Access Tuition

A-Level Physics

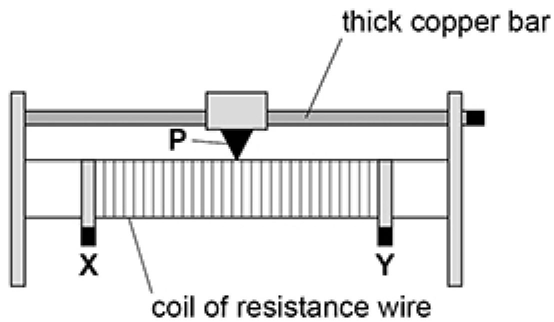
Circuits

Question Paper

Time available: 89 minutes
Marks available: 65 marks

1. **Figure 1** shows a variable resistor that has a maximum resistance of $25\ \Omega$.
A sliding contact **P** is mounted on a thick copper bar. **P** can be set to any position between **X** and **Y**.

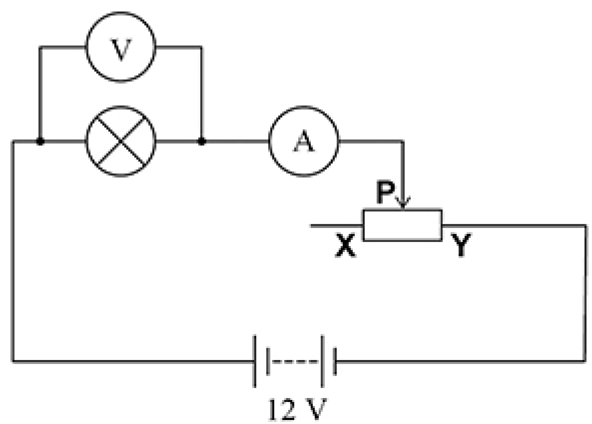
Figure 1



(a) **Figure 2** shows the variable resistor being used to investigate the variation of current with voltage for a filament lamp.
The normal operating voltage of the lamp is $12\ \text{V}$.

The $12\ \text{V}$ battery has negligible internal resistance.

Figure 2



The position of **P** is adjusted so that the reading on the voltmeter is at its minimum value of $0.75\ \text{V}$.

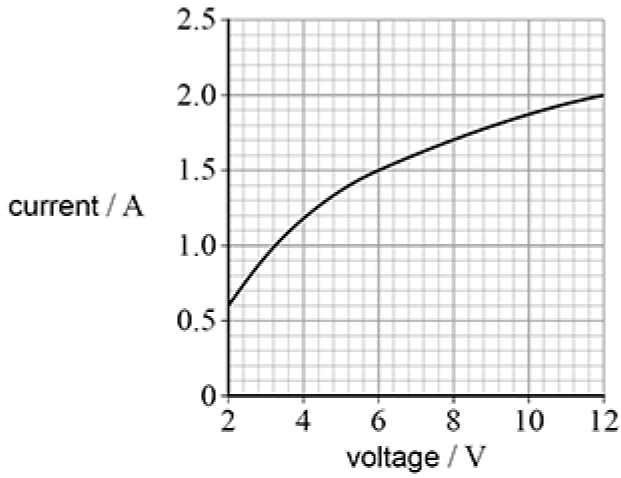
Calculate the resistance of the lamp when the voltmeter reading is $0.75\ \text{V}$.

resistance = _______________ Ω

(2)

(b) **Figure 3** shows the variation of current with voltage for the lamp between 2 V and 12 V.

Figure 3



Calculate the resistance of the lamp when the voltage across the lamp is 8.0 V.

resistance = _______________ Ω

(2)

(c) Explain, in terms of electron movement, why the resistance of the filament lamp changes as the voltage changes as shown in **Figure 3**.

___

___

___

___

___

___

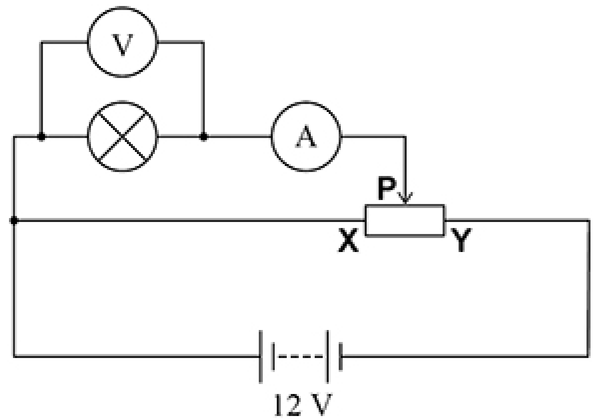
___

___

(3)

(d) **Figure 4** shows an alternative circuit used to investigate the variation of current with voltage for the lamp.

Figure 4



The circuit components are the same as in **Figure 2**.
When the voltage across the lamp is 12 V its resistance is 6.0 Ω.

P is moved to position **Y**.

Calculate the total resistance of the circuit.

total resistance = _______________ Ω

(2)

(e) Calculate the power transferred by the battery when **P** is at position **Y**.

power = _______________ W

(2)

(f) A student wants to control the brightness of the lamp.

He gives two reasons why the circuit in **Figure 4** is better than the circuit in **Figure 2** for controlling the brightness. The two reasons are:

- the **Figure 4** circuit can achieve a greater range of voltages across the lamp
- the **Figure 4** circuit is more efficient at transferring energy to the lamp.

Discuss, without calculation, whether either of these two reasons is correct.

(3)

(Total 14 marks)

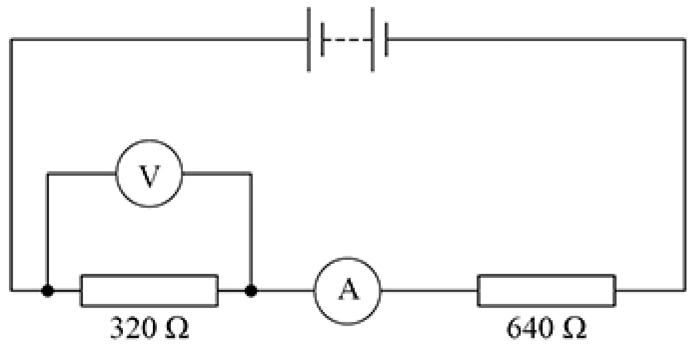
2. A battery has an emf of 5.30 V and negligible internal resistance.

(a) State what is meant by an emf of 5.30 V for this battery.

(2)

(b) **Figure 1** shows the battery connected into a circuit.

Figure 1



The ammeter is ideal.

The voltmeter is non-ideal and has a resistance R.

The reading on the voltmeter is 1.05 V when it is connected across the 320 Ω resistor.

Show that the reading on the ammeter is approximately 7 mA.

(2)

(c) Show that the resistance R of the voltmeter is approximately 300 Ω.

(3)

(d) The voltmeter is now connected across the battery terminals.

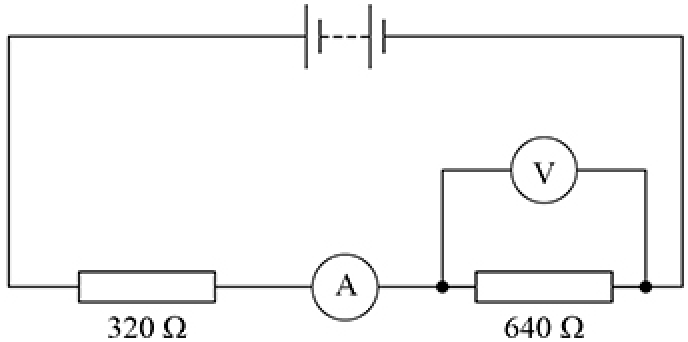
Calculate the power dissipated in the voltmeter.

power = _______________ W

(2)

(e) The voltmeter is now connected across the 640 Ω resistor as shown in **Figure 2**.

Figure 2



The reading on the voltmeter is 2.10 V.

When the voltmeter was connected across the 320 Ω resistor, as shown in **Figure 1**, the reading on the voltmeter was 1.05 V.

Explain why the sum of these voltmeter readings does **not** equal the emf of the battery.

____

____

____

____

____

____

____

____

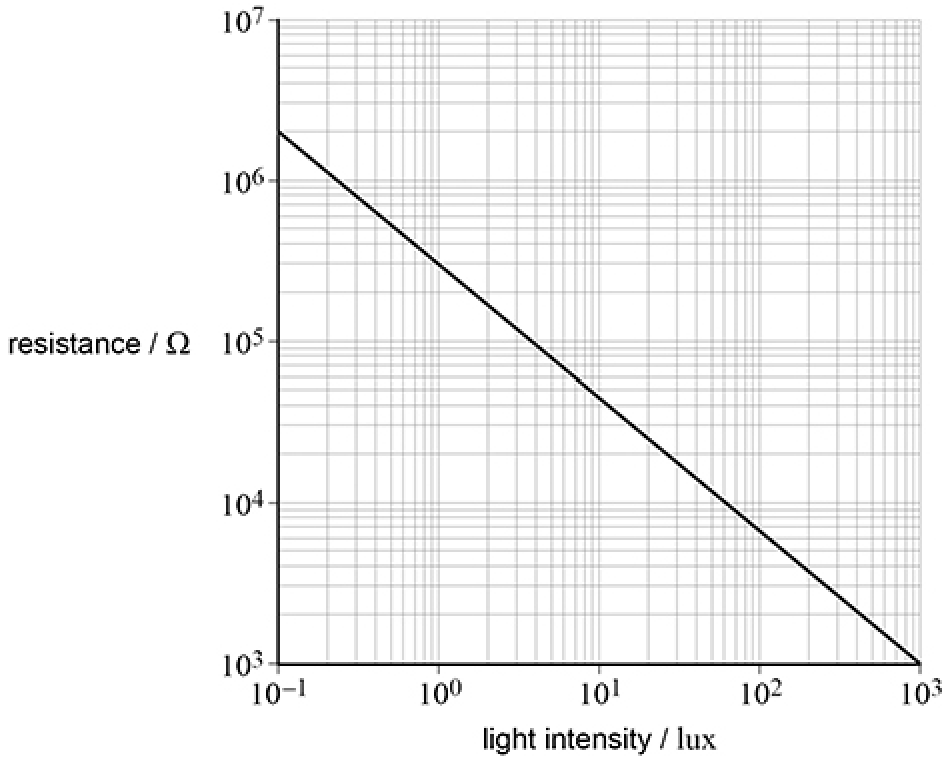
____

____

(2)
(Total 11 marks)

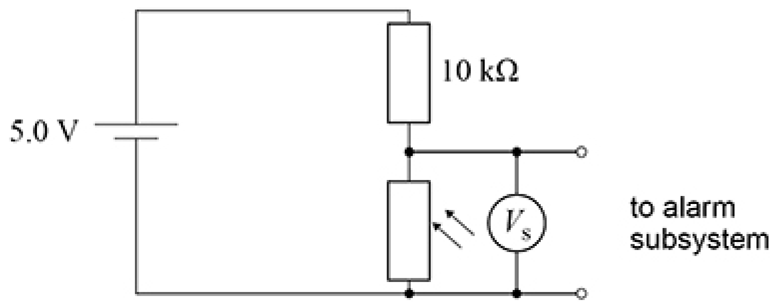
3. **Figure 1** shows how the resistance of an LDR varies with light intensity.

Figure 1



The LDR is used as part of an alarm system in a dim room. **Figure 2** shows one proposal for a sensor circuit for this system.

Figure 2



The power supply to the sensor has an emf of 5.0 V and a negligible internal resistance. A negligible current is drawn from the sensor circuit by the alarm subsystem.

A light beam illuminates the LDR. When the light beam is broken the LDR is not illuminated by the light beam. This causes the alarm to sound.

The table below shows how the light intensity at the LDR changes.

	Light intensity / lux
LDR illuminated by light beam	4.0
LDR **not** illuminated by light beam	1.0

(a) Show that the current in the sensor circuit when the LDR is **not** illuminated by the light beam is approximately 16 μA.

(2)

(b) The alarm sounds when the potential difference Vs across the LDR changes by more than 25% of the power supply emf.

Discuss whether the circuit shown in **Figure 2** is suitable.
Support your answer with a calculation.

___

___

(3)
(Total 5 marks)

4. 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)

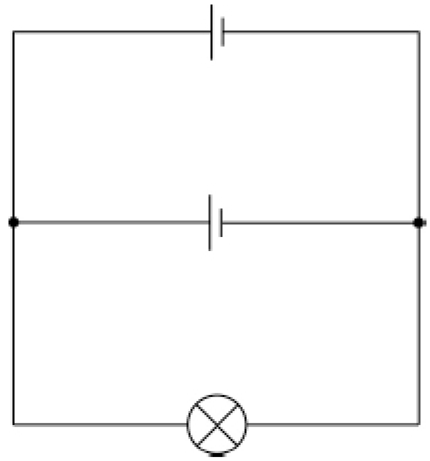
(d) The cell stores 14 kJ of energy when it is fully charged. The cell's emf and internal resistance are constant as the cell is discharged.

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.

___

___

___

___

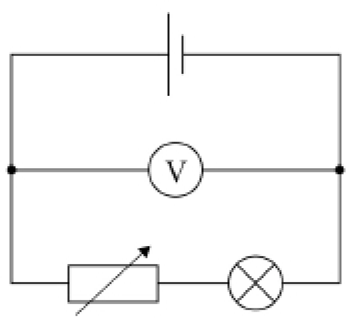
___

___

___

(3)
(Total 14 marks)

5. The diagram shows a practical circuit in which a variable resistor is used to control the brightness of a lamp. The voltmeter reading is monitored as the variable resistor is adjusted to make the lamp brighter.



(a) Explain why the reading on the voltmeter decreases as the brightness of the lamp increases.

___

___

___

___

___

___

(2)

(b) The variable resistor is adjusted so that the lamp is at its brightest. The reading V_1 on the voltmeter is noted. A second identical cell is then connected in parallel with the cell in the diagram above. The new reading V_2 on the voltmeter is noted.

Explain why V_2 is greater than V_1.

____

____

____

____

____

____

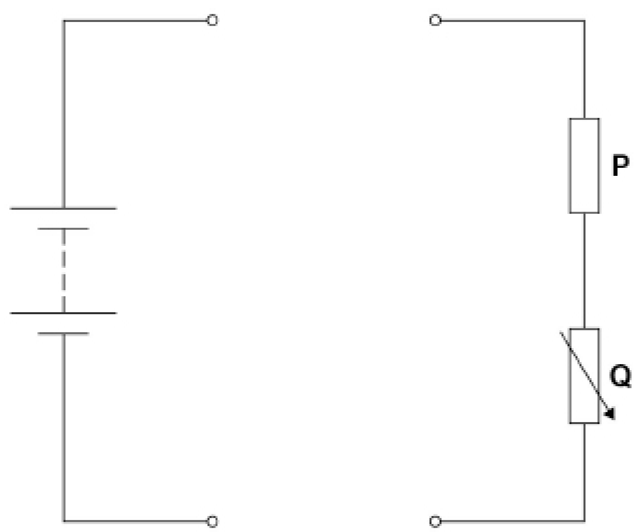
(2)

(Total 4 marks)

6. **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.

____

____

____

____

____

____

____

____

____

____

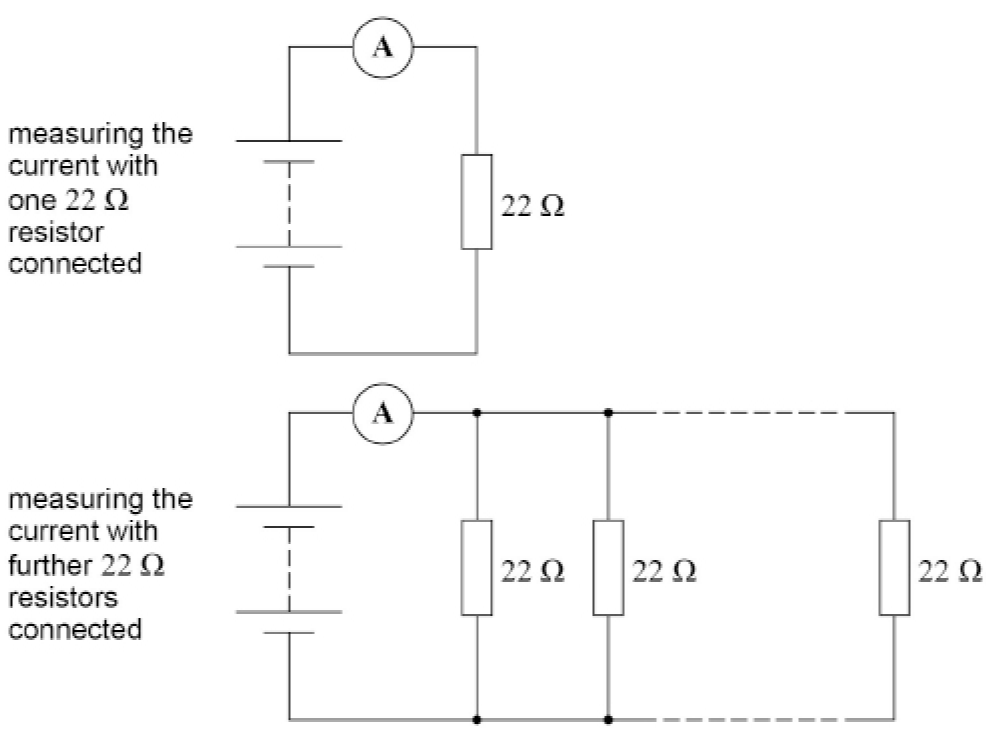
____

____

(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.

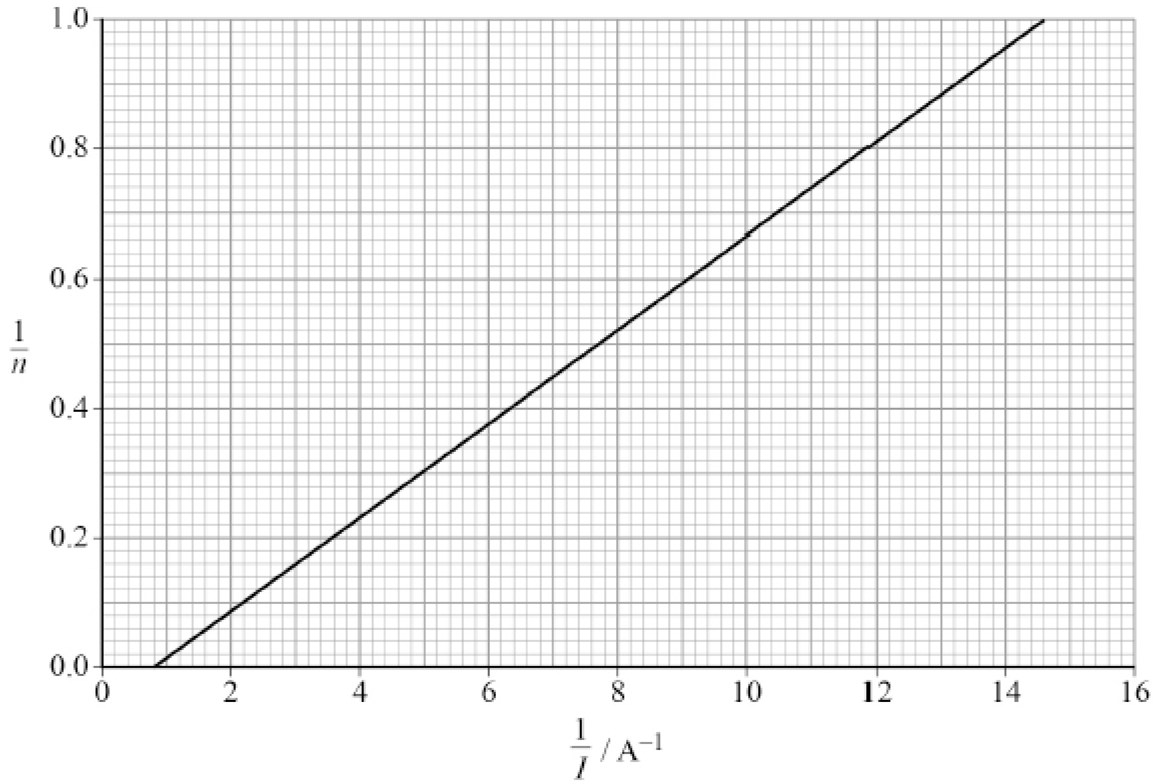
The number n of 22 Ω resistors in the circuit is increased as shown in **Figure 2**. The current I is measured after each resistor is added.

It can be shown that

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

Figure 3 shows a graph of the experimental data.

Figure 3

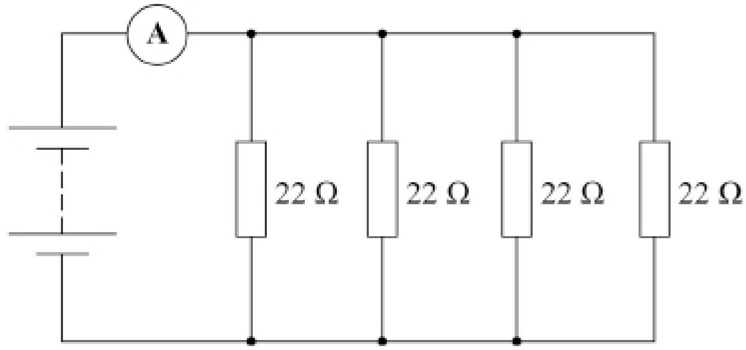


(c) Show that ε is about 1.6 V.

(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*.

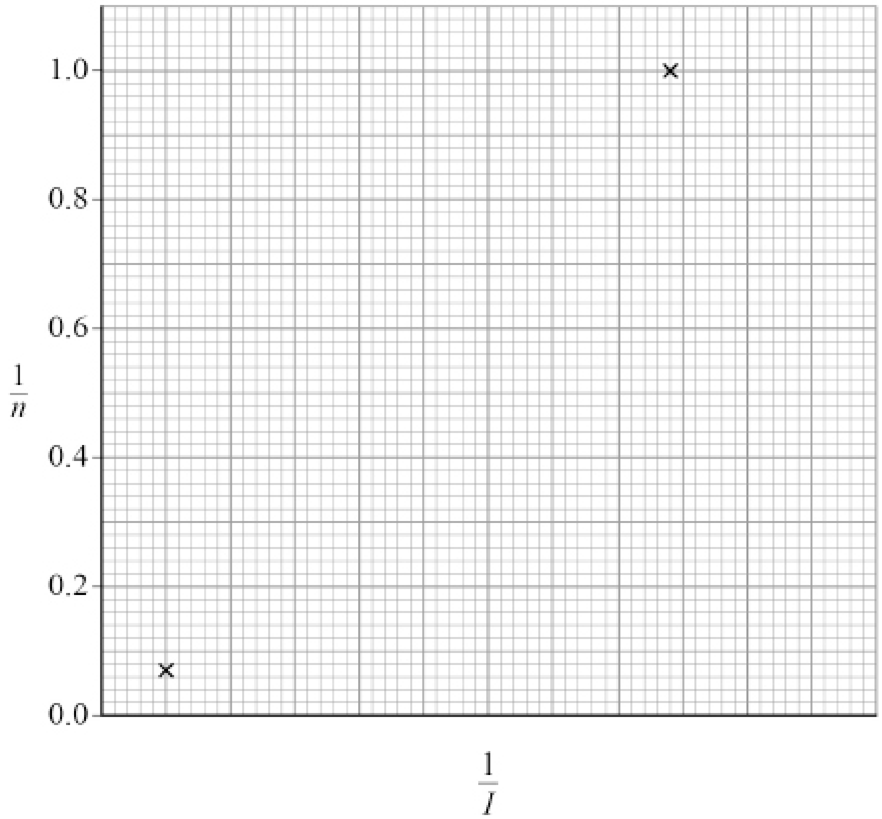
pd = _______________ V

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)