WJEC (Eduqas) Physics A-level

Topic 2.3: D.C. Circuits

Notes

Electric Circuits and Conservation Laws

Parallel Circuits and Conservation of Charge

In **parallel circuits**, the current in each branch must add up to the current through the source (e.g. battery). Each charge flowing will go through one of the branches.

In a given time (Δt) a current (I) flows through a circuit with currents $I_1, I_2 \ldots I_n$ through the n branches. The total charge to flow through the circuit must be equal to $I\Delta t$ because this is the charge through the source and charge must be conserved.

Therefore the charges that have passed through each branch must be equal to:

$$I_1\Delta t, I_2\Delta t \ldots I_n\Delta t$$

The sum of these charges is:

$$\Delta t\,(I_1 + I_2 + \ldots + I_n)$$

This must be equal to $I\Delta t$ and hence:

$$I_1 + I_2 + \ldots + I_n = I$$

The potential differences in parallel circuit branches are all **equal**.

Series Circuits and Conservation of Energy

In **series circuits**, the sum of the potential differences across all the components is equal to the potential difference of the source. Every charge will go through all components in 'series' – one after the other.

In a given time (Δt) a charge (ΔQ) flows through a series circuit. If there are n components with potential differences across them $V_1, V_2 \ldots V_n$. The energy used in each component is equal to the charge through the component multiplied by the potential difference:

$$(\Delta Q)\,V_1 + (\Delta Q)\,V_2 + \ldots + (\Delta Q)\,V_n = E_1 + E_2 + \ldots + E_n$$

$$(\Delta Q)\,(V_1 + V_2 + \ldots + V_3) = E_1 + E_2 + \ldots + E_n$$

Because energy must be conserved in the circuit, the sum of energies used in the components (ignoring energy lost in the wires) must be equal to the energy supplied by the battery or source:

$$(\Delta Q)\,(V_1 + V_2 + \ldots + V_3) = E$$

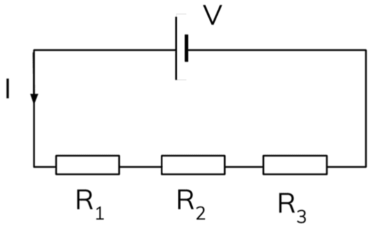
$$(\Delta Q)\,(V_1 + V_2 + \ldots + V_3) = (\Delta Q)\,V$$

$$\Rightarrow V_1 + V_2 + \ldots + V_3 = V$$

Resistors in Series and Parallel

Series

In series, **resistors add up**.



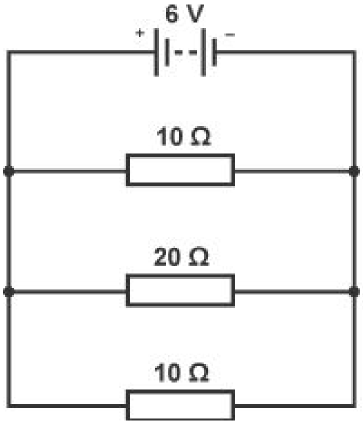
https://senecalearning.com/resources/gcse/physics/electricity/series-and-parallel-circuits/

The total resistance in a series circuit is found as the sum of all resistors in the circuit:

$$R = R_1 + R_2 + R_3$$

Parallel

In parallel, to combine resistors you need to take the **reciprocal of the sum of the reciprocals** of individual resistances.



https://www.bbc.co.uk/education/guides/z8b2pv4/revision/3

The total resistance is R an found from the reciprocals of the other resistors:

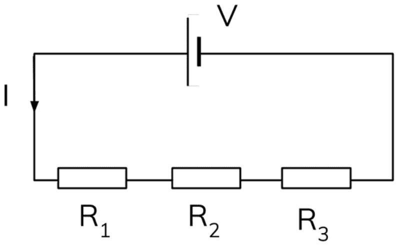
$$\frac{1}{R} = \frac{1}{10} + \frac{1}{20} + \frac{1}{10}$$

$$\frac{1}{R} = \frac{1}{4}$$

$$\Rightarrow R = 4\ \Omega$$

Potential Dividers

Potential dividers are circuits which aim to deliberately **divide the potential difference from a source** to two or more components. Potential difference is **shared** based on resistance.



In this example, the potential difference across R_1 is V_1. Because the **current through the circuit is the same everywhere** it can be said:

$$\frac{V_1}{R_1} = I$$

But:

$$I = \frac{V}{R} = \frac{V}{R_1+R_2+R_3}$$

$$\frac{V_1}{R_1} = \frac{V}{R_1+R_2+R_3}$$

$$\Rightarrow V_1 = V \times \frac{R_1}{R_1+R_2+R_3}$$

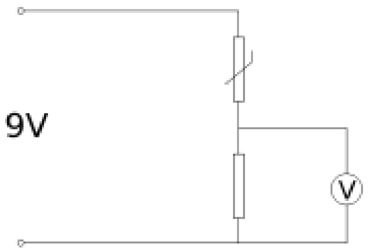
Similarly:

$$V_2 = V \times \frac{R_2}{R_1+R_2+R_3}$$

$$V_3 = V \times \frac{R_3}{R_1+R_2+R_3}$$

LDRs and Thermistors

Light dependent resistors (LDRs) and thermistors can be used in potential divider circuits to alter the output of a device. For example, in a **temperature sensing system** you may have a circuit that looks like the following,



http://commons.wikimedia.org/wiki/File:Thermistor_potential_divider.svg

As the temperature of the surroundings rise, the resistance of the thermistor falls. Therefore, the potential difference across the thermistor falls and the potential difference across the fixed resistor rises.

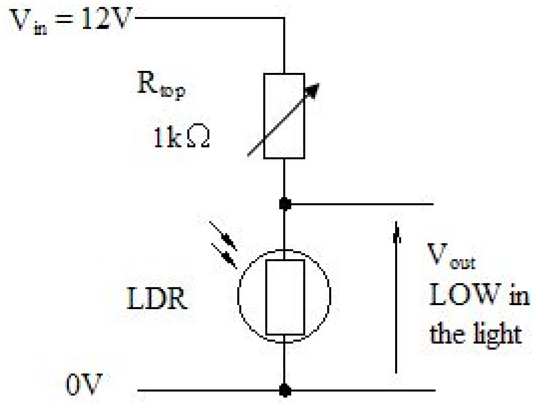
You could find a suitable value of the fixed resistor such that when the surroundings reach a certain temperature, using a scale attached to the voltmeter, the temperature can be displayed on the voltmeter. However, you would need to first **calibrate** the voltmeter.

Another example is in a light sensing system. An application of this would be for street lamps – turning on when dark enough and turning off when light enough.

As **the light intensity increases**, resistance of the LDR decreases and so the **potential difference across it decreases**.

Using some more complicated circuits you could design the circuit with an LED which only turns on above a specific potential difference. By calibrating the circuit, you could make sure that when the light intensity goes below a certain value, the LED turns on.

Electromotive Force



http://www.markedbyteachers.com/as-and-a-level/science/sensors-cwk-the-aim-of-this-coursework-is-to-construct-a-potential-divider-circuit-with-a-light-dependent-resistor-ldr-and-observe-how-light-intensity-affects-the-voltage-output.html

Electromotive force (e.m.f) is the energy supplied per unit charge in a circuit from the source to produce the potential difference across the two terminals of the source.

However, when current flows, energy is lost across internal resistance of the source. You can model this internal resistance as a fixed resistor of resistance (r) inside the source.

When you have a current (I), potential difference across the source (V), and e.m.f (E), the potential difference across the internal resistance is:

$$Ir$$

Therefore, the potential difference we measure across the source is Ir less than the e.m.f.

$$\Rightarrow V = E - Ir$$

Cells in Series

With multiple cells in series, you **simply add up the e.m.f** of each cell and **add up the internal resistance** of each cell to make one cell with an e.m.f and internal resistance. Then, you can use the equation above to calculate the total potential difference across the circuit (excluding internal resistance) and then calculate the currents through each component.