AS Level Physics

Chapter 7 – Electricity

7.6.1 Internal Resistance

Notes

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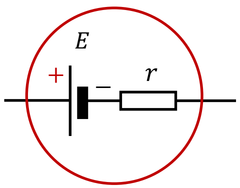
Internal Resistance, e.m.f., terminal p.d., lost volts

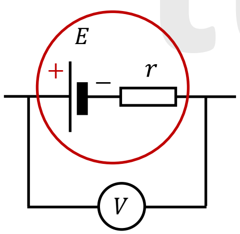
Resistance is a result of electrons colliding with atoms and losing energy.

Chemical energy, in a battery or cell, is used to make electrons move. As electrons move, they collide with atoms within the battery – therefore batteries also have a resistance. This is called internal resistance.

When batteries or cells are used, internal resistance causes them to heat up.



The internal resistance of a source can be represented as a resistor (labelled "r" for internal resistance). This resistor is drawn in series with the standard symbol for a cell or battery as illustrated in the diagram opposite. The red circle is optional; it shows that E and r are part of the same component.



When a voltmeter is connected across the terminals of an electrical supply (such as a cell or battery), it shows the cell or battery's **Terminal p.d.** (measured in Volts, V).

When an 'ideal' voltmeter (i.e. it has infinite resistance) is connected to a cell or battery that is not part of an external circuit, then zero current is drawn and you get:

$$\textbf{voltmeter reading} = \textbf{cell e.m.f.}\,(E)$$

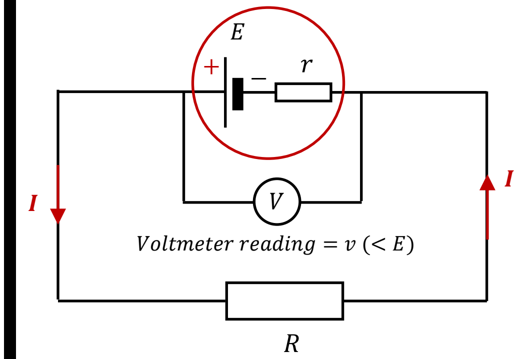
For more information about e.m.f please see pack 8.1 Circuit Symbols, E.m.f., p.d.

Therefore:

The electromotive force, e.m.f. (E) can be defined as the terminal p.d. (potential difference) of a cell or battery as long as it is NOT supplying a current

$$cell\ e.m.f.\,(E) = terminal\ p.d.$$

Internal Resistance, e.m.f., terminal p.d., lost volts



The circuit opposite shows a cell with an e.m.f. (E) and internal resistance r connected to an external resistor of resistance R. The current from the cell flows through its own internal resistance as well as the external resistance. As a result, the voltmeter reading is less than E.

That's because when a current passes through a cell, the cell's internal resistance converts some of the energy into heat.

This drop in voltage is referred to as the cell's "LOST VOLTS", and it is proportional to the current.

The voltmeter's reading (V), that is less than E, is the cell's terminal p.d. as well as the p.d. across the resistor R.

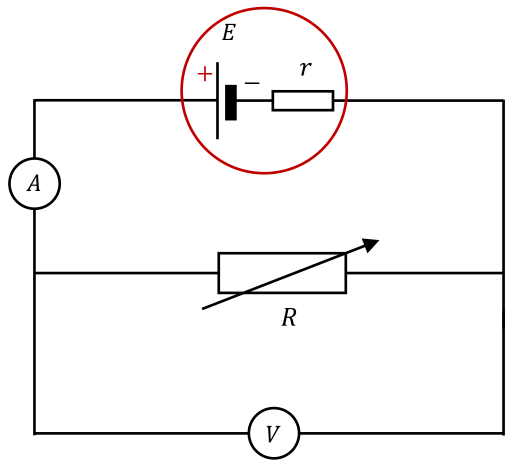
The current flows through a combined resistance (R + r) and applying Kirchhoff's 2^{nd} Law to the circuit we get:

$$E = I(R + r)$$
$$E = IR + Ir$$
$$since\ V = IR$$
$$E = V + Ir$$

Therefore:

$$e.m.f. = terminal\ p.d. + lost\ volts$$

Investigating the internal resistance and e.m.f.



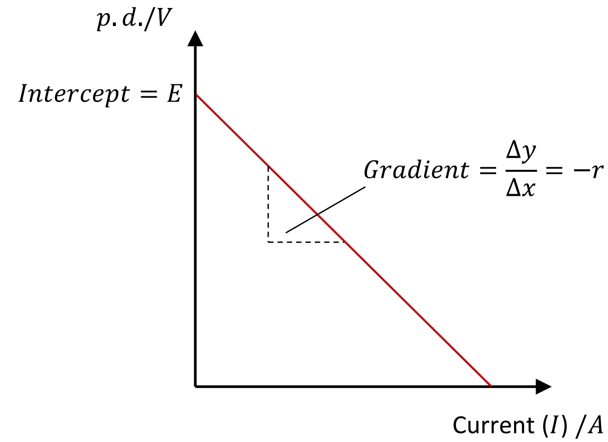
The circuit illustrated above is used to determine the e.m.f. (E) and internal resistance (r) of a cell with greater accuracy.

To calculate the internal resistance (r) of the source change the value of the variable resistor (R) in this circuit and measure the corresponding current (I) and p.d. (V).

Record these values and plot the graph of p.d. (V) against current (I).

Then draw a line of best fit on the plotted graph, as shown opposite.

Investigating the internal resistance and e.m.f.



E.m.f. (E), terminal p.d. (V), current (I), and internal resistance (r) are linked by the following equation:

$$E = V + Ir$$

Rearranging gives:

$$V = -Ir + E$$

Comparing with the equation for a straight line:

$$y = mx + c$$

This tells us:

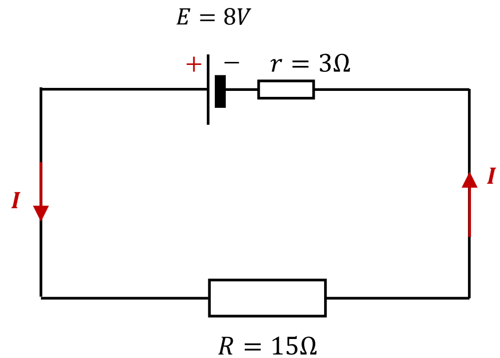
- The intercept on the vertical axis is E.
- The gradient is $-r$.

Using a high-resistance voltmeter

Connecting a high-resistance voltmeter across the terminals of a power source provides an easier way to measure its e.m.f. Because there is a small current flowing through the voltmeter, there will be little lost volts - this means you will measure a value which is slightly less than the e.m.f. In most cases, the difference is not significant.

Worked Example

A resistor is connected across an 8V e.m.f power supply with an internal resistance of 3Ω. What is the current flowing through the resistor, and what is the terminal p.d. of the supply?



Step 1: Calculate the total resistance in the circuit:

$$R + r = 15\Omega + 3\Omega = 18\Omega$$

Step 2: Calculate the current that flows:

$$I = \frac{E}{R+r} = \frac{8V}{18\Omega} = 0.44A$$

Step 3: Calculate the terminal p.d.:

$$V = IR = 0.44A \times 15\Omega = 6.7\ V$$

1.3V has been 'lost' in overcoming the internal resistance.

Please see '7.6.2 Internal Resistance worked examples' pack for exam style questions.

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