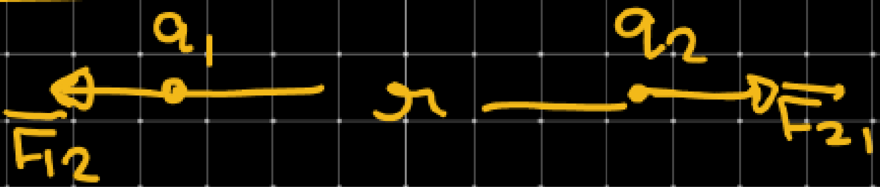
Coulomb's law:



$$|\vec{F}_{12}| = |\vec{F}_{21}| = F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}.$$

$$\boxed{\vec{F}_{12} = -\vec{F}_{21}}$$

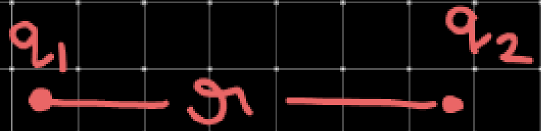
$\varepsilon_0 \rightarrow$ Permittivity of free space.

$$\varepsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{N\text{-}m^2}$$

$[\varepsilon_0]$ — JEE main

Force b/w Point charge q_1 & q_2

In vacuum



$$F_{q_1 q_2} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

ε_0 = Permitivity of free space.

In medium.

$$F_m = \frac{1}{4\pi\varepsilon}\frac{q_1 q_2}{r^2}$$

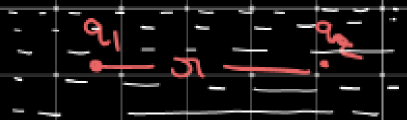
ε = Permitivity of medium

In vacuum

$$F_{air} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

ε_0 = Permitivity of free space.

In medium



$$F_m = \frac{1}{4\pi\varepsilon}\frac{q_1 q_2}{r^2}$$

ε = Permitivity of medium

$\varepsilon =$

$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_0}$$

$$\varepsilon = \varepsilon_r \varepsilon_0$$

$$F_m = \frac{1}{4\pi\varepsilon_0 \varepsilon_r}\frac{q_1 q_2}{r^2}$$

$$F_m = \frac{F_{air}}{\varepsilon_r}$$

$$\varepsilon_r \geq 1$$

Relative permitivity:

$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_0} = \frac{\text{Permitivity of medium}}{\text{Permitivity of freespace}}$$

⇒ Water → $\varepsilon_r = 81$

↳ Permitivity of water = $81\varepsilon_0$

$$\varepsilon_r = \frac{\varepsilon_{water}}{\varepsilon_0}$$

$$81 = \frac{\varepsilon_{water}}{\varepsilon_0}$$

$$\boxed{\varepsilon_{water} = 81\varepsilon_0}$$

Q1) $2\times10^{-3}C$ —— 2m —— $18\times10^{-6}C$

Water $\varepsilon_r = 81$

$\varepsilon_w = 81\varepsilon_0$

$$F_{air} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

$$= 9\times10^9\times\frac{2\times10^{-3}\times18\times10^{-6}}{2^2}$$

$$F_{air} = 9\times9\times10^{9}\times10^{-9}$$

$F_{air} = 81$ Newton.

$2\times10^{-3}C$ —— 2m —— $18\times10^{-6}C$

$\varepsilon = \varepsilon_0\varepsilon_r$

$$F_{med} = \frac{1}{4\pi\varepsilon}\frac{q_1 q_2}{r^2}$$

$$F_{med} = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{q_1 q_2}{r^2}$$

$$F_{med} = \frac{81}{\varepsilon_r}$$

$$F_{med} = \frac{81}{81} = 1N$$

#7 Find minimum possible Force b/w two point charges placed at 1m distance.

q_1 ——— 1m ——— q_2

minimum possible charge $= \pm 1.6 \times 10^{-19}$ C

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

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

$$F = 9\times10^{9}(q_1)(q_2)$$

$$F = K(e)(e)$$

$$\boxed{F = ke^2}$$

$$F_{min} = 9\times10^{9}\times(e)(e)$$

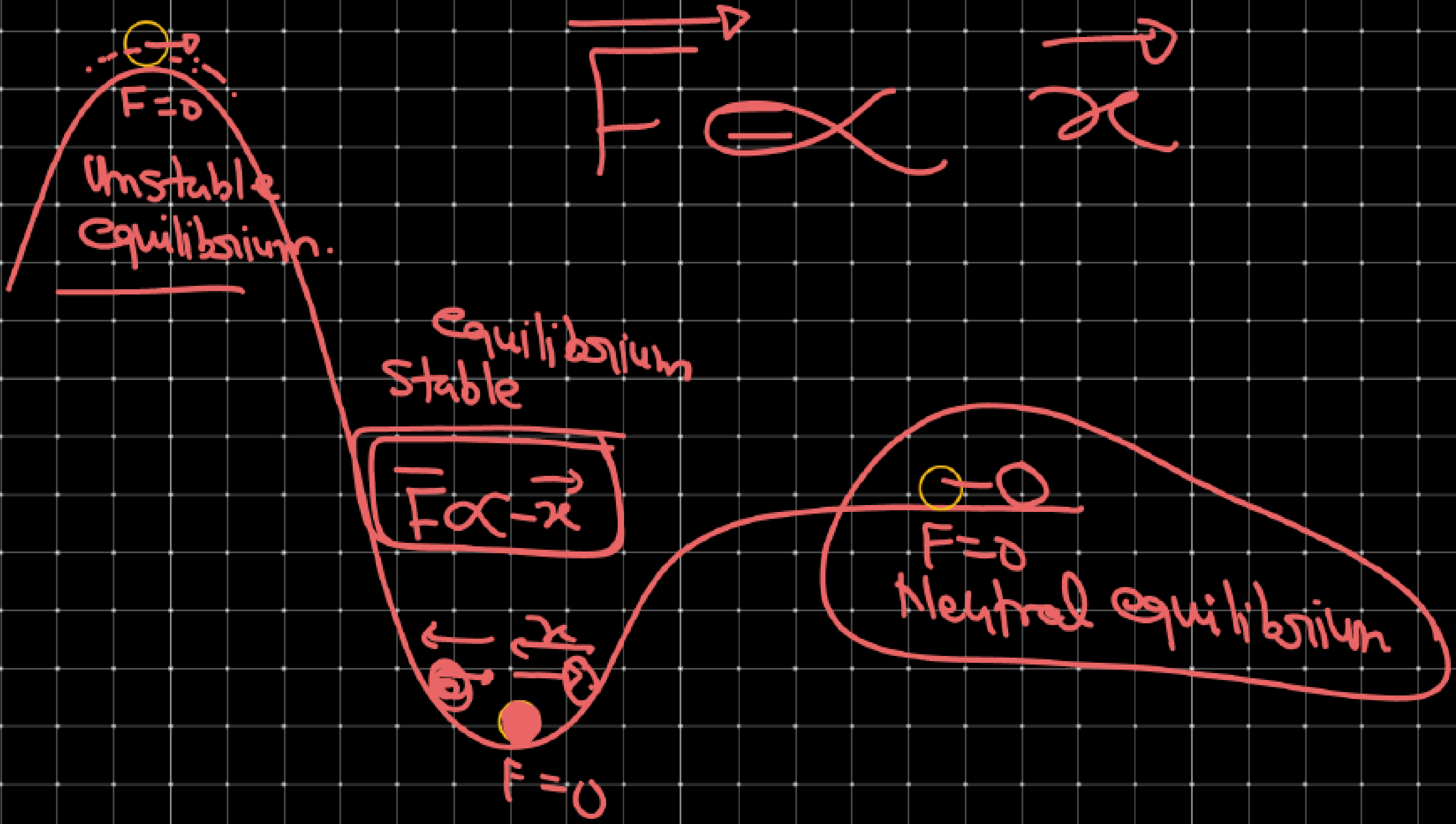
$$F_{min} = 9\times10^{9}\times(1.6\times10^{-19})(1.6\times10^{-19})$$

Equilibrium of charge:-

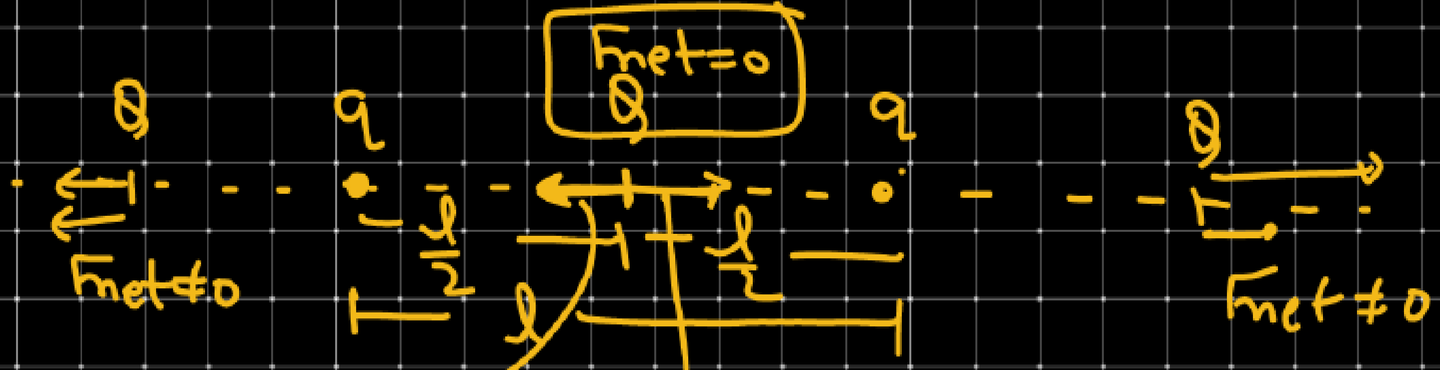
Fnet force = 0

Equilibrium ($F_{net} = 0$)

- Stable equilibrium
- Unstable equilibrium
- Neutral equilibrium.


F ∝ −x
F=0
Unstable equilibrium.
Stable equilibrium
F ∝ −x
x
F=0
F=0
Neutral equilibrium

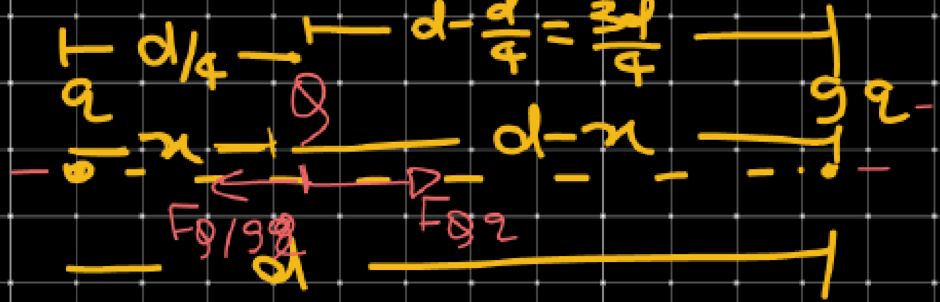
(#) Find position where third charge (Q) placed such that third charge is in equilibrium.



$$\frac{1}{4\pi\varepsilon_0}\frac{qQ}{\left(\frac{l}{2}\right)^2}$$

$$\frac{1}{4\pi\varepsilon}\frac{qQ}{\left(\frac{l}{2}\right)^2}$$

(*)



Q - Third charge

Find location where third charge is placed such that Net Force on third charge is zero.

$$F_{Q/9q} = F_{Qq}$$

$$\frac{K(9q)Q}{(d-x)^2} = \frac{KqQ}{x^2}$$

$$\frac{9}{(d-x)^2} = \frac{1}{x^2}$$

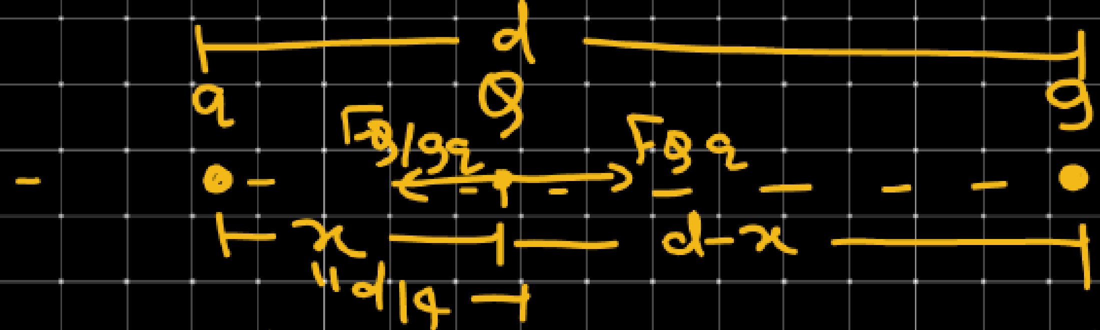
$$9x^2 = (d-x)^2$$

$$(3x)^2 = (d-x)^2$$

$$3x = d-x$$

$$4x = d$$

$$x = \frac{d}{4}$$



$$F_{Q/9q} = F_{Q/q}$$

$$\frac{KQ(9q)}{(d-x)^2} = \frac{KqQ}{x^2}$$

$$\frac{9}{(d-x)^2} = \frac{1}{x^2}$$

$$9x^2 = (d-x)^2$$

$$3^2x^2 = (d-x)^2$$

$$9x^2 = (d-x)^2$$

$$(3x)^2 = (d-x)^2$$

$$3x = d-x$$

$$4x = d$$

$$x = \frac{d}{4}$$

$$(3x)^2 = (d-x)^2$$

$$3x = d-x$$

$$3x+x = d$$

$$4x = d$$

$$x = \frac{d}{4}$$

Q) Find location of third charge where Fnet on third charge is zero.

$\boxed{\frac{d}{3} \text{ from } q}$

$F \propto \frac{q_1 q_2}{r^2}$

$d + \frac{d}{3} = \frac{4d}{3}$ from q_2

Fnet to

$$F_{Qq} = F_{Q(-16q)}$$

$$\frac{kQq}{x^2} = \frac{kQ(16q)}{(d+x)^2}$$

$$\frac{1}{x^2} = \frac{16}{(d+x)^2}$$

$$(d+x)^2 = 16x^2$$

$$(d+x)^2 = (4x)^2$$

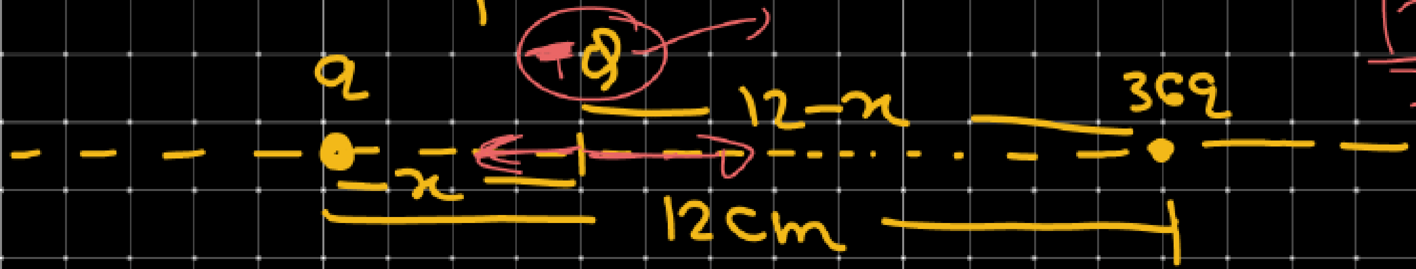
$$d+x = 4x$$

$$d = 4x - x = 3x$$

$$3x = d$$

$$\boxed{x = \frac{d}{3}}$$

Q) Find location of third charge, where third charge is in equilibrium.



$\frac{12}{7}$ cm from q

$$F_{qq} = F_{q(36q)}$$

$$\frac{kqq}{x^2} = \frac{kq(36q)}{(12-x)^2}$$

$$(12-x)^2 = 36x^2$$

$$(12-x)^2 = (6x)^2$$

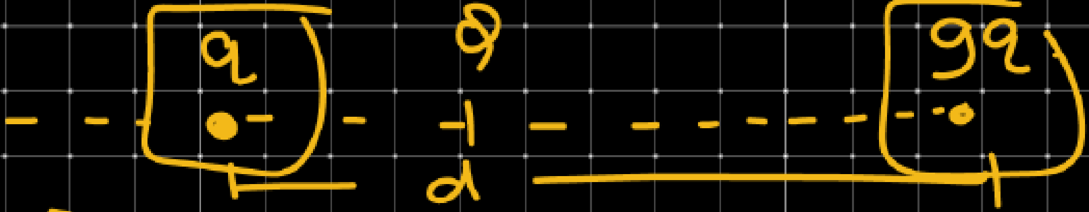
$$12-x = 6x$$

$$12 = 7x$$

$$x = \frac{12}{7}\,\text{cm}$$

System is in equilibrium

(i) Net force in all charge is zero.



Find Position of third charge & value of Charge such that whole system is in equilibrium.

Solve) (i) first we find position of third Charge where net Force is zero on third Charge.

(ii) Second step then we find Net Force on any other charge & taken equal to zero.