

Circuits

Kirchhoff's second law: In any electrical circuit, the sum of the electromotive force is equal to the sum of the potential differences in a closed loop:

$$\sum \mathcal{E} = \sum V \text{ around closed loop}$$

In DC circuits, charge and energy are also conserved.

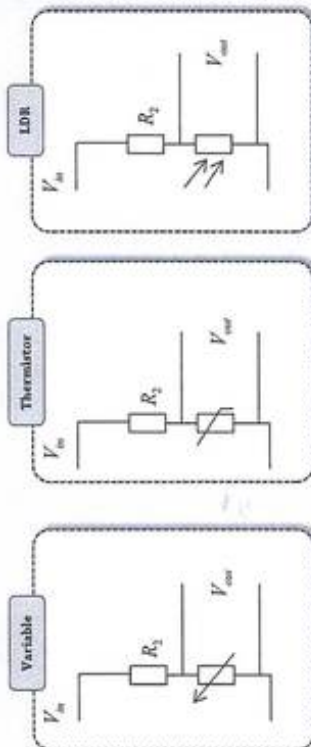
Energy and power equations:

$P = \text{power}$	$E = IVt$	$P = IV$
$E = \text{energy}$		
$I = \text{current}$		
$R = \text{resistance}$	$P = I^2 R$	$P = \frac{V^2}{R}$
$V = \text{voltage}$		

Potential divider

A potential divider is the name of a circuit that can be used to alter the potential difference across an output when connected to a fixed input.

A variable component can be introduced to the circuit, which varies in resistance and, therefore, varies the voltage output of the circuit. In this case, the potential divider circuit can be used as a sensing circuit.



A **variable potential divider** is a potential divider with a sliding contact. In this case, the voltage output between two of the terminals can be varied by altering the sliding contact.

Series and parallel circuits

Series circuits:

$$R_T = R_1 + R_2 + R_3 + \dots$$

$$I_T = I_1 = I_2 = I_3 = \dots$$

$$V_T = V_1 + V_2 + V_3 + \dots$$

- Cells can be connected in series if a higher voltage needs to be supplied to the circuit.

Parallel circuits:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

$$I_T = I_1 + I_2 + I_3 + \dots$$

$$V_T = V_1 = V_2 = V_3 = \dots$$

- Cells can be connected in parallel to increase the current through the circuit.

Electromotive force and internal resistance

Terminal potential difference, V : the potential difference supplied by an electrical power source

Electromotive force (emf), $\mathcal{E}$: the electrical energy given to charge carriers per unit charge – the potential difference present when there is no current in the source (an ideal cell)

Internal resistance, r : the resistance of a source that results in energy loss as a charge passes through the source, causing a difference between emf and terminal potential difference

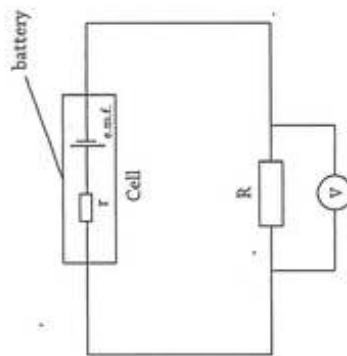
Equations:

$$\mathcal{E} = I(R + r)$$

$$\mathcal{E} = V + Ir$$

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

To visualise the situation, a cell can be thought of as being comprised of a power source and a small resistor.



When there is current in the cell, work has to be done by the charge carriers as they flow through the cell. This results in an energy loss, as some energy is transferred into heat and, therefore, not all the energy supplied by the e.m.f. is supplied to the rest of the circuit – some volts are 'lost'.

Therefore, the terminal potential difference supplied to the circuit will be less than the e.m.f. of the source.

The internal resistance and e.m.f. of a power source can be determined by varying the current supplied to a circuit and noting the corresponding measured terminal potential difference, and then comparing the equation for a straight line:

$$y = mx + c$$

to the e.m.f. equation:

$$V = \mathcal{E} - Ir$$

Therefore,

$$\text{gradient} = -r \text{ and } y\text{-int except} = \mathcal{E}$$

