Q1.

Figure 1 shows a circuit for controlling the current I in a filament lamp **L_1**.
The battery has negligible internal resistance.

Figure 1

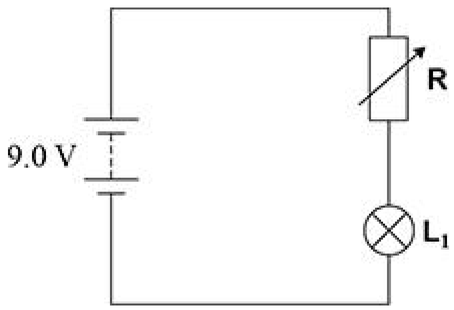
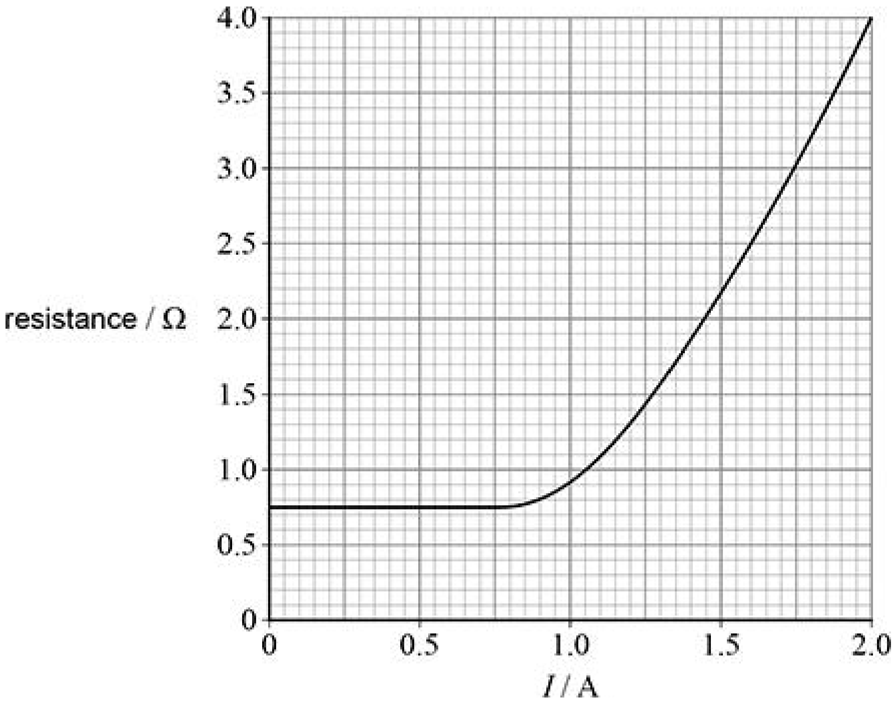


Figure 2 shows how the resistance of **L_1** varies with I.

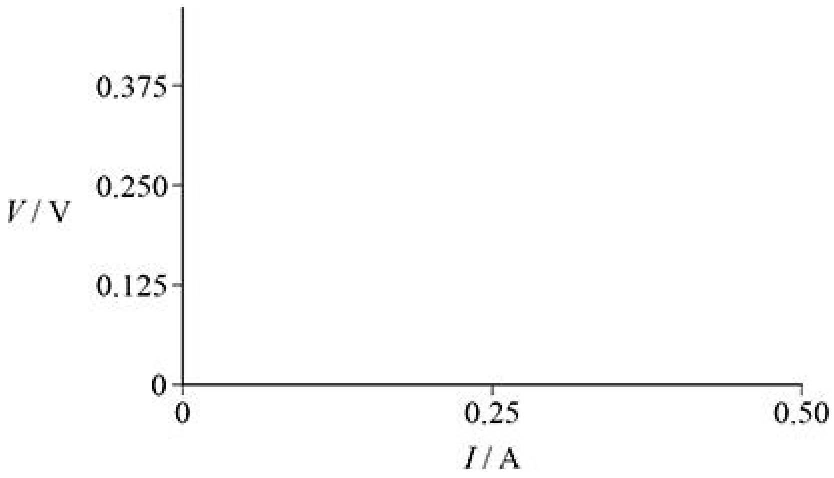
Figure 2



(a) The current in **L_1** is increased from 0 to 0.50 A.
The potential difference V across **L_1** is 0.375 V when I is 0.50 A.

Draw, on **Figure 3**, a V–I graph for **L_1** in the current range 0 to 0.50 A.

Figure 3



(1)

(b) Calculate the power dissipated in **L_1** when I is 1.9 A.

power dissipated = ____________________ W

(2)

(c) The variable resistor **R** in **Figure 1** is adjusted until I is 1.5 A and V is 3.3 V.

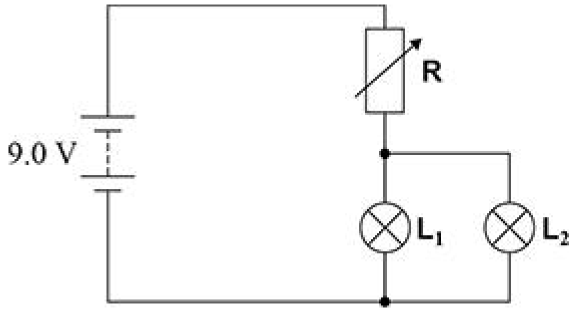
Calculate the resistance of **R**.

resistance of **R** = ____________________ Ω

(2)

(d) **Figure 4** shows a second lamp L_2, identical to L_1, connected to the circuit.

Figure 4



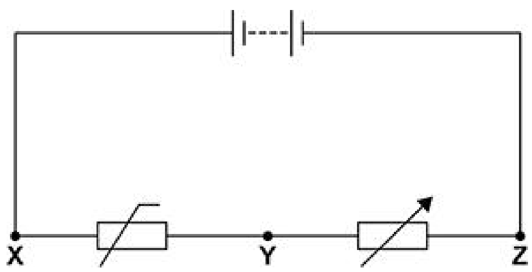
R is adjusted so that the potential difference across L_1 is again 3.3 V.

Deduce, without calculation, the change in the resistance of **R**.

(3)
(Total 8 marks)

Q2.

The circuit in the figure below is used as part of a temperature sensor.
The battery has an emf of 6.5 V and negligible internal resistance.



The initial temperature of the thermistor is 22 °C.
At this temperature the resistance of the thermistor is 350 Ω and the circuit current is 12 mA.

(a) Calculate the resistance of the variable resistor.

resistance = ____________________ Ω

(2)

(b) The resistance R of the thermistor at temperature θ in K is given by:

$$R = R_0 e^{B\left(\frac{1}{\theta} - \frac{1}{\theta_0}\right)}$$

where R_0 is the resistance at the initial temperature θ_0 in K, and B is a constant.

The temperature of the thermistor is increased to 318 K.
The variable resistor is adjusted so that the circuit current is again 12 mA.
The potential difference across the thermistor is now 3.2 V.

Determine B.
State an appropriate unit for your answer.

B = ____________________ unit = ____________________

(5)

(c) Explain why the current in the thermistor needs to be controlled.

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(2)

(d) Explain how ammeters and voltmeters can be used in the circuit in the figure above to demonstrate the conservation of charge and the conservation of energy.

Refer to points **X**, **Y** and **Z** in your answer.

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(2)

(Total 11 marks)

Q3.

This question is based on a method to determine the resistivity of a wire (required practical activity 5).

Figure 1 shows a micrometer screw gauge.

Figure 1

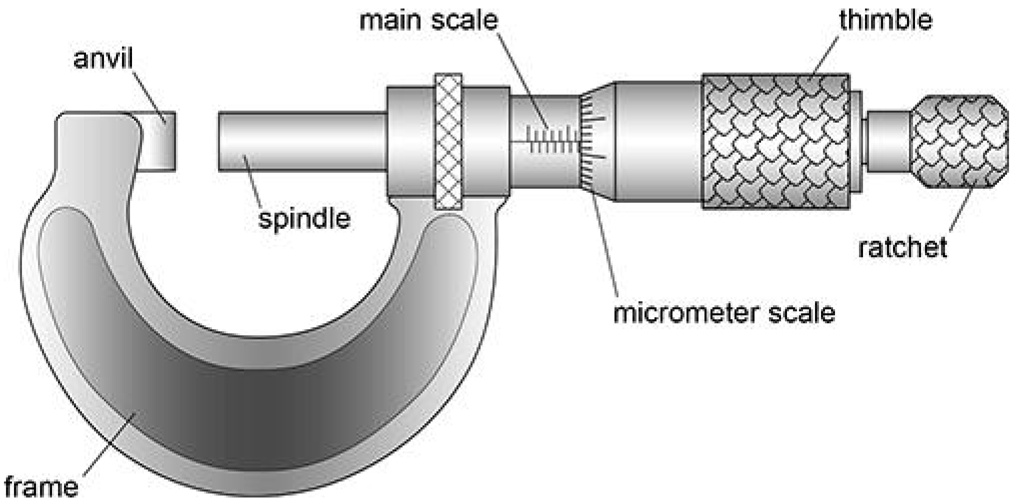
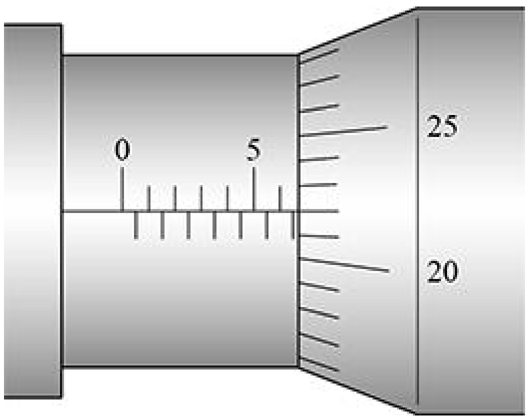


Figure 2 shows an enlarged view of the scales.

Figure 2



(a) State, in mm, the resolution of the main scale.

resolution = ____________________ mm

(1)

(b) What is the reading on the micrometer?

Tick (✓) **one** box.

6.22 mm	☐
6.72 mm	☐
6.78 mm	☐
8.22 mm	☐

(1)

(c) A wire **X** is placed in the gap between the anvil and the spindle.

State and explain how this gap is closed just before taking a reading of the diameter of **X**.

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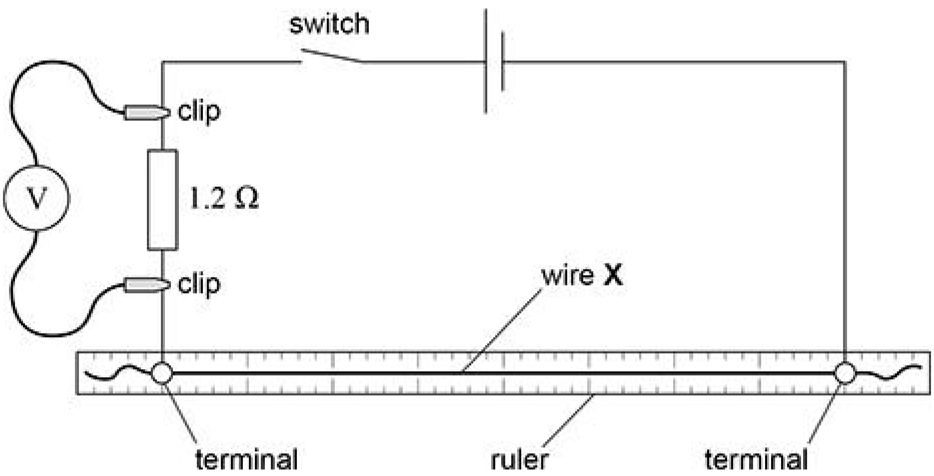
(1)

Figure 3 shows a circuit used to determine the resistance per metre of wire **X**.

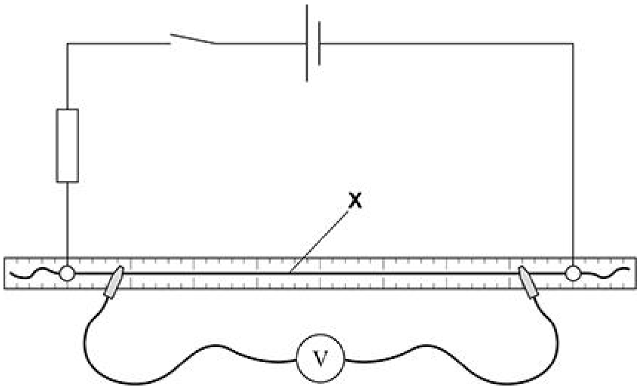
Figure 3



Two terminals are used to mount **X** on a ruler.
Clips are used to connect a voltmeter across the 1.2 Ω resistor.
When the switch is closed, the voltmeter reading is 931 mV.

The switch is then opened and the voltmeter is connected to **X** as shown in **Figure 4**.

Figure 4



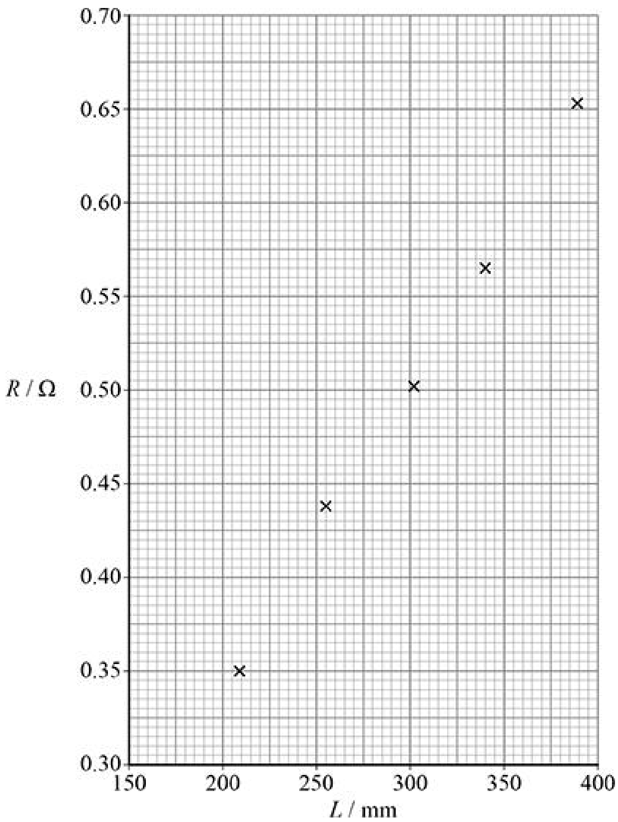
(d) When the switch is closed, the voltmeter reading is 397 mV.

Show that, for the arrangement in **Figure 4**, the resistance R of the wire between the clips is about 0.5 Ω.

(2)

The length of wire between the clips is L.
Values of R are determined for different values of L.
Figure 5 shows these data.

Figure 5



(e) Determine the resistance per metre of **X**.

resistance per metre = ____________________ $\Omega\ m^{-1}$

(2)

(f) The table below shows the resistance per metre of various metal wires.
The diameter of **X** is one of the values of d shown in the table below.

	Resistance per metre of wire / $\Omega\ m^{-1}$			
d / mm	**copper**	**tungsten**	**alumel**	**nichrome**
0.38	0.151	0.504	3.15	9.73
0.93	0.0247	0.0824	0.515	1.59
1.63	0.00805	0.0268	0.168	0.518
2.08	0.00494	0.0165	0.103	0.318
3.66	0.00160	0.00532	0.0333	0.103

Identify the metal used for **X**.
Go on to determine the resistivity of the metal.
State an appropriate SI unit for your answer.

metal used for **X** = ____________________

resistivity = ____________________ SI unit = ____________________

(4)

(g) A student adds error bars for R and L to each point on **Figure 5**.

She estimates that

- each value of R has a percentage uncertainty of 6%
- each value of L has an absolute uncertainty of 5 mm.

Compare her error bars for the point at L = 209 mm with her error bars for the point at L = 388 mm.

(2)

(h) Outline how error bars are used to determine the uncertainty in the gradient of a linear graph.

(2)

(Total 15 marks)

Q4.

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

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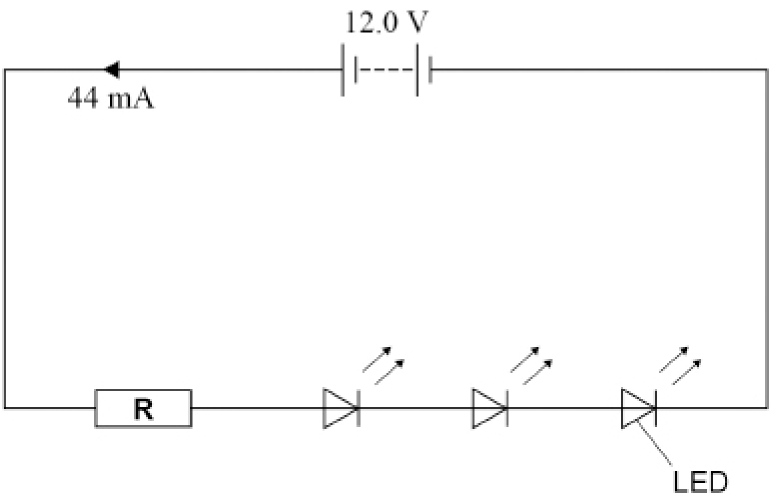
(1)

Figure 1 shows the circuit diagram for a battery-powered torch.
The circuit contains three identical light emitting diodes (LEDs) and a resistor **R**.
The current in the circuit is 44 mA.

Figure 1



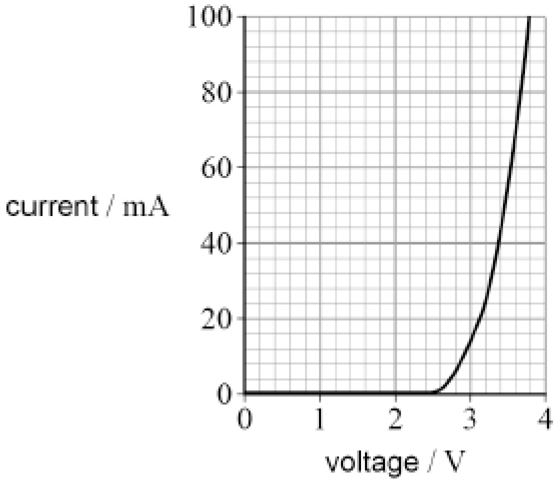
(b) Calculate the number of electrons that pass a point in the circuit in 37 minutes.

number of electrons = ____________________

(2)

Figure 2 is the current–voltage characteristic for an LED used in the torch.

Figure 2



(c) Determine the power output of one LED when the torch is on.

power output = ____________________ W

(3)

The battery has an emf of 12.0 V and an internal resistance of 1.5 Ω.

(d) Determine the resistance of **R** in **Figure 1**.

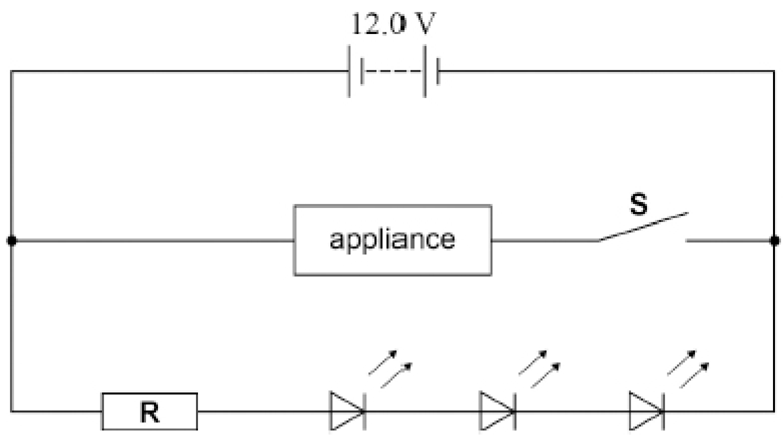
resistance = ____________________ Ω

(4)

(e) Another appliance is connected to the battery as shown in **Figure 3**.

The current in the battery is 3.5 A when switch **S** is closed.

Figure 3



Each LED requires a voltage of at least 2.9 V to light.

Deduce whether the LEDs will light when **S** is closed.

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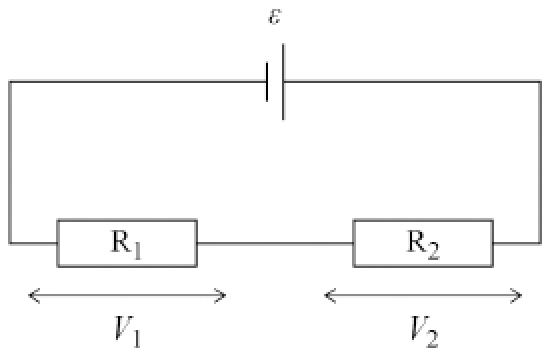
(3)

(Total 13 marks)

Q5.

(a) In **Figure 1** the cell has emf ε and internal resistance r.

Figure 1



The current in the circuit is I.

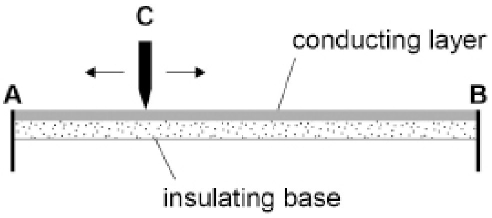
The potential difference (pd) across R_1 is V_1 and the pd across R_2 is V_2.

Explain how the law of conservation of energy applies in this circuit.
You should consider the movement of one coulomb of charge around the circuit.

(2)

Figure 2 shows a variable resistor made with a thin conducting layer on an insulating base.

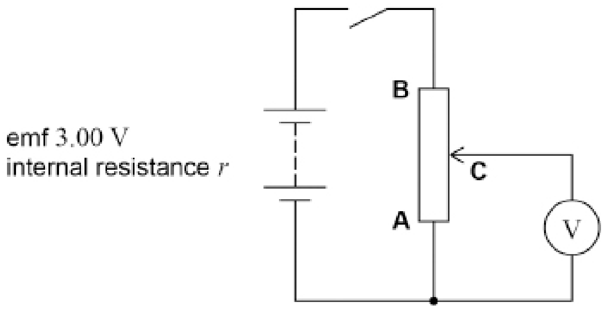
Figure 2



The conducting layer has constant width and thickness and has connections at the ends **A** and **B**.
C is a sliding contact that can move along the surface of the conducting layer between **A** and **B**.

Figure 3 shows a circuit that uses the variable resistor as a potential divider.

Figure 3



The variable resistor is connected to a battery of emf 3.00 V and internal resistance r. The resistance of the conducting layer between **A** and **B** is 125 Ω.

(b) The sliding contact **C** is moved to end **B** of the variable resistor. The switch is closed. The digital voltmeter reads 2.89 V.

Show that r is approximately 4.8 Ω.

(3)

(c) **C** is set at $\frac{1}{5}$ of the distance between **A** and **B**. The thickness of the conducting layer is uniform so the resistance between **A** and **C** is 25.0 Ω.

Determine the voltmeter reading at this setting.

voltmeter reading = ____________________ V

(2)

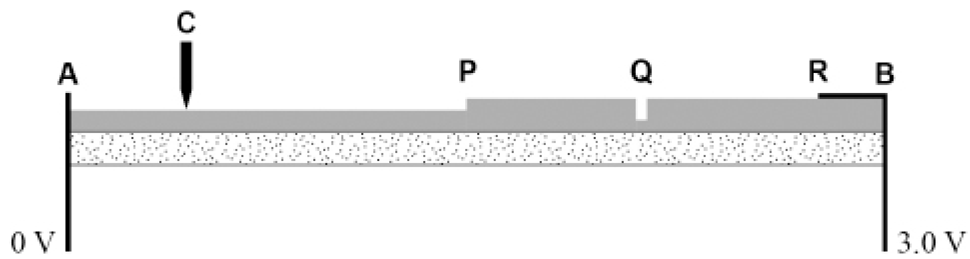
(d) **Figure 4** shows a variable resistor similar to the one shown in **Figure 2** but with the following three manufacturing faults:

- at **P** the conducting layer changes in thickness so that **AP** is thinner than **PB**
- at **Q** there is a scratch into the surface of the conducting layer and across its full width
- from **R** to **B** the conducting connector is laid over the conducting layer.

The width of the conducting layer is constant.

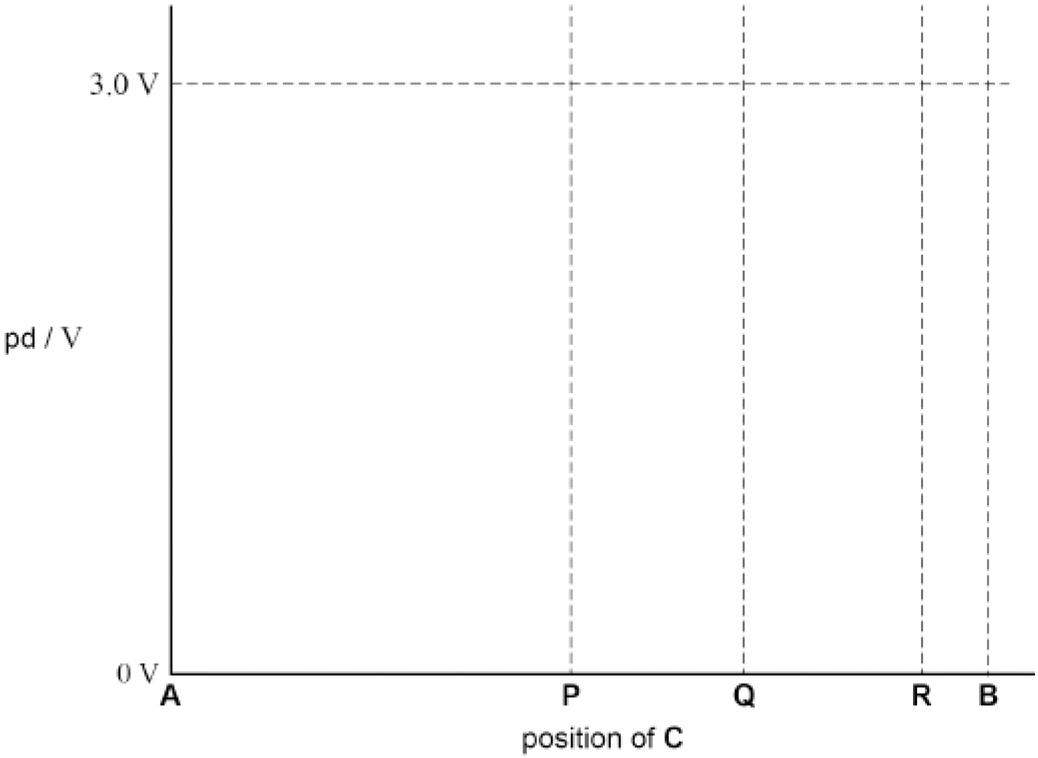
A pd of 3.0 V is applied across **A** and **B**.
C is moved from **A** to **B**.

Figure 4



Sketch, on the axes in **Figure 5**, a graph to show how the pd between **A** and **C** varies as **C** is moved from **A** to **B**.

Figure 5



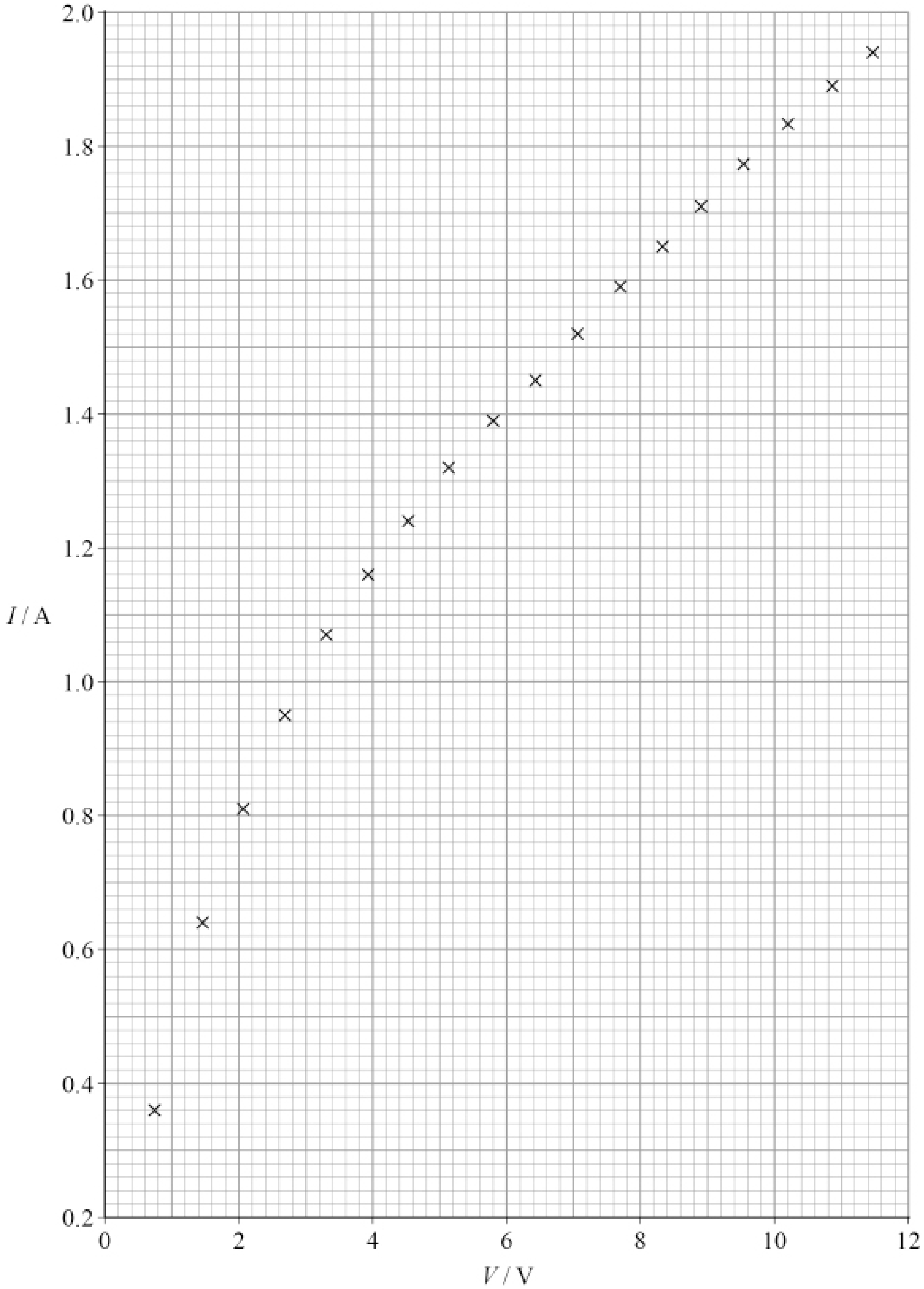
(4)

(Total 11 marks)

Q6.

Figure 1 is a plot of current–voltage data for a filament lamp **L**.

Figure 1



The current I was measured as the voltage V across **L** was increased at a steady rate.
These data were obtained using a current sensor and a voltage sensor connected to a data logger.
The logger recorded data at a rate of 2.5 Hz.

(a) Determine, in $\mathrm{V\,s^{-1}}$, the rate of increase of V.

rate of increase of V = ____________________ $\mathrm{V\,s^{-1}}$

(2)

(b) State **two** advantages of using data logging for this experiment.

1 ____

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2 ____

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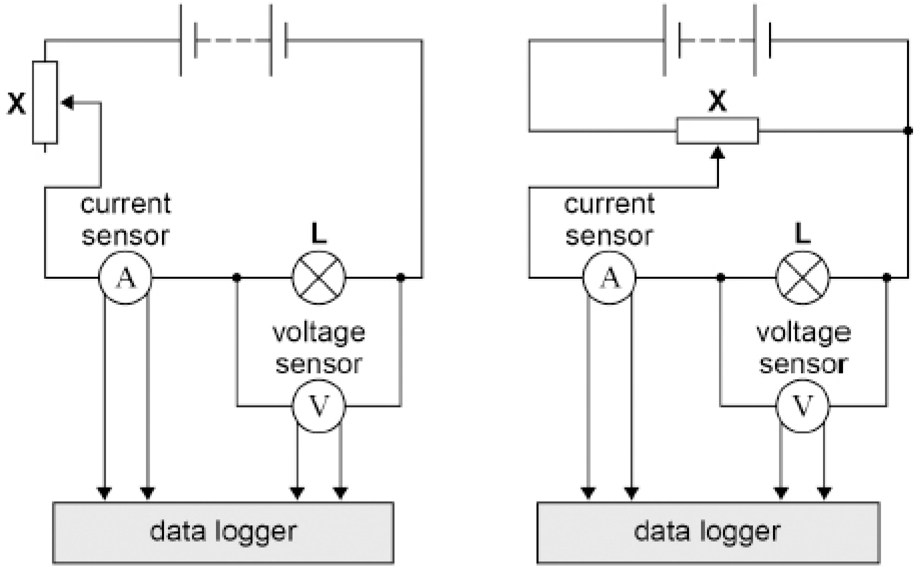
(2)

(c) **Figure 2** shows two circuits that can be used to collect current–voltage data.

Figure 2



circuit 1 **circuit 2**

The dc supply has an emf of 12 V and negligible internal resistance.
The current sensor and the voltage sensor behave as ideal meters.

In circuit **1**:

- **X** is used as a variable resistor with a maximum resistance of 14.9 Ω
- when **X** is set to maximum resistance, the resistance of **L** is 2.3 Ω.

In circuit **2**, **X** is used as a potential divider.

Discuss, with reference to circuit **1 and** circuit **2**, whether either circuit can produce all the data shown in **Figure 1**.
Support your answer with a calculation.

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(4)

The table below shows some values of V that are plotted on **Figure 1** and corresponding results for I and for the power P dissipated in **L**.

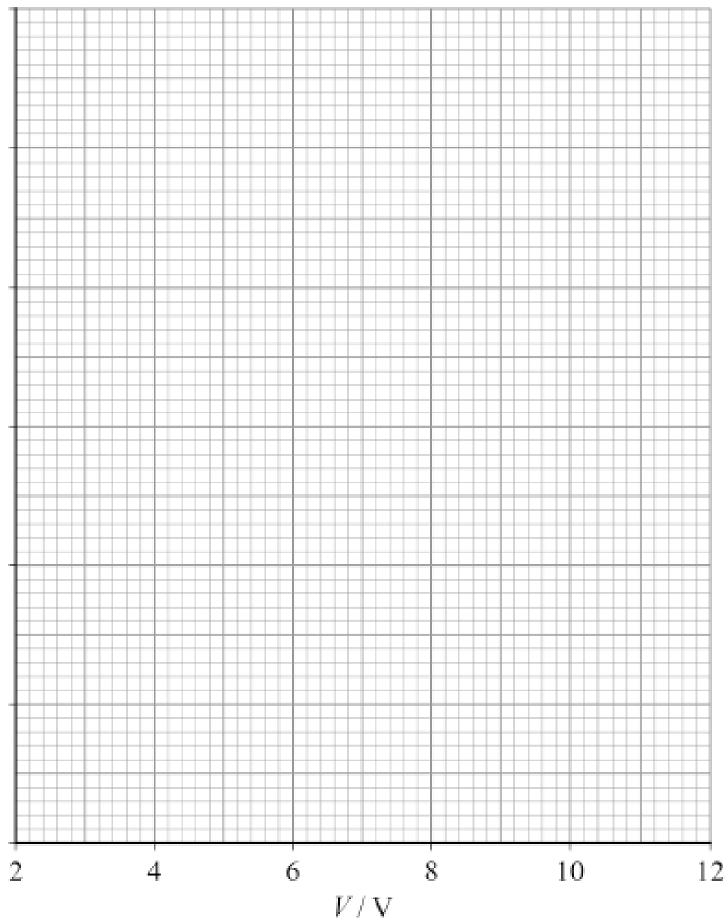
V / V	I / A	P / W
3.30	1.07	3.53
5.17	1.32	
7.69	1.59	12.2
9.58		
11.47	1.94	22.3

(d) Complete the table below above.

(3)

(e) Plot on **Figure 3** a graph of P against V.
You should use only the data in your completed table.

Figure 3



(3)

(f) **L** is connected to a 12 V power supply of negligible internal resistance. **L** then dissipates its rated power P_r .

A second lamp, identical to **L**, is now connected in series with **L**.

Determine the percentage of P_r that is dissipated in this circuit.

percentage = ____________________ %

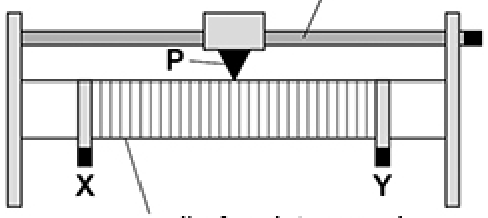
(2)

(Total 16 marks)

Q7.

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**.

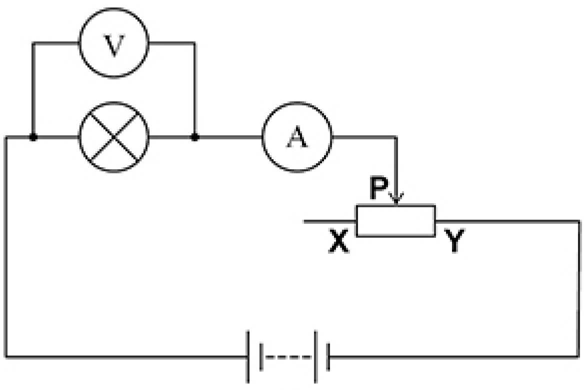
Figure 1



(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 $0.75\ \text{V}$.

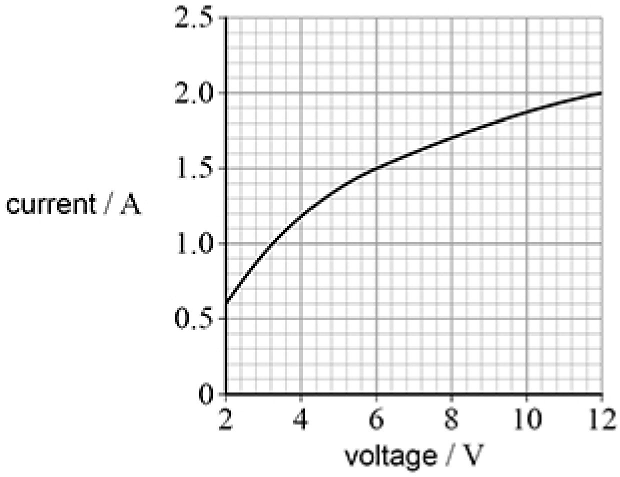
Calculate the resistance of the lamp when the voltmeter reading is $0.75\ \text{V}$.

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**.

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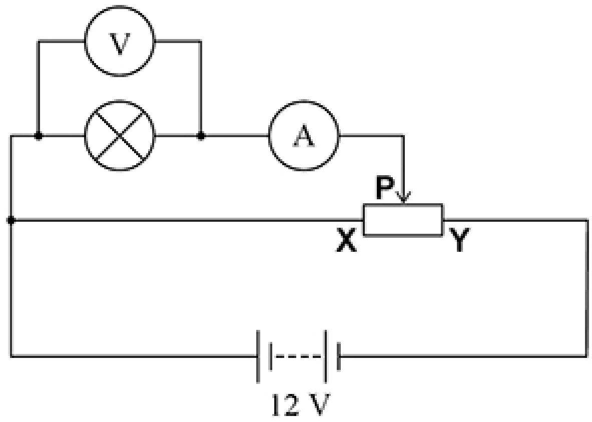
(3)

(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.

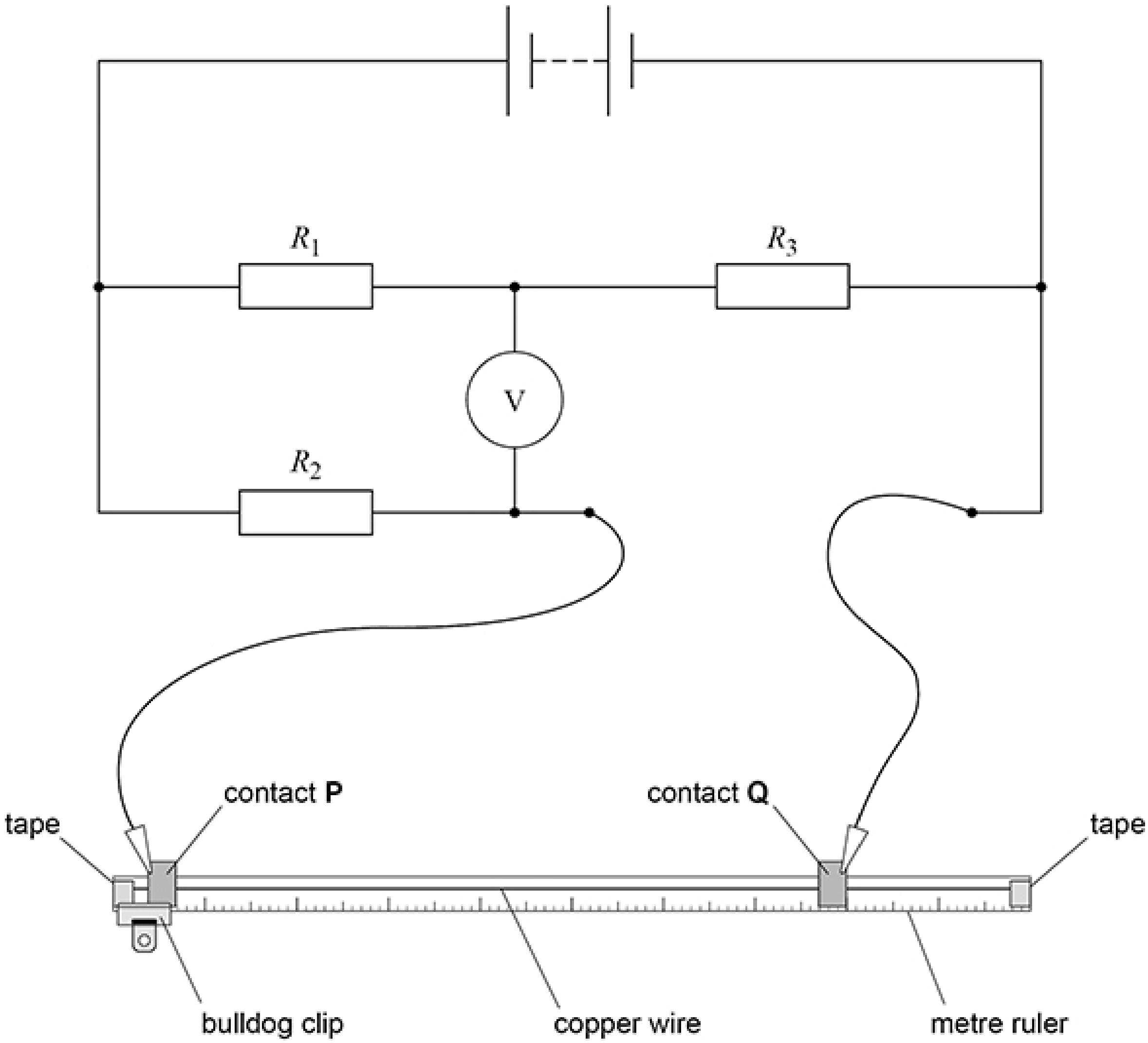
(3)

(Total 14 marks)

Q8.

Figure 1 shows a circuit used to find the resistance per unit length of a copper wire.

Figure 1

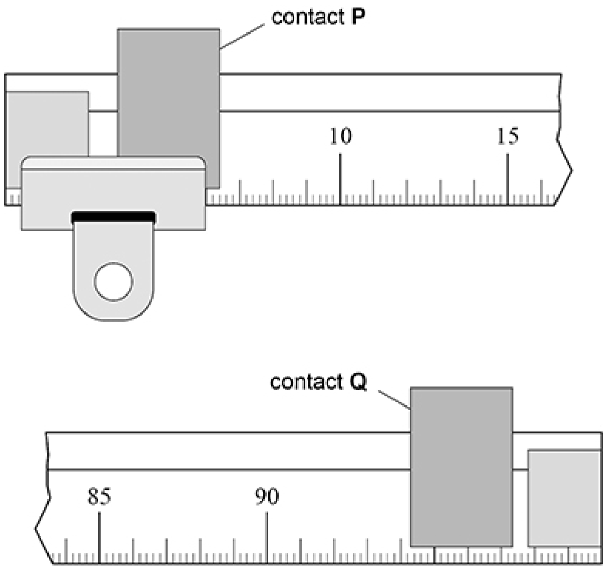


The copper wire is fixed with tape to a metre ruler that has 2 mm graduations. Contact **P** is placed on the wire close to one end of the ruler and held firmly in place using a bulldog clip.
When contact **Q** is placed on the wire as shown in **Figure 1** the voltmeter shows a non-zero reading.

Q is moved along the wire until the voltmeter reading is zero.

Figure 2 shows enlarged views of the position of **P** and the new position of **Q**.

Figure 2



(a) Determine, in m, the length x of copper wire between **P** and **Q**.

x = _______________ m

(1)

(b) When the voltmeter reading is zero:

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

where R_4 is the resistance of the copper wire between **P** and **Q**.

Determine, in $\Omega\ \mathrm{m}^{-1}$, the resistance per unit length of the copper wire.

$R_1 = 2.2\ \mathrm{M\Omega}$
$R_2 = 3.9\ \mathrm{k\Omega}$
$R_3 = 75\ \Omega$

resistance per unit length = _______________ $\Omega\ \mathrm{m}^{-1}$

(2)

(c) The diameter d of the copper wire is approximately $0.4\ \text{mm}$.

Suggest:

- a suitable measuring instrument to accurately determine d
- how to reduce the effect of random error on the result for d.

(3)

(d) Determine the resistivity ρ of copper.

diameter d of the copper wire = $0.38\ \text{mm}$

ρ = ____________ $\Omega\ \text{m}$

(2)

The copper wire is replaced with a constantan wire of diameter $0.38\ \text{mm}$.

$$\frac{\text{resistivity of constantan}}{\text{resistivity of copper}} = 30$$

(e) Suggest **one** change to the circuit to make the voltmeter read zero for the same value of x as in part (a).

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(1)

(f) Calculate, in mm, the diameter of a constantan wire that has the **same** resistance per unit length as the copper wire.

diameter = ______________ mm

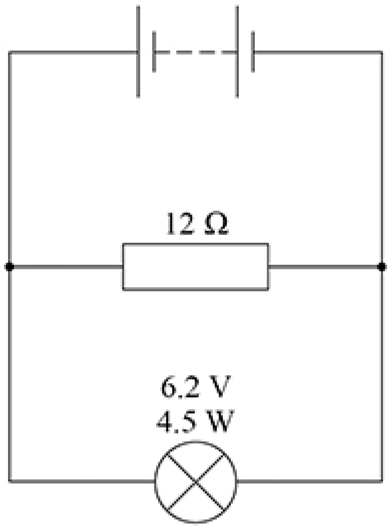
(1)

(Total 10 marks)

Q9.

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 $6.2\ \text{V}$.

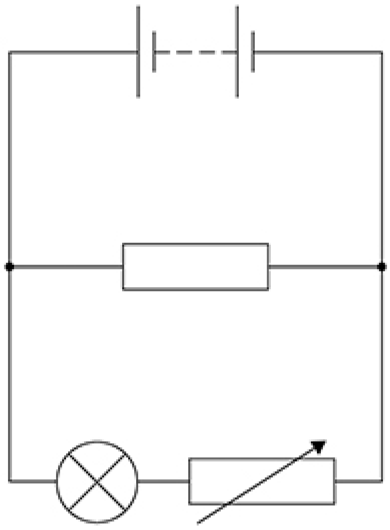
Calculate the emf of the battery.

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 mm to make the variable resistor. A 5.0 m length of this wire has a resistance of $9.0\ \Omega$.

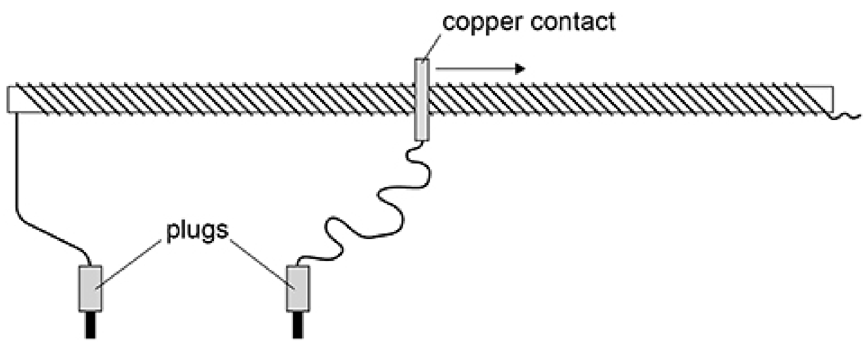
Calculate the resistivity of the wire.

resistivity = _______________ Ω 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.

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(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.

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(2)

(Total 11 marks)