RMIT UNIVERSITY
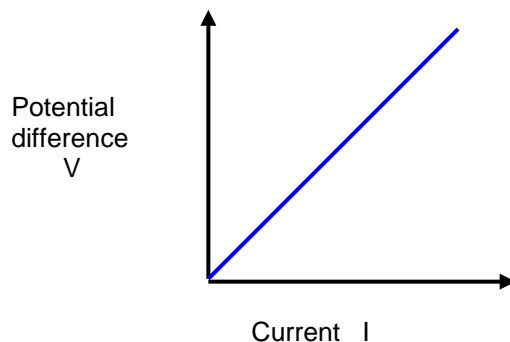
PE1.2: OHM'S LAW

Resistance R

Under constant physical conditions the potential difference (change in voltage) is proportional to the current ($V \propto I$), and is given by Ohm's Law:

$$V = I \times R$$

Potential difference V

Current   I

Ohmic Conductors

R (the slope of the V-I graph above) is a constant for a given conductor under these conditions and is called the resistance. (Unit: Ohm Ω). The circuit element is said to be ohmic, commonly known as an **ohmic conductor**.

$$\text{Since } P \,=\, VI \quad \text{and} \quad V \,=\, IR, \quad P \,=\, I^2R \,=\, \frac{V^2}{R}$$

Example 1

An ohmic conductor of 5Ω is supplied with a voltage which can vary from 1V to 100V.
(a) What will be the range of current that will flow in it?
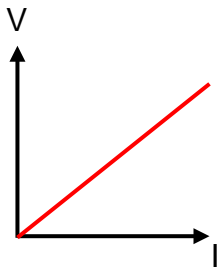(b) How much energy will be dissipated (used up) in the resistor each second?

(a) For 1V: V=I $\times$ R, I=V/R = 1/5 = 0.2A; For 100V: V=I $\times$ R, I=V/R = 100/5 = 20A
(b) At 1V, 0.2A means that 0.2C flow through the resistor each second. Recall: I=q/t.
Therefore, 1V: E=V×q = 1×0.2 = 0.2J.
Similarly, at 100V, E = Vq = 100 $\times$ 20 = 2000J
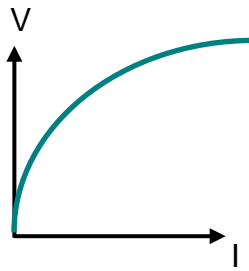
Non-Ohmic Conductors

Devices that have a constant resistance, as described above, are known as ohmic conductors. The graph of V versus I is a straight line that must go through the origin. If the graph is not a straight line then the device is called a **non-ohmic conductor**. See graphs below.

Light bulbs such as car headlamps are common examples of non-ohmic conductors. As the voltage increases, the current will not increase in proportion, as shown in the graph below.
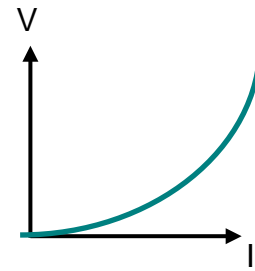
Other non-ohmic conductors include devices whose resistance changes with light or temperature. These are particularly useful as detectors in sensors which need to respond to changes in light (see diode graph below) or temperature levels.
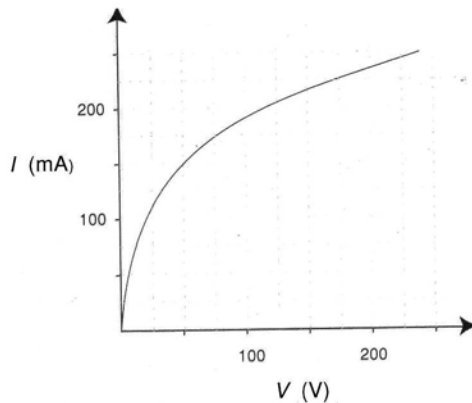

Ohmic Conductor
eg, resistor

Non-Ohmic Conductor
eg, car headlamp bulb

Non-Ohmic Conductor
eg, diode

Example 2

The graph at left represents the I-V characteristics of a non-ohmic device. What is the resistance at
(a) 50V (b) 150V (c) 200V

Note: This is an I-V graph, not a V-I graph. The slope at any point would be the **inverse** of the resistance.

Resistance is given by R = V/I **at any point on the graph**. Note that the current is given in mA (100mA = 0.1A, since 1A = 1000mA).
(a) At 50V, R = 50V/150mA = 50/0.15 = 333.3Ω
(b) At 150V, R = 150V/210mA = 150/0.21 = 714.2Ω
(c) At 200V, R = 200V/240mA = 200/0.24 = 83.3Ω

Resistivity ρ

The resistance of a wire is a measure of the ability of the wire to impede the flow of electrons along its length. It can be shown that the resistance:
- increases if the wire is longer, L.
- decreases if the wire is thicker, which means it has a larger cross-sectional area, A.
- depends on the metal used for the wire, ρ (rho).

These can be summarised in the formula:

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

resistance R is measured in Ω,
resistivity ρ (rho) is measured in Ωm, and depends on the metal used
L is measured in metres m

Example 3

Normal household wiring uses 1.8mm diameter copper wire. The resistivity of copper is $\rho = 1.7 \times 10^{-8}$ Ωm.
(a) What is the resistance of a 10m long piece of this copper wire?
(b) What voltage drop will there be along it if a current of 10A is flowing through it?

(a) The cross-sectional area (which is a circle) of the wire is given by:
$A = \pi \times r^2 = 3.14 \times (0.9 \times 10^{-3})^2 = 2.5 \times 10^{-6}$ m^2.   Note: mm is converted to metres.

$R = \rho L/A = 1.7 \times 10^{-8} \times 10/(2.5 \times 10^{-6}) = 0.068\Omega$
If the wire is carrying a 10A current there will be a voltage drop of:
$V = I \times R = 10 \times 0.068 = 0.68$V along the length of the wire.

Exercise

1. A student finds that the current through a resistor is 3.5A while a voltage of 2.5V is applied to it.
   (a) What is the resistance?
   (b) The voltage is then doubled and the current is found to increase to 7.0A. Is the resistor ohmic or not?

2. Rose and Rachel are trying to find the resistance of an electrical device. They find that at 5V it draws a current of 200mA and at 10V it draws a current of 500mA. Rose says that the resistance is 25Ω, but Rachel maintains that it is 20Ω. Who is right and why?

3. Nick has an ohmic resistor to which he has applied 5V. He measures the current at 45mA. He then increases the voltage to 8V. what current will he find now?

4. Lisa finds that when she increases the voltage across an ohmic resistor from 6V to 10V the current increases by 2A.
   (a) What is the resistance of the resistor?
   (b) What current does it draw at 10V?

5. The resistance of a certain piece of wire is found to be 0.8Ω. What would be the resistance of:
   (a) a piece of the same wire twice as long?
   (b) a piece of the same wire double the thickness?

6. If the resistance of a copper wire 20m long and 1mm in diameter is 0.44Ω, what will be the resistance of the same length of wire 2mm in diameter?

Answers
Exercise

1. (a) 0.71Ω (b) ohmic 2. Both right at different voltages 3. 72mA 4. (a) 2Ω (b) 5A
5. (a) 1.6Ω (b) 0.2Ω 6. 0.11Ω.