- ***Candidates should be able to*** :
  - *Recall and use appropriate circuit symbols.*
  - *Interpret and draw circuit diagrams using these symbols.*
  - *Define **potential difference (p.d.).***
  - *Select and use the equation* **W = VQ**
  - *Define the **volt.***
  - *Describe how a **voltmeter** may be used to determine the p.d. across a component.*
  - *Define **electromotive force (e.m.f.)** of a source, such as a cell or power supply.*
  - *Describe the difference between **e.m.f.** and **p.d.** in terms of energy transfer.*

- ***CIRCUIT SYMBOLS*** *1*

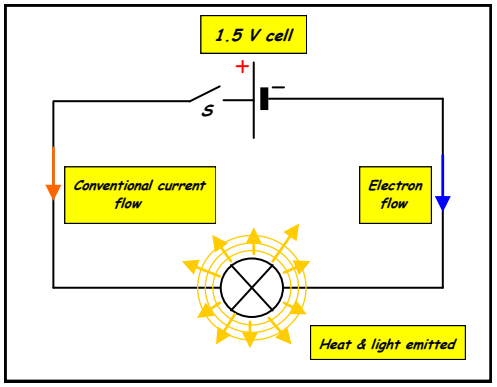
| Symbol | Component name | Symbol | Component name |
|---|---|---|---|
| | connecting lead | | variable resistor |
| | cell | | microphone |
| | battery of cells | | loudspeaker |
| | fixed resistor | | fuse |
| | power supply | | earth |
| | junction of conductors | | alternating signal |
| | crossing conductors (no connection) | | capacitor |
| | filament lamp | | thermistor |
| V | voltmeter | | light-dependent resistor (LDR) |
| A | ammeter | | semi-conductor diode |
| | switch | | light-emitting diode (LED) |

- ***You must memorise the circuit symbols shown above.***
- ***You must be able to interpret and draw circuit diagrams using these symbols.***

- ***ENERGY, POTENTIAL DIFFERENCE & ELECTROMOTIVE FORCE***

- *Consider the circuit shown opposite.*

*When switch (S) is closed, each free electron in the circuit is given a fixed amount of* **electrical potential energy** *as it passes through the cell.*




- *The electrons flow in the direction shown and* **do work** *as they pass through the light bulb, transferring all their* **electrical potential energy** *into* **light (useful) and heat (wasted) energy** *which is emitted by the bulb.*

- *After delivering all their electrical energy to the bulb, each electron returns to the cell via the positive terminal, to be given more electrical energy to deliver to the bulb.*

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

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

- **Potential difference** *is measured in* **VOLTS (V).**



***1 VOLT*** *is the potential difference between two points in a circuit in which* ***1 JOULE*** *of electrical energy is transferred to other energy forms when* ***1 COULOMB*** *of charge flows between them.*

**1 VOLT = 1 JOULE PER COULOMB**

$$1\ V = 1\ J\ C^{-1}$$

- *If* **W** (J) *of* **electrical energy** *is transferred when* **Q** (C) *of* **charge** *flows between two points in a circuit, then the* **potential difference, V** (V) *between the two points is given by :*

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

(V) = (J) / (C)

*So,* $W = QV$

*And since,* $Q = It$,

$$W = ItV$$

(J) = (A) (s) (V)

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

- ***EXAMPLES***

  - *If* **50 J** *of work is done (or energy is transferred) when* **5 C** *of charge passes through a component, the p.d. across the component is :*

    V = W/Q = 50/5 = **10 V**

  - *If an electrical supply has an e.m.f. of* **12 V**, *it means that* **each coulomb** *of charge which passes through the supply is given :*

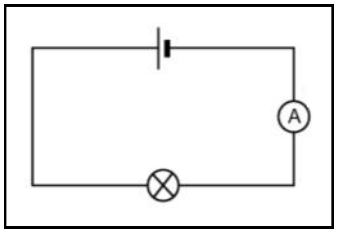
    W = QV = 1 x 12 = **12 J** (of electrical energy)

- *The difference between* **ELECTROMOTIVE FORCE (e.m.f.)** *and* **POTENTIAL DIFFERENCE (p.d.)** *may be summarised as follows :*

| **E.m.f.** *(voltage across an electrical source) is a voltage where ……* | **p.d.** *(voltage across circuit components) is a voltage where ……* |
|---|---|
| **Electrical energy is being transferred from the source to the charge.** | **Electrical energy of the charge is being transferred to other energy forms in the circuit components.** |

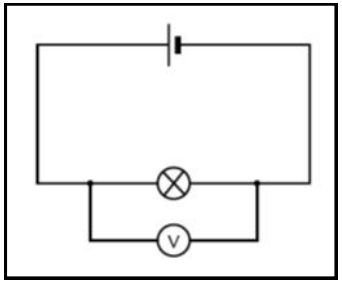


- **AMMETERS** *measure the current through a component and are connected* **IN SERIES** *as shown opposite.*




*Ammeters should have a* ***very low*** *electrical resistance (ideally zero) so as not to affect the current in the circuit.*

- **VOLTMETERS** *measure the p.d. between two points in a circuit and are connected* **IN PARALLEL** *(i.e. between the two points).*




*Voltmeters should have a* ***very high*** *electrical resistance (typically ≈ 1 MΩ and ideally infinite) so as to draw as little current as possible.*

- **HOMEWORK QUESTIONS**

**1** Calculate the amount of energy transferred to ***50 C*** of charge by :

(a) A ***12 V*** battery, (b) A ***6.0 kV*** high-voltage supply.

**2** A ***12 V*** car battery drives a current of ***2.5 A*** through a circuit for ***5.5 minutes.*** Calculate :

(a) The amount of ***charge*** which flows round the circuit in this time.

(b) The ***energy*** which is transferred to the charge by the battery.

(c) The ***energy*** which the charge transfers to the circuit components.

**3** When the ignition key is turned in a car, the ***12 V*** battery supplies a current of ***180 A*** to the starter motor for a time of ***1.8 s.*** How much ***energy*** is drawn from the battery?

**4** (a) Use energy considerations to distinguish between ***potential difference (p.d.)*** and ***electromotive force (e.m.f.).***

(b) Which of the following is the correct answer for an alternative unit for ***e.m.f.*** or ***p.d.?***

$J\ s^{-1}$ $J\ A^{-1}$ $J\ C^{-1}$

***(OCR AS Physics - Module 2822 - June 2001)***