ELECTROSTATICS

electric charge at rest

Early but unsuccessful practical jokes

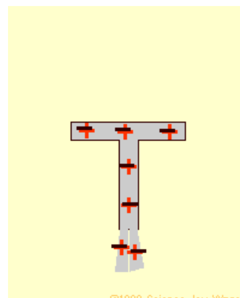
Thales of Miletus (~600 BC)
- rub amber
  - attracts small particles
- elektron - Greek word for amber

Ben Franklin
- 2 types of electric charge
- Positive - Negative

Law of Electrical Charges
- like charges repel
- unlike charges attract

Electroscope measures
- electric charge
- by movement of
  - thin metal leaves

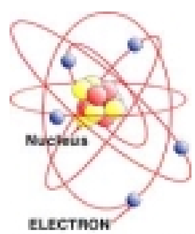
es+ | es- | charge | induct1 | induct2 | charge2



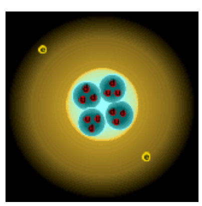
ELectron Theory of Matter

Modern View

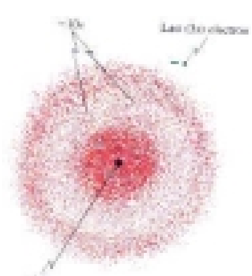
Matter composed of **Atoms** with



- positive **Nucleus**
- **Proton** (**p**): positive (+) charge
- **Neutron** (**n**): electrically neutral



- negative **Electron cloud**
- **Electron** (e^-): negative (-) charge
- model: "orbit" nucleus

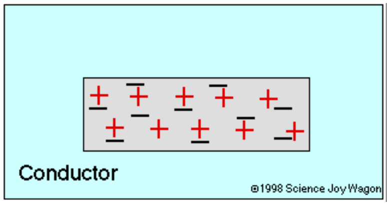


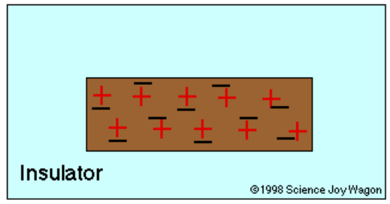
- quantum mechanics: fill
  - probability cloud

Electric forces
- hold atoms in matter together
  - molecules - liquids - solids
- determine bulk properties and chemistry

Electron movement between atoms
determines electric conduction properties

conductors
semiconductors
insulators





Conservation of Charge

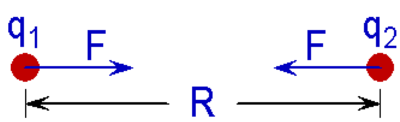
Electric charge can not be created or destroyed.
The total charge in the universe is constant.

Force between Electric Charges

Coulomb's Law - inverse square law - like gravity

$q1, q2$ electric charges
in Coulombs C
unit of charge
R distance between charges
K 9×10^9 Nm^2/C^2

$$F = k \frac{q_1 q_2}{R^2}$$



Electric Charge is Quantized - Milliken

charge on proton = -charge on electron, **e**
EXACTLY!
$= 1.6 \times 10^{-19}$ C

Quarks (3 quarks make a neutron or proton)
have charges $\pm e/3$ or $\pm 2e/3$

VOLTAGE - Electric Potential

work done (in Joules) to move 1 Coulomb
of charge between 2 points
depends on other charges

Electric Potential = work/charge **$V = W/Q$**
volt = Joule/Coulomb
units: **$V = J/C$**
usually used as **$W = QV$**

In a typical TV picture tube each electron is accelerated
by passing through an electric potential of ~20 kV.

If the electron mass is 9.1×10^{-31} kg,
  how much KE does it gain?
  how fast is it going?

$W = QV = (1.6\times10^{-19}\ C)(20\times10^{3}\ V) = 3.2\times10^{-15}\ J$

$KE = \frac{1}{2}mv^2$, $v^2 = 2KE/m = 2(3.2\times10^{-15}\ J)/(9.1\times10^{-31}\ kg)$

$v^2 = 0.703\times10^{16} m^2/s^2$, so $v = 8.4\times10^{7}$ m/s 28% of c!

CURRENT - moving Electric Charge

current = (quantity of charge moving past a point)/time

$I = Q/t$ units: ampere = coulomb/second **A = C/s** (amps)

charge on 1 electron, $-e = 1.6\times10^{-19}$ C
so 1 C = (1 C)(1 electron/1.6×10^{-19} C) = 6.2×10^{18} electrons

A 60 watt lightbulb has a current of 0.5 A.
What quantity of charge flows through it in 1 hour?

$I = Q/t$, so $Q = It = (0.5\ A)(1\ hr)(3600\ s/hr) = 1800\ C$

Electrons move in solids (not protons)
  flow opposite to current direction (thanks to B. Franklin)

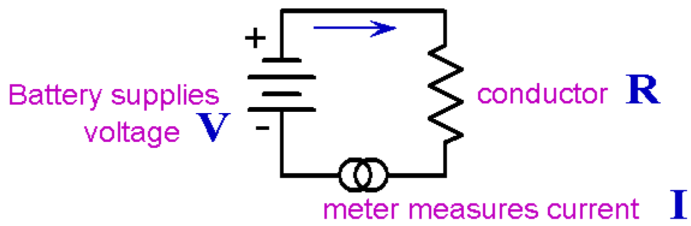
Classification of Solids by Electrical Resistance

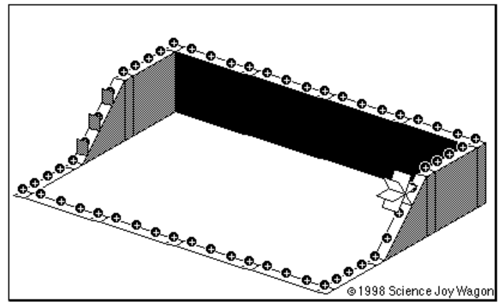
  how easy electrons flow

INSULATORS	no flow glass, plastic, rubber, diamond
SEMICONDUCTORS	small flow, depends on T Silicon, Germanium
CONDUCTORS	easy flow metals, graphite
SUPERCONDUCTORS	no resistant at all! no friction Lead, Tin, Mercury T < 8 K

OHM'S LAW - Resistance

Georg Simon Ohm (1787-1854)
How current flows in Conductors.





for a given conductor at fixed temperature:

$$\frac{\text{SUPPLIED VOLTAGE}}{\text{MEASURED CURRENT}} = \frac{V}{I} = R = \text{RESISTANCE}$$

units: Ohm = Volt/ampere $\Omega = V/A$

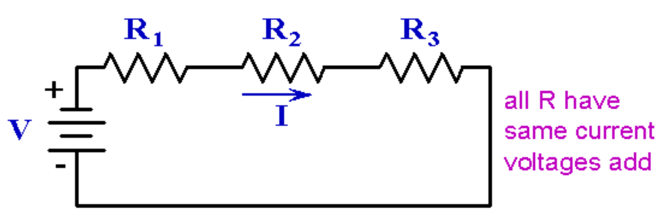
A VCR draws 0.5 A from a 110 V wall socket. What is R?

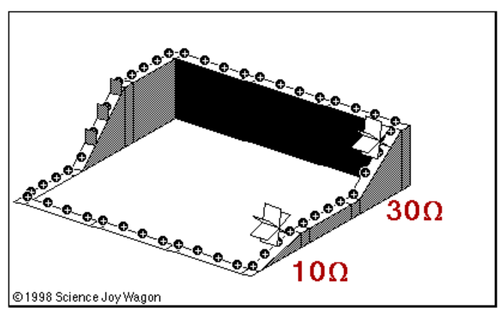
$R = V/I = (110\ V)/(0.5\ A) = 220\ \Omega$

Series Circuit:

if one R breaks, all current stops

$R_{total} = R_1 + R_2 + R_3 + \ldots$

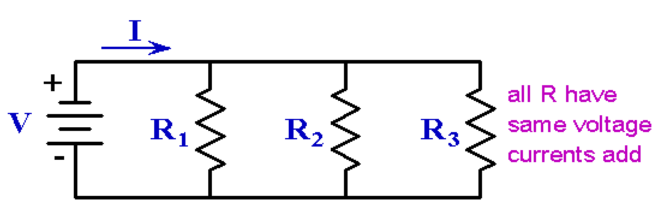


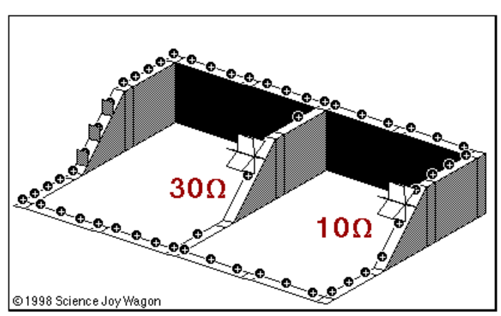


Parallel Circuit:

if one R breaks, other current continues

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$





ELECTRIC POWER and ENERGY

remember: power = work/time $P = W/t$

electric: $W = QV$

so electric power: $P = QV/t$

but $Q/t = I$ = current

giving: power = current × voltage $P = IV$

units: watt = ampere×Volt

with Ohm's Law

$V = IR$ or $I = V/R$, so

$$P = I^2R \quad \text{or} \quad P = V^2/R$$

Energy used = total work = Power × time

typical unit: **kilowatt hour (kW-hr)**

If FPL charges $0.10/kW-hr, how much does it cost to keep a 100 W light bulb on for a day?

energy = Pt = (100 W)(1 kW/1000 W)×(1 day)(24 hr/day) = 2.4 kW-hr

cost = (2.4 kW-hr)($0.10/kW-hr) = $0.24

A single Car headlight draws 6 amps from the 12 Volt battery.

a) What is its resistance?

b) How much power does it use?

c) Are car headlights connected in series or parallel? Sketch a circuit diagram.

d) How much power do 2 headlights use?

e) If 3 headlights are connected in series, how much current would flow? What is the power?

For a single headlight: I = 6A, V = 12V, so:

a) $R = V/I = (12\text{ V})/(6\text{ A}) = 2.0\ \Omega$

b) $P = I^2R = (6\text{ A})^2 \times (2.0\ \Omega) = 72$ W, or $P = V^2/R = (12\text{ V})^2/(2.0\ \Omega) = 72$ W

or $P = IV = (6\text{ A})(12\text{ V}) = 72$ W

c) parallel, so if one burns out the other can still work

d) 2 headlights use twice the power of one, P = 144 W

e) 3 in series, R's add, so $R_{total} = 3 \times (2.0\ \Omega) = 6.0\ \Omega$

$I_{total} = V/R_{total} = (12\text{ V})/(6.0\ \Omega) = 2.0$ A

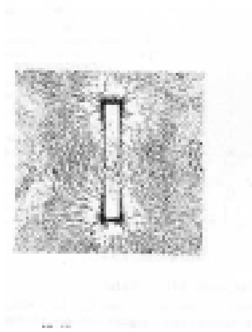
$P = IV = (2.0\text{ A})(12\text{ V}) = 24$ W

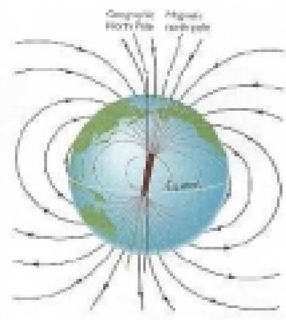
Magnetism

from moving electric charge - currents

spinning nucleus
nuclear magnetism - MRI

orbiting electrons
magnetic atoms - Iron, Nickel
domain atoms aligned together
permanent magnet - domains aligned





currents - coils of wire - electromagnets
force between current and magnetic field
basis of motors and generators