A-Level Physics

Current-Voltage Characteristics

Question Paper

Time available: 64 minutes
Marks available: 51 marks

1. A battery of emf 7.4 V and negligible internal resistance is used to power a heating element inside a glove. The heating element has a resistance of 3.7 Ω.

(a) The designers state that the battery can produce a current of 2.0 A in the heating element for 240 minutes.

Calculate the energy dissipated in the heating element in this time.

energy dissipated = _____ J

(3)

(b) The length of the heating element needed is about 0.85 m.
The designer considers using a carbon fibre tape for the heating element.
The table gives information for the carbon fibre tape.

Cross-sectional area / m^2	**Resistivity / Ω m**
4.9×10^{-6}	2.0×10^{-5}

Deduce whether the carbon fibre tape is suitable for making the heating element for the glove.

(2)

(c) A light emitting diode (LED) is used to indicate that the switch in the glove is closed, as shown in **Figure 1**. Resistor R limits the current in the LED.

Figure 1

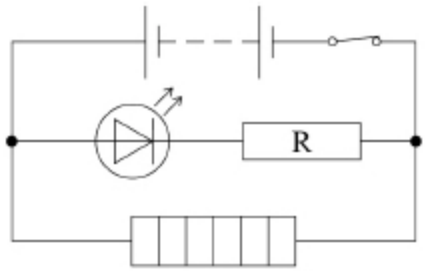
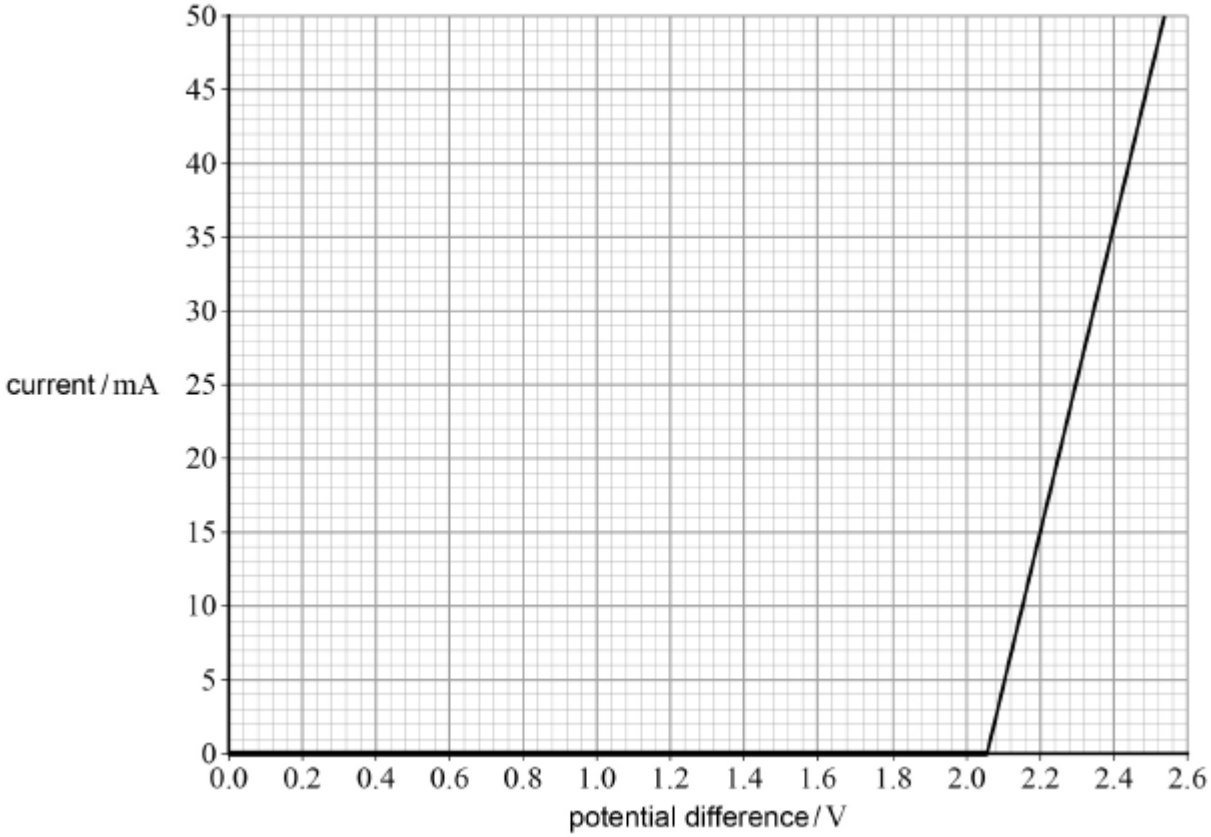


Figure 2 shows part of the characteristic graph for the LED.

Figure 2



The circuit is designed so that the potential difference across the LED is 2.2 V when the switch is closed.

Calculate the resistance of R.

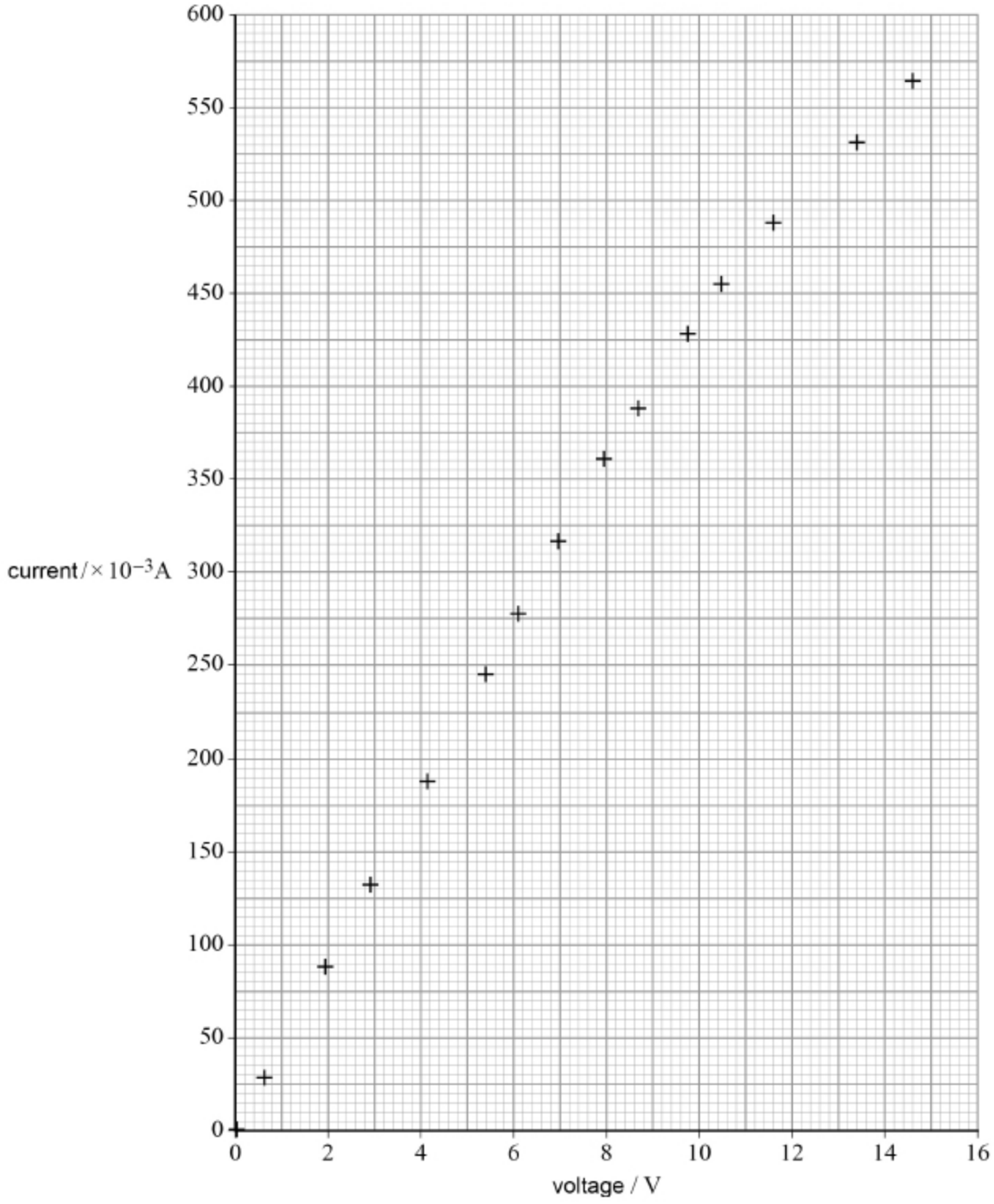
resistance = _____ Ω

(4)

(Total 9 marks)

2. This question is about an experiment to obtain current–voltage data for a resistor **R**.
Figure 1 shows a plot of current–voltage data for **R**.

Figure 1



(a) Draw a best-fit line for the data on **Figure 1**.

(1)

(b) Identify the data point with the greatest value of current and voltage at which **R** obeys Ohm's law.

Draw a circle around this data point on **Figure 1**.

(1)

(c) When **R** obeys Ohm's law it has a resistance of 22.2 Ω.

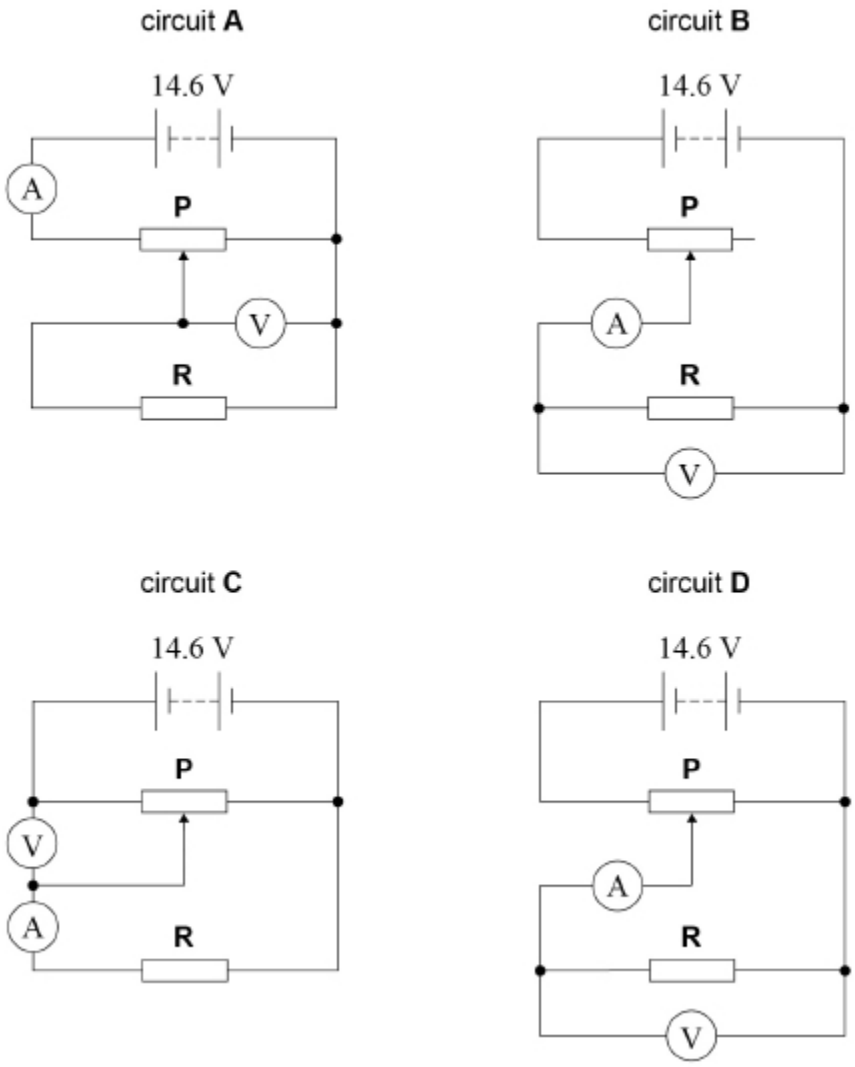
Determine the percentage increase in the resistance of **R** from its 22.2 Ω value to its value when the current is 550×10^{-3} A.

percentage increase = _____

(2)

(d) One of the circuits **A** to **D** shown in **Figure 2** was used to obtain the current–voltage data in **Figure 1**. The maximum resistance of resistor **P** is twice the resistance of **R**.
The battery has an emf of 14.6 V and negligible internal resistance.

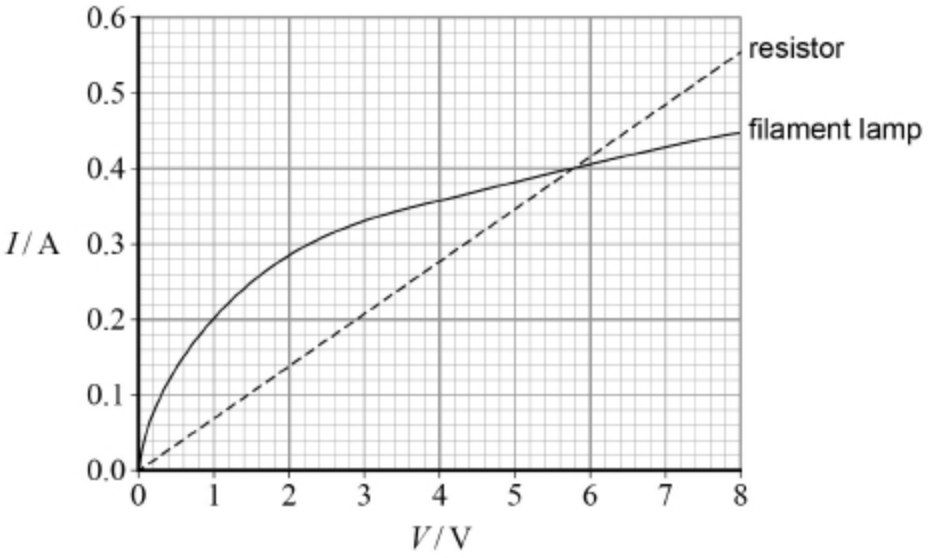
Figure 2



Deduce which **one** of these circuits was used to directly obtain the current–voltage data in **Figure 1**.
You should include in your answer an explanation of why each of the other circuits is **not** suitable to obtain the data directly from the voltmeter and ammeter readings.

(4)
(Total 8 marks)

3. The graph below shows the current–voltage (I–V) characteristics for a resistor and a filament lamp.



(a) Explain, in terms of electron motion, why the I–V characteristic for the filament lamp is a curve.

(4)

(b) Determine the resistance of the resistor.

resistance = _____ Ω

(1)

(c) The resistor and the filament lamp are connected in series with a supply of variable emf and negligible internal resistance.

Determine the emf that produces a current of 0.18 A in the circuit.

emf = _____ V

(3)

(d) The resistor and filament lamp are now connected in parallel.

Determine the resistance of the parallel combination when the emf of the supply is adjusted to be 4.0 V.

resistance = _____ Ω

(3)

(e) The resistance of the filament lamp at its working temperature is 14 Ω.

The filament has a length of 0.36 m and a diameter of 32 μm.

Calculate the resistivity of the metal that is used for the filament when the lamp is at its working temperature.

Give an appropriate unit for your answer.

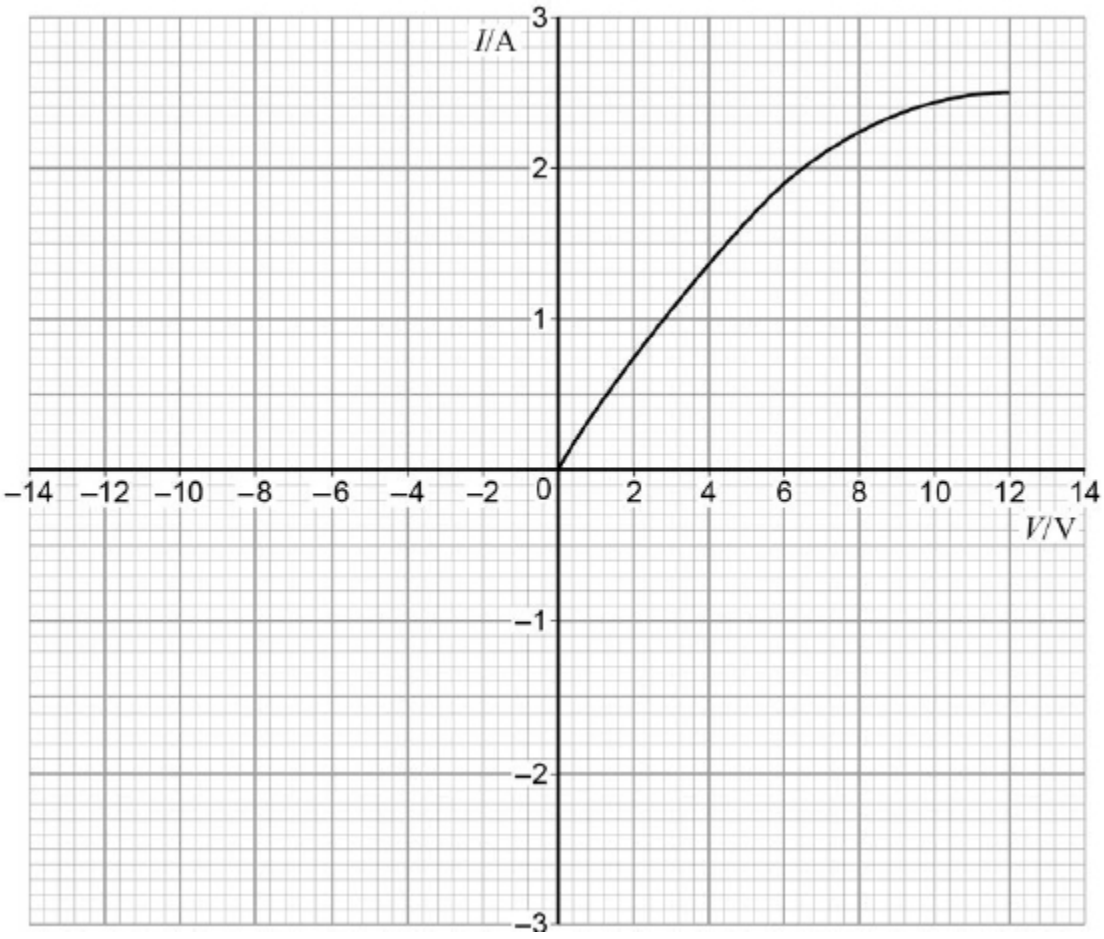
resistivity = _____ unit _____

(3)

(Total 14 marks)

4. **Figure 1** shows the current–voltage ($I-V$) characteristic of the lamp used in a car headlight up to its working voltage.

Figure 1



(a) Draw on **Figure 1** the characteristic that would be obtained with the connections to the supply reversed.

(2)

(b) Lamps are marked with their working voltage and the power used at this voltage.
For example, a lamp for use in a torch may be marked 2.5 V 0.3 W.

Deduce the marking on the lamp for the car headlight.

lamp marking =_____ V _____ W

(2)

(c) Determine the resistance of the lamp when the potential difference (pd) across it is half the working voltage.

resistance _____ Ω

(1)

(d) Explain, without further calculation, how the resistance of the lamp varies as the voltage across it is increased from zero to its working voltage.

_____

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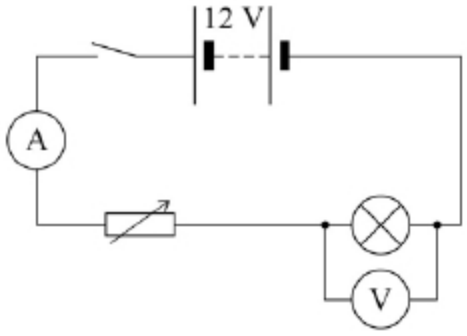
(3)

(e) A student suggests that the circuit shown in **Figure 2** is suitable for collecting data to draw the *I*−*V* characteristic of the lamp up to its working voltage. The maximum resistance of the variable resistor is 6.0 Ω and the internal resistance of the power supply is 2.0 Ω. The resistance of the ammeter is negligible.

Figure 2



Discuss the limitations of this circuit when used to collect the data for the characteristic.

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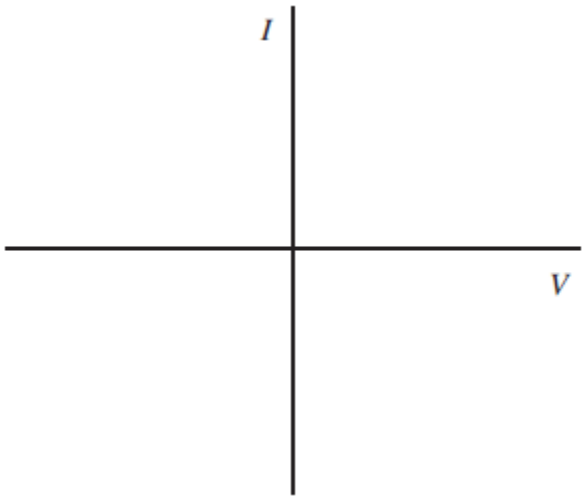
(2)

(Total 10 marks)

5. (a) Sketch, on **Figure 1**, the current−voltage (IV) characteristic for a filament lamp for currents up to its working power.

Figure 1



(2)

(b) (i) State what happens to the resistance of the filament lamp as the current increases.

_____

(1)

(ii) State and explain whether a filament lamp is an ohmic or non−ohmic conductor up to its working power.

_____

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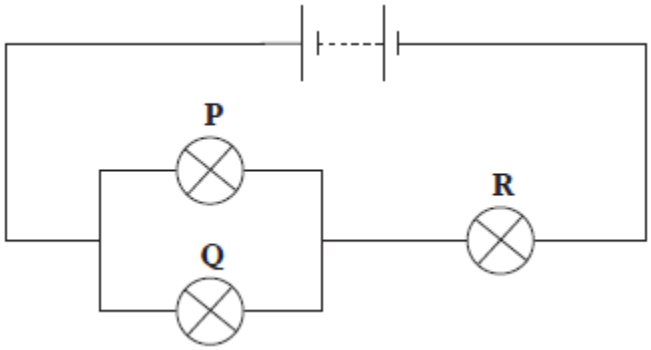
(1)

(c) Three identical filament lamps, **P**, **Q** and **R** are connected in the circuit shown in **Figure 2**.

Figure 2.



The filament in lamp **Q** melts so that it no longer conducts. Explain why lamp **P** becomes brighter and lamp **R** becomes dimmer.

_____

_____

_____

_____

_____

_____

(2)

(d) A filament lamp, **X**, is rated at 60 W 230 V. Another type of lamp, **Y**, described as 'energy saving' has the same light intensity output but is rated at 11 W 230 V.

(i) Calculate the electrical energy converted by each lamp if both are on for 4 hours a day for a period of 30 days.

electrical energy converted by **X** = _____ J

electrical energy converted by **Y** = _____ J

(2)

(ii) Suggest why the two lamps can have different power ratings but have the same light intensity output.

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(2)

(Total 10 marks)