A-Level Physics

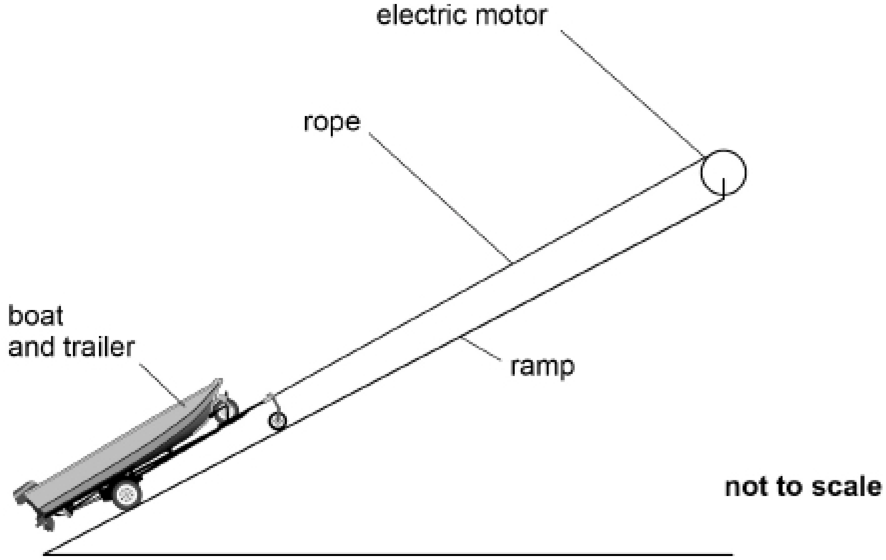
Basics of Electricity

Question Paper

Time available: 59 minutes
Marks available: 49 marks

1. This question is about the initial motion of a boat and trailer when pulled up a ramp as shown in **Figure 1**.

Figure 1

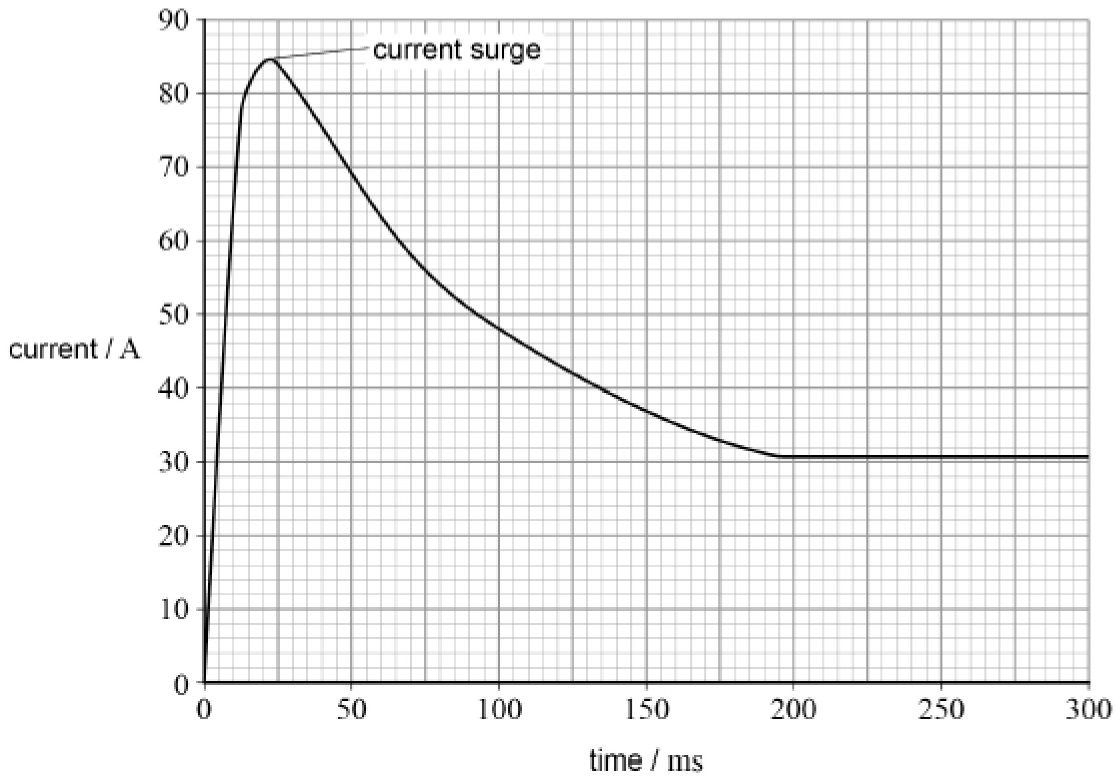


The boat and trailer are pulled by a motor which is connected to a 24 V battery of negligible internal resistance.

The motor is switched on at time $t = 0$

Figure 2 shows how the current in the motor's circuit varies with time.

Figure 2



(a) Determine the total energy input by the 24 V battery to the motor in the first 200 ms.

total energy input = ____________________ J

(3)

(b) The boat and trailer are initially at rest. In the first 200 ms the boat and trailer are raised through a vertical height of 3.3×10^{-2} m and the speed increases to 0.85 m s^{-1}.

Assume that all the useful energy output by the motor is transferred into kinetic energy and gravitational potential energy of the boat and trailer.
The boat and trailer have a total mass of 180 kg.

Determine the average efficiency of the motor during these first 200 ms.

average efficiency = ____________________

(3)

(c) Either of the circuits shown in **Figure 3a** and **Figure 3b** could be used to reduce the initial current surge.

Figure 3a

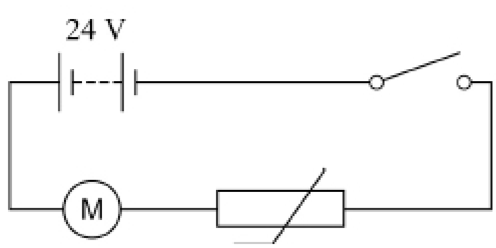
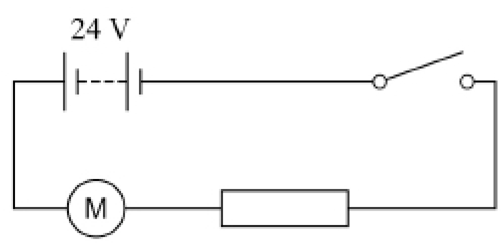


Figure 3b



The thermistor and the fixed resistor have the same resistance when they are at the temperature of the surroundings.

When the surge has ended, the boat and trailer continue to move at a constant speed to the top of the ramp.

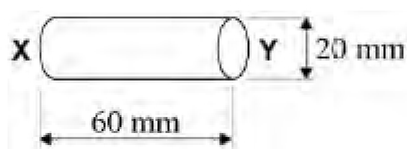
Explain, with reference to the properties of the thermistor and the fixed resistor, why using the thermistor is preferable to using the fixed resistor.

(3)

(Total 9 marks)

2. **Figure 1** shows a cylinder of conducting putty which is 60 mm long and 20 mm in diameter.

Figure 1



(a) The conducting putty obeys Ohm's law.

State Ohm's law.

(1)

(b) A 1.50 V dc supply of negligible internal resistance is connected across the ends **X** and **Y** of the cylinder of putty. The resistance of the cylinder of putty is 20.0 Ω.

Calculate, in mA, the current in the putty.

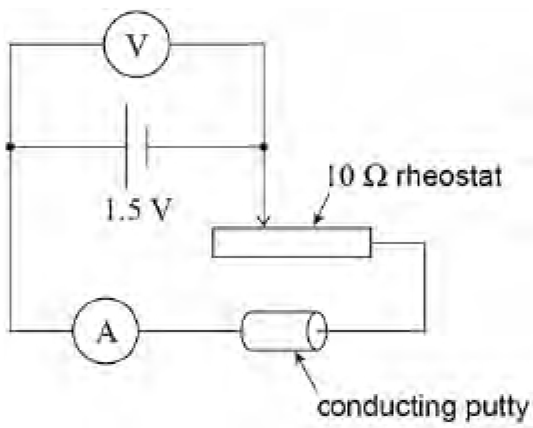
current = ________________ mA

(1)

(c) A student suggests an arrangement for demonstrating that the putty obeys Ohm's law.

Discuss any problems that make the circuit and components shown in **Figure 2** unsuitable for this purpose.

Figure 2



(4)

(d) Show that the resistivity ρ of the putty can be calculated using the formula

$$\rho = \frac{R}{l^2} \times \textit{volume of the cylinder}$$

where R is the resistance of the cylinder and l is the length of the cylinder.

(1)

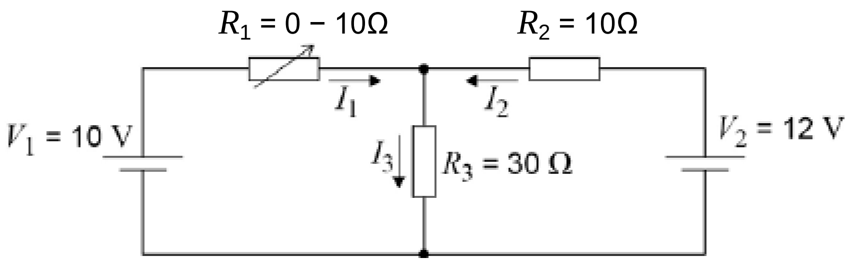
(e) Calculate, using the formula in part **(d)**, the resistivity of the putty. Give an appropriate unit for your answer.

resistivity = ________________ unit = _____________

(3)

(Total 10 marks)

3. The cells in the circuit shown in the figure below have zero internal resistance. Currents are in the directions shown by the arrows.



R_1 is a variable resistor with a resistance that varies between 0 and 10 Ω.

(a) Write down the relationship between currents I_1, I_2 and I_3.

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(1)

(b) R_1 is adjusted until it has a value of 0 Ω.

State the potential difference across R_3.

potential difference = ______________________ V

(1)

(c) Determine the current I_2.

current = ______________________ J

(2)

(d) State and explain what happens to the potential difference across R_2 as the resistance of R_1 is gradually increased from zero.

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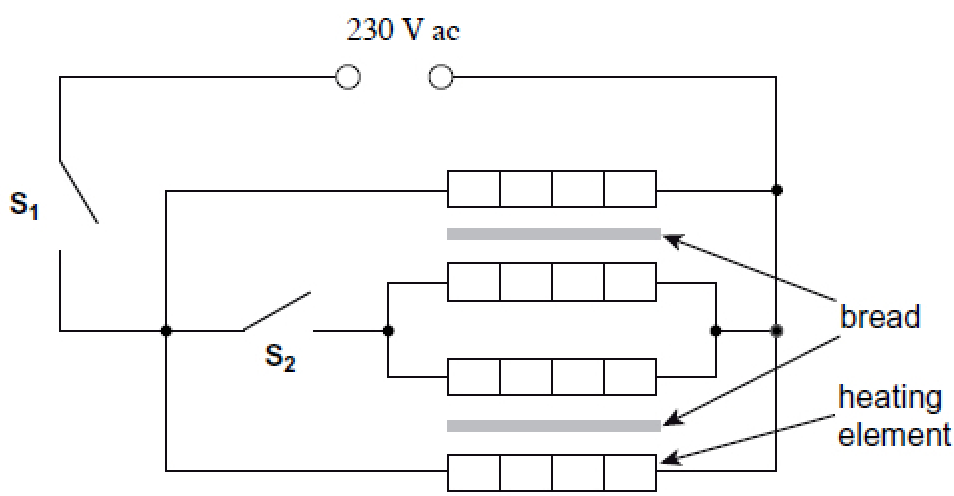
(3)

(Total 7 marks)

4. The diagram shows the circuit diagram for a two-slice electric toaster that is operated at a mains voltage of 230 V.



The toaster has four identical heating elements and has two settings: normal and low. On the normal setting both sides of the bread are toasted. On the low setting, only one side of the bread is toasted. The setting is controlled by switches $\mathbf{S_1}$ and $\mathbf{S_2}$.

The table shows the position of each switch and the power for each setting.

Setting	$\mathbf{S_1}$	$\mathbf{S_2}$	**Power / W**
Low	closed	open	400
Normal	closed	closed	800

(a) Calculate the current in $\mathbf{S_2}$ when the normal setting is selected.

current ____________________ A

(2)

(b) (i) Show that the resistance of **one** heating element is approximately 260 Ω when the toaster is operating at its working temperature.

(2)

(ii) Calculate the total resistance when the normal setting is selected.

resistance ____________________ Ω

(2)

(iii) Each heating element is made of nichrome wire of diameter 0.15 mm.
The nichrome wire is wrapped around an insulating board.

Determine the length of nichrome wire needed to provide a resistance of 260 Ω.

resistivity of nichrome at the working temperature = 1.1×10^{-6} Ω m

length of wire ____________________ m

(3)

(c) Explain why the resistivity of the nichrome wire changes with temperature.

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(3)

(d) The nichrome wire has an equilibrium temperature of 174°C when the toaster is operating.

Calculate the peak wavelength of the electromagnetic radiation emitted by the wire.

Give your answer to an appropriate number of significant figures.

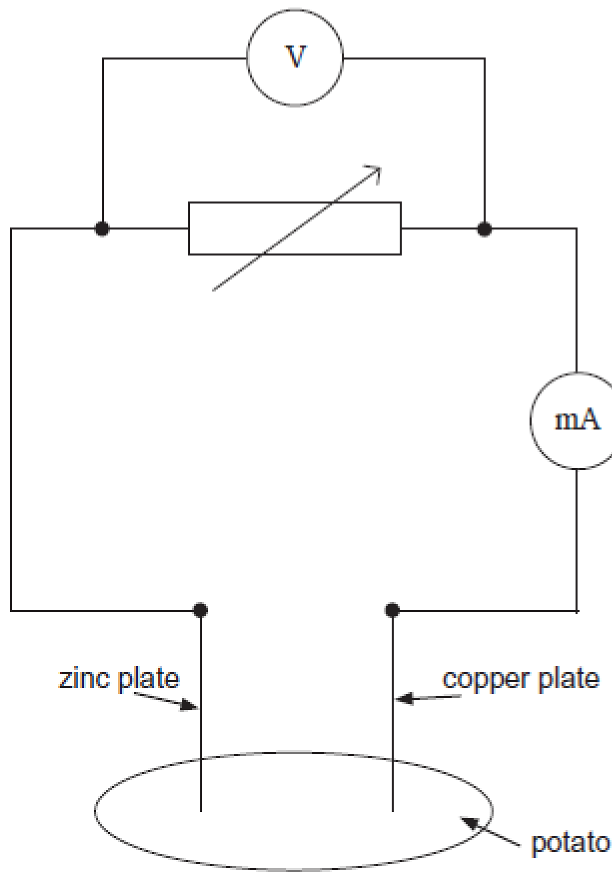
peak wavelength ____________________ m

(3)

(Total 15 marks)

5. 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.

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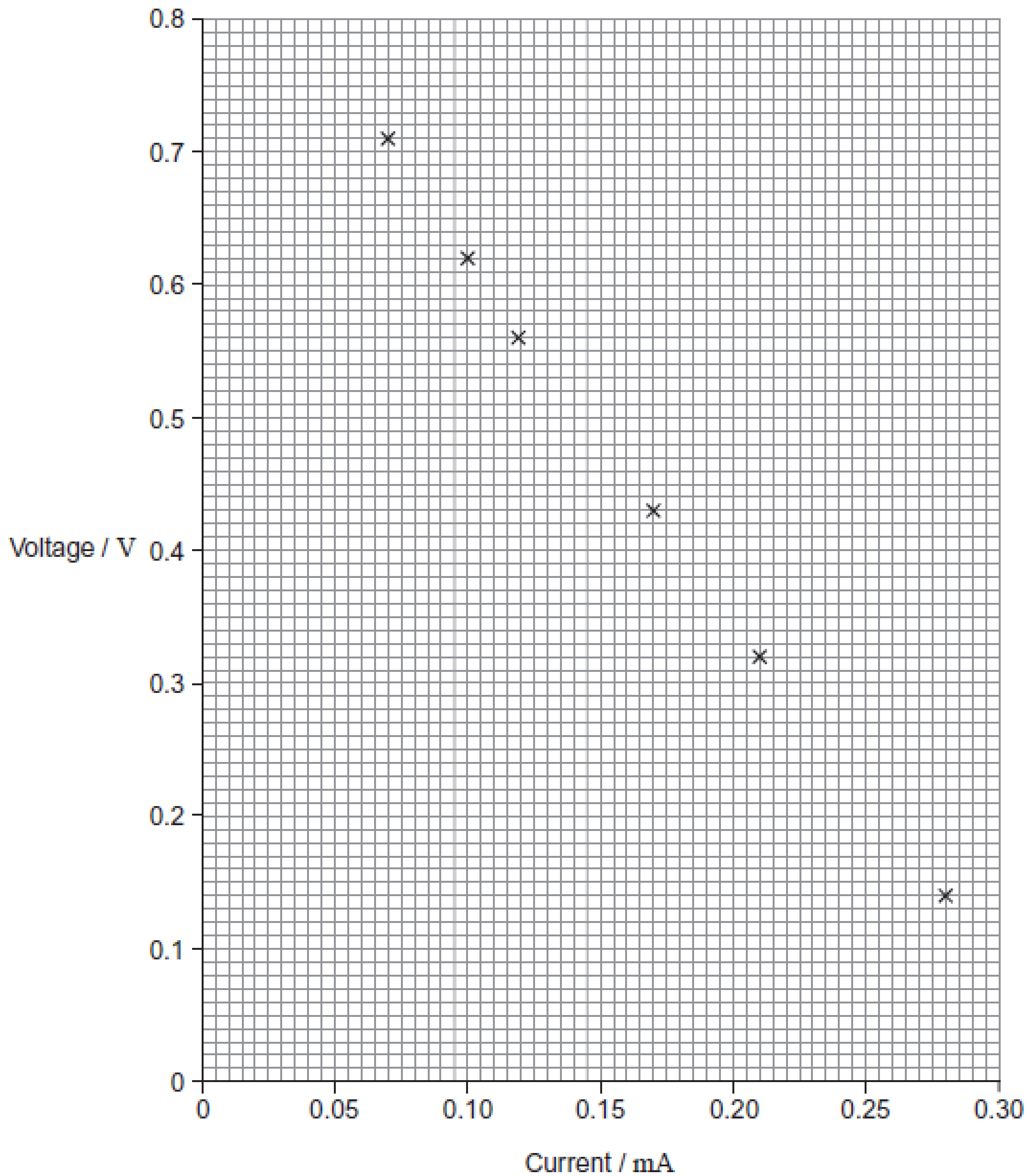
(2)

(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.

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(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.

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(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.

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(2)

(Total 11 marks)