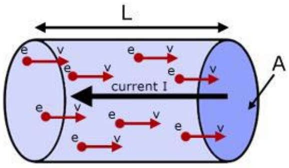
Electricity

PHYSICS

A. ELECTRIC CURRENT

- **Electric current** is a flow of **charge carriers**
- **Charge is quantised**, they are always an **integer multiple of 1.6 x 10^{-19} C**
- The total charge (C) passing through a point is equal to the **product of the current (A) and the time (s)** for which the current flows

$$Q = It$$



- The current passing through a conductor is

$$I = Anvq$$

Where
I = Current (A)
A = Cross-sectional area of conductor (m²)
v = Average drift velocity of the charge carriers (m/s)
n = Charge carrier density per unit volume
q = Charge of each charge carrier (C)

B. POTENTIAL DIFFERENCE

- The **potential difference (p.d)** between two points is **the energy transferred, or work done, by each coulomb of charge** as it moves from one point to another

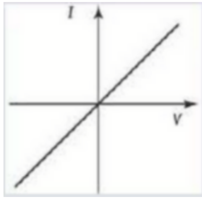
$$V = \frac{W}{Q}$$

C. RESISTANCE AND RESISTIVITY

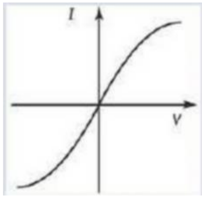
- **Resistance (R)** is defined as the **ratio of the potential difference across a conductor and the current through it**

$$R = \frac{V}{I}$$

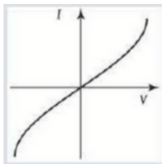
- **I – V Characteristics** of various components
  1. **Metal wire**
     Current is proportional to p.d, the **metal has a constant resistance**



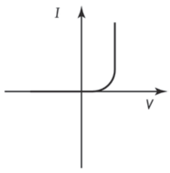
  2. **Filament lamp**
     At low currents, the current is proportional to p.d, **but at higher currents, the resistance increases** due to the higher temperature



  3. **Thermistors**
     At low temperatures, the resistance is high. **Resistance decreases as the temperature increases**



  4. **Diode**
     No current will pass in one direction, but **once the p.d reaches a certain value, there is very little resistance**



  5. **Light-Dependent Resistors** Resistance decreases as light intensity increases

- Ohm's Law
  For a metallic conductor at **constant temperature**, the current in the conductor **is proportional** to the p.d

- **Resistivity (ρ)** is a measure of how strongly a material resists electrical current, its relationship with resistance (R) is as follows

$$R = \rho \frac{L}{A}$$

Where:
R = Resistance (Ω)
ρ = Resistivity (Ωm)
L = Length (m)
A = Cross-sectional area (m^2)

D. POWER

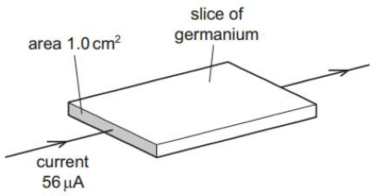
- The power produced (dissipated) in an electrical device is as follows

$$P = VI$$
$$P = I^2 R$$
$$P = \frac{V^2}{R}$$

E. EXERCISE

1. [9702_s18_qp_13_030]

A slice of germanium of cross-sectional area $1.0cm^2$ carries a current of $56\mu A$. The number density of charge carriers in the germanium is $2.0 \times 10^{13} cm^{-3}$. Each charge carrier has a charge equal to the charge on an electron



What is the average drift velocity of the charge carriers in the germanium?

Solution

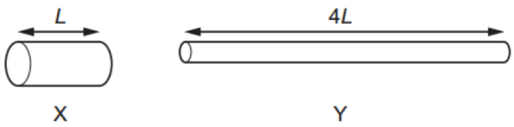
Recall the **formula I = Anvq** and change the variables to **SI values**

$$I = Anvq$$
$$v = \frac{I}{Anq}$$
$$v = \frac{56 \times 10^{-6}}{1 \times 10^{-4} \times 2 \times 10^{13} \times 10^{6} \times 1.6 \times 10^{-19}}$$
$$v = 17.5 \times 10^{-2}\ ms^{-1}$$

So the average drift velocity is $0.18\ ms^{-1}$ (rounded)

2. [9702_w17_qp_11_035]

Two copper wires X and Y have the same volume. Wire Y is four times as long as wire X



What is the ratio $\frac{resistance\ of\ wire\ Y}{resistance\ of\ wire\ X}$?

Solution

Notice the difference in cross-sectional area and length of the two

Recall the **formula $R = \frac{\rho L}{A}$**

This means $R \propto L$ **and** $R \propto \frac{1}{A}$, so we can compare them

But **first** we need to **find A** by **comparing their volume** because they have **the same value**

$$V_x = V_y$$
$$A_x \times L_x = A_y \times L_y$$
$$A_x \times L = A_y \times 4L$$
$$\frac{A_x}{A_y} = \frac{4L}{L}$$

With this we can move on to **comparing their R**

$$\frac{R_y}{R_x} = \frac{L_y}{L_x} \times \frac{A_x}{A_y}$$
$$\frac{R_y}{R_x} = \frac{4L}{L} \times \frac{4L}{L}$$
$$\frac{R_y}{R_x} = \frac{16}{1}$$

So the ratio is 16

3. [9702_w15_qp_11_033]

The Atlantic torpedo is a large electric fish capable of generating a voltage of 220 V between its tail and its head. This drives a pulse of current of 15A lasting for a time of 2.0ms. The fish produces 200 pulses per second

What is the average power output of the fish?

Solution

First we need to find **its energy** which is **power x time**

$$E = VIt$$
$$E = 220 \times 15 \times 2 \times 10^{-3}$$
$$E = 6.6J$$

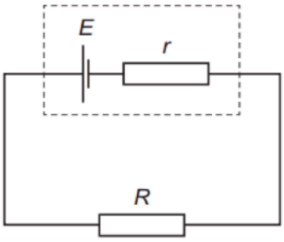
Then we could find its **average power** which is **total energy / time**

$$Avg\ Power = \frac{Total\ E}{t}$$
$$Avg\ P = \frac{Pulses \times E}{t}$$
$$Avg\ P = \frac{Pulses}{t} \times E$$
$$Avg\ P = \frac{200}{second} \times 6.6$$
$$Avg\ P = 1320\ W$$

So the average power is 1.3kW (rounded)

4. [9702_s18_qp_13_031]

A cell of electromotive force (e.m.f) E and internal r is connected to an external resistor of resistance R, as shown



What is the power dissipated in the external resistor?

Solution

Because **we dont know the p.d.** between the **external resistance** we will use the formula **P=IIR**

First we need to find the **current through them** by using the ohm law

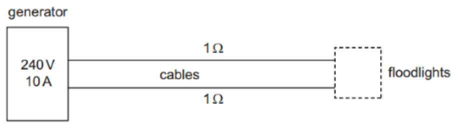
$$Total\ I = \frac{Total\ V}{Total\ R}$$
$$I = \frac{E}{R + r}$$

Hence the **power dissipated by the resistor** is **(R is the resistance of external resistor)**

$$P = I^2 R$$
$$P = \left(\frac{E}{R + r}\right)^2 R$$
$$P = \frac{E^2 R}{(R + r)^2}$$

5. [9702_s17_qp_13_032]

The diagram shows a portable generator connected by cables to floodlights. The generator produces a current of 10A at a constant potential difference (p.d.) of 240V. The total resistance of the vables is 2Ω



What is the p.d. V across, and the power P delivered to the floodlights?

Solution

First we need to calculate the total resistance of the system using ohm's law

$$R = \frac{V}{I}$$
$$R = \frac{240}{10}$$
$$R = 24$$

The total resistance is 24Ω which **includes the 2Ω** from the cables, so the resistance of the **floodlights** is $24 - 2 = \mathbf{22\Omega}$

Now we can calculate the Power which is

$$P = I^2 R$$
$$P = 10^2 \times 22$$
$$P = 2200\ W$$

And its p.d. by **comparing it to the p.d. of the generator**

$$V_F = \frac{R_F}{R_{total}} \times V_G$$
$$V_F = \frac{22}{24} \times 240$$
$$V_F = 220\ V$$

So its p.d is 220 V and its power is 2200 W