MEGA LECTURE

Edexcel

A Level

A Level Physics

ELECTRICAL CIRCUITS: Electrical Quantities (Answers)

Name:

M M E

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Total Marks: /30

1. This question is about the variation of quantities such as current, voltage and resistance in simple electrical circuits containing a variety of standard components.

Total for Question 1: 11

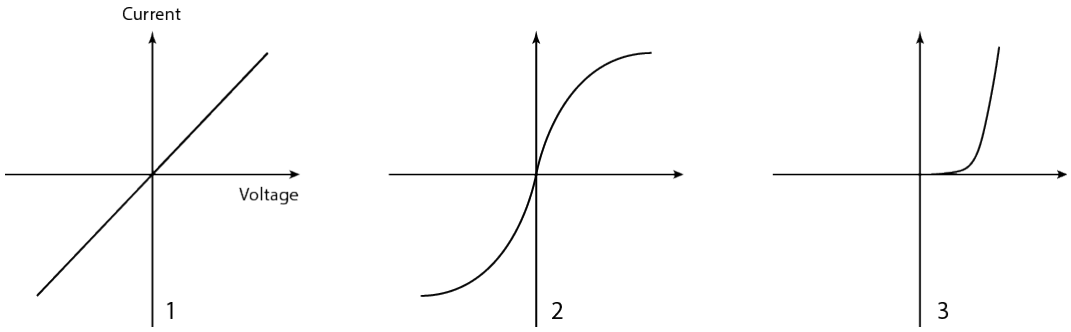

Figure 1: I-V characteristics for three different circuit components.

(a) State Ohm's Law. [1]

Solution: $I \propto V$

(b) Assign one of the following components to each of the characteristic graphs in Figure 1: filament lamp, semiconductor diode, resistor. [3]

Solution:
1: resistor
2: filament lamp
3: diode

(c) Why have these been plotted on graphs of current against potential difference rather than current against electromotive force? [1]

Solution: EMF is concerned with energy being put into the circuit; PD is concerned with energy used by components.

(d) For the diode, state the value of the resistance when a backward bias is applied. [1]

Solution: Zero

(e) Sketch the following graphs: [2]

i. Resistance against temperature for an ntc thermistor.

ii. Current against voltage for an ntc thermistor.

Solution:
(i) Non-linear decrease of resistance as temperature increases. Concave up.
(ii) inverse of the filament lamp i.e. concave up in the positive quadrant and concave down in the negative quadrant.

(f) The current in a filament is 8 A. In the time during which Patrick is using the lamp, 8×10^{22} electrons pass through a given point in the circuit. For how long has he been using the lamp? [3]

Solution: 1600 s

2. Frances is exploring the electrical properties of a piece of wire. She observes that:
(a) for a given current, doubling the length, L, of the wire doubles the potential difference (P.D.) and the resistance, R.
(b) for a given P.D., doubling the wire's diameter, d, causes R to decrease by a factor of 4.

Total for Question 2: 11

(a) On the basis of Frances' observations, which of these relationships is true: [3]

i. $R \propto A$ and $R \propto L$
ii. $R \propto 1/A$ and $R \propto 1/L$
iii. $R \propto 1/A$ and $R \propto L$
iv. $R \propto d^2$ and $R \propto L$

Solution: Option 3.

(b) Use this to define resistivity, ρ, in terms of d, R and L. [2]

Solution: $\frac{\pi d^2 R}{4L}$

(c) Figure 2 is a characteristic graph for a circuit component. Calculate the resistivity at the point for which the curves tangent has been drawn given that the component is cylindrical, has a length of 8 cm and has a radius of 1.5×10^{-5} m. [3]

Solution: 1.8×10^{-8}

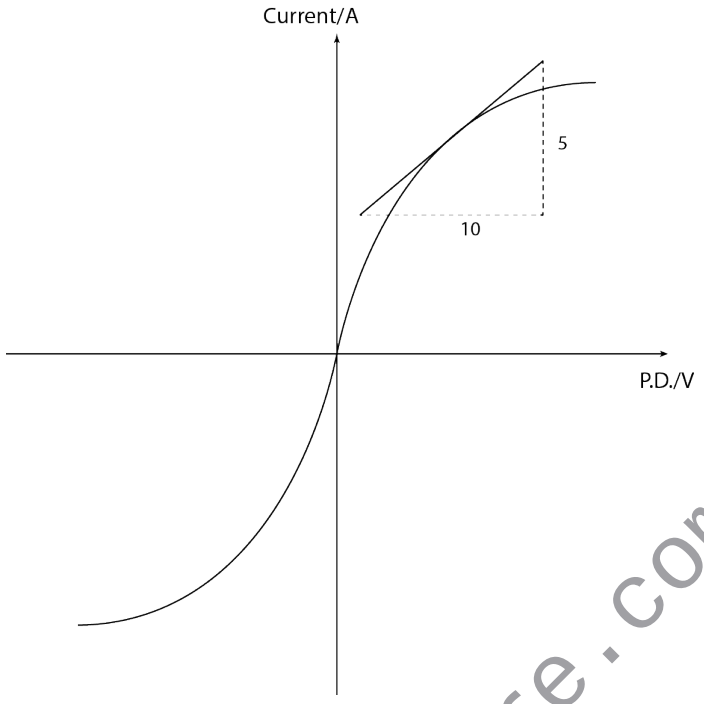

Figure 2: Characteristic graph for a particular circuit component.

(d) Explain how, using the characteristic, it is possible to deduce that, for this component, resistivity increases with temperature. [3]

Solution: As temperature increases, so too does current. But, on the characteristic, as current increases the gradient decreases i.e. R increases. Since $\rho = \frac{AR}{L}$, if R increases but the dimensions remain unchanged, ρ will also increase.

3. When a circuit containing a filament lamp is switched on, the lamp lights up very quickly (almost instantaneously). However, this does not correspond to the speed at which electrons travel through the circuitry. In this question you will calculate the speed at which electrons move in a wire.

   Venetia is building a simple circuit. Half way around, she runs out of wire of type 'A'. For the remainder, she therefore uses type 'B'. The two wires are joined with no other incoming or outgoing wires.

   Total for Question 3: 5

   (a) Type A has a radius of 4 mm and a resistivity of 10×10^{28} Ωm. In contrast, type B has a radius of $4\sqrt{2}$ mm and a resistivity 5×10^{28} Ωm. By what factor does the electron drift velocity, v, change as charge carriers move around the circuit? [3]

   Solution: No change.

   (b) If the resistance is 2 Ω and the voltage reads 10 V, calculate v in each of the wire types. [2]

   Solution: 6.2×10^{-6} ms^{-1}

4. This question is about semiconductors.

Total for Question 4: 3

(a) Which of these statements is false? [1]

i. Insulators have a very low band-gap energy.
ii. Insulators have very few electrons available for conduction.
iii. If a lot of energy is put in, insulators undergo other types of failure before they conduct.

Solution: Option 1.

(b) The number of delocalised electrons in semiconductors... [1]

i. ... is high compared with metals.
ii. ... increases with temperature.
iii. ... decreases with temperature.

Solution: Option 2.

(c) Which two of these statements are true? [1]

i. The valence band electrons in a semiconductor carry charge around the circuit.
ii. Electrons in the conduction band have greater energy than those in the valence band.
iii. Holes act as effective positive charges.

Solution: Options 2 and 3.