Charge is quantized in units of |e|.

We don't know why

SI unit of Charge ⇒ Coulomb
MKS

def: Amount of charge flowing thru wire in 1 second
When ~~current~~ current in wire is 1 Ampere

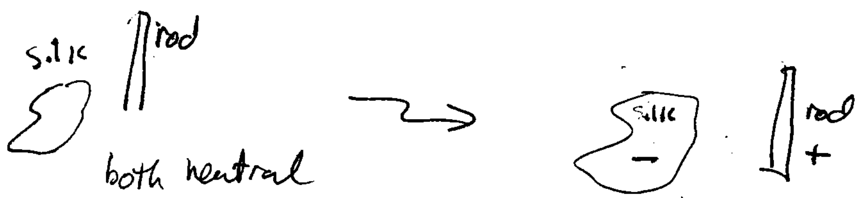
$$e = 1.602177 \times 10^{-19}\ C$$

The "fluid" is electrons

⇒ pith ball DEMO

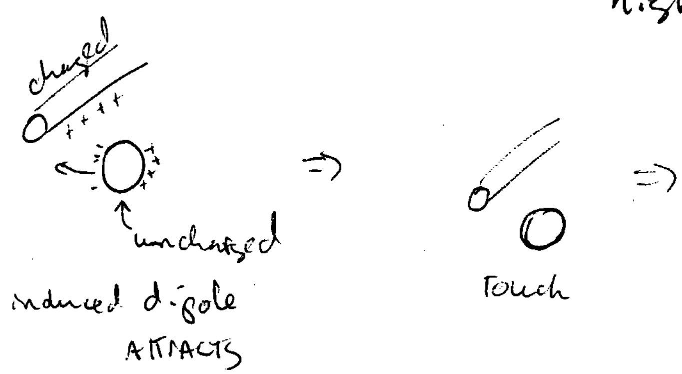
Conductor — electrons free to move about
insulator — electrons locally bound

electric charge is conserved.



Expts at large scale and "quantum scale"
Find this to be true to a very high precision

Ask why



⇒ show silk has opposite charge

Return to Coulomb

Coulomb's law

$$\vec{F}_{1,2} = \frac{k q_1 q_2}{r_{12}^2} \hat{r}_{12}$$

in MKS ~~$k = 8.99 \times 10^9 N \cdot m^2/C^2$~~

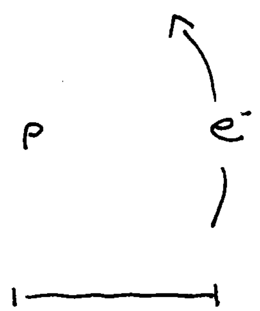
⇒ what would units of k be in MKS system?

$$k = 8.99 \times 10^9 \; N \cdot m^2 / C^2$$

⇒ what's w/ the vectors? why needed

⇒ what does the little "^" mean?

<u>Examples</u> –



H atom

Bohr radius (see later in semester)

$= 5.29 \times 10^{-11}$ m

$m_p = 1.67 \times 10^{-27}$ kg

$m_e = 9.11 \times 10^{-31}$ kg

$$F_{gravity} = \text{attractive} = -\frac{G m_p m_e}{r^2}$$

$$= -\frac{\left(6.67\times10^{-11}\ \frac{N\cdot m^2}{kg^2}\right)(1.67\times10^{-27}\ kg)(9.11\times10^{-31}\ kg)}{(5.29\times10^{-11}\ m)^2}$$

$$= 3.6\times10^{-47}\ N$$

⇒ What are units of a Newton? How do you figure it out?

$$F_{em} = \frac{\left(8.99\times10^{9}\ \frac{N\cdot m^2}{C^2}\right)(1.6\times10^{-19}\ C)(-1.6\times10^{-19}\ C)}{(5.29\times10^{-11}\ m)^2}$$

$$= -8.2\times10^{-8}\ N$$

CHECK UNITS

⇒ neg sign means what?

$$\frac{F_{em}}{F_{grav}} = 2\times10^{39} \quad !!$$

⇒ Steve's Trick about signs!!

(b) Calculate velocity of e^-

⇒ How do I do this? ~ centripetal acceleration

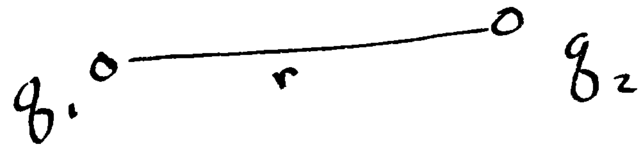
$$|F_{em}| = \frac{m v^2}{r}$$

⇒ circular motion $F = \frac{mv^2}{r}$!!

$$\frac{8.2\times10^{-8}\ N\ (5.29\times10^{-11}\ m)}{(9.11\times10^{-31}\ kg)} = v^2$$

$$v = 2.2\times10^{6}\ m/s$$

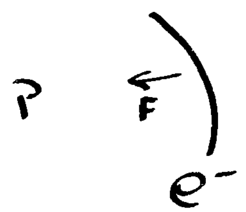
Last class



Coulombs law $\quad \vec{F} = \frac{k q_1 q_2}{r^2} \hat{r}$

- sign → attractive
+ sign → repulsive

Example



Hydrogen Atom

$m_e = 9.11 \times 10^{-31}$ kg

~radius ~ 5.3×10^{-11} m

$q_e = q_p = 1.6 \times 10^{-19}$ coul

(a) Velocity of e^- ?

$$F_{centripetal} = \frac{mv^2}{r}$$

Electrostatics

$$\frac{k q_1 q_2}{r^2} = \frac{mv^2}{r} \leadsto v = 2.2 \times 10^6 \ m/s$$

(b) How much energy is required to ionize Hydrogen ?

just about the most fundamental question you can ask abt the element

lots of chemistry in this

(c) energy required to ionize Hydrogen

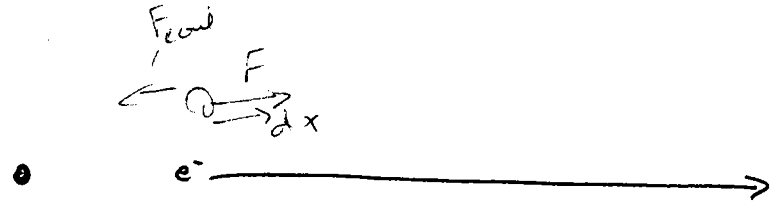
⇒ How do I do this ?

do as Σ of segments

energy = work

work = $\int F \cdot dx$

work ⇒



$$work = \int_{r_0}^{\infty} F \cdot dx$$

$$= \int_{r_0}^{\infty} \frac{k|q_1 q_2|}{r^2} dr = k|q_1 q_2| \int_{r_0}^{\infty} \frac{dr}{r^2}$$

$$work = k|q_1 q_2| \left[-\frac{1}{r} \right]_{r_0}^{\infty} = k|q_1 q_2| \frac{1}{r_0}$$

already TAKE into account "–" sign by choosing direction of force

$$= \frac{\left(8.99 \times 10^9 \frac{N \cdot m^2}{C^2}\right)\left(1.6 \times 10^{-19} C\right)^2}{\left(5.29 \times 10^{-11} m\right)} = ~~3.1 \times 10^{3}~~ \; 4.3 \times 10^{-18} J$$

~~Means I have to~~

1 Joule = 6.2×10^{18} eV

$$(4.3 \times 10^{-18} J)\left(6.2 \times 10^{18} \frac{eV}{J}\right) = 26.9 \text{ eV}$$

e^- already has

$$F = \frac{mv^2}{r} \rightarrow v^2 = \frac{k q_1 q_2}{r m}$$

$$\frac{1}{2} mv^2 = \frac{1}{2} \frac{k q_1 q_2}{r} = E_{e^-}^{KE}$$

∴ E needed to ionize = 13.5 eV