AS Level Physics

Chapter 8 – Energy, Power and Resistance

8.1.1 Circuit Symbols, E.m.f and p.d.

Notes

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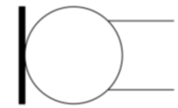
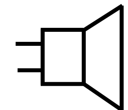
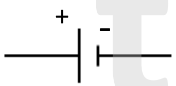
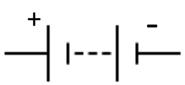
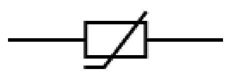
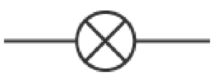
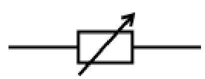
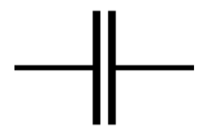
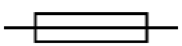
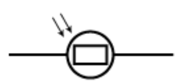
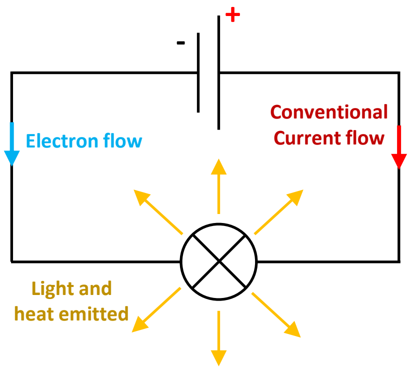
CIRCUIT SYMBOLS

Symbol	Component name and description	Symbol	Component name and description	Symbol	Component name and description
	Wire: Made from a metallic conductor to allow current to easily pass from one part of the circuit to another.		**Voltmeter** An instrument used to measure potential difference (voltage).		**Direct Current (D.C.) Power Supply** In direct current the electric current only flows in one direction.
	**Switch (Open)** Off switch – in the open position no current flows as the circuit is broken.		**Ammeter** An instrument used to measure current.		**Microphone** Converts sound waves into electrical signals.
	**Switch (Closed)** On switch – in the closed position the current flows as the circuit is complete.		**Fixed Resistor** Restricts the flow of electrical current that can flow to a particular component.		**Loudspeaker** Converts electrical energy into sound.
	**Cell** Supplies the electrical energy to the circuit – the longer line on the left is the positive (+) terminal and the shorter end is the negative (-) terminal.		**Diode** A device which only allows current to flow in one direction.		**Earth** A reference point in an electrical circuit from which a common return path for electric current is provided, or a direct physical connection to the Earth. There are several reasons for connecting to earth in an electrical circuit.
	**Battery** A battery is more than one cell.		**Thermistor** The word combines thermal and resistor. This is a type of resistor whose resistance is dependent on temperature more than in a standard resistors.		**Alternating Current (A.C.) Power Supply** Is an electric current which periodically reverses direction. Your mains supply is alternating current.
	**Lamp** Converts electrical energy to light.		**Variable resistor** Used to control current.		**Capacitor** A device that stores electrical energy in an electric field. This is not the same as a cell or a battery.
	**Fuse** A safety device designed to melt if the electrical current flowing through it exceeds a specified value, thereby breaking the circuit.		**Light dependant resistor (LDR)** Converts light to electrical resistance. The greater the light intensity shining on the LDR the lower its resistance.		**Light Emitting Diode (LED)** A LED is a semiconductor device that emits visible light when an electric current passes through it.

Potential Difference (p.d.) or Voltage

- Electricity is used to transfer energy from place to place. When a battery is connected to a light bulb, electricity transfers energy from the battery to the bulb in order to produce light.

- This is because the cell pushes current (a flow of charge/electrons) in the circuit and through the lamp.



- Each free electron in the circuit passes through the cell and is given a fixed amount of electrical potential energy. The electrons then flow in the direction shown above and do work as they pass through the light bulb. This is where the electrons electrical potential energy gets transferred into light (useful) and heat (wasted) energy which is then emitted by the bulb.

- When the electrons have deposited their electrical energy to the bulb, they return to the cell via the positive terminal and the electrons pick up more electrical energy to deliver back to the bulb.

- **The work done by each electron = the light and heat energy given out by the bulb = the electric potential energy lost by each electron**

The POTENTIAL DIFFERENCE (p.d.) or VOLTAGE, is the amount of electrical energy transferred to other energy forms PER COULOMB of charge flowing between any two points in a circuit.

OR

The p.d., or voltage, is the energy transfer per coulomb of charge that flows between any two points in a circuit.

Potential Difference (p.d.) or Voltage

- Potential difference is measured in VOLTS (V)

The potential difference is 1 VOLT, across two points in a circuit, when there is 1 coulomb of charge flowing between them and 1 Joule of electrical energy is transferred to other energy forms.

$$1\ VOLT = 1\ JOULE\ PER\ COULOMB$$
$$1\ V = 1\ J\ C^{-1}$$

Therefore, work needs to be done in order to make electric charge flow through a conductor. This means Potential difference (p.d.), or voltage, is the energy converted per unit charge moved. Hence potential difference, or voltage between two points is given by the formula below:

$$V = \frac{W}{Q}$$

Where:
V = **Potential difference, or Voltage** measured in **Volts, V.**
W = **Energy** measured in Joules, J. (This is the energy transfer.)
Q = **Charge** measured in coulombs, C.

Therefore**:** $$W = QV$$

And since, $Q = It$

$$W = ItV$$

Where:
I = **Current** measured in **Amperes or Amps, A.**
t = **time** measured in **seconds, s.**
V = **Potential difference, or Voltage** measured in **Volts, V.**

ELECTROMOTIVE FORCE (e.m.f.)

The ELECTROMOTIVE FORCE (e.m.f.) of an electrical source is the ELECTRICAL ENERGY given to each coulomb of charge.

The e.m.f. can be found as the voltage shown on a cell or battery. This is the amount of energy that is given to each coulomb of charge passing around the circuit. The useful p.d. across a component is less than the e.m.f of the cell as some voltage is 'lost' whilst current is pushed through the cell.

- A $3\ V$ cell gives $3\ J$ to each coulomb.
- A $9.5\ V$ battery gives $9.5\ J$ to each coulomb.
- The $230\ V$ mains gives $230\ J$ to each coulomb.

Remember e.m.f. is measured in Volts (V).

Use the formula below to calculate the e.m.f.:

Epsilon is used as the symbol for e.m.f. to avoid confusion with E which is used for energy and electric field.

$$\boldsymbol{\varepsilon} = \frac{\boldsymbol{W}}{\boldsymbol{Q}}$$

Where:
$\boldsymbol{\varepsilon}$ = **Electromotive force e.m.f.** measured in **Volts, V.**
$\boldsymbol{W}$ = **Energy** measured in Joules, $\boldsymbol{J}$. (This is the energy transfer.)
$\boldsymbol{Q}$ = **Charge** measured in coulombs, $\boldsymbol{C}$.

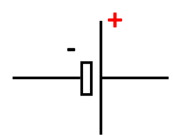
DIFFERENCE BETWEEN p.d. and e.m.f.

The difference between Electromotive force (e.m.f.) and potential difference (p.d.) is:

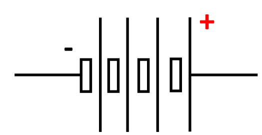
- E.m.f. of a power supply is the work done in pushing 1 coulomb of charge around a complete circuit. In other words, this is the electrical energy that is being transferred from a source (such as a battery) to a charge.
- When energy is delivered from each passing coulomb of charge through a component, this is called P.d. In other words, this is the electrical energy being transferred from the charge to other energy forms (such as light and heat) in a component present in a circuit (e.g. a bulb).

COMBINING e.m.f.

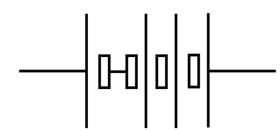
The voltages of two or more cells (or other sources of e.m.f.) can be added up when they are connected in series. However, they must be connected positive-to-negative; otherwise, as in bellow in figure 3, the e.m.f.'s will subtract.



$E = 1.5V$



$E = 4 \times 1.5V = 6V$

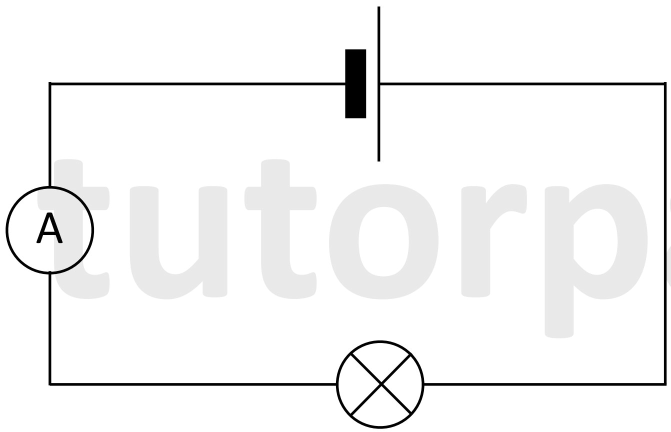


$E = 3 \times 1.5V - 1.5V$
$E = 3V$

USING AMMETERS

Ammeters are used to measures the current through a component and are connected in series as shown below.

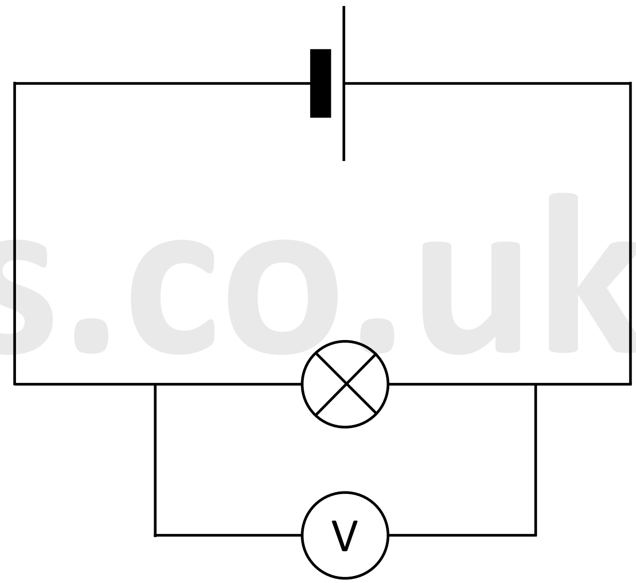
Ammeters have a low electrical resistance (ideally zero) to not affect the current in the circuit.



USING VOLTMETERS

Voltmeters are used to measure the p.d. between two points in a circuit and are connected in parallel (i.e. between the two points) as shown below.

Voltmeters have a high electrical resistance (usually $\approx 1\ M\Omega$ and ideally infinite) so that they draw the least amount of current as possible.



THE ELECTRONVOLT (eV)

We use electronvolt (eV) as a unit for energy because photon energies are very small and it is more convenient to use electronvolt than it is to use Joules.

When an electron moves across two points separated by a p.d. of $1\ V$, the energy transferred is $1\ eV$.

e is the charge on an electron = 1.6×10^{-19} C.

Therefore:

$$1\ electron\ volt = e \times V = 1.6 \times 10^{-19} C \times 1\ JC^{-1}$$
$$1eV = 1.6 \times 10^{-19} J$$

It is assumed that light doesn't just behave as a wave but can also behave as a 'particle' which we call photons. We will revisit photons and the electonvolt at a later stage in more detail.

To convert from J to eV: divide by 1.6×10^{-19}.

To convert from eV to J: multiply by 1.6×10^{-19}.

ACCELERATING ELECTRONS

When an electron is accelerated between two electrodes (a cathode and an anode), electrical potential energy (eV) is converted into kinetic energy. This is the fundamentals of how an electron gun operates, but we will learn more about this at a later stage.

Keeping the above information in mind and if we know the voltage at which an electron is accelerated, we can calculate its kinetic energy using the following formula:

$$eV = \frac{1}{2}mv^2$$

The equation can be used for any charged particles, including protons (charge +e) and ions.

Worked example 1:

What is the kinetic energy of a proton accelerated through 4500V?

$$6500V \times 1.6 \times 10^{-19} J = 7.2 \times 10^{-16} J$$

So the kinetic energy of the proton is $7.2 \times 10^{-16} J$.

Please see ‘8.1.2 Circuit symbols, e.m.f. and p.d. worked examples’ pack for exam style questions.

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