# 4.2 - Energy, Power, and Resistance

## Potential Difference and EMF

- Potential difference is the energy transferred per unit charge from electrical energy to other forms, such as light and sound.
- EMF is the energy transferred from an energy source, such as chemical energy in cells, to electrical energy.

$$W = \epsilon Q$$

$$W = VQ$$

The change in kinetic energy of one particle accelerated through a potential difference is:

$$qV = \frac{1}{2}mv^2$$

... where q is its charge and v is the velocity gained in this acceleration.

## Resistance and Ohm's Law

Ohm's law states that the current through a conductor is directly proportional to the potential difference across it provided that physical conditions, such as temperature, remain constant.

$$V = IR$$

... where V is potential difference across a component, I is current through it, and R is its resistance.

Wires can also have resistance. At a constant temperature, this is based on their resistivity rho (which is a property of the material), its length L, and its cross sectional area A.

## Resistivity

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

However, resistivity can also change with temperature. At higher temperatures, metal ions have more kinetic energy, so vibrate more vigorously. Furthermore, free electrons drift through the metal more quickly. This increases the rate of collisions between electrons and metal ions, reducing the flow of electrical current. As such, we can describe components as being an ohmic or non-ohmic conductor based on whether or not current and p.d. are directly proportional. E.g.:

- A normal resistor is an ohmic conductor.
- A thermistor is non-ohmic.
- A lamp is non-ohmic, as heat is generated in the filament in the process of creating light.

# I-V Characteristics of Different Components

| | |
|---|---|
| Resistor | Ohmic |
| NTC thermistor | Non-ohmic, as resistance decreases with an increase in temperature. Ohmic behavior observed if in a constant temperature - however, a flow of current can cause it to heat itself up. Thermistors are created to be very sensitive to temperature changes. |
| Light dependent resistors | Non-ohmic, as resistance varies with light. Ohmic behavior observed if in a constant light intensity. |
| **Filament lamp** | Non-ohmic, as this component works by heating up the filament to incredible temperatures in order to make it glow.<br><br>> “ Current has a heating effect, and the **increased temperature** causes more collisions with free electrons, causing an increase in the vibrational kinetic energy of the metal ions. This increases the resistant of the lamp Since V=IR, the current does not increase linearly with voltage. |
| Diode / LED | Non-ohmic, as they have a threshold voltage (~0.5-0.6 ohms). Once reached, however, there is a linear I-V relationship. |

# Electrical Power

Power is the rate at which energy is transferred from one form to another.

$$
\begin{aligned}
P &= \frac{E}{t} \\
&= IV \\
&= I^2R \\
&= \frac{V^2}{R}
\end{aligned}
$$

Cost of energy can be calculated using the unit kilowatt-hour (kWh), which measures the amount of energy transferred by a 1 kW device in one hour.

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