4. *(a)* Define electric current. [1]

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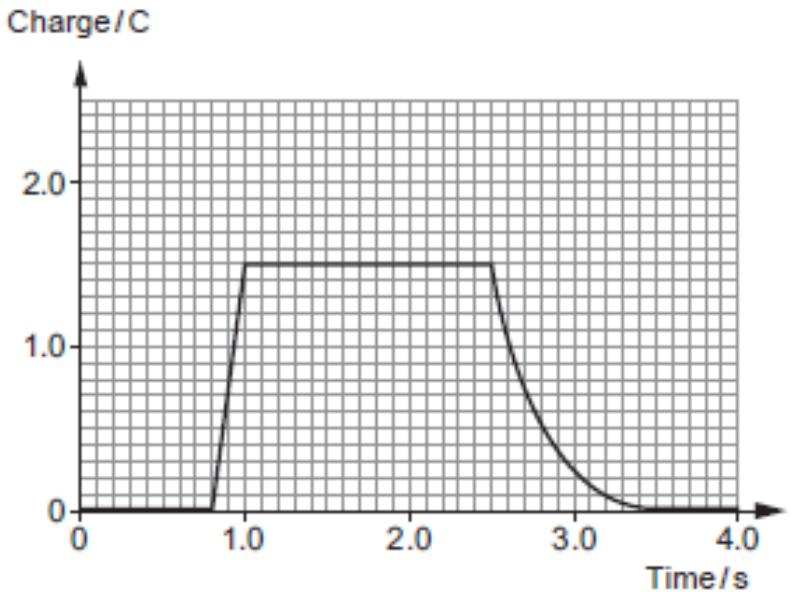
(b) The following graph shows how the **charge** that has passed a point in an electrical circuit varies with time.



(i) Describe how the **current** varies from $t = 0$ to $t = 2.5\,s$ giving appropriate values. [4]

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(ii) **Calculate the current when t = 3.0 s.** [3]

2.

The current I in a metal conductor of cross-sectional area A is given by:

$$I = nAve$$

(a) State the meanings of n and v. [2]

n .....

v .....

(b) Show that the equation is correct in terms of units. [3]

(c) (i) The current in a copper wire is 2.0 A. The wire has a cross-sectional area of 1.2 mm^2 and is 5.0 m long. Calculate the time it takes a free electron in the wire to travel from one end to the other. [Take $n_{copper} = 8 \times 10^{28}\ m^{-3}$.] [3]

(ii) The **same current** (2.0 A) is now passed through a **thinner** wire of the **same length and material**. Use the above equation to explain the effect this change would have on the time for an electron to travel from one end to the other. [3]

3.

(a) (i) The current in a wire depends on its **resistance**. Explain, in terms of free electrons, how this resistance arises when a potential difference is applied across the wire. [2]

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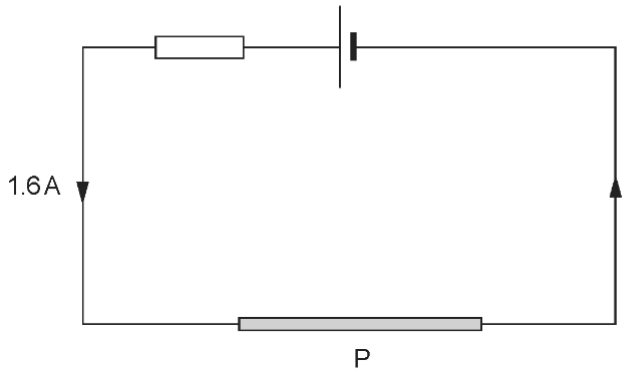
(ii) The wire (labelled P in the diagram) is connected to a fixed voltage source and a resistor to limit the current as shown. The wire is 0.4 m long and has a cross-sectional area of $2.0 \times 10^{-6}\,m^2$. When the current is 1.6 A it dissipates 1.8 J of energy in 1 minute. Calculate its resistivity. [4]



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(b) (i) The current, I, in a wire of cross-sectional area, A, is given by the formula:

$$I = nAve$$

Derive the formula. You may include a clearly labelled diagram. [4]

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(ii) Calculate the drift velocity of the free electrons in the wire in *(a)*(ii) when the current through it is 1.6 A. [$n = 6.4 \times 10^{28}\,m^{-3}$] [2]

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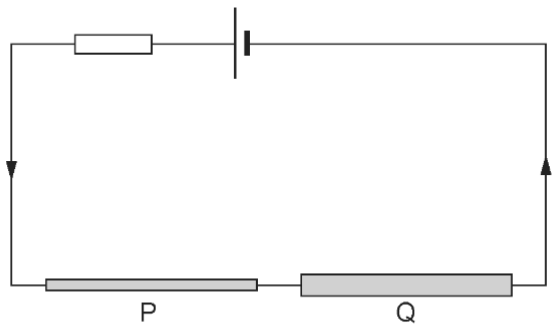
(iii) Wire P is now connected to another wire, Q, of the same material but with **twice** the cross-sectional area. The wires are connected to the same fixed voltage source and resistor.



Complete the following sentences by **circling the correct option** given in brackets.

(I) The current in the circuit containing both wires is **[less than 1.6 A] [equal to 1.6 A] [more than 1.6 A]**. [1]

(II) The current in P is **[less than] [the same as] [greater than]** the current in Q. [1]

(III) The electron drift velocity in Q is **[half] [the same as] [twice] [four times]** the electron drift velocity in P. [1]

4.

(a) Derive, giving a labelled diagram, the relationship between the current I through a metal wire of cross sectional area A, the drift velocity, v, of the free electrons, each of charge e, and the number, n, of free electrons per unit volume of the metal. [4]
($I = nAve$).

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(b) Calculate the drift velocity of free electrons in a copper wire of cross sectional area $1.7 \times 10^{-6} m^2$ when a current of 2.0A flows. [$n_{copper} = 1.0 \times 10^{29} m^{-3}$]. [2]

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(c) A potential difference is required across the copper wire in order for the current to flow. The size of the current depends on the wire's *resistance*. Explain in terms of free electrons, how this resistance arises. [2]

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(d) The copper wire in *(b)* is of length 2.5 m. When it carries a current of 2.0 A, it dissipates energy at the rate of 0.1 W. Calculate its resistivity. [4]

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(e) A second copper wire has the same volume as the wire in *(d)*, but is longer.
Complete the table below indicating whether the quantity given is **bigger**, **smaller** or **the same** for this longer wire. [3]

Quantity	**For the longer wire this quantity is ...**
Cross-sectional Area	
n, number of free electrons/unit volume	
Resistivity	