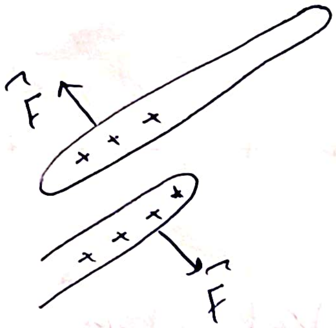
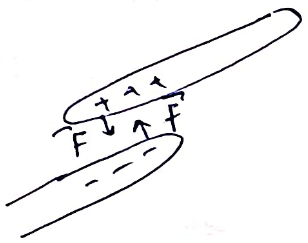
Ch 21: Coulomb's Law



→ Two charged rods of the same sign repel each other.



→ Two charged rods of opposite singns attrect each other.

- Eletric charges : → positive charge
  → negative charge

- In most every day objects, there are about equal number of negatively charged particles & positively charged particles (balanced or neutral)
  ⇒ the net charge is zero

⇒ Conductors & Insulators:
Materials classified based on their ability to move charge.

- conductors: are materials in which a significant number of electrons are free to move. eg: metals
- Insulators: the charged particles are not free to move. eg: glass, plastic.
- Semiconductors: materials that are intermediate between conductors & insulators. eg: silicon.

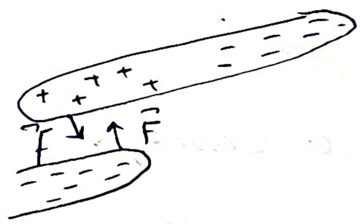
- superconductors : materials that are perfect conductors

⇒ Charged particles :
Atoms : (+) protons + (neutral) neutrons + (-) electrons
nucleus

if # protons = # electrons ⇒ "neutral atom"

* in conductors, the free electrons called conduction electrons

⇒ Induced charges :
which means that some of its positive & negative charges have been separated due to the presence of a near by charge.

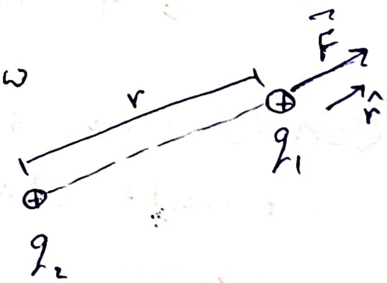


neutral copper

⇒ Coulomb's Law :
describes the electrostatic force between two charged particles.

$$F = k \frac{|q_1|\,|q_2|}{r^2}$$

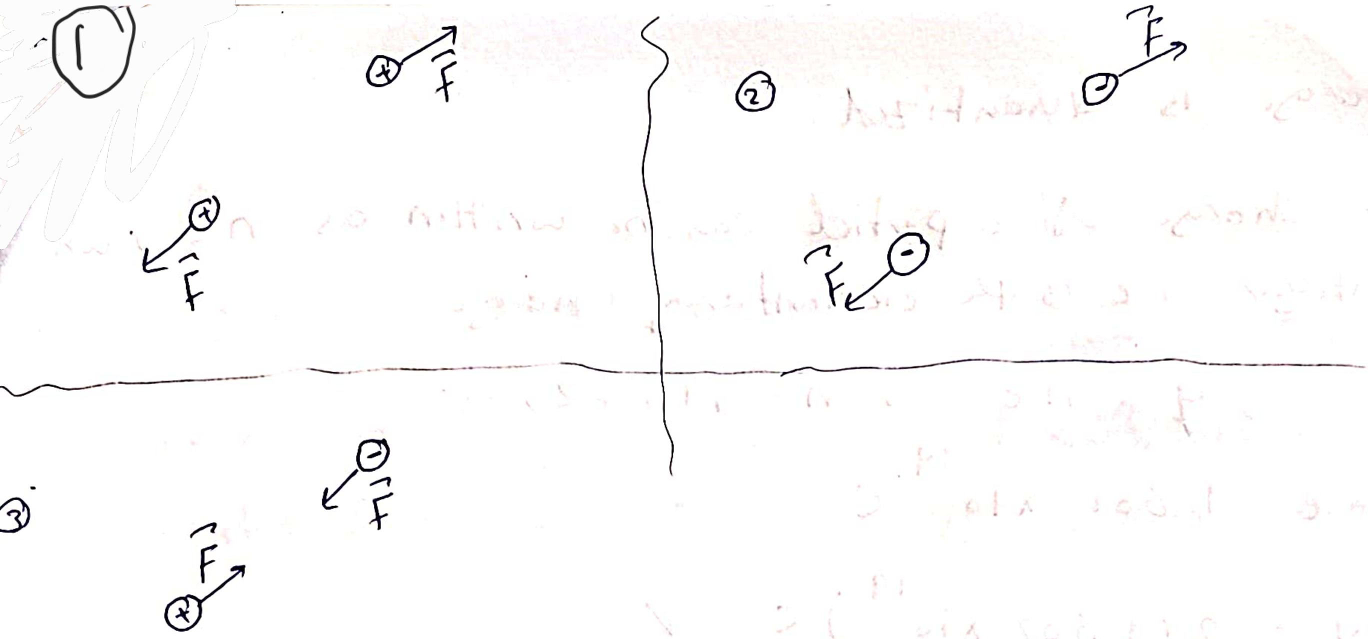
*[inverse square law $\propto \frac{1}{r^2}$]



$k = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ N\,m^2/C^2$ [coulomb's Constant]

$\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/N\,m^2$ [permittivity Constant]

r : seperation distance.



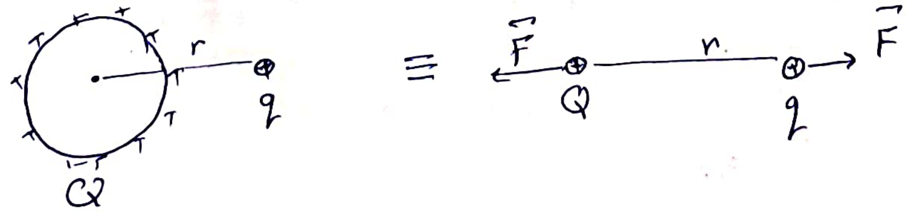
* The electrostatic force vector acting on a charged particle due to a second charged particle is either directly toward the second particle (opposite signs of charge) or directly away from it (same sign of charge)

* Multiple forces: if multiple electrostatic forces act on a parti. , the net force is the vector sum of the individual forces.

$$\vec{F}_{net} = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \cdots$$

* shell theories:

① a charged particle outside a shell with charge uniformly distributed on its surface is attracted or repelled as if the shells charge were concentrated as a particle at its center,



② a charged particle inside a shell with charge uniformly distributed on its surface has no net force acting on it due to the shell

⇒ Charge is Quantized :

The charge of a particle can be written as ne ; where n : integer , e is the elementary charge

$$q = ne \quad ; \; n = \mp 1, \mp 2, \dots$$

$$e = 1.602 \times 10^{-19} \, C$$

$$q = 2(1.602 \times 10^{-19})\,C \quad ✓$$

$$q = 1.5(1.602 \times 10^{-19})\,C \quad ✗$$

⇒ Conservation of charge :

The net electric charge of any isolated system is always conserved.

S.P (21.1)

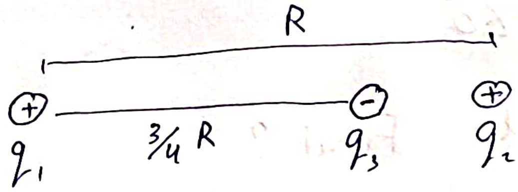
b) $q_1 = 1.6 \times 10^{-19}$ C

$q_2 = 3.2 \times 10^{-19}$ C

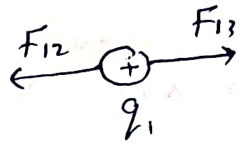
$q_3 = -3.2 \times 10^{-19}$ C

$R = 0.02$ m

Find F_{net} ?



$$\vec{F}_{net} = \vec{F}_{12} + \vec{F}_{13}$$



$$F_{13} = k \frac{q_1 q_3}{r_{13}^2} = \frac{8.99 \times 10^9 \times (1.6 \times 10^{-19})(3.2 \times 10^{-19})}{(\frac{3}{4}(0.02))^2}$$

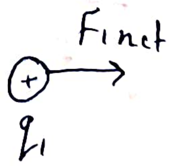
$$= 2.05 \times 10^{-24} \text{ N } (\hat{i})$$

$$F_{12} = k \frac{q_1 q_2}{(r_{12})^2} = \frac{8.99 \times 10^9 (1.6 \times 10^{-19})(3.2 \times 10^{-19})}{(0.02)^2}$$

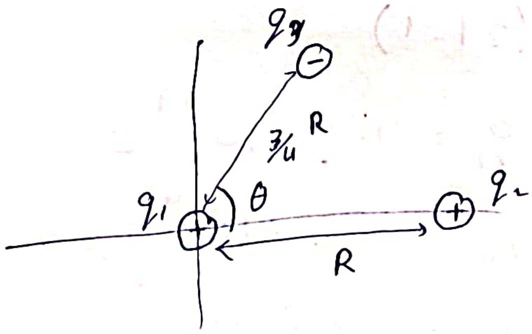
$$= -1.15 \times 10^{-24} \text{ N } (\hat{i})$$

$$\vec{F}_{net} = -1.15 \times 10^{-24} \hat{i} + 2.05 \times 10^{-24} \hat{i}$$

$$= 9 \times 10^{-25} \text{ N } \hat{i}$$



c) $\theta = 60^\circ$

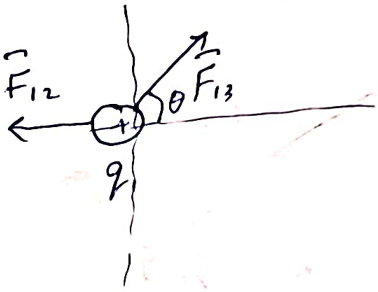


Find $\vec{F}_{1net}$?

$$\vec{F}_{1net} = \vec{F}_{12} + \vec{F}_{13}$$

$$F_{12} = 1.15 \times 10^{-24} \text{ N}$$

$$F_{13} = 2.05 \times 10^{-24} \text{ N}$$



using vector sum :

$$\vec{F}_{12} = -1.15 \times 10^{-24} \, \hat{i}$$

$$\vec{F}_{13} = (2.05 \times 10^{-24} \cos\theta)\,\hat{i} + (2.05 \times 10^{-24} \sin\theta)\,\hat{j}$$

$$= 1.025 \times 10^{-24} \, \hat{i} + 1.775 \times 10^{-24} \, \hat{j} \text{ N}$$

$$\vec{F}_{1net} = \vec{F}_{12} + \vec{F}_{13}$$

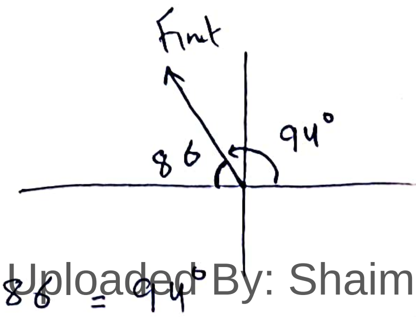
$$= [-1.15 \times 10^{-24} + 1.025 \times 10^{-24}]\,\hat{i} + 1.775 \times 10^{-24} \, \hat{j}$$

$$= -1.25 \times 10^{-25} \, \hat{i} + 1.78 \times 10^{-24} \, \hat{j} \text{ N}$$

$$F_{1net} = \sqrt{F_{1net\,x}^2 + F_{1net\,y}^2}$$

$$= 1.78 \times 10^{-24} \text{ N}$$

$$\theta = \tan^{-1}\left(\frac{F_{1net\,y}}{F_{1net\,x}}\right) = 86$$

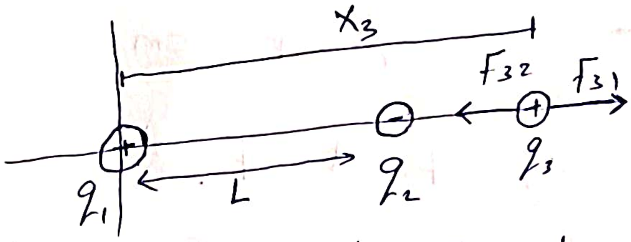


If we want from +x ⇒ 180 - 86 = 94

P5

$q_1 = 6\,\mu C$ at $x_1 = 0$

$q_2 = -2\,\mu C$ at $x_2 = 10$ cm



L = 10 cm, if q_3 is to be located such that the net electrostatic force on it from q_1, q_2 is zero, Find x_3?

$$\sum \vec{F}_3 = 0$$

$$\Rightarrow F_{32} = F_{31}$$

$$\frac{K q_3 q_2}{(x_3 - L)^2} = \frac{K q_3 q_1}{x_3^2}$$

$$\frac{6 \times 10^{-6}}{x_3^2} = \frac{2 \times 10^{-6}}{(x_3 - L)^2}$$

$$\sqrt{\frac{3}{x_3^2}} = \sqrt{\frac{1}{(x_3 - L)^2}}$$

$$\frac{1.73}{x_3} = \frac{1}{x_3 - L} \Rightarrow x_3 = 1.73(x_3 - L)$$

$$0.73\, x_3 = 1.73\, L$$

$$\boxed{x_3 = 2.37\, L = 23.7 \text{ cm}}$$

$$y_3 = 0$$

18 $q_1 = q_2 = -1 \times 10^{-16}$ C

$r = 1.2$ cm

a) Find F ?

$$F = k \frac{q_1 q_2}{r^2} = \frac{8.99 \times 10^{9} (1 \times 10^{-16})(1 \times 10^{-16})}{(1.2 \times 10^{-2})^2}$$

$$= 6.2 \times 10^{-19} \text{ N}$$

b) how many excess electrons are on each drop?

$$q = ne \Rightarrow n = \frac{q}{e} = \frac{1 \times 10^{-16}}{1.6 \times 10^{-19}} = 625 \text{ electron}$$

22 $r = 3.2 \times 10^{-3}$ m

$a_1 = 6 \text{ m/s}^2$, $a_2 = 9 \text{ m/s}^2$

$m_1 = 6.3 \times 10^{-7}$ kg , $q_1 = q_2$

a) Find m_2 ?

$F_1 = m_1 a_1$

$= 6.3 \times 10^{-7} \times 6 = 3.78 \times 10^{-6}$ N

but $F_1 = F_2$ (electrostatic force bt. q_1 & q_2)

$F_2 = m_2 a_2$

$3.78 \times 10^{-6} = m_2 (9)$

$\Rightarrow m_2 = 4.2 \times 10^{-7}$ kg

b) Find q?

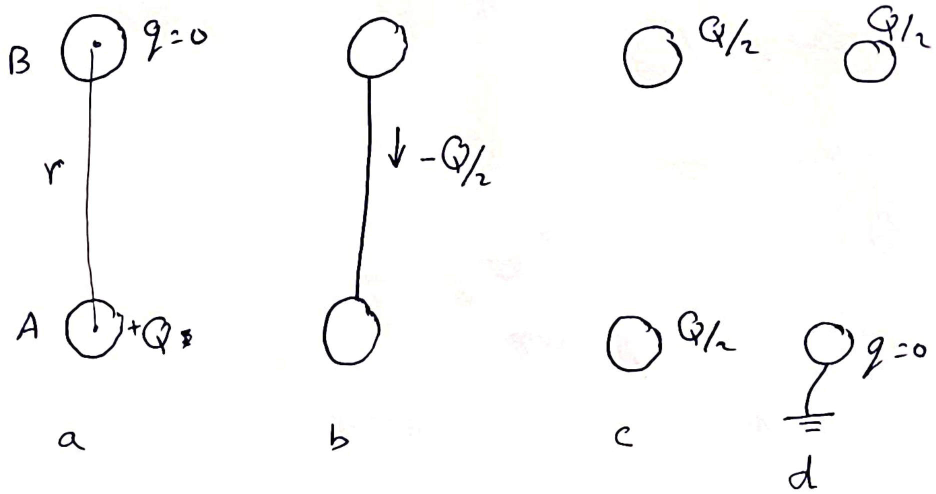
$$F = k\frac{q_1 q_2}{r^2} = \frac{k q^2}{r^2}$$

$$\Rightarrow 8.99\times10^{9}\frac{q^2}{(3.2\times10^{-3})^2} = 3.78\times10^{-6}$$

$$q^2 = 4.3\times10^{-21}$$

$$q = 5.56\times10^{-11}\ C$$

S.P (21-3)



(a) $q_A = +Q$, $q_B = 0$ ⇒ $f = 0$

(b),(c) Free electrons move from B to A until $q_A = q_B = \frac{Q}{2}$

$$F = K \frac{q_A q_B}{r^2}$$

(d) sphere A is grounded ⇒ $q_A = 0$

$$F = 0$$