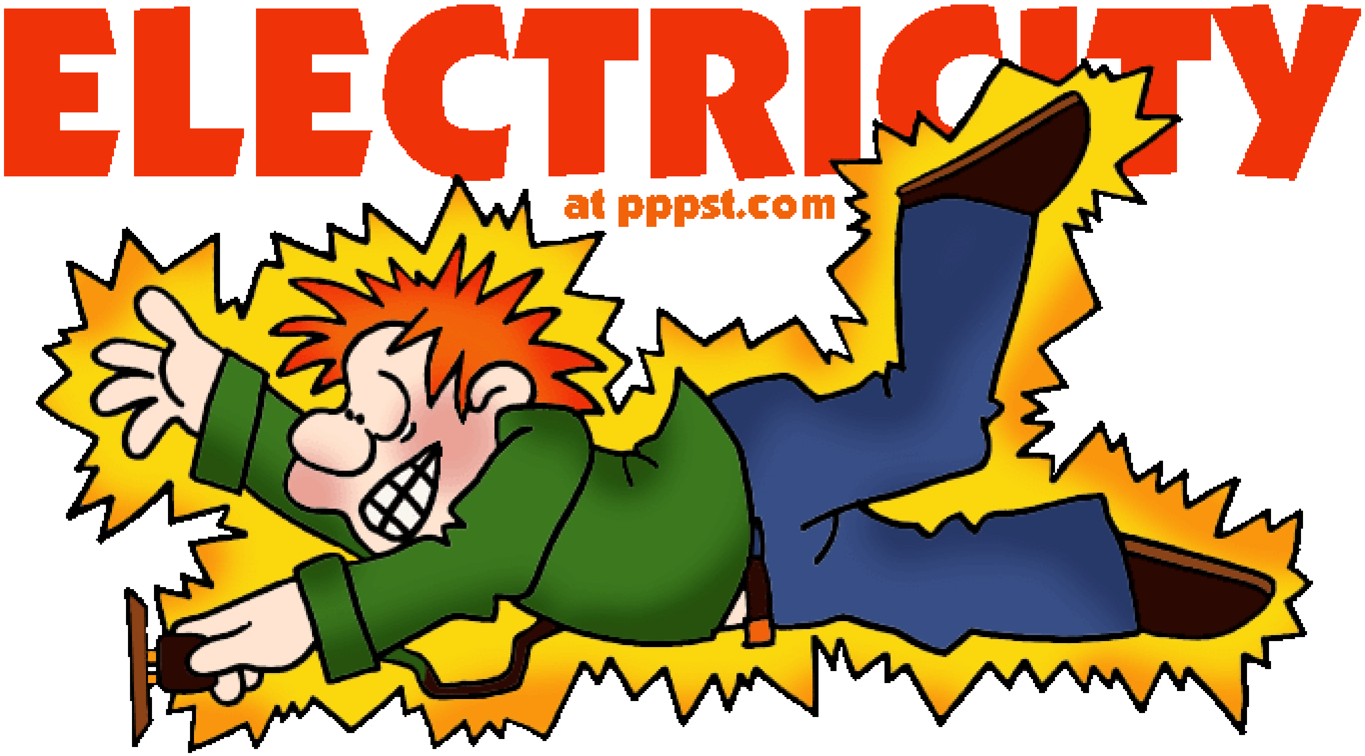

ELECTRICITY
at pppst.com

Electrostatics

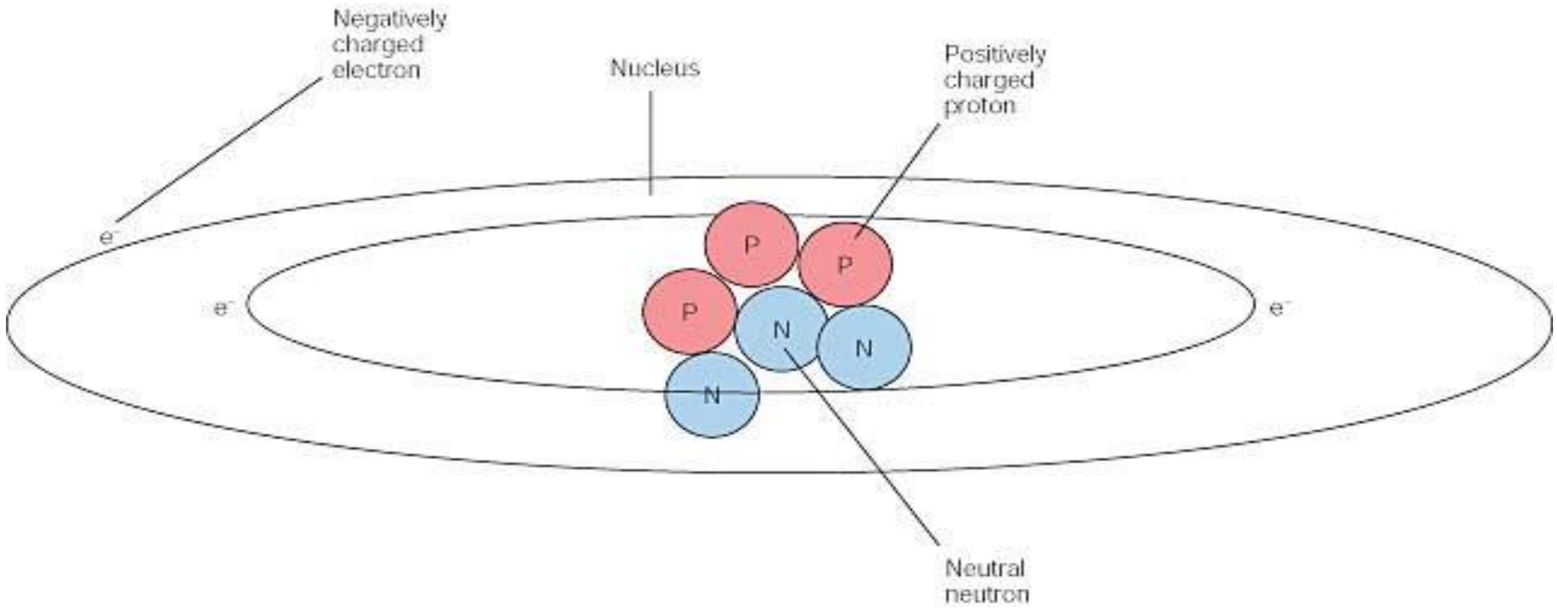
Nay, electrophun!!!

What is electricity?

The collection or flow of electrons in the form of an electric charge

Electric Charge and Electrical Forces:

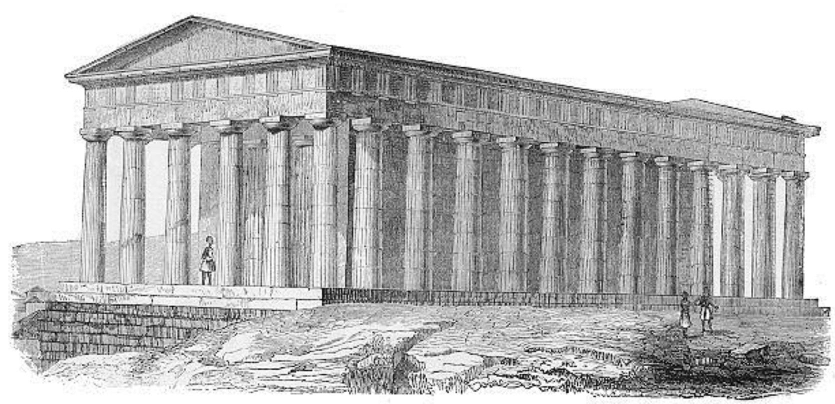
- Electrons have a negative electrical charge.
- Protons have a positive electrical charge.
- These charges interact to create an electrical force.
  - Like charges produce repulsive forces – so they repel each other (e.g. electron and electron or proton and proton repel each other).
  - Unlike charges produce attractive forces – so they attract each other (e.g. electron and proton attract each other).



A very highly simplified model of an atom has most of the mass in a small, dense center called the nucleus. The nucleus has positively charged protons and neutral neutrons. Negatively charged electrons move around the nucleus at much greater distance. Ordinary atoms are neutral because there is a balance between the number of positively charged protons and negatively charged electrons.

History

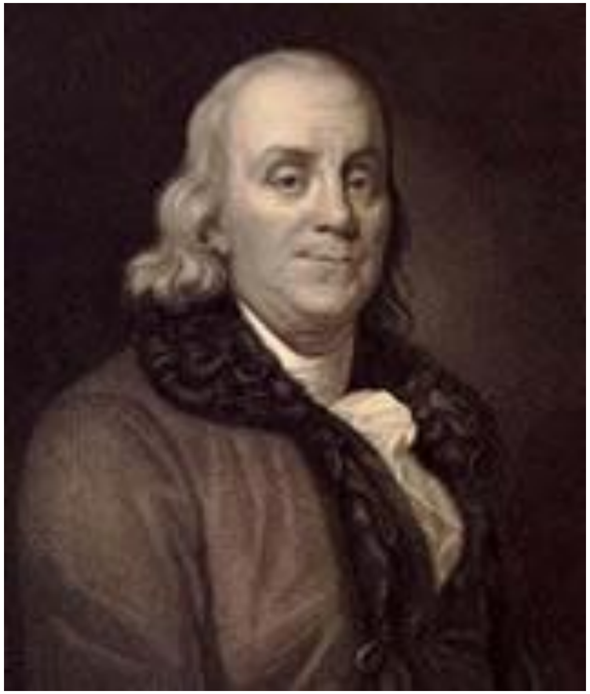
- The word *electricity* comes from the Greek *elektron* which means “amber”.
- The “amber effect” is what we call *static electricity.*

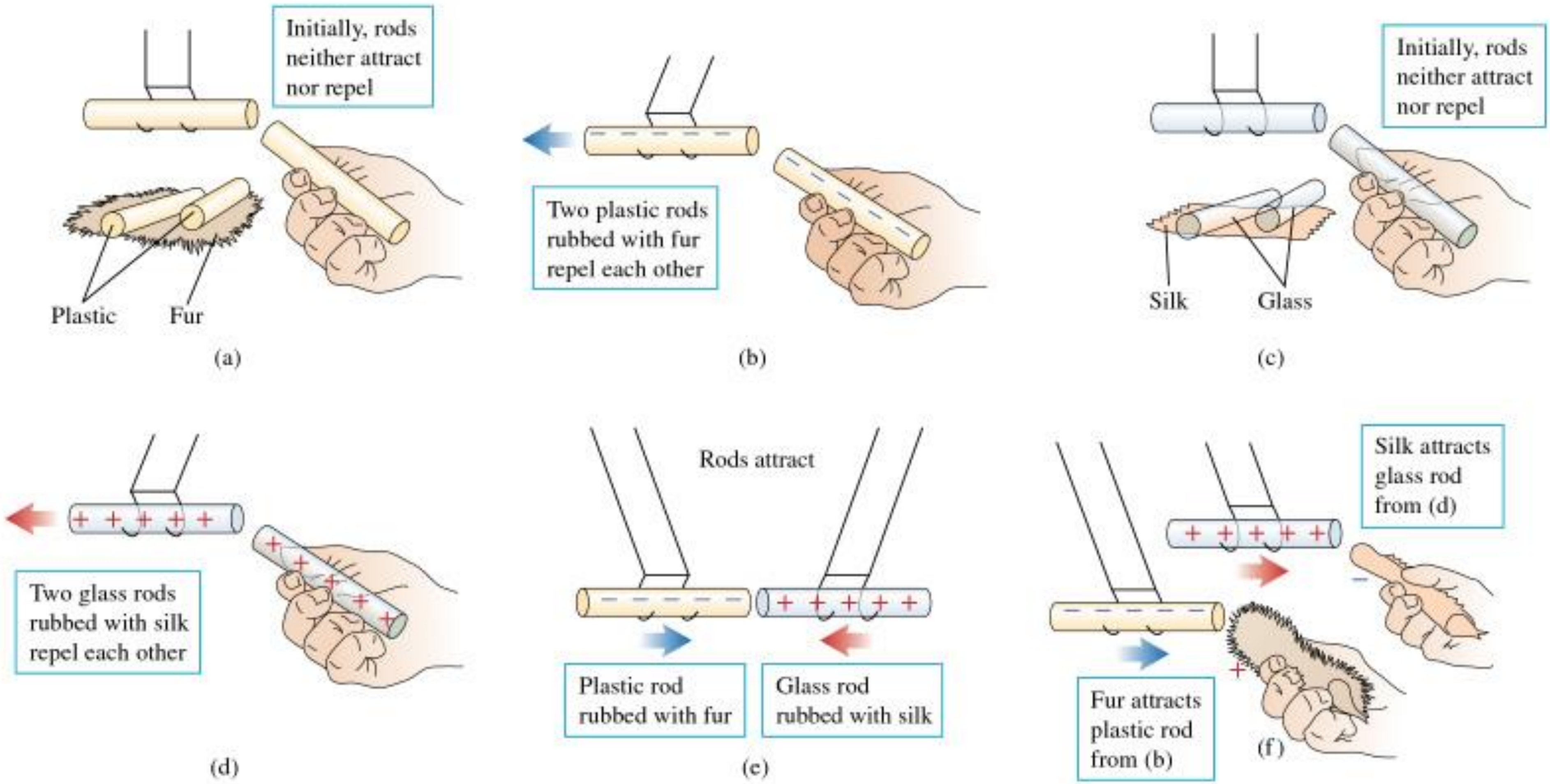


View of the Temple of Theseus at Athens.

History

- Ben Franklin made the arbitrary choice of calling one of the demo situations *positive* and one *negative*.
- He also argued that when a certain amount of charge is produced on one body, an equal amount of the opposite charge is produced on the other body…




Initially, rods neither attract nor repel
Plastic
Fur
(a)
Two plastic rods rubbed with fur repel each other
(b)
Initially, rods neither attract nor repel
Silk
Glass
(c)
Two glass rods rubbed with silk repel each other
(d)
Rods attract
Plastic rod rubbed with fur
Glass rod rubbed with silk
(e)
Silk attracts glass rod from (d)
Fur attracts plastic rod from (b)
(f)

Charge Concepts

- Opposite charges attract, like charges repel.
- Law of Conservation of Charge:
  - The net amount of electric charge produced in any process is zero.
- **Symbol**: q, Q
- **Unit**: C, Coulomb

Elementary Particles

Particle	Charge, (C)	Mass, (kg)
electron	$-1.6x10^{-19}$	$9.109x10^{-31}$
proton	$+1.6x10^{-19}$	$1.673x10^{-27}$
neutron	0	$1.675x10^{-27}$

- If an object has a…
  - + charge → it has less electrons than normal
  - – charge → it has more electrons than normal

$$\#electrons = \frac{q_{total}}{1.6x10^{-19}}$$

Ions and Polarity

- If an atom loses or gains valence electrons to become + or − , that atom is now called an *ion*.
- If a molecule, such as H_2O, has a net positive charge on one side and negative charge on the other it is said to be *polar*

Why does…

Chemistry work?

Physics!!!

The electrostatic forces between ions (within molecules) form bonds called ionic bonds…all bonds are ionic; others, like covalent, are to a much lesser degree so that you can ignore the ionic properties of that type of bond.

Why does…

Biology work?

Physics!!!

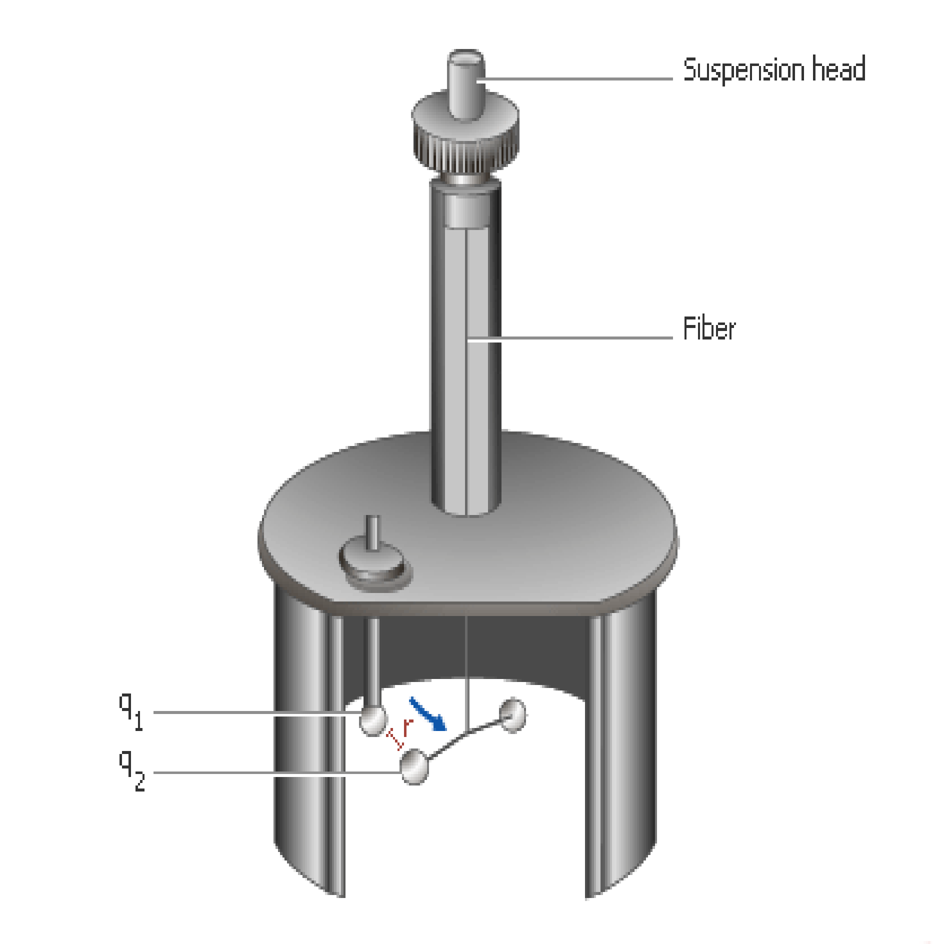
The intermolecular electrostatic forces between polar molecules make such things as the DNA double helix possible.

Electric Force

Coulomb's Law

Using a torsion balance, Coulomb found that: *the electric force between two charges is proportional to the product of the two charges and inversely proportional to the square of the distance between the charges.*

Electric Force



Electric Force

$$\vec{F}_E = k_c \frac{q_1 q_2}{r^2}$$

- q → charge, C
- r → distance between charges, m
- F_E → Electric Force, N → VECTOR
- k_c → coulomb constant, $8.99 \times 10^9 Nm^2/C^2$

Coulomb Constant

$$k_c = 8.99 \times 10^9 \frac{Nm^2}{C^2}$$

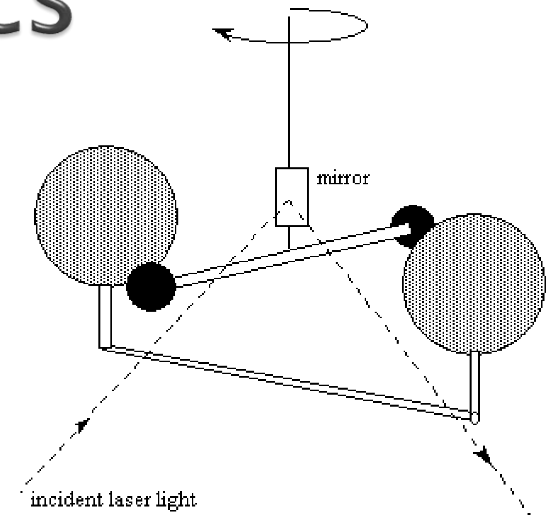
$$or$$

$$k_c = \frac{1}{4\pi\varepsilon_0}$$

$$\varepsilon_0 = 8.854 \times 10^{-12} \frac{C^2}{Nm^2}$$

History of electrostatics

- Basic principles established for macroscopic objects in late 1700s
  - Analysis of interactions between charged objects
  - Phenomenological model
- Applicable over 25 orders of magnitude in length:
  - Earth's magnetic field (10^7 m)
  - Coulomb experiments (10^0 m)
  - α particle scattering (Rutherford, 10^{-13} m)
  - Electron-positron scattering (QED, 10^{-18} m)



Schematic of Cavendish apparatus used by Coulomb. Picture from http://www.fas.harvard.edu/~scdiroff/lds/NewtonianMechanics/CavendishExperiment/CavendishExperiment.html

Coulomb's law

- Every model uses Coulomb's law (somewhere)
- Phenomenological model circa 1785 for charge-charge interactions in a vacuum
- Relates potential to charge for *homogeneous* dielectric materials
- Provides *superposition* of potentials
- Assumptions:
  - Vacuum
  - Point charges
  - No mobile ions
  - Infinite boundaries

$$u(r) = \frac{q_1 q_2}{4\pi\varepsilon_0 r}$$

Electrostatics uses a bewildering number of unit conventions

- Basic unit system can be identified by looking for the "$4\pi\epsilon_0$"

Charge (C)

$$u(r) = \frac{q_1 q_2}{4\pi\varepsilon_0 r}$$

Energy (J)

Vacuum permittivity (8.854×10^{-12} $C^2\ J^{-1}\ m^{-1}$)

Distance (m)

SI units

- Charge: C
- Energy: J
- Distance: m
- Potential: V = J C^{-1}
- Capacitance: F = C V^{-1}

$$e_c = 1.602\times10^{-19}\ \text{C}$$

$$\varepsilon_0 = 8.854\times10^{-12}\ \text{C}^2\ \text{J}^{-1}\ \text{m}$$

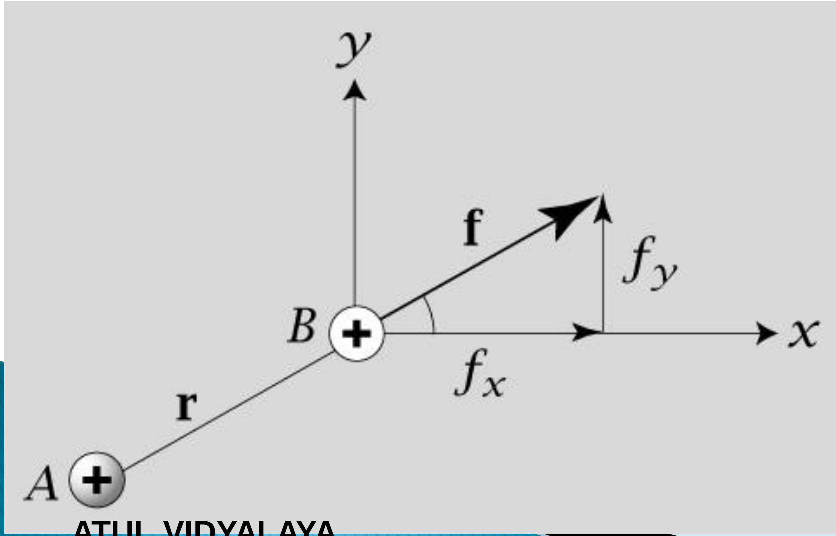
$$N_{av} = 6.022\times10^{23}\ \text{mol}^{-1}$$

$$\frac{N_{av}e_c^2}{4\pi\varepsilon_0} = 1.386\times10^{-4}\ \text{J m mol}^{-1}$$

$$u(r) = \frac{z_1 z_2}{r}\times\left(1.386\times10^{-4}\ \text{J m mol}^{-1}\right)$$

Electrostatic forces

- Force is the negative gradient of the potential
- *Assume* all other terms are constant (homogeneous medium)
- Force is vector-valued



$$f_i = -(\nabla u)_i$$

$$\mathbf{f} = \frac{q_A q_B}{4\pi\varepsilon_0 D r^2}\frac{\mathbf{r}}{r}$$

$$f_r = \frac{q_A q_B}{4\pi\varepsilon_0 D r^2}$$

$$f_x = \frac{q_A q_B}{4\pi\varepsilon_0 D r^2}\cos\alpha$$

$$f_y = \frac{q_A q_B}{4\pi\varepsilon_0 D r^2}\sin\alpha$$

Force on charge B due to charge A.