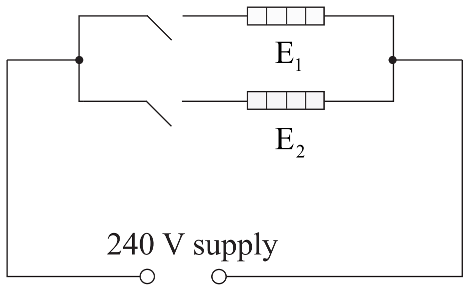
B4. This question is in **two** parts. **Part 1** is about an electrical heater. **Part 2** is about the hydrogen atom.

Part 1 Electrical heater

An electrical heater consists of two heating elements E_1 and E_2. The elements are connected in parallel. Each element has a switch and is connected to a supply of emf 240 V. The supply has negligible internal resistance.



Element E_1 is made from wire that has a cross-sectional area of $6.8\times10^{-8}\,\text{m}^2$. The resistivity of the wire at the operating temperature of the element is $1.1\times10^{-6}\,\Omega\,\text{m}$.

(a) (i) The total length of wire is 4.5 m. Show that the resistance of E_1 is $73\,\Omega$. *[1]*

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(ii) Calculate the power output of E_1 with only this element connected to the supply. *[2]*

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(iii) Element E_2 is made of wire of the same cross-section and material as E_1. The length of wire used to make E_2 is 1.5 m. Determine the total power output when both E_1 and E_2 are connected to the supply. *[3]*

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(Question B4, part 1 continued)

(iv) With reference to the power output, explain why it would be inappropriate to connect the heating elements in series. *[3]*

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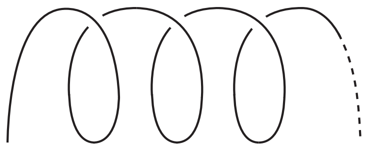
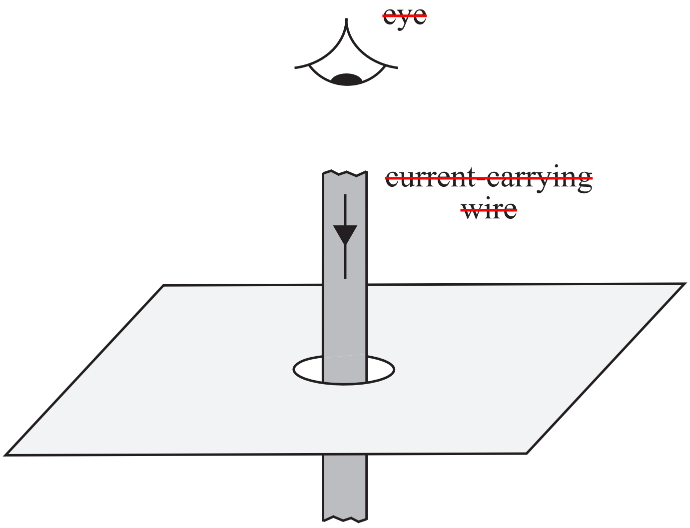
~~(b) Each element in the electrical heater is wound as a coil as shown.~~



~~Each turn of the coil may be considered to act as a current-carrying long straight wire.~~

~~(i) On the diagram, draw the magnetic field around a current-carrying long straight wire. The arrow shows the direction of the current.~~ ~~*[3]*~~



~~(ii) State **and** explain whether the turns of wire will attract or repel one another.~~ *[3]*

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SECTION B

This section consists of four questions: B1, B2, B3 and B4. Answer ***two*** *questions.*

B1. This question is in **two** parts. **Part 1** is about electric fields and electrical resistance. **Part 2** is about radioactive decay.

Part 1 Electric fields and electrical resistance

(a) State, in terms of electrons, the difference between a conductor and an insulator. *[1]*

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(b) Suggest why there must be an electric field inside a current-carrying conductor. *[3]*

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(c) The magnitude of the electric field strength inside a conductor is $55\,\text{N}\,\text{C}^{-1}$. Calculate the force on a free electron in the conductor. *[1]*

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(d) Define *resistance*. *[1]*

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(e) A resistor made from a metal oxide has a resistance of $1.5\,\Omega$. The resistor is in the form of a cylinder of length $2.2\times10^{-2}\,\text{m}$ and radius $1.2\times10^{-3}\,\text{m}$. Calculate the resistivity of the metal oxide. *[2]*

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(Question B1, part 1 continued)

(f) The manufacturer of the resistor in (e) guarantees its resistance to be within ±10% of 1.5 Ω provided the power dissipation in the resistor does not exceed 1.0 W. Calculate the maximum current in the resistor for the power dissipation to be equal to 1.0 W. *[2]*

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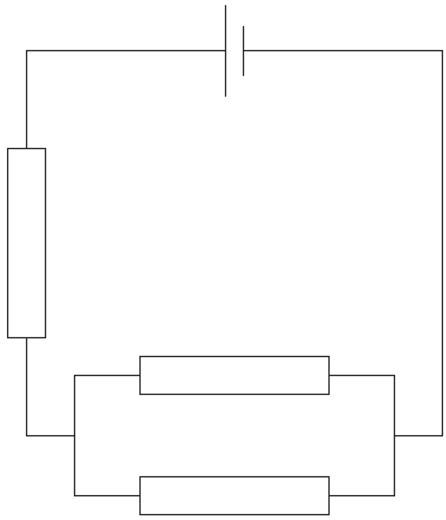
(g) Three of the resistors in (f) are connected in the circuit below.



The cell has an emf of 2.0 V and negligible internal resistance.

(i) Define *emf*. *[1]*

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(ii) Determine the minimum and the maximum power that could be dissipated in this circuit. *[3]*

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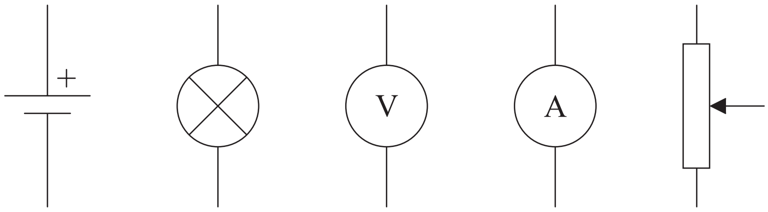
B4. This question is in **two** parts. **Part 1** is about electric circuits. **Part 2** is about electrons.

Part 1 Electric circuits

The components shown below are to be connected in a circuit to investigate how the current I in a tungsten filament lamp varies with the potential difference V across it.

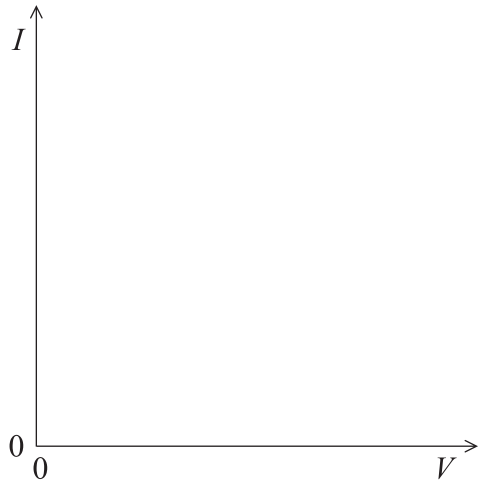


(a) Construct a circuit diagram to show how these components should be connected together in order to obtain as large a range as possible for values of potential difference across the lamp. *[4]*

(This question continues on the following page)

(Question B4, part 1 continued)

(b) On the axes, sketch a graph of I against V for a filament lamp in the range $V=0$ to its normal working voltage. *[2]*



(c) The lamp is marked with the symbols "1.25 V, 300 mW". Calculate the current in the filament when it is working normally. *[1]*

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(d) The resistivity of tungsten at the lamp's working temperature is $4\times10^{-7}\ \Omega\,\text{m}$. The total length of the tungsten filament is 0.80 m. Estimate the radius of the filament. *[4]*

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(e) The cell is connected to two identical lamps connected in parallel. The lamps are rated at 1.25 V, 300 mW. The cell has an emf of 1.5 V and an internal resistance of 1.2 Ω. Determine whether the lamps will light normally. *[4]*

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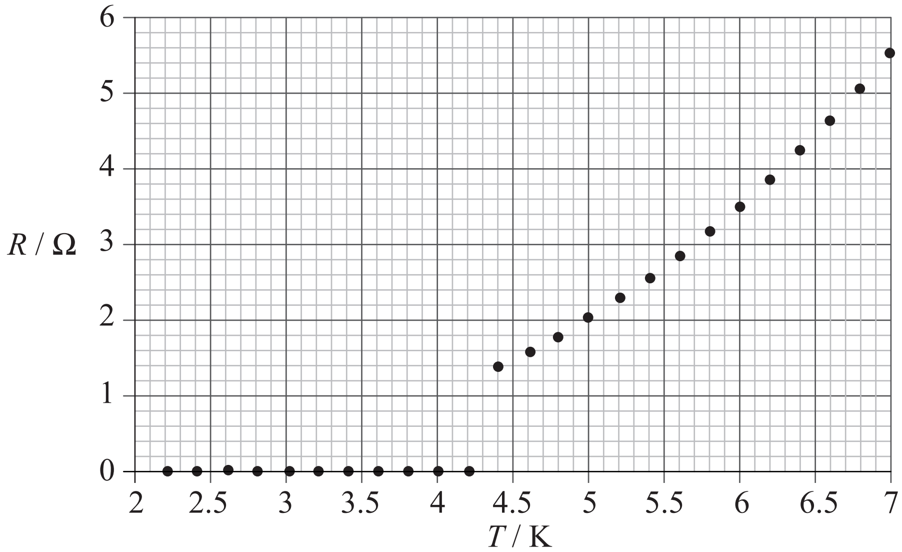
SECTION A

*Answer **all** the questions in the spaces provided.*

A1. This question is about electrical resistance of the metal mercury.

The resistance R of a sample of mercury was measured as a function of the temperature T of the sample. The sample was cooled and data points were taken at temperature intervals of 0.2 K. The uncertainties in R and T are too small to be shown on the graph.



The hypothesis is that resistance is proportional to absolute temperature for temperatures greater than 4.5 K.

(a) (i) Suggest whether the data supports the hypothesis. *[1]*

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(ii) Draw a line of best fit through the data. *[2]*

(b) State the value of R for which the rate of change of resistance of the sample with temperature is least. *[1]*

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(This question continues on the following page)

(Question A1 continued)

(c) At a temperature T_C the resistance suddenly becomes zero.

(i) Use the graph to determine the possible range of the temperature T_C. *[1]*

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(ii) State, to the correct number of significant figures, the value of T_C and its uncertainty. *[2]*

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(iii) Outline how the temperature T_C could be measured more precisely. *[1]*

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(d) Outline **two** reasons why you could not use the data to determine an accurate value for R at room temperature. *[2]*

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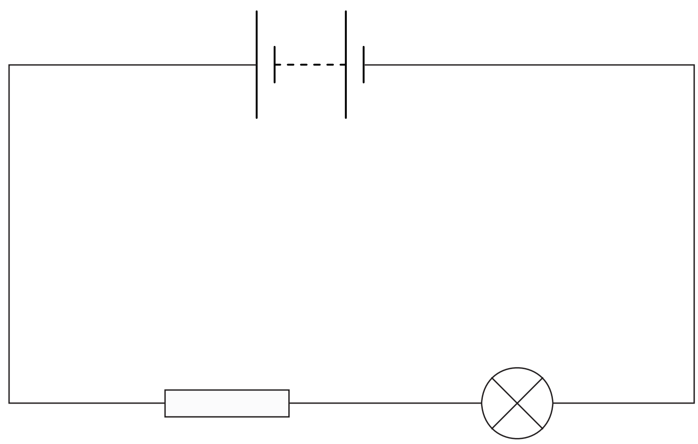
(Question B1, part 1 continued)

(d) A resistor R and a filament lamp L are connected in series with a battery. The battery has an emf of 12 V and internal resistance 4.0 Ω. The potential difference across the filament of the lamp is 3.0 V and the current in the filament is 0.25 A.



(i) Calculate the total power supplied by the battery. *[1]*

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(ii) Calculate the power dissipated in the external circuit. *[2]*

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(iii) Determine the resistance of the resistor R. *[3]*

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A2. This question is about electrical resistance.

(a) A heating coil is to be made of wire of diameter 3.5×10^{-4} m. The heater is to dissipate 980 W when connected to a 230 V d.c. supply. The material of the wire has resistivity $1.3 \times 10^{-6}\,\Omega$ m at the working temperature of the heater.

(i) Define *electrical resistance*. *[1]*

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(ii) Calculate the resistance of the heating coil at its normal working temperature. *[2]*

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(iii) Show that the length of wire needed to make the heating coil is approximately 4 m. *[2]*

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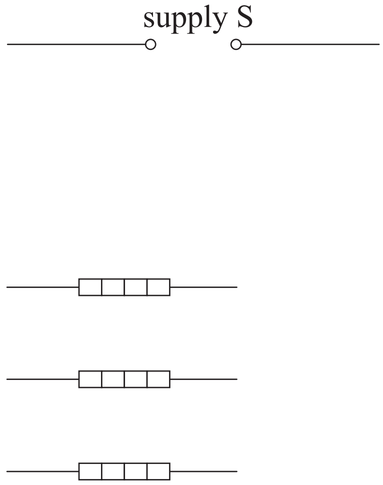
(Question A2 continued)

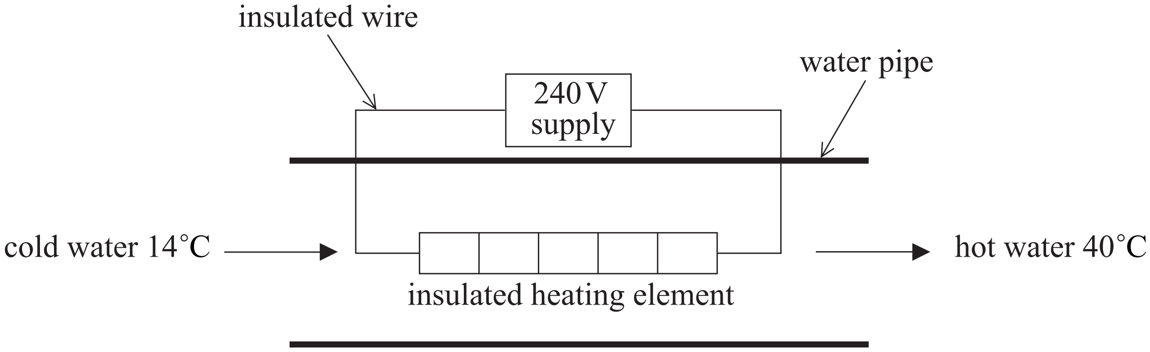
(b) Three identical electrical heaters each provide power *P* when connected separately to a supply S which has zero internal resistance. On the diagram below, complete the circuit by drawing **two** switches so that the power provided by the heaters may be **either** *P* **or** 2*P* **or** 3*P*. *[2]*



B4. This question is in **two** parts. **Part 1** is about heating water for a domestic shower. **Part 2** is about the photoelectric effect.

Part 1 Domestic shower

(a) The diagram below shows part of the heating circuit of a domestic shower.



Cold water enters the shower unit and flows over an insulated heating element. The heating element is rated at 7.2 kW, 240 V. The water enters at a temperature of 14 °C and leaves at a temperature of 40 °C. The specific heat capacity of water is $4.2 \times 10^3 \text{ J kg}^{-1} \text{ K}^{-1}$.

(i) Define *specific heat capacity*. *[1]*

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(ii) Estimate the flow rate of the water. *[4]*

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(Question B4, part 1 continued)

(iii) Suggest **two** reasons why your answer to (a)(ii) is only an estimate. *[2]*

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(iv) Calculate the current in the heating element when the element is operating at 7.2 kW. *[2]*

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(v) Explain why, when the shower unit is switched on, the initial current in the heating element is greater than the current calculated in (a)(iv). *[2]*

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(Question B4, part 1 continued)

(b) In some countries, shower units are operated from a 110 V supply. A heating element operating with a 240 V supply has resistance R_{240} and an element operating from a 110 V supply has resistance R_{110}.

Show that for heating elements to have identical power outputs

$$\frac{R_{110}}{R_{240}} = 0.21.$$ *[3]*

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