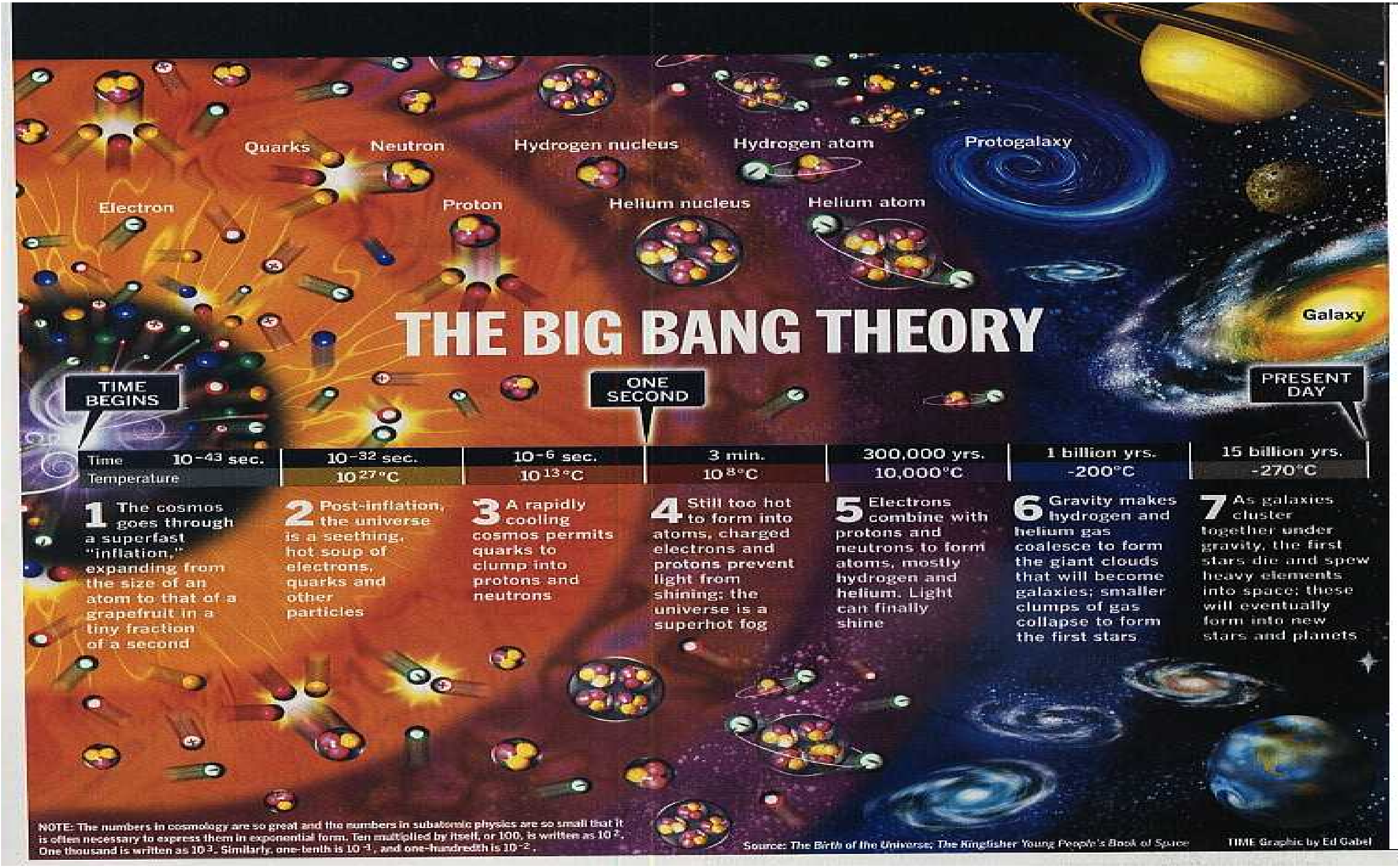
Big Bang / The origin of electronics

MIEET 1º ano

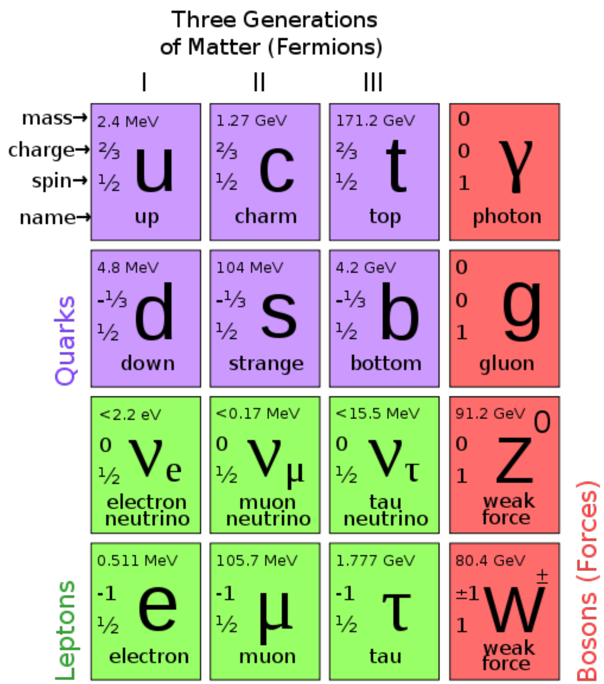
Peter Stallinga UAlg 2011

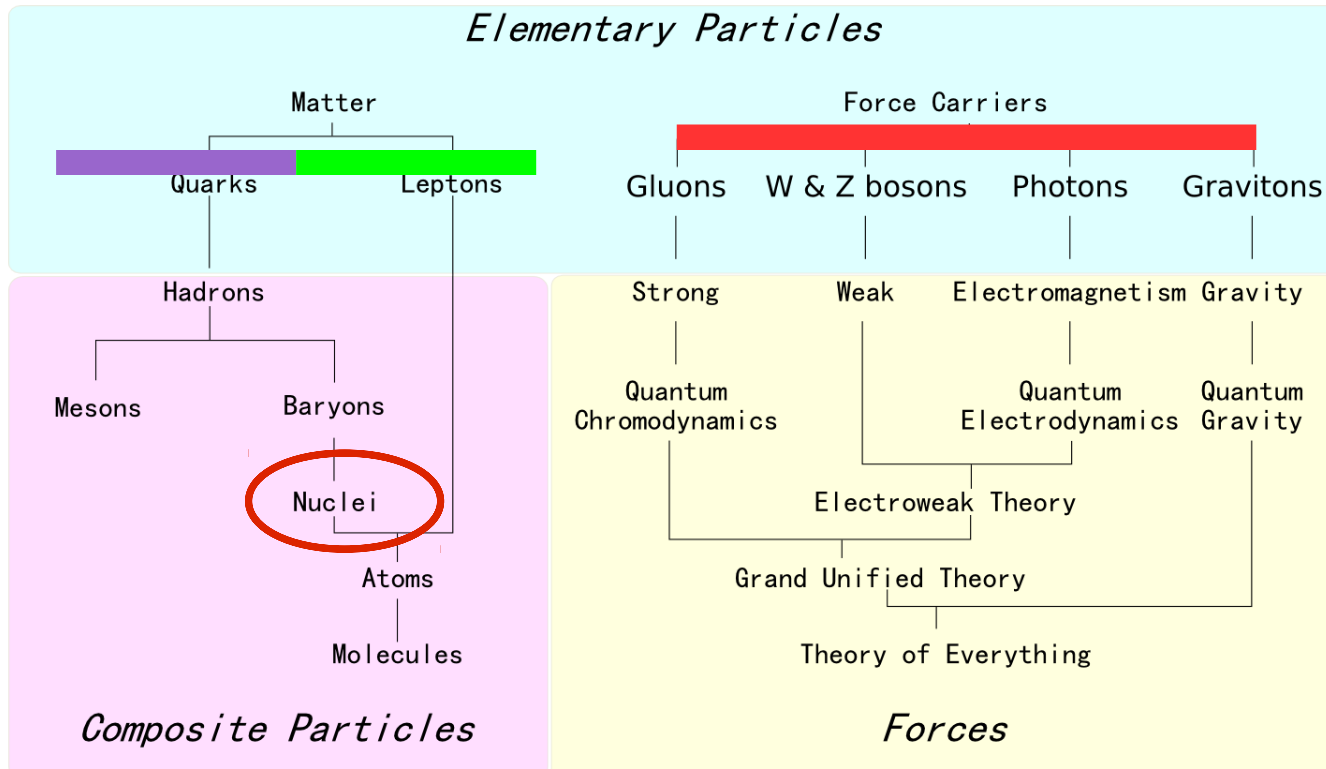
Big Bang Theory

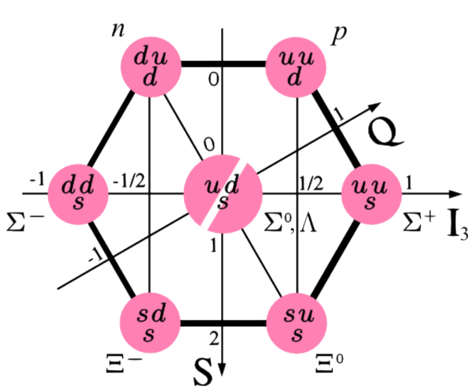


The origin of matter

Everything in the universe has quantum numbers:
- Mass (energy)
- Charge
- Spin
- Baryon number

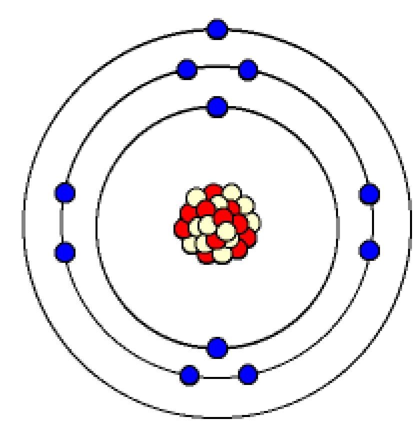






Baryon = 3 quarks
- Neutron (ddu). Charge: -⅓ + -⅓ + ⅔ = 0
- Proton (uud). Charge: -⅓ + ⅔ + ⅔ = 1

Lepton
- Electron (e). Charge: -1



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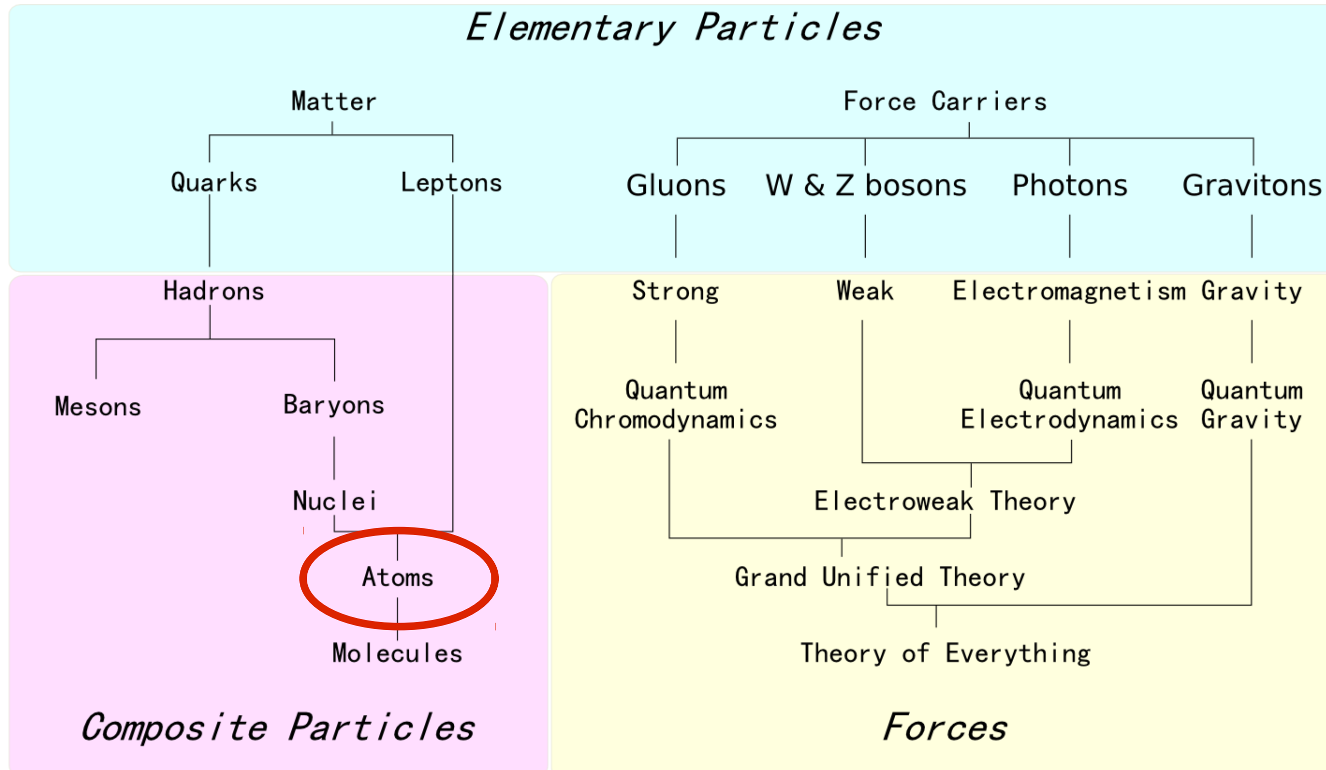
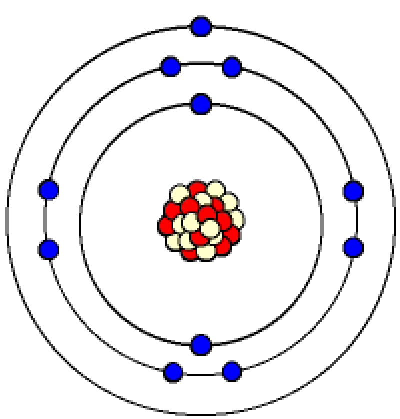
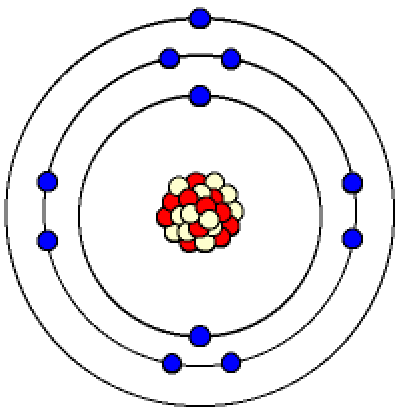


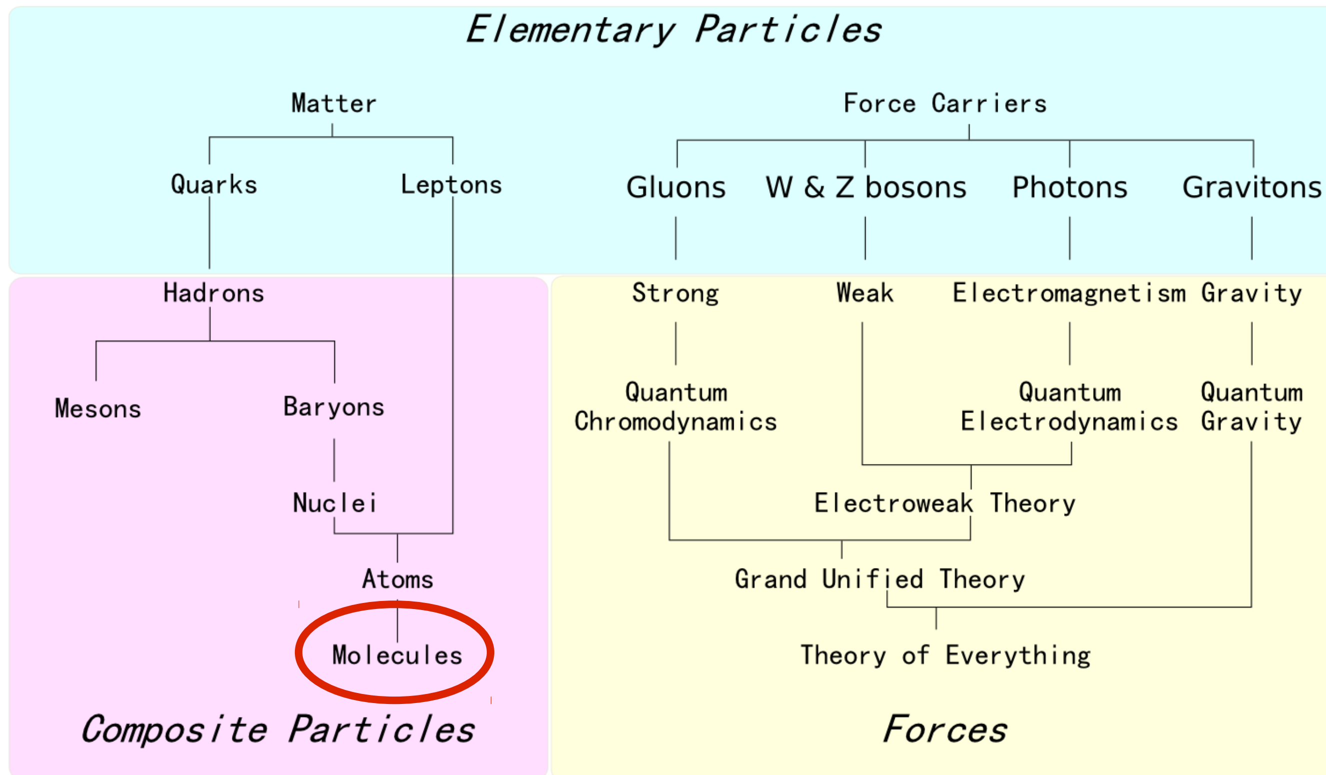


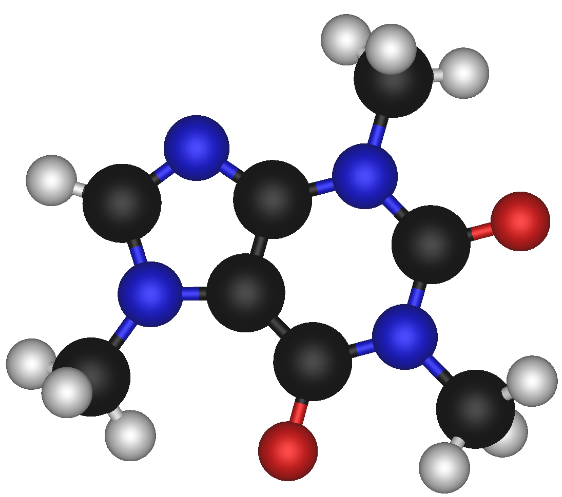
Atom:
n protons + *n* electrons + *m* neutrons
Charge = 0

Example: Na (sodium): *n* = 11, *m* = 11 or 12

The origin of matter



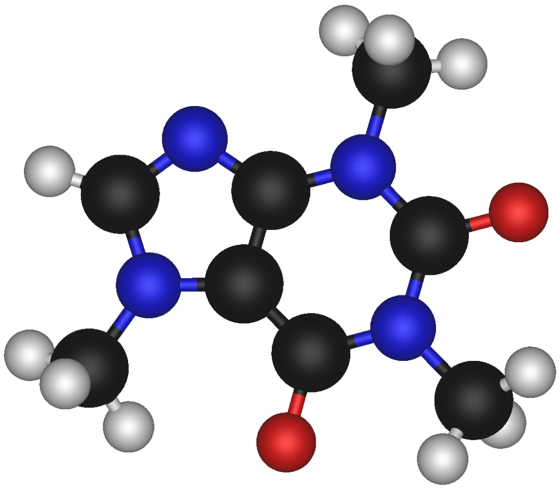


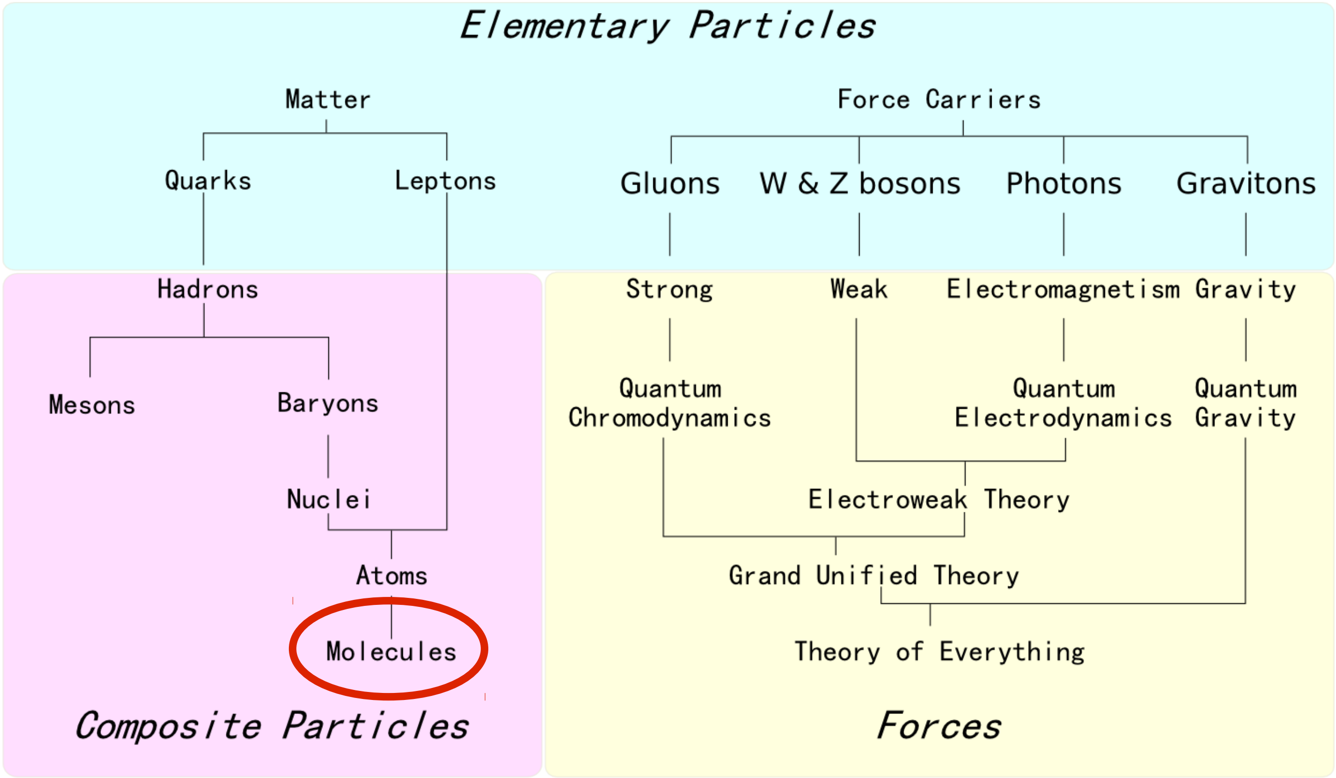


Molecule:
n atom-x + *m* atoms-y, etc.
Charge = 0

Example: Caffeine = 8xC + 10xH + 4xN + 2xO

The origin of matter

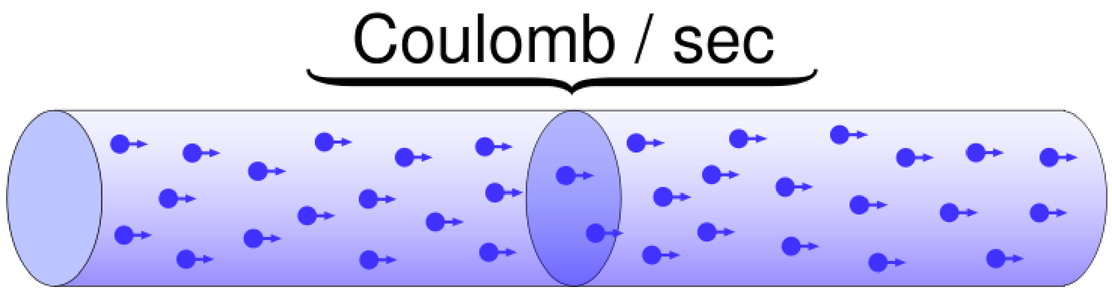


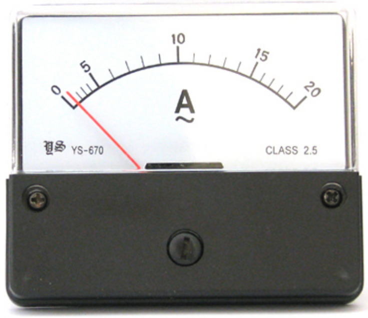


Matter:
Combined molecules
Charge = 0

Example: Human

The origin of current





Current is the passage of charge
- Electrons
- Protons (quarks)

1 unit of charge is q = 1.6x10^{-19} C

1 ampere is by definition 1 coulomb per second (1 A = 1C/s)

In a typical domestic appliance (fx, vacuum cleaner): about 10^{19} electrons per second!

The magnitude of current

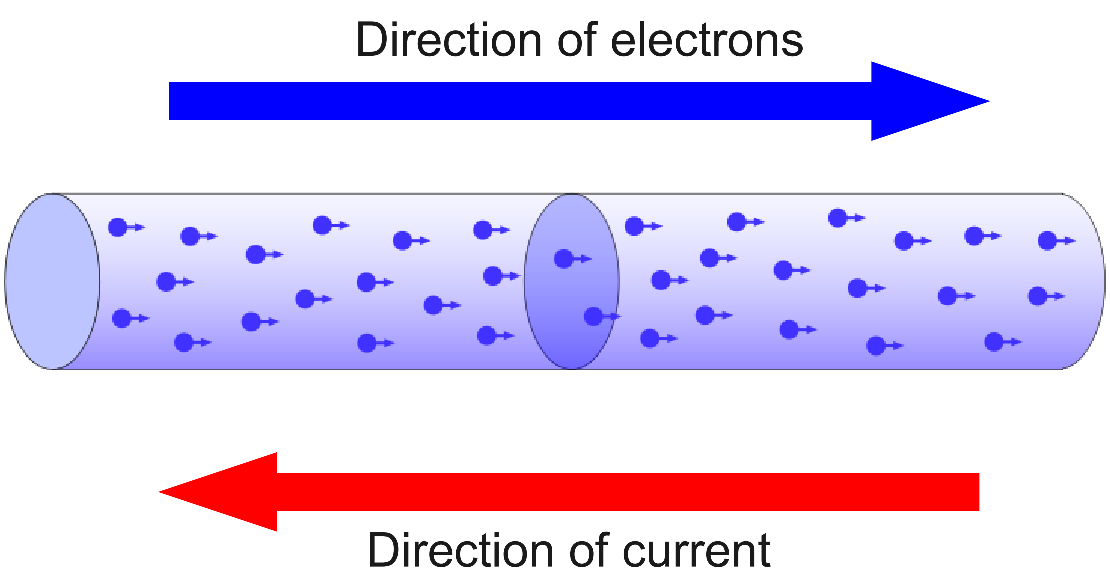
In a typical domestic appliance (fx, vacuum cleaner): about 10^{19} electrons per second!

Ontario Highway 401 (busiest road in the world): 430,000 cars/day

In 1 second in a vacuum cleaner pass as many electrons as cars on that highway in **64 billion years**! (Mote: the universe is only 13.7 billion years old)

The sign of current

Current has opposite sign compared to movement of electrons:



$$I = \mathrm{d}Q/\mathrm{d}t = Q\, v\, A$$

!

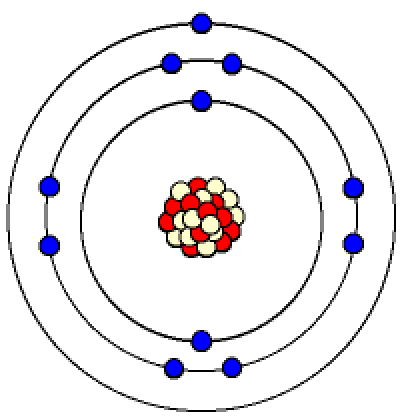
Q: charge (C) = n x ($-q$)
v: velocity (m/s)
A: area (m^2)
n: density of electrons ($1/m^3$)
q: unitary charge (C)
I: current (A = C/s)

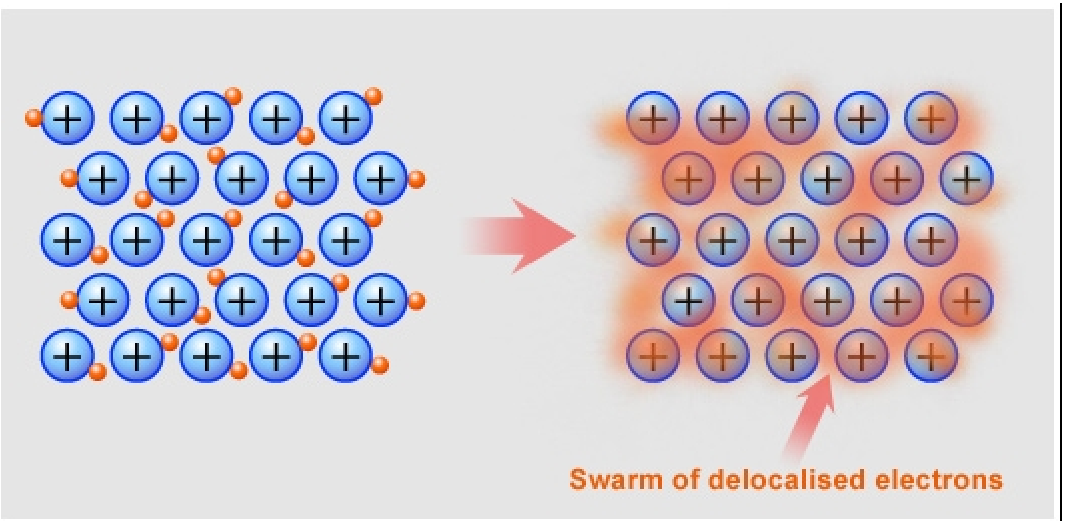
Separation of charge. Metals

Objects (atoms, molecules, humans, resistors, capacitors) have **zero net charge**

To have current, positive and negative charge has to be **separated**

1: In **metals** some of the electrons are disconnected from the nuclei and can move freely



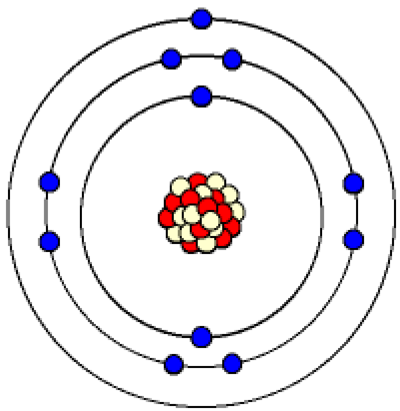


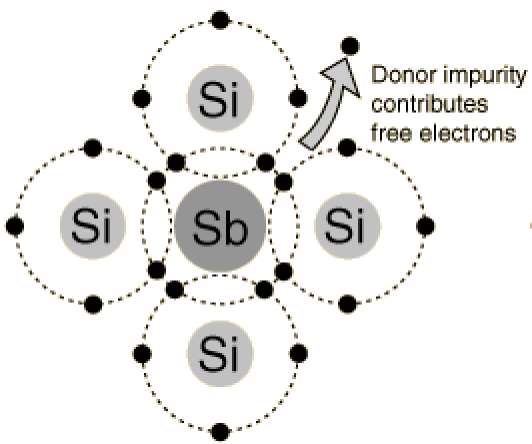
Separation of charge. Semiconductors

Objects (atoms, molecules, humans, resistors, capacitors) have **zero net charge**

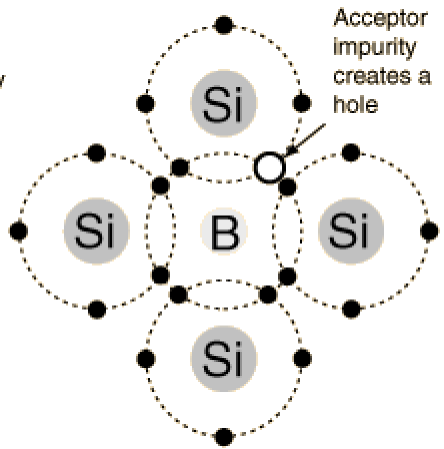
To have current, positive and negative charge has to be **separated**

1: In **semiconductors** some of the atoms have an electron too many or too few for bonding with other atoms





Donor: 1 electron too many

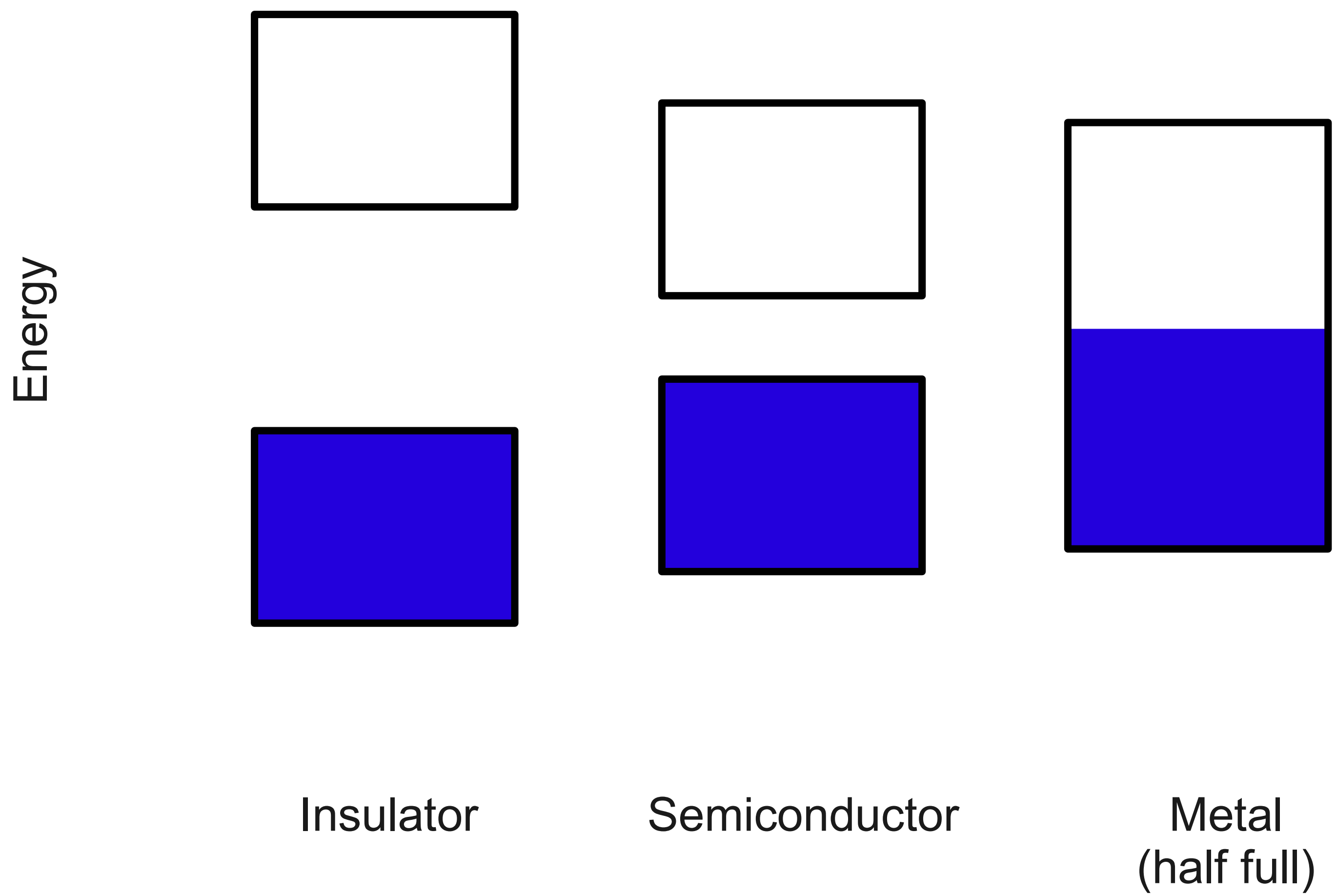


Acceptor: 1 electron too few

Extra electron can be shaken lose from atom to make semiconductor behave like metal

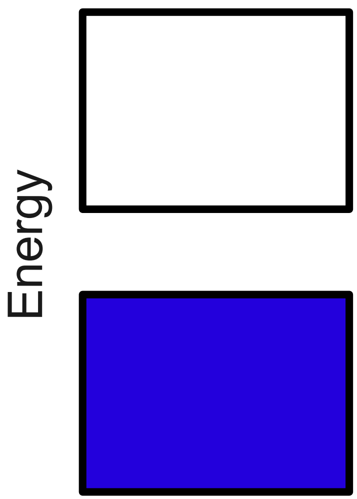
Separation of charge. Band structure

Electrons of materials fill up from lowest energy to highest energy
Not all energies are possible (quantum mechanics. Pauli exclusion principle)

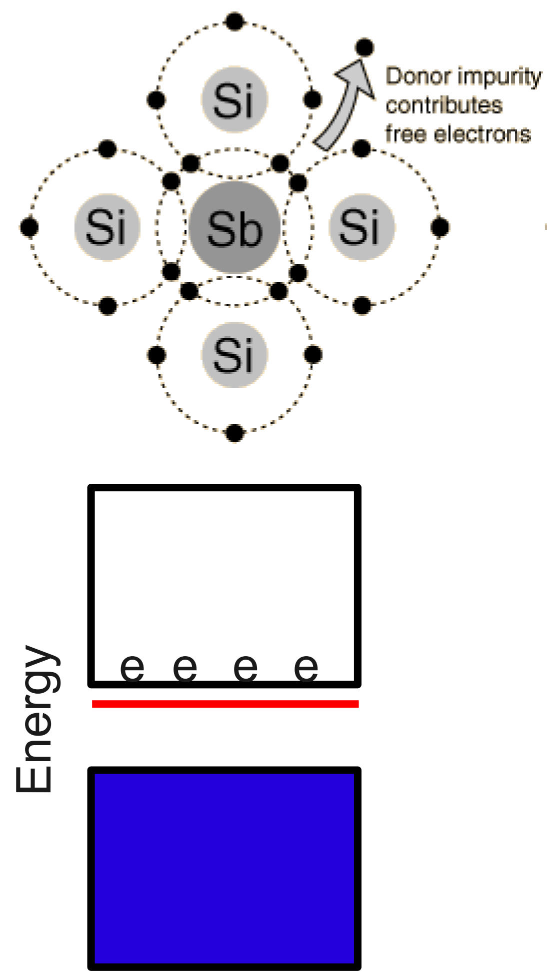


Separation of charge. Band structure

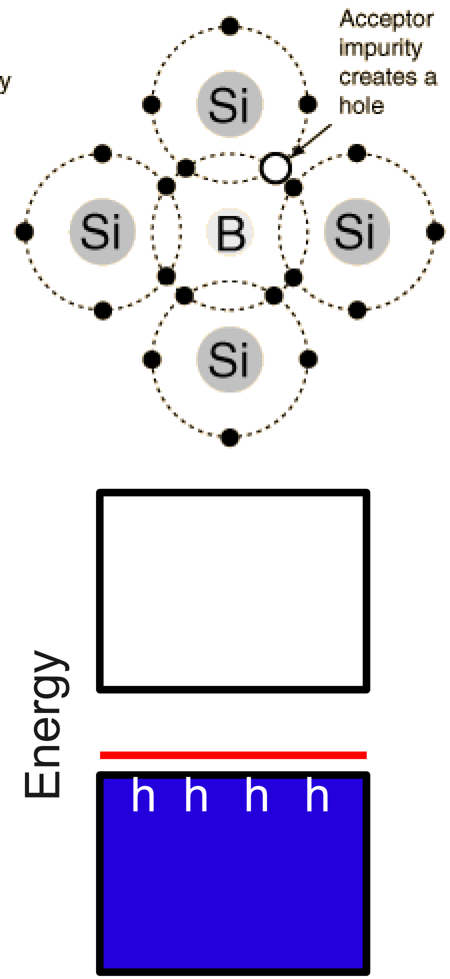
Doping in semiconductors can make charge flow freely



Semiconductor



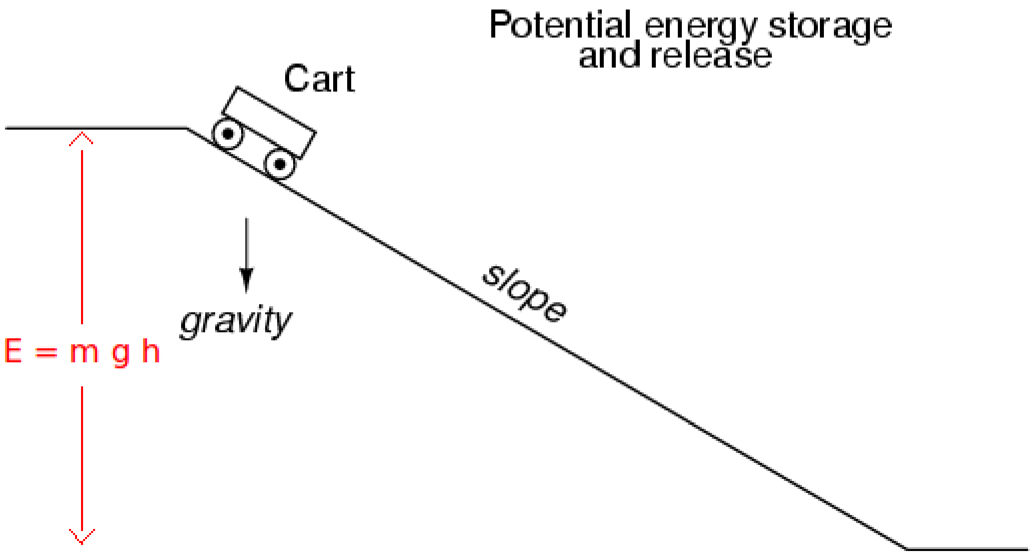
N-type semicon.

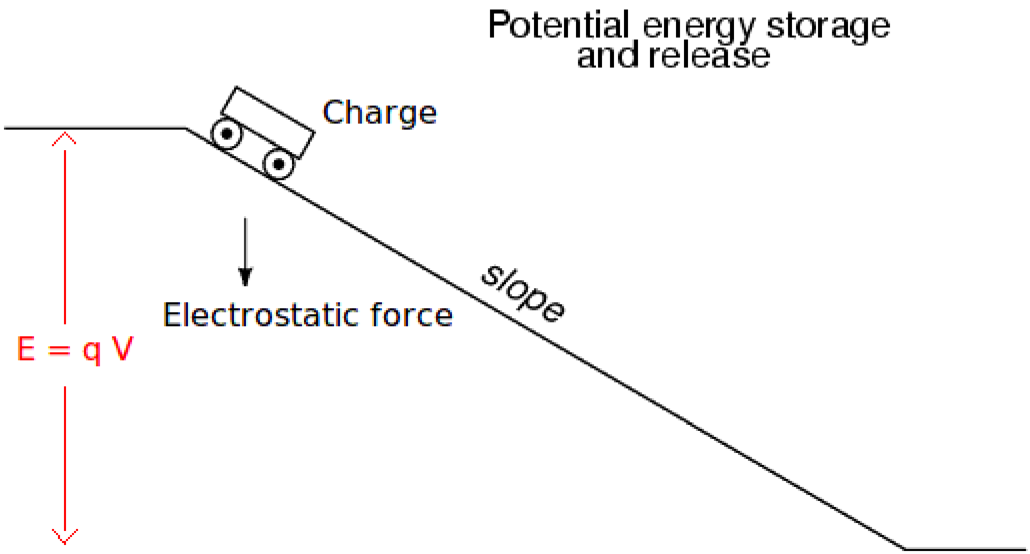


P-type semicon.

Volt

Now that we know what is current. How to make it happen?





Gravity:

Two objects with mass attract each other. Cart + Earth.
Potential energy:

$$E = m\,g\,h$$

Electrostatic interaction:

Two objects with different sign charge attract each other.
Electron + Ion
Potential energy:

$$E = q\,V$$

Volt

Volt (electrical potential) is like mountains

Volt

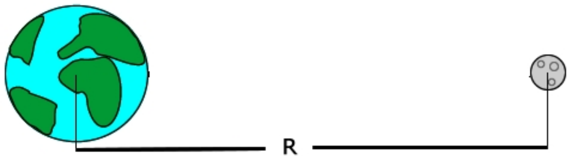
It costs energy to separate the charge. Like separating mass (rolling a ball up a hill)

The volt is per definition the energy per unit charge:

1 volt = 1 joule per coulomb

Volt

Force 2 x 1 kg separated by distance Earth-Moon



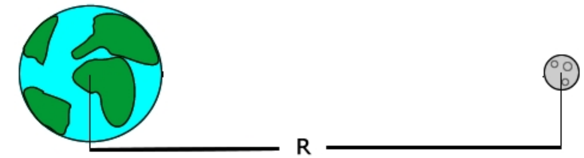
$F = G\, m_1\, m_2 \,/\, R^2$ $\quad$ (G = 6.674x10^{-11} N m^2/kg^2)

R = 3.844x10^8 m

$\boxed{F = 4.5\text{x}10^{-28}\ \text{N}}$

Volt

Force 2 x 1 kg separated by distance Earth-Moon



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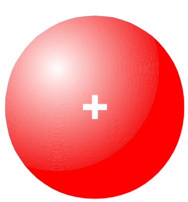
R = 3.844x10^8 m

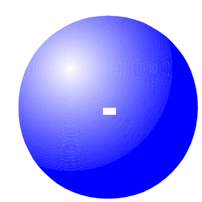
$\boxed{F = 4.5\text{x}10^{-28}\ \text{N}}$

Imagine the two weights stripped of all electrons
(Iron: 26 electrons/atom. Atomic weight: 55.845 u, u = 1.66x10^{-27} kg)
$q_1 = q_2$ = 4.49x10^7 C

$F = k\, q_1\, q_2 \,/\, R^2$ $\quad$ (k = 8.988x10^9 N m^2/C^2)



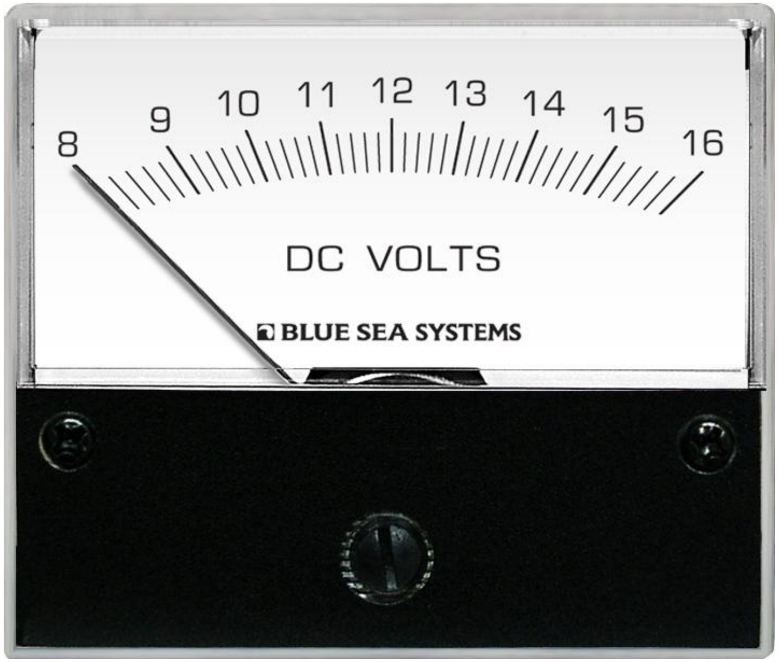
$\boxed{F = 1.2\text{x}10^{8}\ \text{N}}$



Force is 35 orders of magnitude larger!

Voltmeter

We can measure the potential energy with a voltmeter

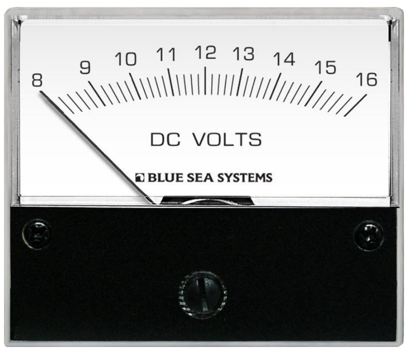


Volt times current is power

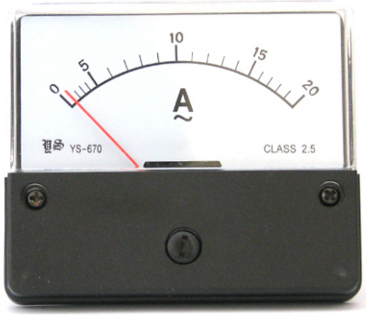
If volt is 'energy per charge' and current is 'charge passing per time', the product of the two is power

volt = joule / coulomb,   ampere = coulomb / second

volt x ampere = (J/C)x(C/s) = joule / second = watt



X



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$$\boxed{V \times I = P}$$

Multimeter

Everything can be measured with a multimeter

Note there is no 'power' meter on a multimeter

kwH

If power is the product of volt and ampere, the integral of power is energy

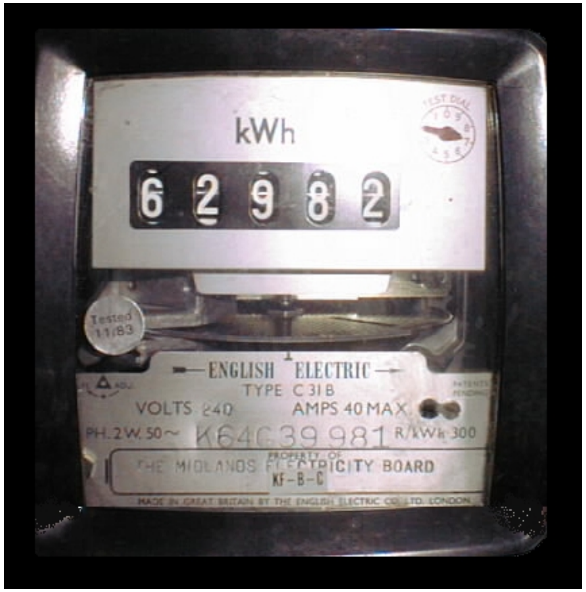
volt = joule / coulomb,   ampere = coulomb / second

volt x ampere = (J/C)x(C/s) = joule / second = watt

energy = power x time
joule = (joule/second) x second

$P(t) = V(t) \times I(t)$

$E = \int P(t)dt = \int V(t)I(t)\, \mathrm{d}t$



MIEET. The levels of knowledge

Physics

Electronics

Digital Electronics

Integrated Circuits

Micro Assembler

Machine Language

Macro Assembler

High Level Programming Languages

Object-oriented Programming

Distributed Programming

Information Processing

Optics / EM Waves

Telecommunications

Internet