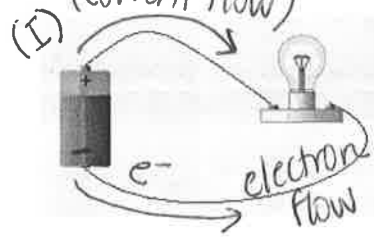
Ms. Rosenthal **Electric Circuits** Spring 2019 (P.3) IB 11

1. In the electric circuit shown, there is a



   a) transfer of energy from one object to another: battery → bulb

   b) transformation of energy from one type of energy to another: chemical PE (battery) → electrical energy (wires) → radiant energy (bulb) → thermal energy (heat)

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: voltage supplier or source of EMF (electromotive force) - NOT A FORCE!

   examples: battery, solar cell, generator

   d) device that uses the energy: source of resistance in a circuit (load)

   examples: motors, lights, appliances, electronics

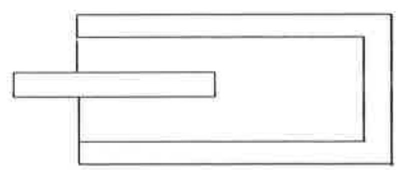
Cell: container in which chemical reactions occur and release electrical energy

Dry cell: AA, AAA, 9V

Wet cell: car battery - liquid acid

Primary cell: non-rechargeable

Secondary cell: rechargeable



Dry Cell

Battery: two or more cells put together

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

$1C \times 1.5V = 1.5J$ $PE_e = qV$

moving charge across voltage results in a gain of energy

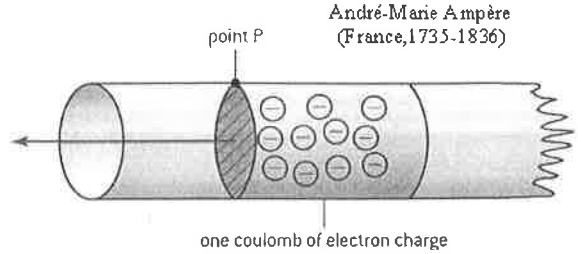
move 1 e^- across 1.5V + it gains 1.5eV of energy

André-Marie Ampère
(France,1735-1836)

Electric current: rate of flow of electric charge

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

one Coulomb of charge passing a point in one second



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

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

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

$I = \frac{q}{t} = \frac{600.C}{240s} = \boxed{2.5A}$

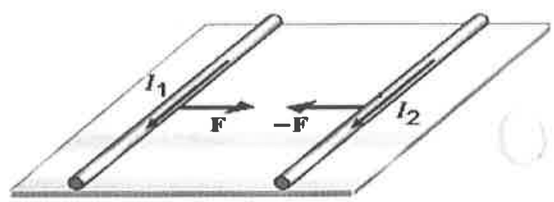
Typical Currents

Computer chip	10^{-12} to 10^{-6}
Current dangerous to a human	10^{-2} to 10^{-1} A
Household light bulb	1 A
Car starter motor	200 A
Lightning	10^{4} A

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

$q = I \cdot t \quad 12\left[\frac{C}{s}\right] \cdot 20s = 240C \times \frac{1 e.c}{1.6\times10^{-19}C}$
$= \boxed{1.5\times10^{21} e.c.}$

Official Definition of One Ampere (1 A) 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.



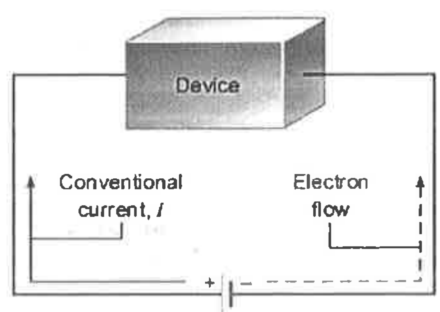
Short form – Current is defined in terms of the force per unit length between parallel current-carrying conductors.

Thomas Edison

Direct Current (DC): current flows in only one direction

Source of DC: batteries, solar cells, semi-conductors

Electron flow: negative charges flow from the negative terminal to positive terminal

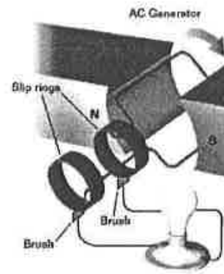


Conventional current: flow is from ⊕ to ⊖

⊕ | | ⊖

Alternating Current (AC):

current which alternates its direction of flow

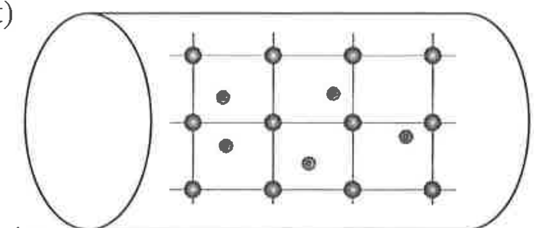


Nikola Tesla

George Westinghouse

Source of AC: AC generators in homes + businesses

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

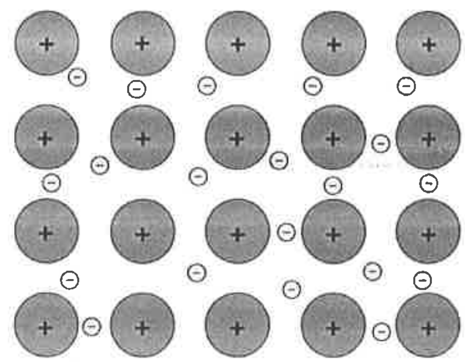


a) positive lattice ions fixed in place

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 . . .

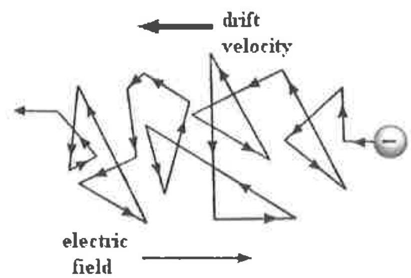


a) an electric field is set up in the conductor,

b ~~a)~~ conduction electrons accelerate to the positive terminal

c ~~b)~~ and collide with lattice ions thus transferring energy to them.

drift speed: net speed of conduction of electrons

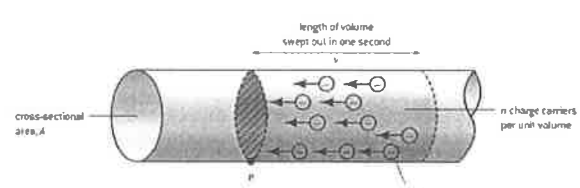


7. Compare the instantaneous speed of the conduction electrons with their drift speed.

Instantaneous speed – 10^6 m/s (high)

Drift speed – one meter/hour (copper wire)

Drift Speed formula



A = cross-sectional area q = charge v = drift speed

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

$$I = nAvq$$

density "n" = # of charge carriers / volume

Derivation

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

a) In one second, the volume of charge carriers passing P is equal to Volume = $A \cdot \ell$

$D = \frac{\text{\# of charge carriers}}{V = (A \cdot \ell)}$ ↓ "n"

b) The total number of charge carriers in this volume is $n(A \cdot \ell)$

# of charge carriers = "n" × volume

# of charge carriers = nV

c) The total charge of the charge carriers in this volume is $(qnA\ell)$

$I = q/t$

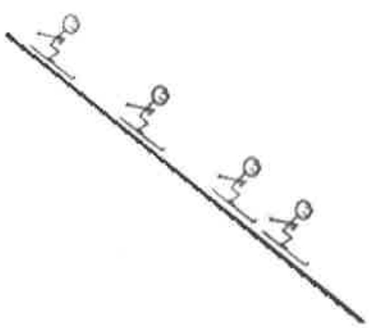
d) Therefore, the current is $I = qnA\left(\frac{\ell}{t}\right) = \boxed{qnAv = I}$

$v = d/t$ or $(\ell/t) = v$

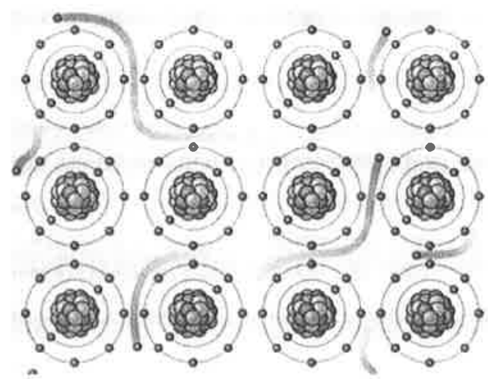
8. A copper wire of diameter 0.65 mm carries a current of 0.25 A. There are 8.5 x 10^{28} charge carriers in each cubic meter of copper. Calculate the drift speed of the charge carriers.

$A = \pi r^2$ $\quad v = \frac{I}{qnA} = \frac{(0.25A)}{(8.5\times10^{28}/m^3)(\pi)\left(\frac{0.65\times10^{-3}m}{2}\right)^2(1.6\times10^{-19}C)} = \boxed{5.5\times10^{-5}\frac{m}{s}}$

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.

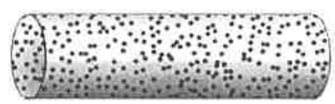


Resistance of a Wire

1. What is the cause of resistance in a wire? collisions between conduction electrons + lattice ions

Symbol: R

Unit: Ω ohm



Factor	Symbol	Unit	Less Resistance	More Resistance	Relationship
Length	L	m	L_1	L_2	direct
Cross-sectional Area	A	m^2	A_1	A_2	inverse
Resistivity	ρ	Ω·m	Copper	Aluminum	direct
Temperature	T	K	T_1	T_2	—

usually higher temp = higher resistance