WJEC (Eduqas) Physics A-level

Topic 2.2: Resistance

Notes

Potential Difference

Potential difference is what causes electrons to start flowing in a conductor. It is a supply of energy to the charge carriers. Potential difference (p.d.) is the **energy supplied per unit charge**:

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

The unit of p.d. is the volt (V). The volt is equivalent to one joule per coulomb (using the above equation) or $1\ V = 1\ JC^{-1}$.

Resistance

Resistance is a measure of how difficult it is for current to flow. It is given by the ratio of potential difference to current:

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

Resistance is measured in ohms (Ω). $1\ \Omega = 1\ VA^{-1}$. A higher resistance means a larger potential difference is required to produce a current.

Resistance occurs due to **collisions between the free electrons and the ions** in the conductor. It means it is harder for the electrons to pass through the conductor.

If you increase the temperature of a conductor, the ions move around more energetically so more energy is transferred from the electrons to the ions, meaning it becomes harder for the electrons to flow and so **resistance rises**. The resistance of conductors tends to rise approximately **linearly with temperature**.

In the other direction, when you have free electrons colliding with ions in metals you increase the kinetic energy (in vibrations) of the ions thus increasing the temperature of the metal.

Ohm's Law

Ohm's law states that the current through a conductor is proportional to the potential difference across the conductor for all values of current and p.d. The ratio of V to I remains constant for all values of V and I.

There is a common misconception that people say that the equation $V = IR$ is Ohm's law. It is not the case.

Ohm's law says that R **is constant for all values of V and I**. Conductors which have this property are ohmic and conductors which don't are non-ohmic. $V = IR$ is **always true** independent of whether a component is ohmic or not.

Resistivity

Resistivity is a general measurement of how much a material resists the flow of current. It is a property of a material. Resistivity is given by the equation:

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

- R is the **resistance** of the conductor
- L is the **length** of the conductor
- A is the **cross-sectional area** of the conductor
- ρ is the **resistivity** of the material

You can rearrange the equation in various ways to find an unknown quantity.

$$\rho = \frac{RA}{L}$$

The units of resistivity are therefore:

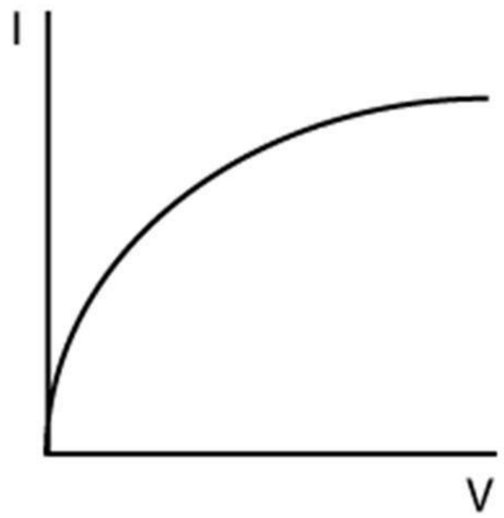
$$\frac{\Omega m^2}{m} = \Omega m$$

This unit is called the **ohm-metre**. A higher resistivity means a higher resistance for a given size of conductor.

I-V Characteristics

Combining our knowledge of current and potential difference, we can produce graphs to show how current varies when we vary potential difference in an appliance / load. The plot of **current against voltage** is called an **I-V characteristic** – because it is a specific relationship for that type of appliance.

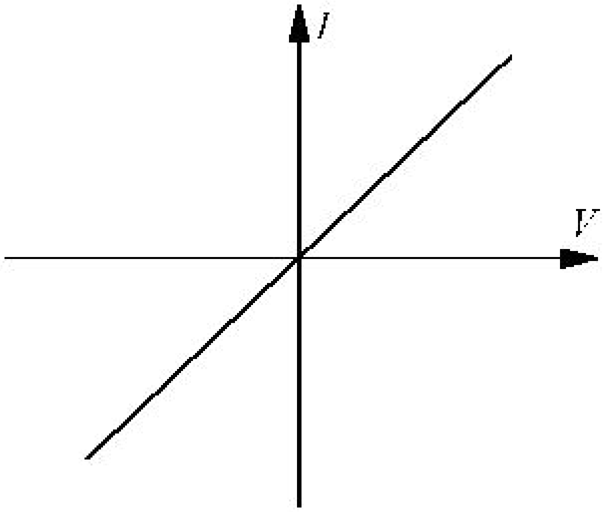
Filament of a Lamp



We can see the graph is not straight but is **curved**. As a potential difference is applied across a lamp, a current begins to flow in the lamp causing it to light. However, this current flow means some heat energy is dissipated in the filament. This causes the filament to heat up and then the **resistance increases**.

Therefore, a larger increase in potential difference is needed to increase the current and the graph becomes shallower as the resistance keeps increasing.

Metal Wire at Constant Temperature



This graph shows that the current is directly proportional to potential difference and so the resistance is constant as current increases. Therefore, a metal wire at a constant temperature is an **ohmic conductor**.

Power

Power is the amount of **energy transferred per unit time**. In electric circuits power can be found using various parameters:

$$P = IV$$

$$P = IV = I(IR) = I^2R$$

$$P = IV = \frac{V}{R}V = \frac{V^2}{R}$$

Superconductivity

Superconductivity is when a material conducts with **zero resistance**. A material will begin to do this when it is cooled to below a certain temperature. Not all materials can become superconductors. The temperature below which a superconductor must be cooled is called the **transition temperature**.

Superconducting Materials

Most metals show superconductivity and will have transition temperatures a **few degrees higher than absolute zero**.

Initially, it was thought that superconductivity was not possible above 30K. In 1987, a Nobel prize was awarded for the discovery of superconductivity of a material at a transition temperature of 35K. Higher transition temperatures were later found to exist. Some materials are described as **high temperature superconductors** which have transition temperatures above 77K.

Uses of Superconductors

Superconductors can be used as **magnets** to make vehicles (such as trains) 'float'. Normal electromagnets would have to be larger and would waste a lot of energy as heat. This is useful because friction with the ground is almost all removed, making the vehicle **much more efficient**.

MRI scanners use **superconducting** magnets to expose the human body to a strong magnetic field. Then, protons in the body are forced to **align** with the field. A **radiofrequency pulse** (short electromagnetic signal) is sent to force a change in the alignment of the protons. The pulse is turned off and the protons return to their aligned state with the static magnetic field. In the process, they release **electromagnetic radiation** and the amount of energy released and the time it takes to do so will vary depending on the types of tissue or molecules etc.

Superconducting magnets are often used in **particle accelerators** to alter the paths of subatomic particles.