- ***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*

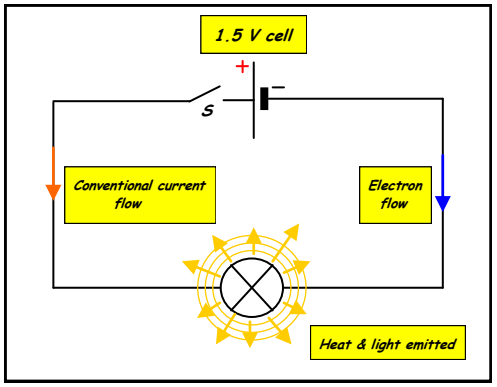
Symbol	Component name	Symbol	Component name
	connecting lead		variable resistor
	cell		microphone
	battery of cells		loudspeaker
	fixed resistor		fuse
	power supply		earth
	junction of conductors		alternating signal
	crossing conductors (no connection)		capacitor
	filament lamp		thermistor
V	voltmeter		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.***

FXA © 2008

- ***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 :*

$$V = \frac{W}{Q} \quad (V) = \frac{(J)}{(C)}$$

So, $W = QV$

And since, $Q = It$,

$$W = ItV \quad (J) = (A)(s)(V)$$

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

FXA © 2008

- ***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 :*

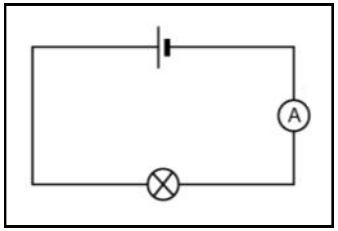
    W = QV = 1 x 12 = **12 J** (of electrical energy)

- *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.**

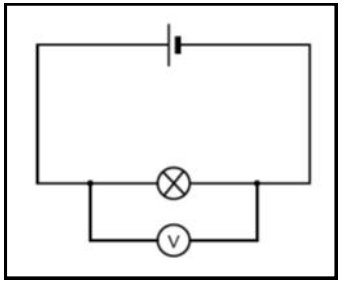
- ***USING AMMETERS & VOLTMETERS*** *3*

- **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.*

FXA © 2008

- **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)