Electric Circuits

1. In the electric circuit shown, there is a

a) transfer of energy from battery to bulb

b) transformation of energy from chem potential energy -> electrical energy -> light

2. In general, an electric circuit contains a:

a) closed pathway for transfer of energy – complete circuit

b) flow of electrons that transfer the energy:- current

c) source of electrical potential energy: Source of 'Electromotive force' (EMF) or potential difference (or voltage)
examples: battery, solar cell, generator

d) device that uses the energy: source of resistance in circuit (load)
examples: light bulb, motor, hair dryer...

An Analogy

. . . is similar to . . .

What is a "cell?"
a container in which a chemical reaction occurs to release electrical energy

Dry cell:
dry chemicals - DC, AA, AAA, watch battery, etc.

Wet cell: liquid acid - car battery

Primary Cell: non-rechargeable

Secondary Cell: rechargeable

Electric Circuits

Battery: two or more cells connected together

3. What does it mean for a cell to be rated at 1.5 V?

provides 1.5 J of energy to every coulomb of charge that passes through it

Electric Current

Electric Current: rate of flow of electric charge carriers

4. How much is 1 ampere (1 amp) of current?

One coulomb of charge passes a point in one second

Formula: $I = \frac{q}{t}$

Units: $\left[\frac{C}{s}\right] = [A]$

5. What is the current in a wire in which 600. C of charge pass a point every 4.0 minutes?

$I = q/t = \frac{600\,c}{4 \cdot 60\,s} = 2.5\,A$

Electric Current

6. If a 12.0 A current is allowed to flow for 20. seconds in a circuit, how many elementary charges pass that point?

$I = q/t$

$q = I \cdot t = 12\ c/s \cdot 20\ s$

$240\ c \left(\frac{1\ e.c.}{1.6 \times 10^{-19}\ c} \right)$

)

Official Definition of One Ampere (1 A) of current – a fundamental unit
One ampere is the amount of current flowing in each of two infinitely-long parallel wires of negligible cross-sectional area separated by a distance of one meter in a vacuum that results in a force of exactly 2 x 10^{-7} N per meter of length of each wire.

Short form – Current is defined in terms of the force per unit length between parallel current-carrying conductors.

Electric Current

Direct Current (DC): Current in which the charge flows in one direction only

Source of DC: DC batteries, solar cells

Electron flow:
negative charge carriers (electrons) flow from negative to positive

Conventional current:
positive charge carriers flow from positive to negative

Electric Current

Alternating Current (AC): Current in which the charges alternate their direction of flow

Source of AC: AC generator

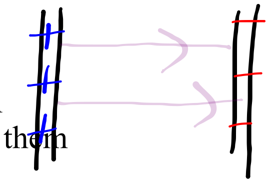
Model for the structure of a metal conductor (like a wire or filament)

a) positive lattice ions fixed in place

b) freely moving conduction electrons that carry charge

Without an applied potential difference... electrons move randomly

When a potential difference is applied across the conductor..
- a) an electric field is set up in the conductor
- b) conduction electrons accelerate to the positive terminal
- c) and collide with lattice ions thus transferring energy to them



Drift speed: net speed of conduction electrons

7. Compare the instantaneous speed of the conduction electrons with their drift speed.

Instantaneous speed- very high (near speed of sound in metal)

Drift speed - very low (one hour for one meter of copper wire)

Drift Speed Formula

A = cross sectonal area

q = charge

v = drift speed

n = charge density = number of charge carriers per unit volume (per 1 m^3 of volume)

Derivation

In the figure above, charge carriers, each with charge q, move past point P with a speed v.

$V = A \cdot (v \cdot t)$

a) In one second, the volume of charge carriers passing P is equal to

b) The total number of charge carriers in this volume is $nV = nAvt$

c) The total charge of the charge carriers in this volume is

$\Delta Q = nVq = nAvtq$

d) Therefore, the current is

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

A   I

8. A copper wire of diameter 0.65 mm carries a current of 0.25 A. There are 8.5 x 10^{28} charge carriers in each cubic meter of copper. Calculate the drift speed of the charge carriers.   n

9. If the drift velocity is so small, why does the light bulb light as soon as the battery is connected?

Conduction electrons already in the filament start to move as soon as the electric field is set up in the circuit by the battery. It is these electrons, not the electrons from the battery, that collide with the lattice ions in the filament immediately and transfer enough energy to them to make the filament glow.

Resistance of a Wire

1. What is the cause of resistance in a wire?

Collisions between conduction electrons and lattice ions

Symbol: R   Units: [Ω]

Factors	Symbol	Unit	Less Resistance	More Resistance	Relationship
Length	L	[m]			1. direct
Cross-sectional Area	A	[m²]			1. inverse
Resistivity	ρ	[Ω·m]			1. direct
~~Temperature~~	T	[K]			

Resistance of a Wire

What type of wire is the best conductor (least resistance)?

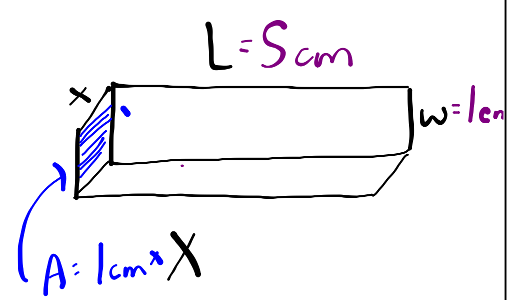
Formula for a conducting wire at a constant temperature . . .

$$R = \frac{\rho L}{A}$$

$A \leftarrow \pi r^2$

$\rho \leftarrow 35 \times 10^{-5}\ \Omega \cdot m$

$$R = \frac{\rho\,(5\,cm)}{X \cdot 1\,cm}$$



Resistance of a Wire

2. What are the properties of wire that is the best conductor (has the least resistance)?

shorter, larger A, low temp

3. What are the properties of wire that is the worst conductor (has the most resistance)?

long, higher temp, thin

4. To make a wire with the lowest resistance, what material would you use? Highest resistance?

silver $\rho \sim 1.6 \times 10^{-8}\ \Omega\, m$

nichrome $\rho \sim 10 \times 10^{-8}\ \Omega \cdot m$

5. What is the resistance of a copper wire 2.0 meters long with a cross-sectional area of 6.4×10^{-8} m^2?

$\rho \approx 1.7 \times 10^{-8}\ \Omega \cdot m$

6. a) What is the resistance of a nichrome wire 12 meters long with a diameter of 2.7×10^{-4} meter? $A = \pi r^2$

b) if the diameter of the wire above is doubled, what is its resistance?