Year 11 Resistance

Week 9

Circuits Recall That

1) Current

Current only flow through component if there is a voltage across it Unit: A

2) Voltage

Driving force (“electrical pressure” Unit: V

3) Resistance

Slows the flow down Unit : ohm

4) There's a balance:

Voltage trying to push current around, resistance opposing it – the relative sizes of the Two decide how big the current will be

The Balance

If you increase the voltage — then more current will flow.
If you increase the resistance — then less current will flow
(or more voltage will be needed to keep the same current flowing).

Resistance

Resistance (*R*) of a conductor is defined as the ratio of *potential difference* (V), across the conductor to the *current* (I), flowing through it.

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

V = p.d. in *volt* (V);
R = resistance in *ohm* (Ω); and
I = current in *ampere* (A).

What is Ohm's Law:

- Ohm's Law is made from 3 **mathematical equations** that shows the **relationship** between electric **voltage**, **current** and **resistance**.
- **V** is voltage measured in **volts**
- **I** is current measured in **amperes**
- **R** is resistance measured in **ohms**

Ohms Law Relationship

$$Current, (I) = \frac{Voltage, (V)}{Resistance, (R)} \text{ in } Amperes, (A)$$

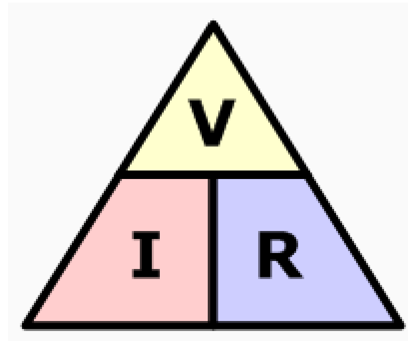
- By knowing any two values of the Voltage, Current or Resistance quantities we can use **Ohms Law** to find the third missing value.
- **To find Voltage (V)**
- [V = I x R]   V (volts) = I (amps) x R (Ω)

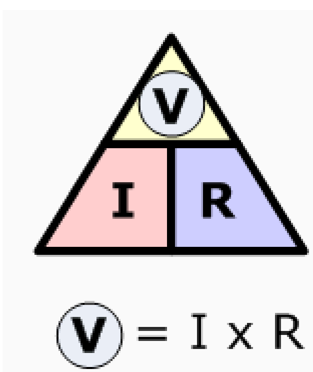
$$V = IR$$

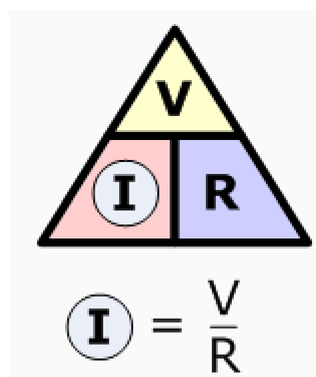
- **To find Current (I)**
- [I = V ÷ R]   I (amps) = V (volts) ÷ R (Ω)
- **To find Resistance (R)**
- [R = V ÷ I]   R (Ω) = V (volts) ÷ I (amps)

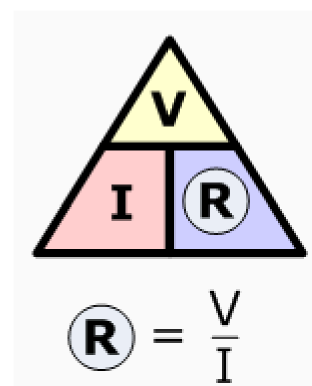
$$\text{resistance} = \frac{\text{p.d.}}{\text{current}}$$

Ohms Law Triangle







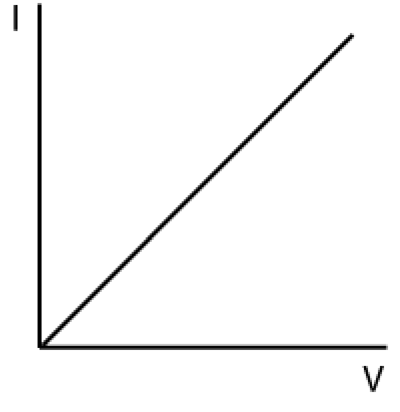


Ohmic and Non-ohmic

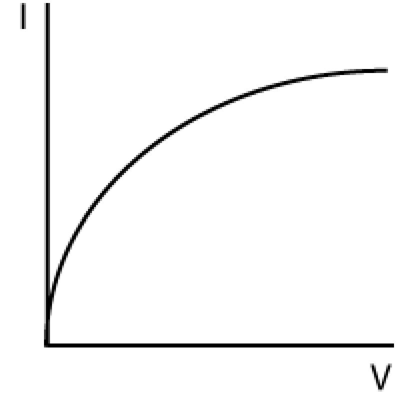
- Any Electrical device or component that obeys "Ohms Law" that is, the current flowing through it is proportional to the voltage across it ($I \alpha V$), such as resistors or cables, are said to be **"Ohmic"** in nature,
- Devices that do not, such as transistors or diodes, are said to be **"Non-ohmic"** devices.

Ohmic nonOhmic Graphs

- Below you can see 2 graphs with current on the vertical axis, and voltage on the horizontal axis.
- Where the graph is a straight line, the voltage is proportional to the current.
- Therefore, only the metallic conductor is an ohmic conductor.

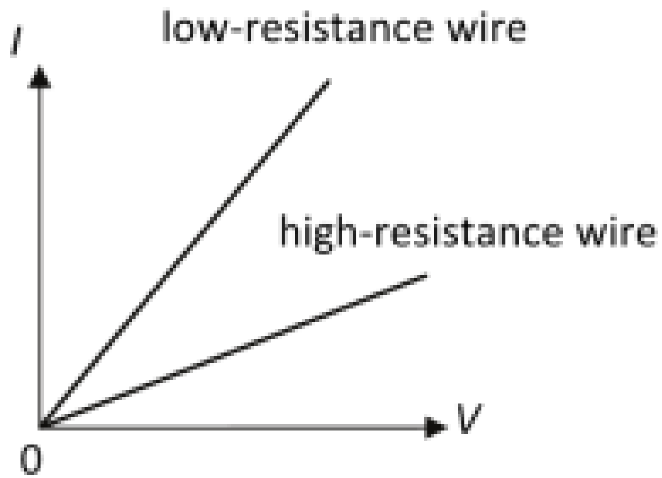


Metallic conductor



Filament lamp

I–*V* characteristic graphs



Metallic conductors obey ohm's law at constant temperature. The graph of $I - V$ characteristic graph is a straight line passing through the origin. It has constant resistance.

When the *p.d.* increases and hence, *current* passing through the conductor increases, more moving electrons collide with the atomic nuclei of the conductor. The atomic nuclei gain kinetic energies and vibrate more

Resistivity

- The **resistivity** of a material is the property that determines its resistance for a unit length and unit cross sectional area of that material.
- Copper, for example, is a better conductor than lead, in other words lead has a higher resistivity than copper.
- You can compare different materials in this way.

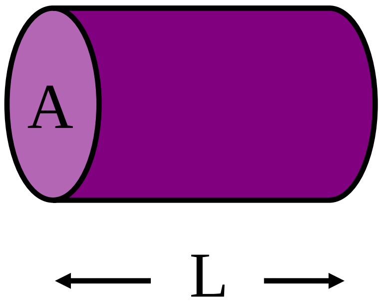
Resistivity Equation

- Resistivity, ρ (the Greek letter rho), is defined by the equation:

$$\rho = \frac{RA}{l} \qquad R = \frac{\rho l}{A}$$

- Where ρ is resistivity, R is the resistance, A is the cross sectional area of the material, and l is the length of the material.
- The units of resistivity are Ohm-meters, Ωm.

Resistivity: consider a piece of wire:



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

Some values of ρ in Ωm at 20°C

Silver	1.59E-8
Copper	1.68E-8
Gold	2.44E-8
Aluminium	2.65E-8
Tungsten	5.6 E-8
Iron	9.71E-8
Platinum	10.6E-8
Nichrome (alloy of Ni, Fe, Cr)	100E-8

ρ - Resistivity in Ωm

L - Length of the wire in m

A - Cross sectional area of the wire (πr^2)

R - Resistance of the wire in Ohms

Determining the resistance

Besides temperature, experimental results showed that the *resistance* (R) of a given conductor also depends on its composition and size. *Resistance*, R is found to be:

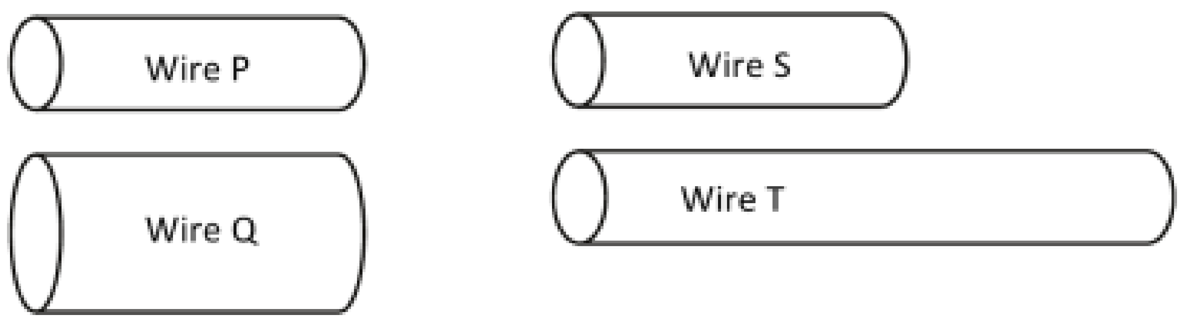
directly proportional to its **length**, L (*i.e.*, $R \propto L$);

inversely proportional to its **cross-sectional area**, A (*i.e.*, $R \propto 1/A$);

dependent on the **type of material**.

$$R = \rho \frac{L}{A} \quad \text{or} \quad \rho = \frac{RA}{L}$$

where, R = resistance in *ohm* [Ω];
A = cross-sectional area of conductor in *metre*^{2} [m^2];
L = length of conductor in *metre* [m]; and
ρ = resistivity of material in *ohm-metre* [Ω m].



Thinner wires (P) have higher *resistance* than thicker wires (Q) (for similar lengths and material).

Longer wires (T) have higher *resistance* than shorter wires (S) (for similar thickness and material)

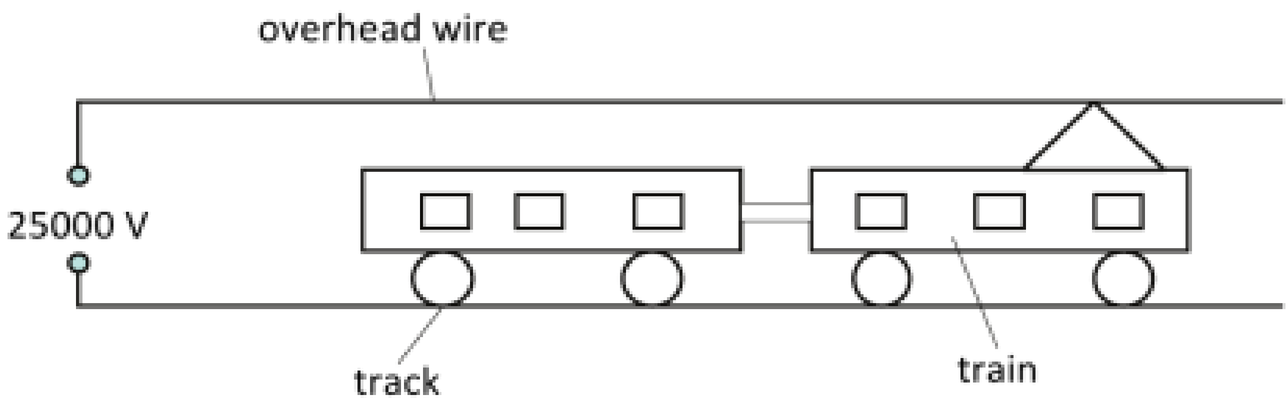
Worked Example 1

Find the resistance of 1 km of an copper wire which has a cross section area of $5.00\times10^{-5}\,\text{m}^2$ and resistivity $1.72\times10^{-8}\,\Omega\text{m}$.

$$\text{Resistance of 1 km of wire } = \frac{\rho l}{A} = \frac{\left(1.72\times10^{-8}\right)\times\left(1000\right)}{5.00\times10^{-5}} = 0.344\,\Omega$$

Worked Example 1 continued

The figure below shows how power is supplied to trains on track. A 25 kV supply is used and the current from the train returns from the track beneath. The resistance of the wire is the answer in (a) and the resistance of the track is considered to be negligible.



(i) The train requires 6700 kW of power when it is near to the power supply. Find the current needed.

$$I = \frac{P}{V} = \frac{6700 \times 10^3}{25000} = 268 \text{ A}$$

Worked Example 1 continued

A current of 140 A is supplied when the engine is 50 km away from the supply. Find

1. The resistance between the overhead wire between the train and the power supply
2. The p.d across the train
3. The power that is supplied to the train
4. The fraction of the power that is used by the train.

1. Resistance $= 0.344 \times 50 = 17.2\,\Omega$ **(ans)**

2. Potential difference across train = supply voltage – potential difference across wire

   $= 25000 - (140 \times 17.2) = 22592$ V = 22.6 kV **(ans)**

3. Power supplied to engine $= IV = 140 \times 22592 \quad = 3160$ kW **(ans)**

4. Fraction of power supplied which is used by train

   $$= \frac{3163 \times 10^3}{6700 \times 10^3} = 0.472 \text{ (3sf)}$$ **(ans)**