OCR A Physics A-level

Topic 4.3: Electrical circuits

Notes

Series and parallel circuits

Kirchhoff's second law

Kirchhoff's second law states *in any circuit the sum of the electromotive force is equal to the sum of the potential difference in a closed loop.* This is a result of the **conservation of energy**.

In a series circuit, the current at every point in the circuit will be the same. The e.m.f. will be split so that the total p.d. across each component is equal to the e.m.f. As a result the total resistance of a circuit containing resistors in series will be the equal to the sum of the resistance of each component, $R_t = R_1 + R_2 + \ldots$

In a parallel circuit, the current in each loop adds up to the total current. The p.d. across each loop is the same. This results in the total resistance of the circuit being given by the formula

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$$

where R_1 and R_2 are the total resistance values for each loop within the circuit. Within each loop in the circuit, the current is the same at each point, and the p.d. is split across the components in the loop.

Internal resistance

Internal resistance and lost volts

A source of e.m.f has some **internal resistance**. This means that not all of the energy transferred to the charge carriers is available to the circuit, as some is transferred to the internal resistance of the cell. This results in a difference between the measured p.d. across the terminals of the power supply, and the actual e.m.f. of the cell, which is referred to as the '**lost volts**', and is equal to the **p.d. across the internal resistor**.

The internal resistance can be modelled as the source of e.m.f. ε being in series with its internal resistance r. For a circuit with this power source attached to a resistor of resistance R, we can use the equation

$$\boldsymbol{\varepsilon = I(R + r)}$$

to model the circuit. IR is equal to V, the terminal p.d. of the cell, and Ir is equal to the lost volts.

In A-level exam questions, you may be told the internal resistance of the cell as either a value or as an unknown value to determine. If the question does not mention internal resistance, you can assume that it is **negligible** and can be ignored in calculations.

Techniques to determine internal resistance

To determine the internal resistance of a cell, the cell with internal resistance r is connected in series to an ammeter and a variable resistor. A voltmeter is connected in parallel around the cell. The resistance of the variable resistor is varied, and the V and I readings recorded. The equation

$\varepsilon = V + Ir$ is rearranged to $V = \varepsilon - Ir$. When a graph of terminal p.d. (V) against current (I) is plotted, the y intercept of the graph will be the e.m.f. of the cell and the **negative gradient** will be the internal resistance of the cell.

Potential dividers

Potential divider circuits

From Kirchhoff's second law, we know that in a series circuit the current is constant, and the p.d. splits in a ratio **proportional to the resistance** of each component.

$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

where V_1 and R_1 are the p.d. and resistance for the first component, and V_2 and R_2 are the p.d. and resistance for the second component. We can rearrange this to get

$$\frac{V_1}{R_1} = \frac{V_2}{R_2}$$

By considering the ratio of the resistance for one component with the total circuit resistance, we can determine the potential difference across this component, using the formula

$$V_{out} = \frac{R_2}{R_1 + R_2} \times V_{in}$$

Where V_{in} is the e.m.f. of the circuit, and V_{out} is the potential difference across R_2.

Potential divider circuits are set up with a potential difference distributed across 2 resistors, with one of the resistors being connected to another circuit which uses the V_{out} potential difference. One of the resistors is typically a **sensor or variable resistor**, so that the resistance can be altered. When the resistance of the V_{out} resistor is decreased in proportion to the total circuit resistance, the p.d. across this resistor, V_{out}, will also decrease.

Techniques to investigate potential divider circuits

A **thermistor or LDR** can be used to **vary the output** of a potential divider circuit (such as in street lamps or air conditioning systems). When V_{out} is across a thermistor, a greater p.d. will be provided when the temperature decreases, because this increases the resistance of the thermistor. These circuits can be investigated using water baths and lamps to **simulate different environments**, with a voltmeter across the desired component used to record the changes in V_{out} as the environmental factors affecting the resistance of the component are varied.