Intro to Potential Difference, Current, and Resistance

- The pump in an aquarium is like the cell/battery in a circuit:

Pump of Aquarium	- pumps out water with a certain "flow rate", or number of mL per second.
Cell/battery of Circuit	- pumps out electrons with a certain "flow rate" or number of charges (electrons) per second.

- The "flow rate" of the water or the electrons is called the current.

→ In any electrical circuit current (I) = $\frac{\#\,charges}{s}$ (read "number of charges per second")

→ The unit for current is amperes, or A.
e.g. for a given circuit, I = 4.2A (there is a current of 4.2 amperes or A)

- The current is the same everywhere in an aquarium circuit, as it is the same everywhere in an electrical circuit.

- The "force" of the aquarium pump is the same idea as the emf of a cell/battery.

emf = electromotive force (ε) → unit for emf is volts (V)

e.g. $\varepsilon = 6V$ refers to the emf of a cell as being 6 volts (V)

- The filter of an aquarium is like a resistor (e.g. light bulb) in an electrical circuit. The filter offers a resistance to the flow of water in the aquarium circuit. Using a thicker or a dirtier filter will reduce the flow of the water throughout the whole aquarium circuit. Likewise, a light bulb offers resistance to the flow of charged particles in a circuit. Using a resistor (light bulb) with a larger amount of resistance will lower the current (# charges/s) flowing throughout an electrical circuit.

→ The symbol for resistance is R.

→ The unit of resistance is ohms, Ω.

e.g. a specific light bulb might have a $R = 3\Omega$ (resistance of 3 ohms, or Ω)

→ As R increases, I decreases.
As R decreases, I increases.

The intensity of a current (I) depends on the emf of the cell, and it depends on the amount of resistance(R) offered by the resistor.

As ε increases, I increases
As ε decreases, I decreases

As R increases, I decreases
As R decreases, I increases

Formula to Know: $\varepsilon = IR$

- We can see from this formula that ε and I are directly proportional (as one increases, so does the other), and that I and R are indirectly proportional (as one increases the other decreases).

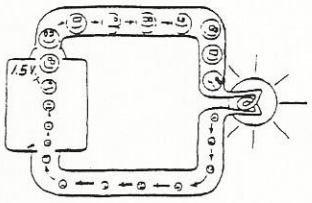
More on Resistance (R)

- Resistance is defined as the obstruction to the flow of current.
- Resistance is found in all components that **use electricity** (e.g. filament of light bulb, heating element of kettle).
- Like the aquarium filter, which slows down water, resistors resist the flow of charges.
- The greater the resistance, the more difficulty the charges have in moving through the resistor, therefore the smaller the current.
- Symbol is R, unit is Ω (ohm) (Greek letter omega).

More on Electromotive Force, emf (ε)

- The emf characterizes the power supply (i.e. we would only talk about emf in reference to a power supply.).
- The emf is the maximum voltage supplied by a cell; it's written on the cell (e.g. 9V).
- Symbol is ε (Greek letter epsilon), unit is V (volts).
- If emf increases, that means that the "force" applied to charges is increased, therefore current (rate of flow of charges) increases.

  - charges gain energy as they pass through the cell (from – to +). The charges carry that energy to the power consumer (e.g. light bulb) where the E is used.

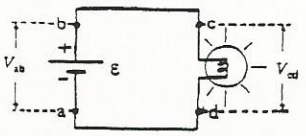


Voltage/Potential Difference = the change in E between any two points in a circuit (not necessarily between the two points that represent the two ends of the cell).

Potential difference = voltage

emf = the change in E between the two ends of the power supply; the voltage or potential difference across the battery.

V_{bc} = voltage between points b and c = 0 (since no E was used between points b and c)
V_{ab} = emf (ε) of cell
V_{cd} = voltage of light bulb



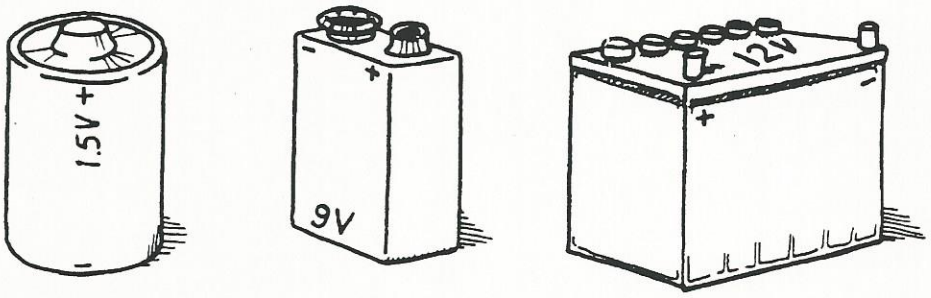
NB. V_{ab} represents an increase in E
V_{cd} represents a decrease in E

But no – or + values are used in reference to voltage.

Different Types of Power Supplies

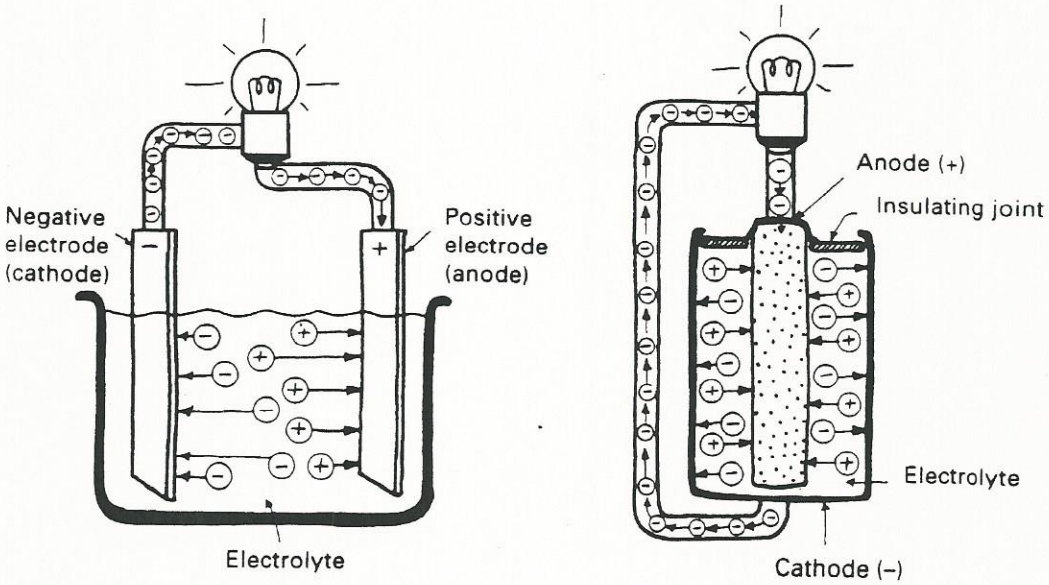
- all power supplies have an emf.

Examples of electromotive force



The emf of a cell, a battery and a car battery. Emf is represented by the symbol ε and is expressed in volts.

1. The Cell



- a simple cell has two electrodes immersed in an electrolyte

electrode: a strip of metal that conducts electricity
electrolyte: a salt water solution (also conducts electricity)

- chemical reactions between the electrodes and the electrolyte cause electrons (charges) to flow through conducting wire from one electrode to the other (from – electrode to the + electrode). Thus, electrons flow through the E consumer (in this case, a light bulb) which is connected to the conducting wires.

- carbon-zinc cell is the most common cell on the market.

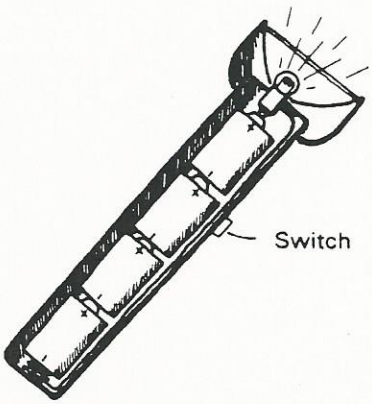
- alkaline cells last longest, are most expensive, and do not run down as quickly if left unused. (that's why they are best for remote controls, flashlights, camera flashes, smoke detectors, etc.)

- A cell produces a weak emf (≈1.5V).

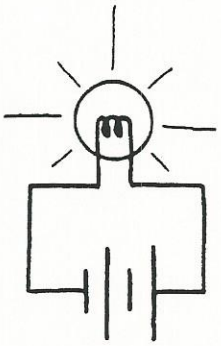
- For greater power, cells are grouped together to form batteries.

  e.g. a flashlight battery contains two or more cells; the positive electrode of the first is connected to the negative electrode of the second, and so on.

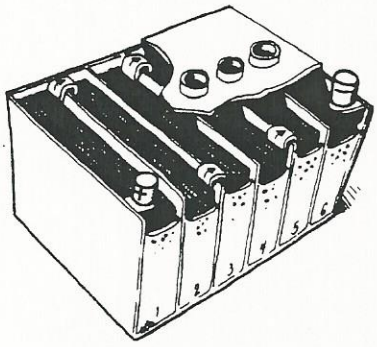
Examples of batteries



a) A battery composed of a series of four cells



b) A circuit diagram: the battery is represented by its conventional symbol.



c) A car battery

- Sometimes many cells are found in a single shell. e.g. 6V, 9V, car batteries.

N.B. Alessandro Volta created the first cell in 1793; the unit the "volt" and "voltage" are in his honor.

Some review...

1. a) The light bulb goes on when the circuit is _____ (open or closed); it goes off when the circuit is _____ (open or closed).

   b) In everyday language, we say "I turn on the light" when the circuit is _____ (open or closed) and "I turn off the light" when the circuit is _____ (open or closed).

2. Name the components of a simple electric circuit.

3. In an electric circuit, what is the role of the:

   a) power supply?

   b) conducting wires?

4. What factors influence the electric current intensity in the kettle circuit?

5. What is the difference between a cell and a battery?

6. What type of cell would you choose for your television remote control? Justify your answer.

7. What is a synonym for voltage?

8. What is the difference between emf and voltage?

Summary of Variables so Far:

Variable	Symbol	Unit
electromotive force, emf	ε	V, volts
potential difference	V	V, volts
current	I	A, amperes
resistance	R	Ω, ohms
charge	Q	C, coulombs

Summary of Formulas So Far:

$\varepsilon = IR$

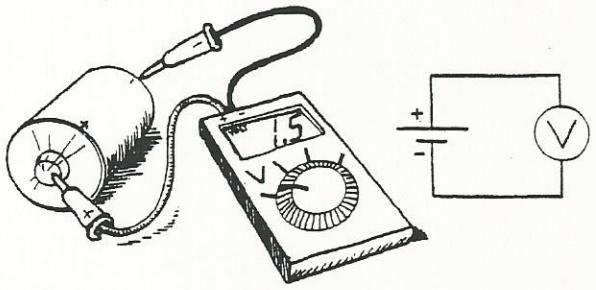
$I = \frac{Q}{t}$

$V = IR$

Measuring Devices

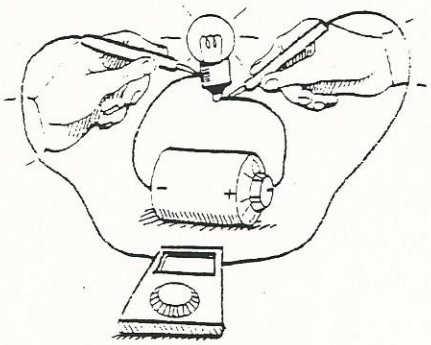
Voltmeter: used to measure **potential difference**. It can therefore measure the emf of a power source, or the voltage difference between any two points in a circuit.

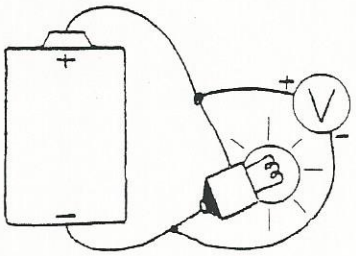
Symbol for voltmeter:

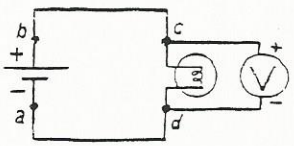


- The emf of a cell is found by hooking up the two terminals of the voltmeter to the two ends of the cell (see diagram to the right above).
- The voltmeter is connected in **parallel** so that it can measure the difference between the two points to which it is connected.

Parallel connection: means that there is an alternate path created through which charge can flow. A component connected in parallel will have only part of the current flow through it.



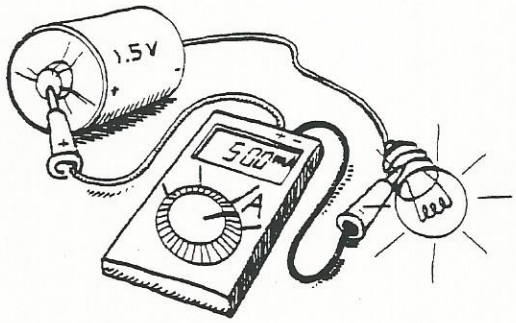


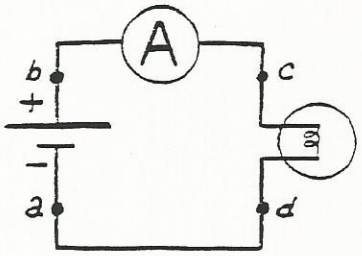


The voltmeter has a large resistance so that very few electrons will flow through it – the majority will travel through the other path (through the cell or the resistor – e.g. light bulb – in the circuit).

Ammeter: used to measure the **intensity of the current.**

Symbol: 





- The ammeter is connected in series so that all of the current in the circuit can flow through it. All of the current must flow through it so that it can measure the amount of the current.

  Series connection: if a component is connected in series then all of the current will flow through it.

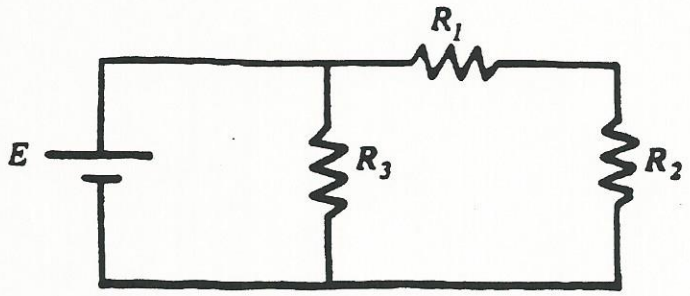
- The ammeter has a negligible (very small) resistance so that all of the current can pass through it (so that it can be measured), but no energy will be used up; so that it does not change the total resistance (or the current) in the circuit.

N.B. A "multimeter" can function as a voltmeter or an ammeter. It just has to be set to that function.

1. You wish to measure the voltage at the terminals of resister R_1 in the circuit shown below.

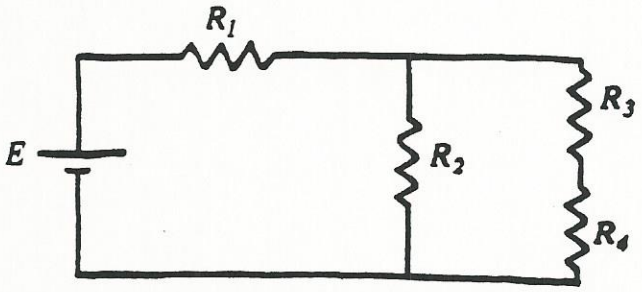
a) What device should you use? (If you use a multimeter, what function should it be set to?)

b) On the diagram, illustrate how this device is connected.



c) Is the measuring device connected in series or in parallel? Explain why it is connected in this way.

2. You wish to measure the current flowing through resistor R_3 of the circuit shown below.



a) What device should you use? (If you use a multimeter, what function should it be set to?)

b) On the diagram, illustrate how this device is connected.

c) Is the measuring device connected in series or in parallel? Explain why it is connected in this manner.

3. Indicate whether each of the following statements is true (T) or false(F).

_____ a) All circuit components that use electricity have resistance.

_____ b) According to convention, electric current flows through the circuit from the positive terminal of the power source to the negative terminal of the power source.

_____ c) If the emf of a circuit is increased, the current is also increased.

_____ d) Closing the switch prevents current from flowing through the circuit.

_____ e) The voltage level across the terminals of a resister expresses the decrease in energy of the charges flowing through it.

_____ f) In a closed circuit electrons can travel from the power source to the resister in less than a second.

_____ g) The voltage between two points on the same conductor wire is nil (assume that there are no components between the two points).

_____ h) The energy of charges changes only slightly when the charges pass through a conducting wire.

_____ i) Electrons travel more quickly in a resistor than in a conductor.

4. Why should rechargeable batteries be used instead of ordinary (carbon-zinc) batteries as a way of protecting the environment?

5. Why is it better to use alkaline batteries instead of rechargeable batteries in a camera flash?