltmeter is the voltage across R.
Why is V less than ε?

_____

_____

(3)

(b) In order to measure ε and r, an ammeter is used in the circuit, as shown in **Figure 2**.

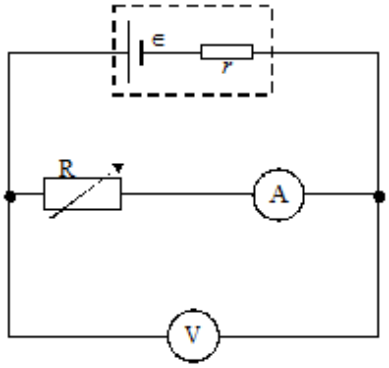
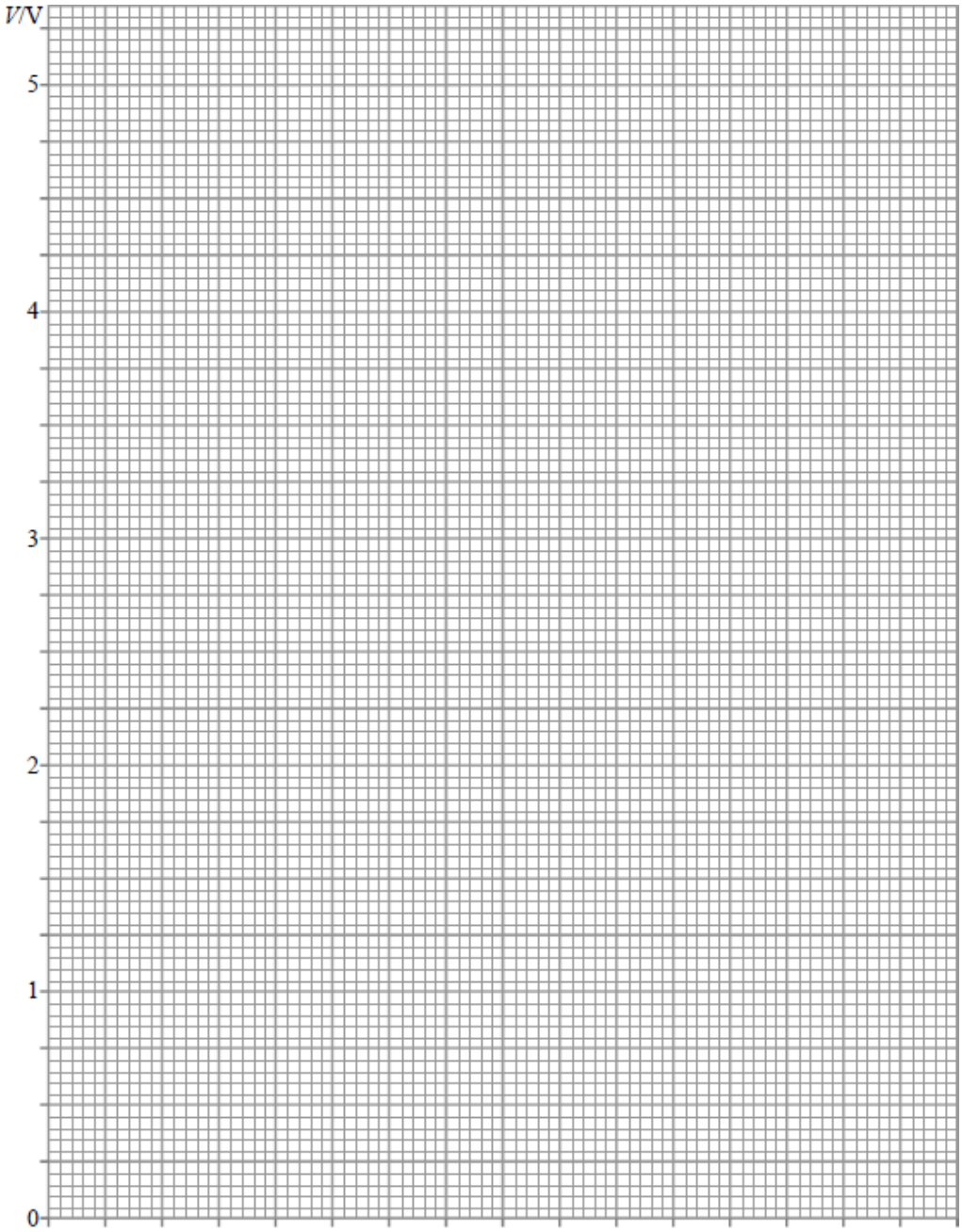


Figure 2

The value of R is decreased in steps and at each step the readings V and I on the voltmeter and ammeter, respectively, are recorded. These are shown in the table.

reading on voltmeter/V	reading on ammeter/A
4.0	0.07
3.0	0.14
2.0	0.21
1.0	0.28

(i) Plot a graph of V (on y axis) against I (on x axis) and draw the best straight line through the points.



(ii) Determine the values of ε and r from the graph, explaining your method.

_____

_____

_____

_____

_____

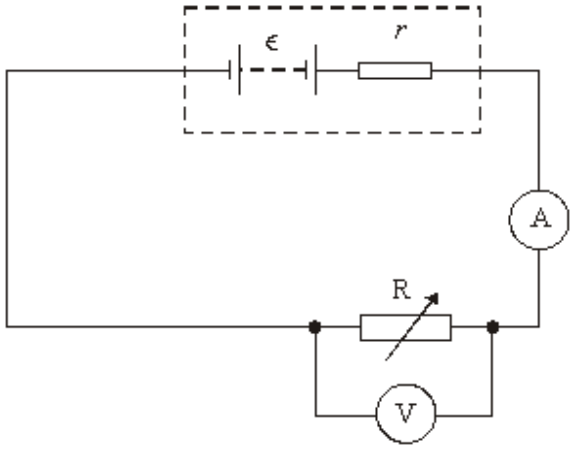
_____

(8)

(Total 11 marks)

Q24.

A battery of emf $\in$ and internal resistance *r* is connected in series to a variable resistor R and an ammeter of negligible resistance. A voltmeter is connected across R, as shown in the figure below.



(a) (i) State what is meant by the emf of the battery.

_____

_____

(ii) The reading on the voltmeter is less than the emf. Explain why this is so.

_____

_____

(2)

(b) A student wishes to measure $\in$ and *r*. Using the circuit shown in the figure above the value of R is decreased in steps and at each step the readings *V* and *I* on the voltmeter and ammeter respectively are recorded. These are shown in the table.

reading on voltmeter/V	reading on ammeter/A
8.3	0.07
6.8	0.17
4.6	0.33
2.9	0.44
0.3	0.63

(i) Give an expression relating *V, I*, $\in$ and *r.*

_____

(ii) Draw a graph of *V* (on the *y*-axis) against *I (*on the *x*-axis) on graph paper.

(Allow one sheet of graph paper)

(iii) Determine the values of ϵ and r from the graph, explaining your method.

ϵ: _____

_____

r: _____

_____

(8)

(Total 10 marks)

Q25.

The electrical energy for a small village of 155 houses is to be generated by a bank of solar cells. The average power used by each house, taken over a year, is 800 W.

The average power per square metre arriving at the surface of the Earth from the Sun is 650 W. The efficiency of the conversion of solar energy to electrical energy is 15%.

(a) (i) Calculate the average power the solar cells need to provide for the whole village.

(1)

(ii) Calculate the total area of solar cells needed to provide the power in (i).

(3)

(iii) Give **one** reason why, in practice, a greater area will need to be covered by solar cells.

_____

_____

(1)

(iv) Suggest **two** problems, other than the large area needed for solar cells, that occur using solar power alone to provide the supply to the village.

_____

_____

_____

_____

(2)

(b) The emf of the bank of solar cells is 230 V.

(i) Calculate the supply current when the village is using 75 kW, assuming the cells have no internal resistance.

(2)

(ii) Calculate the potential difference delivered to the villagers' electrical equipment when the current calculated in (i) is produced in a bank of cells with an internal resistance of 0.050 Ω.

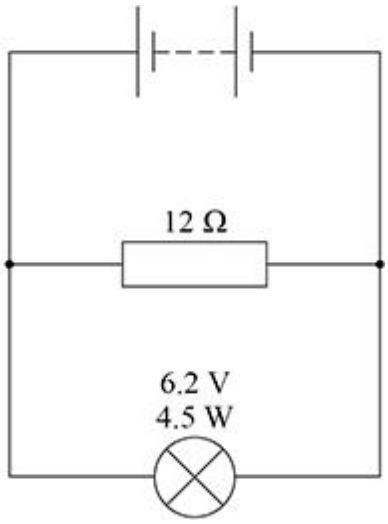
(3)

(Total 12 marks)

Q26.

A student assembles the circuit in **Figure 1**.

Figure 1



The battery has an internal resistance of $2.5\ \Omega$.

(a) Show that the resistance of the $6.2\ \text{V}, 4.5\ \text{W}$ lamp at its working potential difference (pd) is about $9\ \Omega$.

(1)

(b) The terminal pd across the battery is $6.2\ \text{V}$.

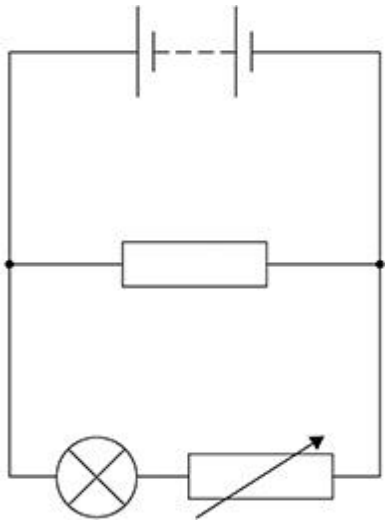
Calculate the emf of the battery.

emf = _____ V

(3)

The student makes a variable resistor to control the brightness of the lamp. **Figure 2** shows her circuit.

Figure 2



(c) She uses a resistance wire with a diameter of $0.19\ \text{mm}$ to make the variable resistor. A $5.0\ \text{m}$ length of this wire has a resistance of $9.0\ \Omega$.

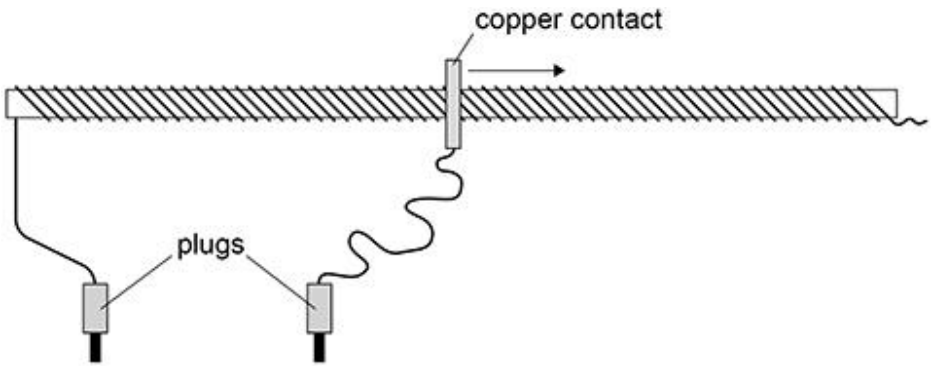
Calculate the resistivity of the wire.

resistivity = _____ $\Omega\ \text{m}$

(3)

(d) **Figure 3** shows the 5.0 m length of wire wrapped around a tube to make the variable resistor.

Figure 3



Two plugs connect the variable resistor into the circuit. A moveable copper contact is used to vary the length of wire in series with the lamp.
When the contact is placed on the tube at one particular position, the lamp is dim. The contact is then moved slowly to the right as shown in **Figure 3**.

Explain, without calculation, what happens to the brightness of the lamp as the contact is moved.

_____

_____

_____

_____

_____

(2)

(e) The student now makes a different circuit by connecting the variable resistor **in parallel** with the lamp.

The contact is returned to its original position on the tube as shown in **Figure 3** and the lamp is dim. The contact is again slowly moved to the right.

Explain, without calculation, what happens to the brightness of the lamp as the contact is moved.

_____

_____

_____

_____

_____

(2)

(Total 11 marks)

Q27.

A car battery has an *emf* of 12 V and an *internal resistance* of 5.0×10^{-3} Ω.

(a) (i) Explain what is meant by the emf of the battery.

_____

_____

(1)

(ii) Explain what is meant by the internal resistance of the battery.

_____

_____

(1)

(b) The battery is used to provide the starting motor of a car with a current of 800 A.

(i) Calculate the potential difference across the terminals of the battery.

answer = _____ V

(2)

(ii) Calculate the rate of dissipation of energy due to its internal resistance stating an appropriate unit.

answer = _____

(3)

(c) State and explain the effect of attempting to use a battery with a much higher internal resistance to start the car.

_____

_____

_____

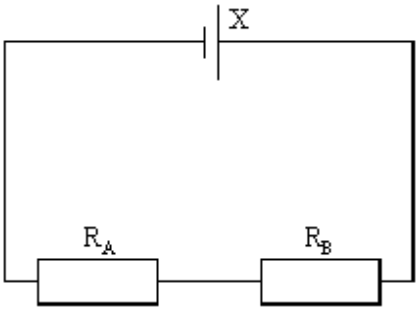
_____

(2)

(Total 9 marks)

Q28.

In the circuit shown in the diagram below cell **X** has an emf of 12 V and a negligible internal resistance. The resistances of R_A and R_B are 10 Ω and 15 Ω respectively.



(a) Calculate the potential difference across R_B.

Potential difference _____

(2)

(b) Cell **X** is replaced by cell **Y** that has an emf of 12 V and an internal resistance of 7.5 Ω. Calculate the terminal potential difference across cell **Y.**

Potential difference _____

(3)

(Total 5 marks)

Q29.

(a) Define the term electromotive force (emf).

_____

_____

(2)

(b) **Figure 1** shows very high resistance voltmeter placed across an 8.00 Ω resistor connected to a cell of emf 1.56 V.

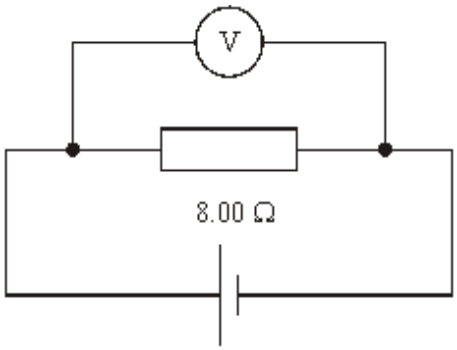


Figure 1

The very high resistance voltmeter registers 1.40 V. Show that the internal resistance of the cell must be about 0.9 Ω.

(3)

(c) A voltmeter, having resistance 24.0 Ω, replaces the very high resistance voltmeter.

(i) Calculate the combined resistance of this voltmeter and the 8.00 Ω resistor connected in parallel.

Combined resistance = _____ Ω

(2)

(ii) Calculate the reading on this voltmeter.

Reading on voltmeter = _____ V

(3)

(iii) Explain why the reading on this voltmeter is different from the reading on the very high resistance voltmeter in part (b).

_____

_____

_____

(1)

(d) Each lead connecting the resistor to the cell is made from a single strand of copper wire. Each lead is 0.30 m long and has a diameter of 2.0 mm. Show that the total potential difference across the two leads is negligible when the cell delivers a current of 0.20 A. resistivity of copper, $\rho = 1.7 \times 10^{-8}$ Ω m.

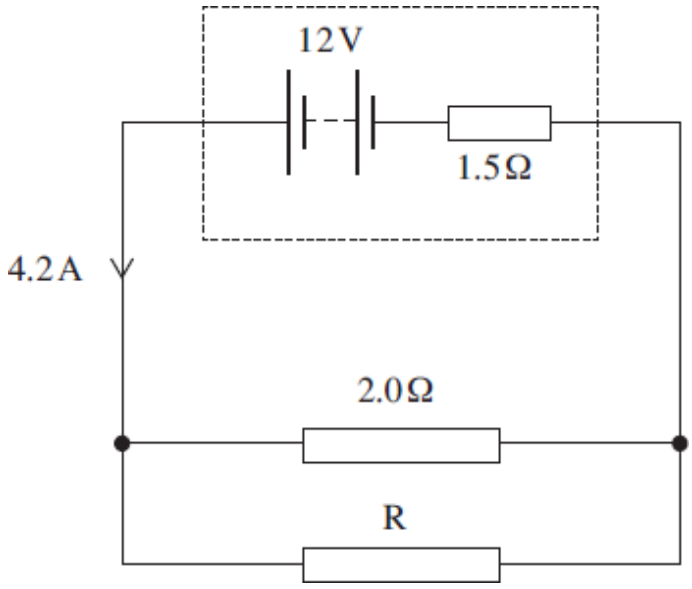
(4)

(Total 15 marks)

State/Explain/Numerical

Q30.

The circuit diagram below shows a battery of electromotive force (emf) 12 V and internal resistance 1.5 Ω connected to a 2.0 Ω resistor in parallel with an unknown resistor, R. The battery supplies a current of 4.2 A.



(a) (i) Show that the potential difference (pd) across the internal resistance is 6.3 V.

(1)

(ii) Calculate the pd across the 2.0 Ω resistor.

pd _____ V

(1)

(iii) Calculate the current in the 2.0 Ω resistor.

current _____ A

(1)

(iv) Determine the current in R.

current _____ A

(1)

(v) Calculate the resistance of R.

R _____ Ω

(1)

(vi) Calculate the total resistance of the circuit.

circuit resistance _____ Ω

(2)

(b) The battery converts chemical energy into electrical energy that is then dissipated in the internal resistance and the two external resistors.

(i) Using appropriate data values that you have calculated, complete the following table by calculating the rate of energy dissipation in each resistor.

resistor	**rate of energy dissipation / W**
internal resistance	
2.0 Ω	
R	

(3)

(ii) Hence show that energy is conserved in the circuit.

_____

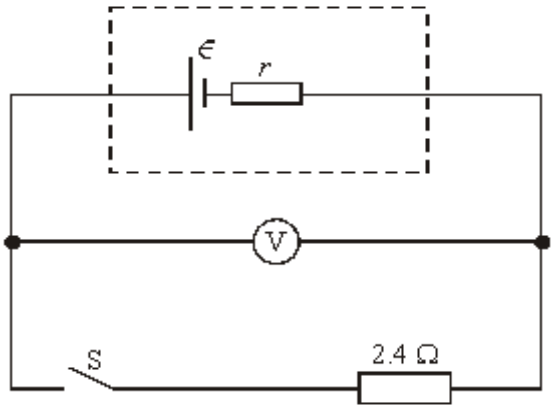
_____

(2)

(Total 12 marks)

Q31.

In the circuit shown the battery has emf $\in$ and internal resistance *r*.



(a) (i) State what is meant by the emf of a battery.

_____

_____

(ii) When the switch S is open, the voltmeter, which has infinite resistance, reads 8.0 V. When the switch is closed, the voltmeter reads 6.0 V.
Determine the current in the circuit when the switch is closed.

_____

_____

_____

(iii) Show that $r = 0.80\ \Omega$.

_____

_____

(4)

(b) The switch S remains closed. Calculate

(i) the power dissipated in the 2.4 Ω resistor,

_____

(ii) the total power dissipated in the circuit,

_____

_____

(iii) the energy wasted in the battery in 2 minutes.

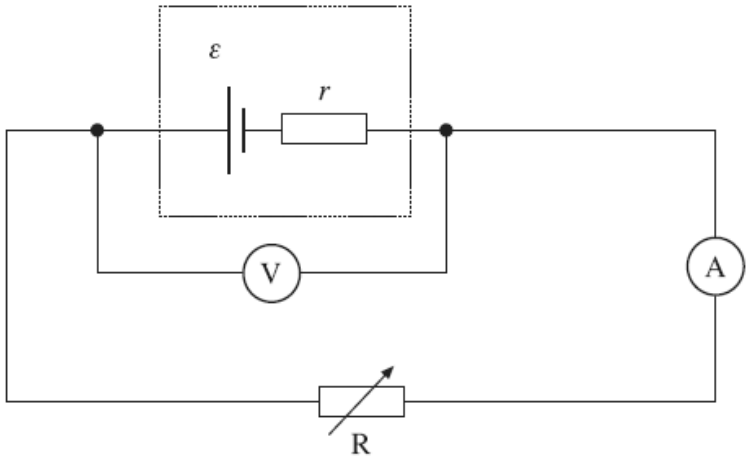
_____

(4)

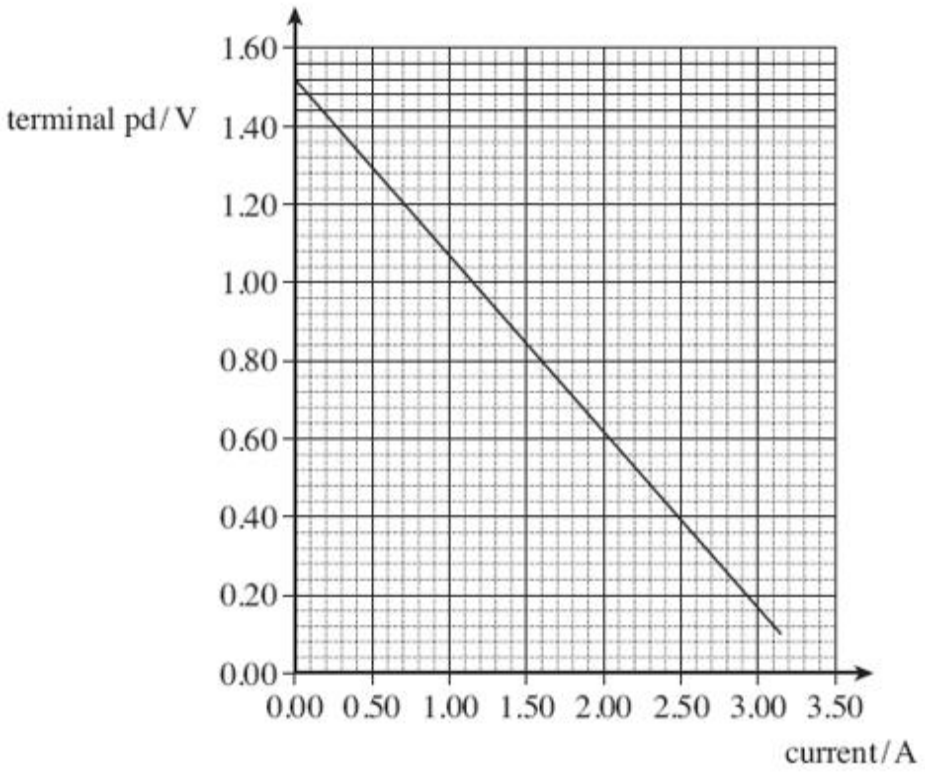
(Total 8 marks)

Q32.

A cell of emf, ε, and internal resistance, r, is connected to a variable resistor R. The current through the cell and the terminal pd of the cell are measured as R is decreased. The circuit is shown in the figure below.



The graph below shows the results from the experiment.



(a) Explain why the terminal pd decreases as the current increases.

_____

_____

_____

_____

(2)

(b) (i) Use the graph to find the emf, ε, of the cell.

answer = _____ V

(1)

(ii) Use the graph above to find the internal resistance, *r*, of the cell.

answer = _____ Ω

(3)

(c) Draw a line on the graph above that shows the results obtained from a cell with

(i) the same emf but double the internal resistance of the first cell labelling your graph **A.**

(2)

(ii) the same emf but negligible internal resistance labelling your graph **B**.

(1)

(d) In the original circuit shown in part (a), the variable resistor is set at a value such that the current through the cell is 0.89 A.

(i) Calculate the charge flowing through the cell in 15 s, stating an appropriate unit.

answer = _____

(2)

(ii) Calculate the energy dissipated in the internal resistance of the cell per second.

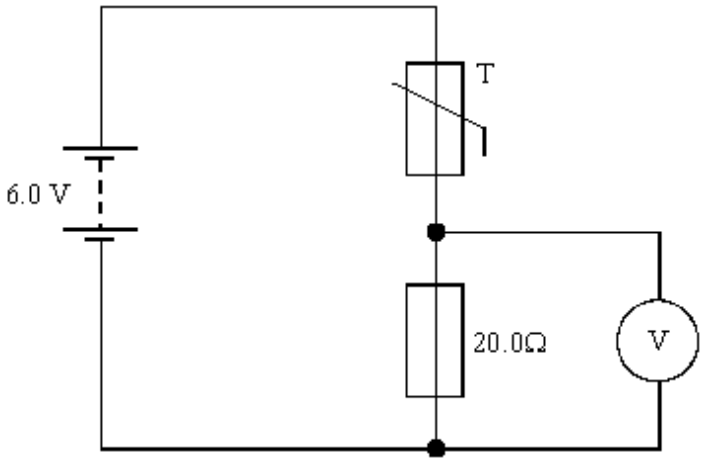
answer = _____ W

(2)

(Total 13 marks)

Q33.

The circuit shown in the diagram below can be used as an electronic thermometer. The battery has negligible internal resistance.



The reading on the digital voltmeter can be converted to give the temperature of the thermistor T which is used as a temperature sensor.

(a) Explain why the reading on the voltmeter increases as the temperature of the thermistor increases.

_____

_____

_____

_____

_____

_____

(2)

(b) When the thermistor is at 80.0 °C the voltmeter reading is 5.0 V. Show that the resistance of the thermistor at this temperature is 4.0 Ω.

(1)

(c) When the thermistor is at 20.0 °C its resistance is 24.5 Ω. Calculate the reading on the voltmeter.

Voltmeter reading _____

(2)

(d) The battery is replaced with another having the same emf but an internal resistance of 3.0 Ω.

(i) Calculate the new voltmeter reading when the thermistor temperature is 80.0 °C.

Voltmeter reading _____

(2)

(ii) State and explain the effect, if any, on the measured temperature when the thermistor is at 20.0 °C.

_____

_____

_____

_____

_____

_____

(1)

(Total 8 marks)

Q34.

A cell has an emf of 1.5 V and an internal resistance of 0.65 Ω.
The cell is connected to a resistor **R**.

(a) State what is meant by an emf of 1.5 V.

_____

_____

_____

(2)

(b) The current in the circuit is 0.31 A.

Show that the total power output of the cell is approximately 0.47 W.

(1)

(c) Calculate the energy dissipated per second in resistor **R**.

energy dissipated per second = _____ J s^{-1}

(2)

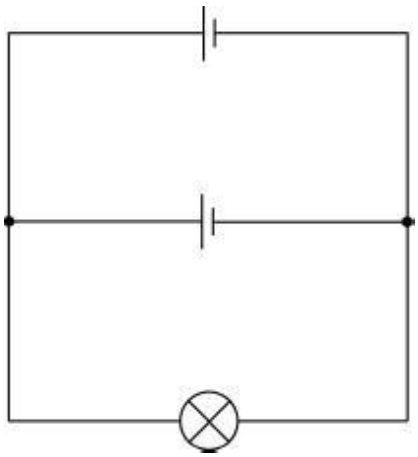
(d) The cell stores 14 kJ of energy when it is fully charged. The cell's emf and internal resistance are constant as the cell is discharged.

Calculate the maximum time during which the fully-charged cell can deliver energy to resistor **R**.

maximum time = _____ s

(2)

(e) A student uses two cells, each of emf 1.5 V and internal resistance 0.65 Ω, to operate a lamp. The circuit is shown in the diagram.



The lamp is rated at 1.3 V, 0.80 W.

Deduce whether this circuit provides the lamp with 0.80 W of power at a potential difference (pd) of 1.3 V.
Assume that the resistance of the lamp is constant.

_____

_____

_____

(4)

(f) The lamp operates at normal brightness across a pd range of 1.3 V to 1.5 V.

State and explain how more of these cells can be added to the circuit to make the lamp light at normal brightness for a longer time.
No further calculations are required.

_____

_____

_____

_____

_____

_____

_____

(3)

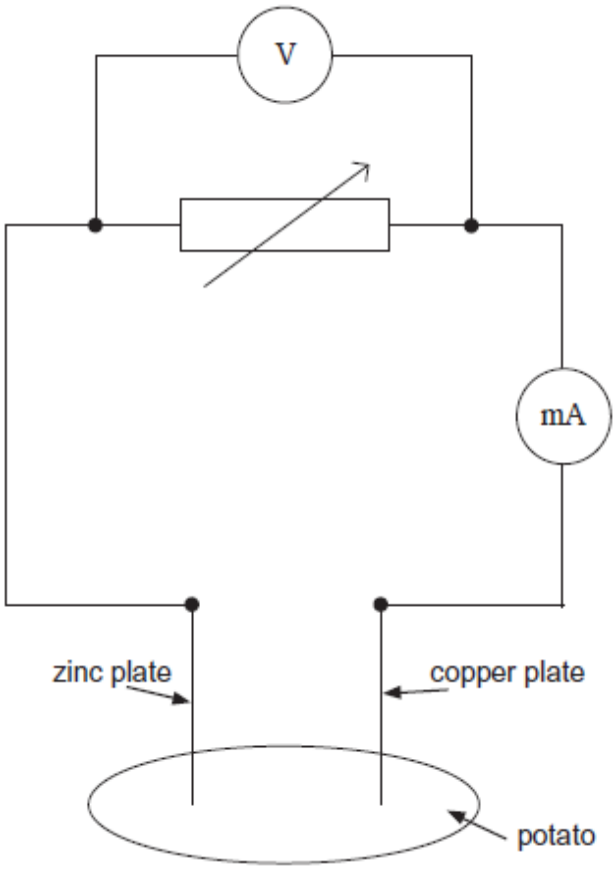
(Total 14 marks)

Practical Skills

Q35.

A 'potato cell' is formed by inserting a copper plate and a zinc plate into a potato. The circuit shown in **Figure 1** is used in an investigation to determine the electromotive force and internal resistance of the potato cell.

Figure 1



(a) State what is meant by electromotive force.

_____

_____

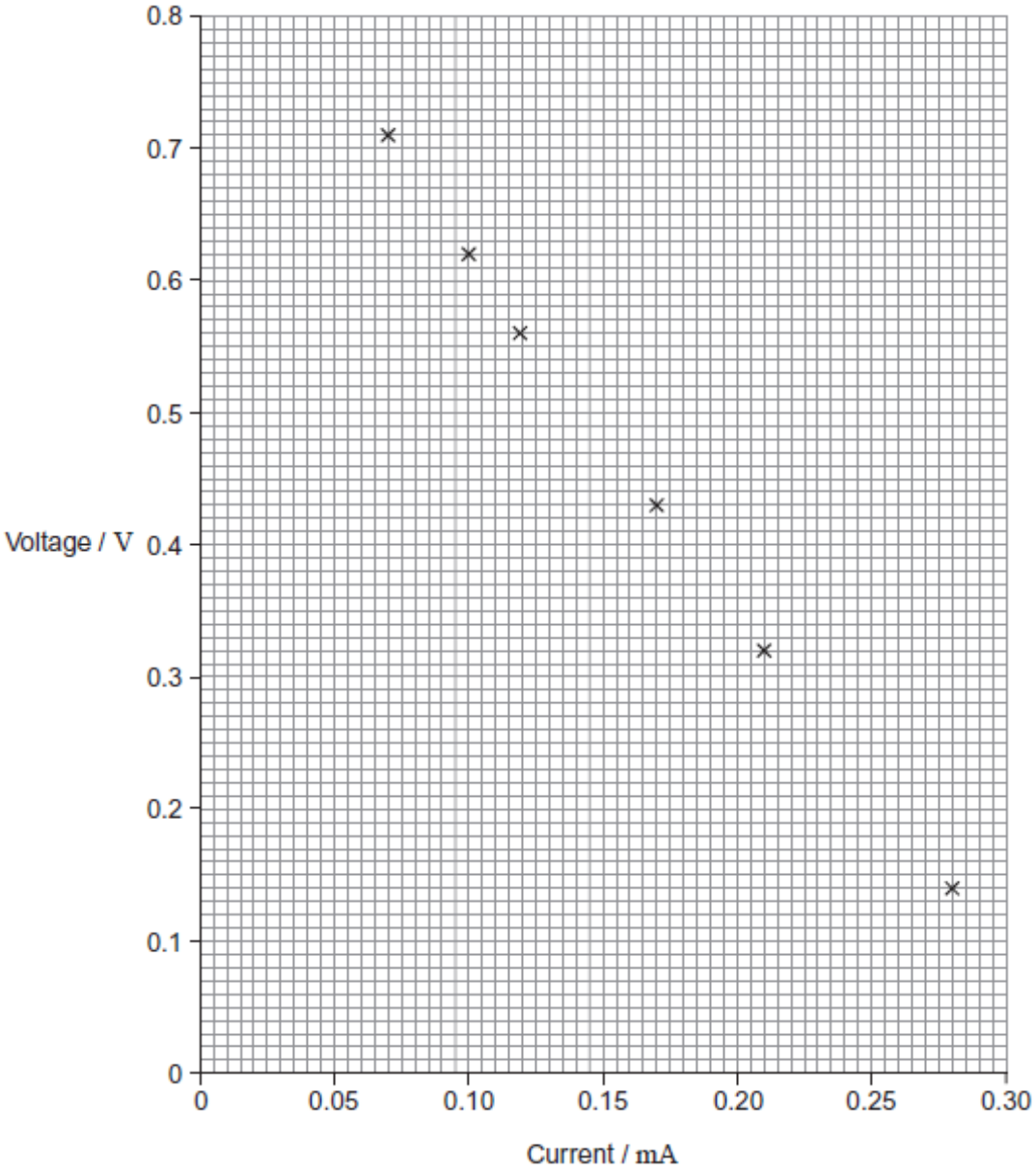
_____

_____

(2)

(b) The plotted points on **Figure 2** show the data for current and voltage that were obtained in the investigation.

Figure 2



(i) Suggest what was done to obtain the data for the plotted points.

_____

_____

_____

_____

(1)

(ii) The electromotive force (emf) of the potato cell is 0.89 V. Explain why the

voltages plotted on **Figure 2** are always
less than this and why the difference between the emf and the plotted voltage becomes larger with increasing current.

_____

_____

_____

_____

_____

_____

_____

(3)

(iii) Use **Figure 2** to determine the internal resistance of the potato cell.

internal resistance = _____ Ω

(3)

(c) A student decides to use two potato cells in series as a power supply for a light emitting diode (LED). In order for the LED to work as required, it needs a voltage of at least 1.6 V and a current of 20 mA.

Explain whether the LED will work as required.

_____

_____

_____

_____

_____

_____

(2)

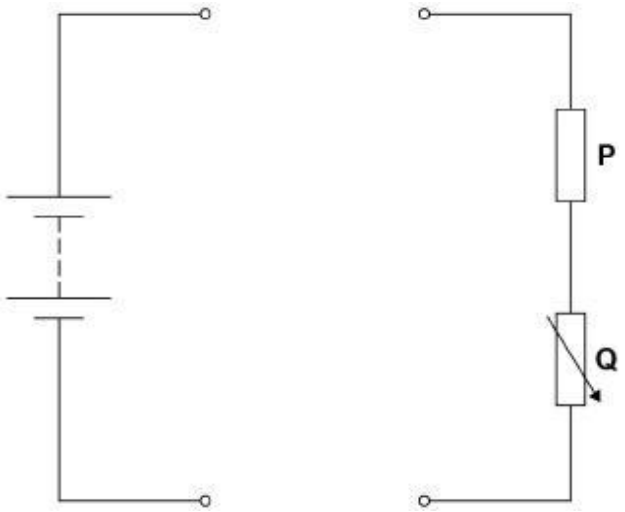
(Total 11 marks)

Q36.

Figure 1 shows a partly-completed circuit used to investigate the emf ε and the internal resistance r of a power supply.

The resistance of **P** and the maximum resistance of **Q** are unknown.

Figure 1



(a) Complete **Figure 1** to show a circuit including a voltmeter and an ammeter that is suitable for the investigation.

(1)

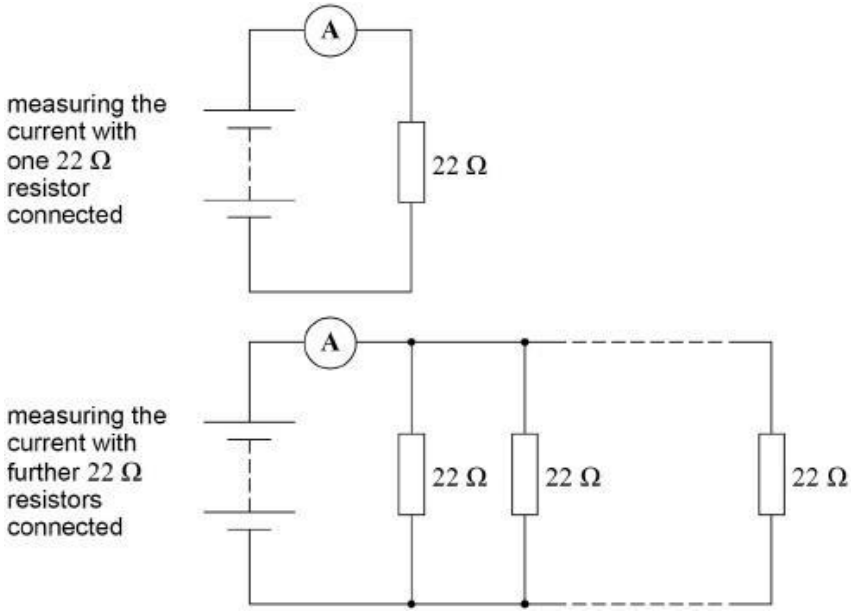
(b) Describe

- a procedure to obtain valid experimental data using your circuit
- how these data are processed to obtain ε and r by a graphical method.

(4)

Figure 2 shows a different experiment carried out to confirm the results for ε and r.

Figure 2



Initially the power supply is connected in series with an ammeter and a 22 Ω resistor. The current I in the circuit is measured.

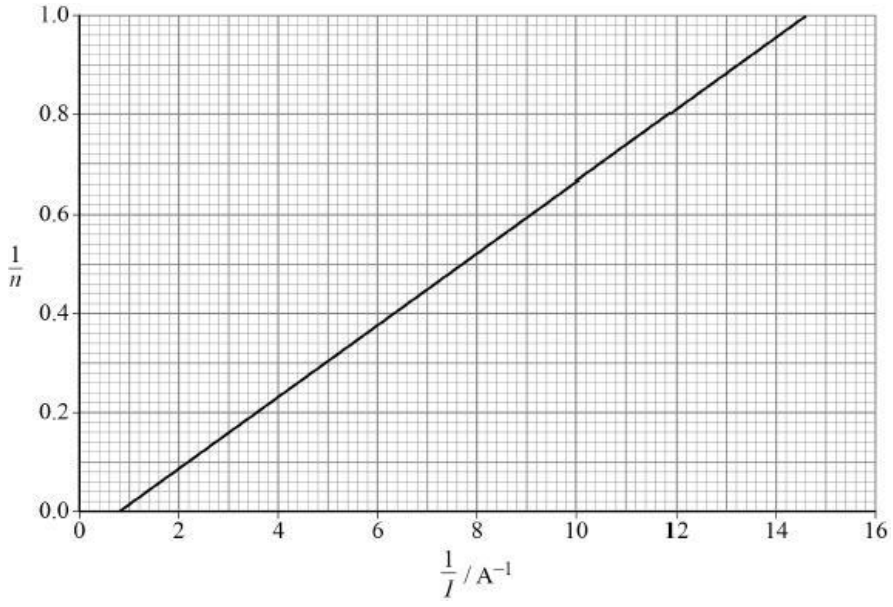
The number n of 22 Ω resistors in the circuit is increased as shown in **Figure 2**. The current I is measured after each resistor is added.

It can be shown that

$$\frac{22}{n} = \frac{\varepsilon}{I} - r$$

Figure 3 shows a graph of the experimental data.

Figure 3

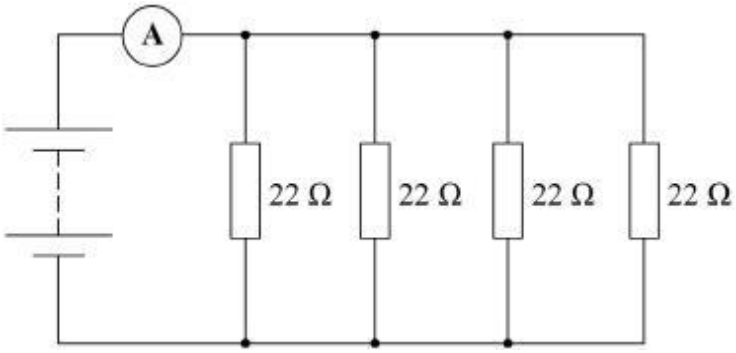


(c) Show that ε is about 1.6 V.

(2)

(d) **Figure 4** shows the circuit when four resistors are connected.

Figure 4



Show, using **Figure 3**, that the current in the power supply is about 0.25 A.

(1)

(e) Deduce, for the circuit shown in **Figure 4**,

- the potential difference (pd) across the power supply
- r.

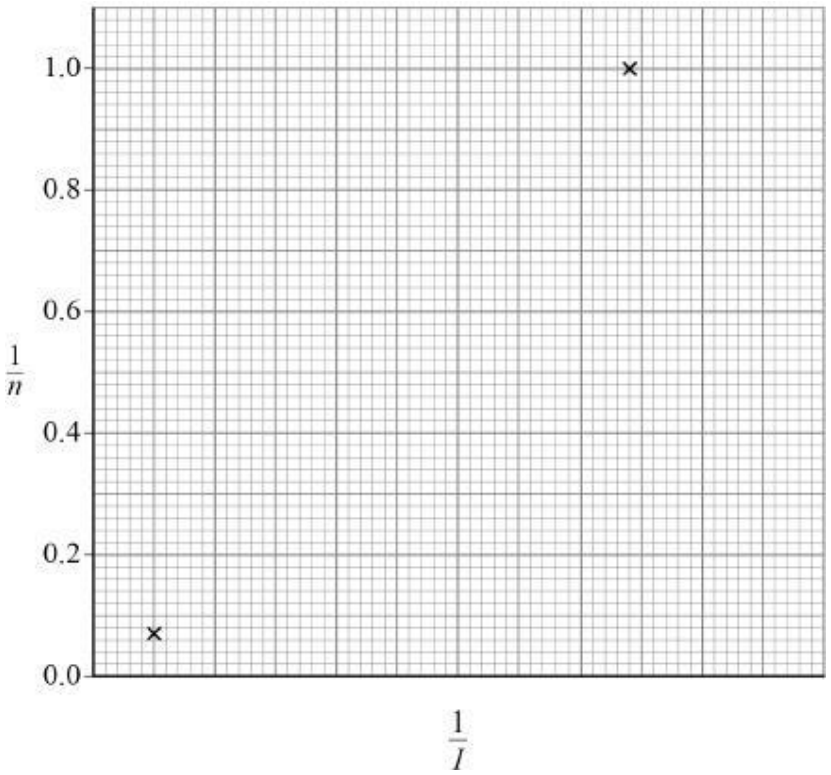
pd = _____ V

r = _____ Ω

(4)

(f) **Figure 5** shows the plots for n = 1 and n = 14

Figure 5



Three additional data sets for values of n between n = 1 and n = 14 are needed to complete the graph in **Figure 5**.

Suggest which additional values of n should be used.
Justify your answer.

(3)

(g) The experiment is repeated using a set of resistors of resistance 27 Ω.

The relationship between n and I is now

$$\frac{27}{n} = \frac{\varepsilon}{I} - r$$

Show on **Figure 5** the effect on the plots for n = 1 and n = 14
You do **not** need to do a calculation.

(2)
(Total 17 marks)

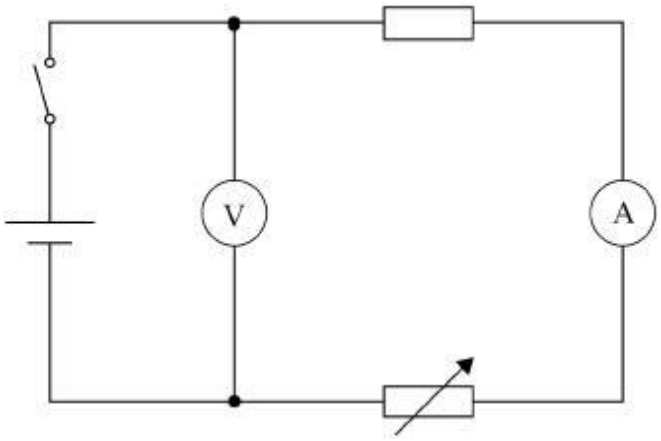
Q37.

Figure 1 shows a circuit used by a student to determine the emf and the internal resistance of a cell.

The cell is connected to a switch, a fixed resistor and a variable resistor.
When the switch is closed, a voltmeter measures the potential difference V across the cell.
An ammeter measures the current I in the circuit.

Readings of V and I are taken as the resistance of the variable resistor is changed from zero to its maximum value.

Figure 1

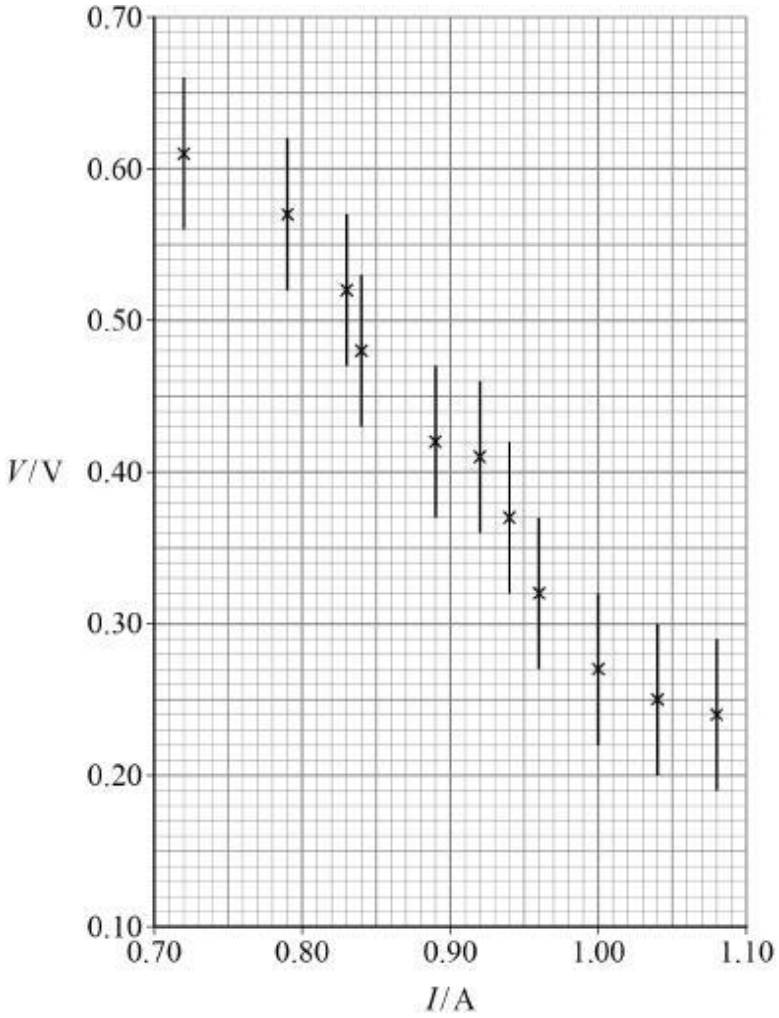


(a) Explain why the student included the fixed resistor in this circuit.

(2)

Figure 2 is a graph of the data recorded for this experiment.

Figure 2



(b) Determine the magnitude of the minimum gradient G_{min} of a line that passes through all the error bars in **Figure 2**.

magnitude of G_{min} = _____

(3)

(c) The maximum gradient G_{max} / V A^{-1} of a line passing through all the error bars in **Figure 2** is –1.3

Determine, using G_{max} and G_{min}, the internal resistance of the cell.

internal resistance = _____ Ω

(2)

(d) The line of best fit passes through the data point (0.94, 0.37).

Determine the emf of the cell.

emf = _____ V

(3)

(Total 10 marks)

Q38.

(a) (i) Describe how you would make a direct measurement of the emf ε of a cell, stating the type of meter you would use.

_____

_____

(1)

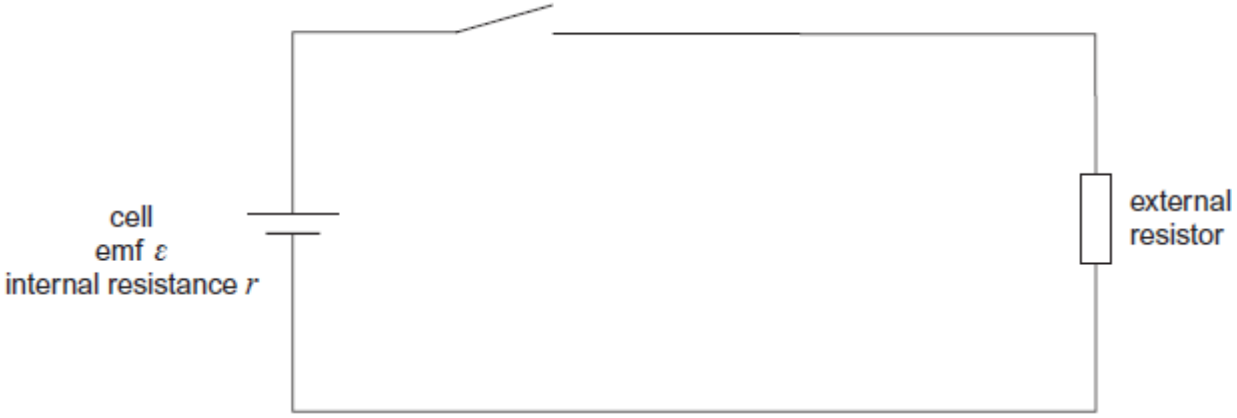
(ii) Explain why this meter must have a very high resistance.

_____

_____

(1)

(b) A student is provided with the circuit shown in the diagram below.



The student wishes to determine the efficiency of this circuit.

In this circuit, useful power is dissipated in the external resistor. The total power input is the power produced by the battery.

$$\text{Efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

The efficiency can be determined using two readings from a voltmeter.

(i) Show that the efficiency = $\frac{V}{\varepsilon}$ where ε is the emf of the cell

and V is the potential difference across the external resistor.

(1)

(ii) Add a voltmeter to the diagram and explain how you would use this new circuit to take readings of ε and V.

(2)

(c) Describe how you would obtain a set of readings to investigate the relationship between efficiency and the resistance of the external resistor. State any precautions you would take to ensure your readings were reliable.

(2)

(d) State and explain how you would expect the efficiency to vary as the value of R is increased.

(2)

(Total 9 marks)

Structured Quantitative

Q39.

A car battery has an emf of 12 V and an internal resistance of 9.5×10^{-3} Ω. When the battery is used to start a car the current through the battery is 420 A.

(a) Calculate the voltage across the terminals of the battery, when the current through the battery is 420 A.

_____

_____

_____

_____

answer _____ V

(2)

(b) The copper cable connecting the starter motor to the battery has a length of 0.75 m and cross-sectional area of 7.9×10^{-5} m^2. The resistance of the cable is 1.6×10^{-3} Ω.

Calculate the resistivity of the copper giving an appropriate unit.

_____

_____

_____

_____

_____

_____

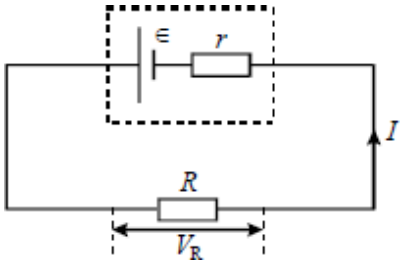
answer _____

(3)

(Total 5 marks)

Q40.

(a) A cell of emf ϵ and internal resistance r is connected in series to a resistor of resistance R as shown. A current I flows in the circuit.



(i) State an expression which gives ϵ in terms of I, r and R.

_____

(ii) Hence show how V_R, the potential difference across the resistor, is related to ϵ, I and r.

_____

(2)

(b) A lamp, rated at 30 W, is connected to a 120 V supply.

(i) Calculate the current in the lamp.

_____

_____

(ii) If the resistor in part (a) is replaced by the lamp described in (b), determine how many cells, each of emf 1.5 V and internal resistance 1.2 Ω, would have to be connected in series so that the lamp would operate at its proper power.

_____

_____

_____

_____

_____

_____

(5)

(Total 7 marks)

Q41.

A student investigates how the power dissipated in a variable resistor, Y, varies as the resistance is altered.

Figure 1 shows the circuit the student uses. Y is connected to a battery of emf ε and internal resistance r.

Figure 1

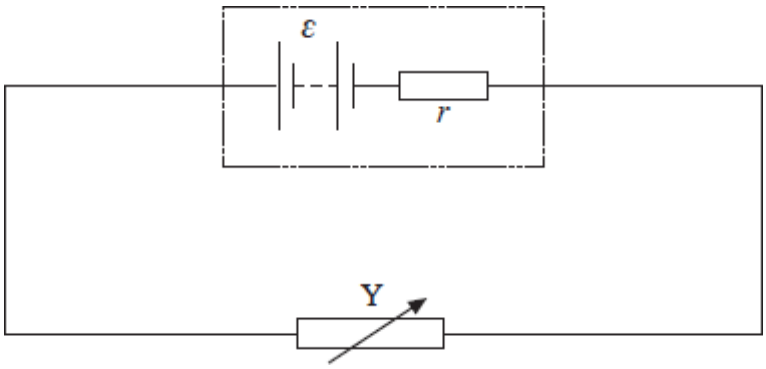
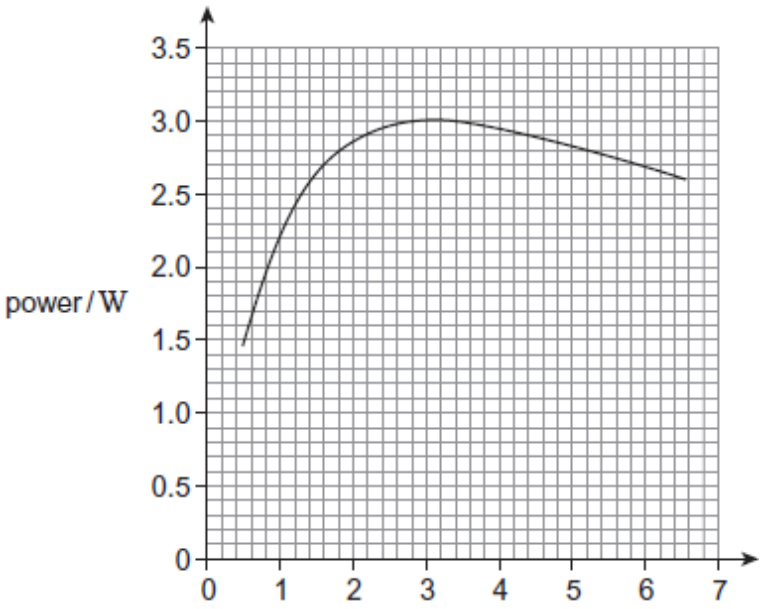


Figure 2 shows the results obtained by the student as the resistance of Y is varied from 0.5 Ω to 6.5 Ω.

Figure 2



(a) Describe how the power dissipated in Y varies as its resistance is increased from 0.5 Ω to 6.5 Ω.

_____

_____

_____

_____

_____

(2)

(b) The emf of the battery is 6.0 V and the resistance of Y is set at 0.80 Ω.

(i) Use data from **Figure 2** to calculate the current through the battery.

current _____ A

(3)

(ii) Calculate the voltage across Y.

voltage _____ V

(2)

(iii) Calculate the internal resistance of the battery.

internal resistance _____ Ω

(2)

(c) The student repeats the experiment with a battery of the same emf but negligible internal resistance. State and explain how you would now expect the power dissipated in Y to vary as the resistance of Y is increased from 0.5 Ω to 6.5 Ω.

_____

_____

_____

_____

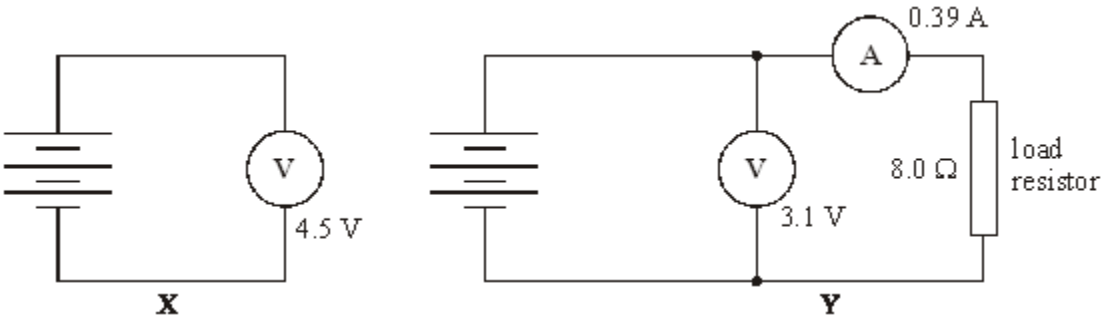
_____

(3)

(Total 12 marks)

Q42.

The diagram below shows two circuits **X** and **Y** that were used by a student to test a battery of three identical cells. In circuit **X** there was no load resistor and in circuit **Y** a load resistor was connected. You can assume that the meters in the circuits were ideal. Their readings are shown on each diagram.



(a) (i) Explain what is meant by the *internal resistance* of a battery and why this explains the difference between the voltages recorded in the two circuits.

_____

_____

_____

_____

_____

_____

_____

(3)

(ii) Calculate the internal resistance of **a single cell**.

Internal resistance _____

(3)

(b) One of the cells in the battery is reversed. Determine the new reading:

(i) on the voltmeter in circuit **X**;

Voltmeter reading in **X** _____

(1)

(ii) on the ammeter in circuit **Y**.

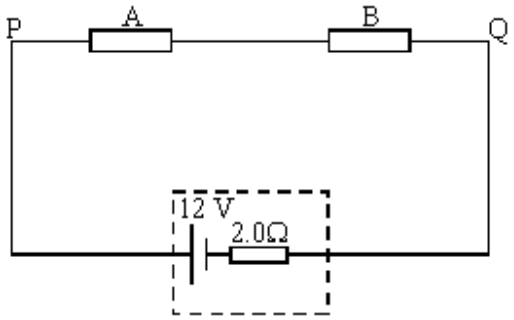
Ammeter reading in **Y** _____

(2)

(Total 9 marks)

Q43.

In the circuit shown, the battery has an emf of 12 V and an internal resistance of 2.0 Ω. The resistors A and B each have resistance of 30 Ω.



Calculate

(i) the total current in the circuit,

(ii) the voltage between the points P and Q,

(iii) the power dissipated in resistor A,

(iv) the energy dissipated by resistor A in 20 s.

(Total 8 marks)