LAKSHYA JEE 2025

Physics

Lecture - ০৪

Electric Charge and Field

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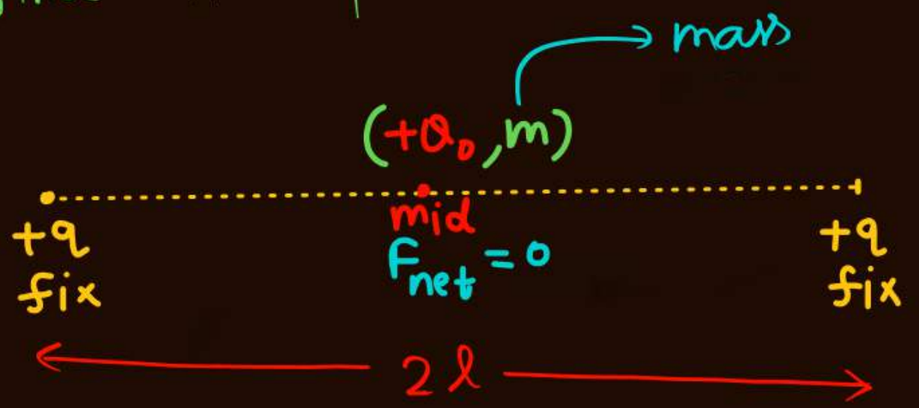
Topics to be covered

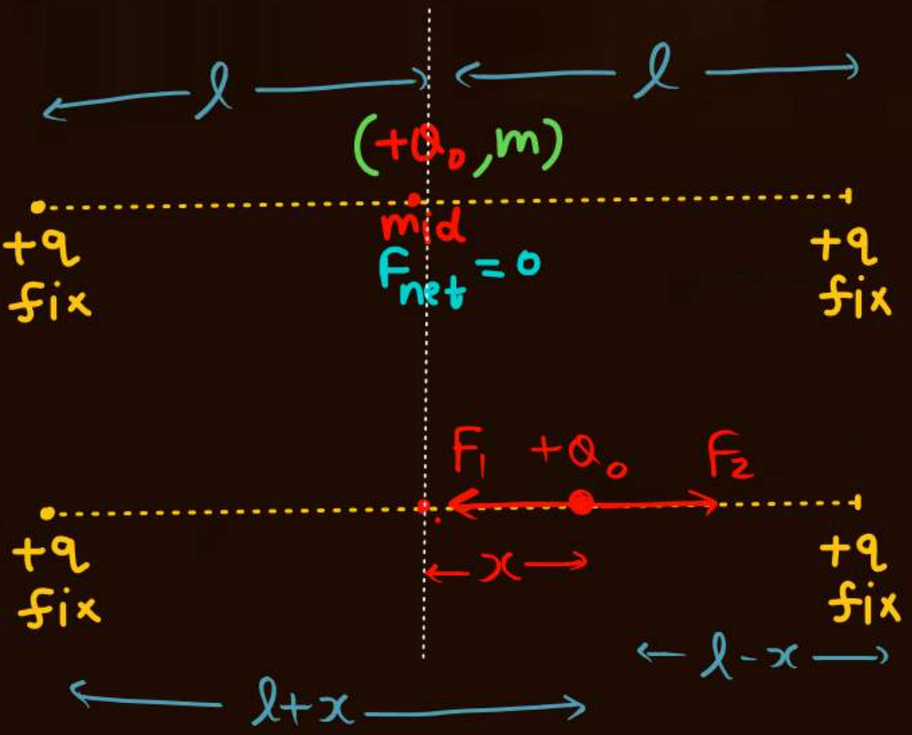
1. Ques Based on SHM + Columb Law
2. # Vector form of Coulomb law
3. # Electric field (Introduction)
4. #

If charge q_0, m is slightly displaced from its mean position along x-axis

Q find time period of oscillation.



Sol^n



$$F_{net} = F_2 - F_1 = \frac{kQq}{(l+x)^2} - \frac{kQq}{(l-x)^2}$$

$$F_{net} = kQq\left[\frac{1}{(l+x)^2} - \frac{1}{(l-x)^2}\right]$$

$$= kQq\left[\frac{(l-x)^2 - (l+x)^2}{(l+x)^2(l-x)^2}\right]$$

$$F_{net} = kQq\left[\frac{-4lx}{(l^2-x^2)^2}\right]$$

$$F_{net} = -\frac{(kQq\,4l)\,x}{(l^2-x^2)^2}$$

SHM ✗

If $x \ll l$ $\quad l^2 - x^2 \approx l^2$

$$F_{net} = -\frac{1}{4\pi\epsilon_0}\frac{(Qq\,4l)}{l^4}x$$

$$\boxed{F_{net} = -\frac{Qq}{\pi\epsilon_0 l^3}x}$$

$$F_{net} = -\frac{Qq}{\pi\epsilon_0 l^3} x$$

$$F_{net} = -kx$$

In SHM If

$$\vec{F_{net}} = -k\vec{x}$$

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$\boxed{T = 2\pi\sqrt{\frac{m}{\frac{Qq}{\pi\epsilon_0 l^3}}}}$$

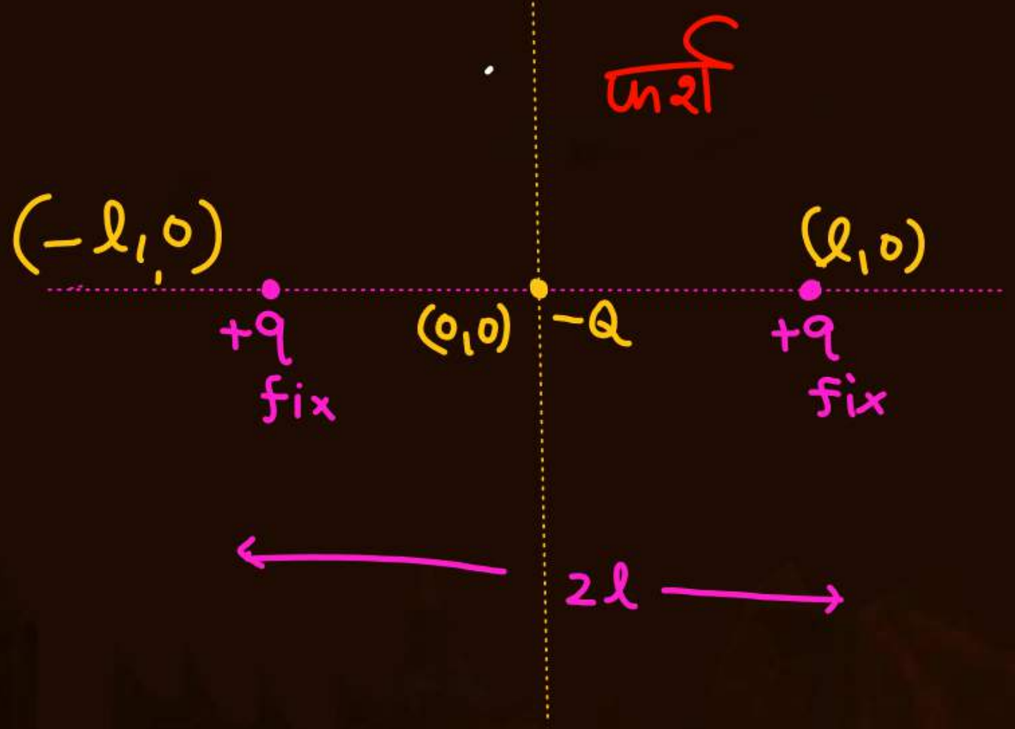
HW

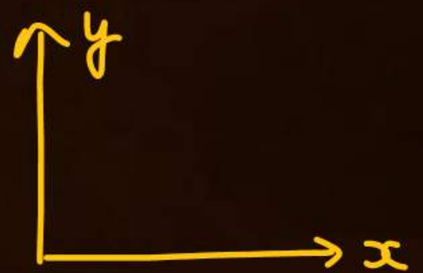
Q

(Will Discuss tomarrow)

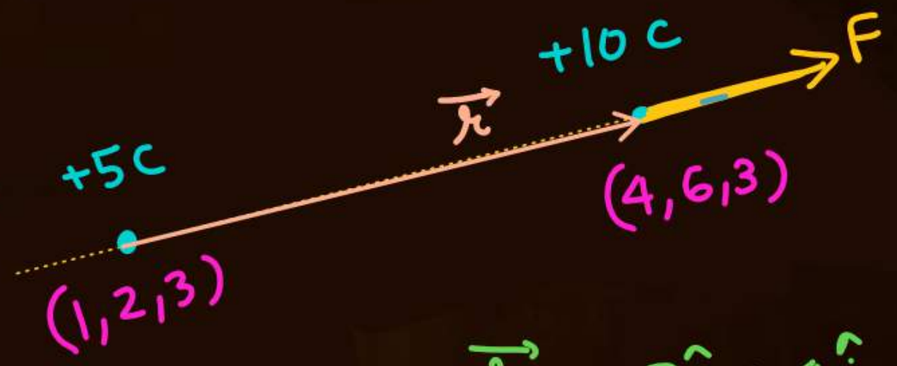
If $-Q$ charge having mass m is displaced slightly along +Y Axis (+y -axis) find time period of oscillation.

(mg → neglected
friction → absent





Q force applied by +5C on +10C in vector form



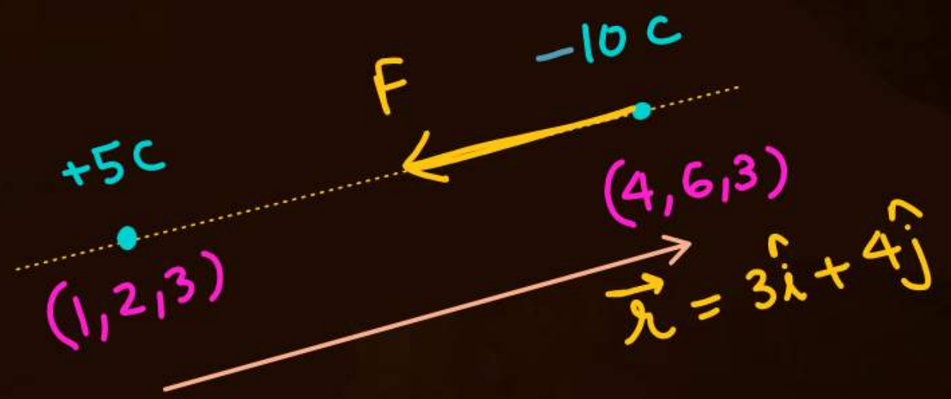
$$\vec{F} = \frac{Kq_1q_2}{r^2}\hat{r} = \frac{9\times10^9\times5\times10}{25}\times\left(\frac{3\hat{i}+4\hat{j}}{5}\right)$$

$$= 36\times10^8\left(3\hat{i}+4\hat{j}\right)$$

$$\vec{r} = 3\hat{i}+4\hat{j}$$

$$\hat{r} = \frac{3\hat{i}+4\hat{j}}{5}$$

Q force applied by $+5C$ on $-10C$ in vector form



$$= \frac{Kq_1q_2}{r^2}(-\hat{r})$$

magnitude ⟹ direction

$$= \left(\frac{9\times10^9 \times 5 \times 10}{25}\right)\left(-\frac{3\hat{i}+4\hat{j}}{5}\right) = -36\times10^8(3\hat{i}+4\hat{j})$$

इसे पढ़ना नहीं है

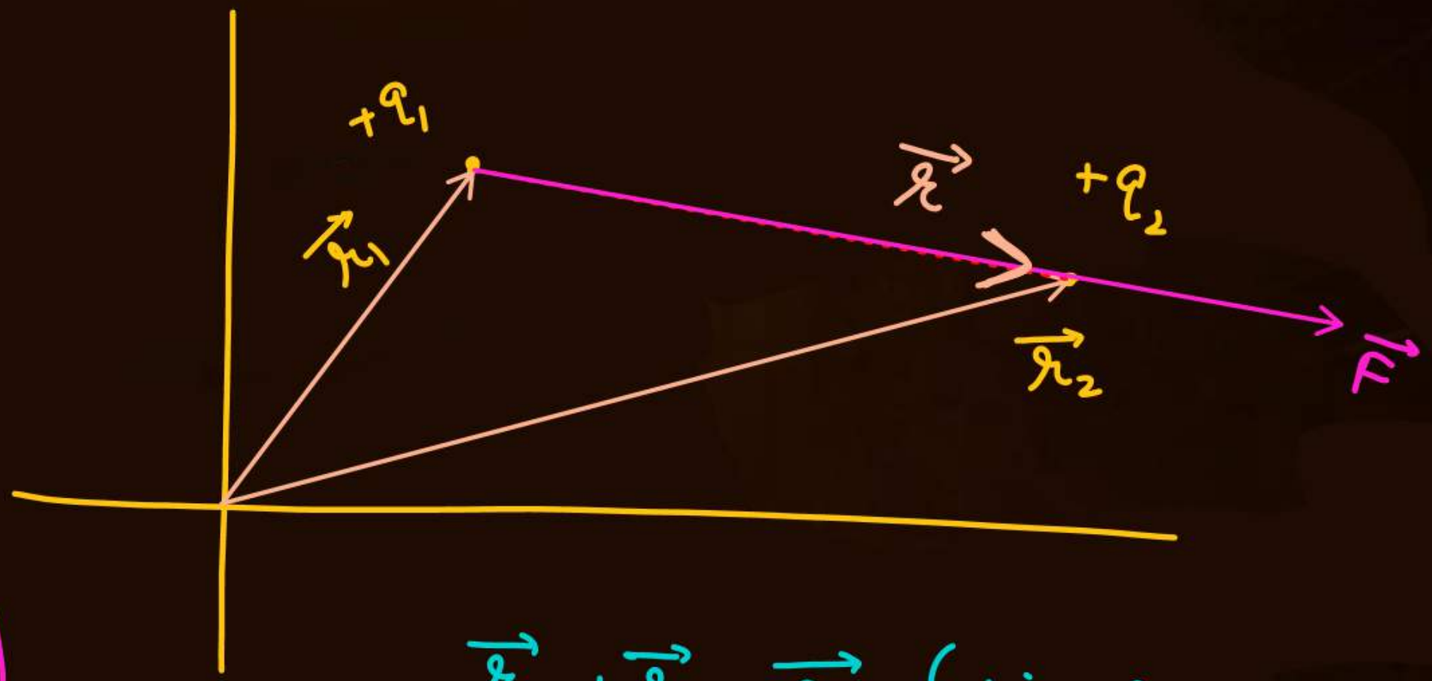
Note

force by q_1 on q_2

$$= \frac{Kq_1q_2}{r^2}\hat{r}$$

$$= \frac{Kq_1q_2}{|\vec{r}_2-\vec{r}_1|^2}\cdot\frac{\vec{r}}{|\vec{r}_2-\vec{r}_1|}$$

$$= \frac{Kq_1q_2}{|\vec{r}_2-\vec{r}_1|^3}(\vec{r})$$



$\vec{r}_1 + \vec{r} = \vec{r}_2$ (triangle Law)

$\vec{r} = \vec{r}_2 - \vec{r}_1$

S.K.C

trick

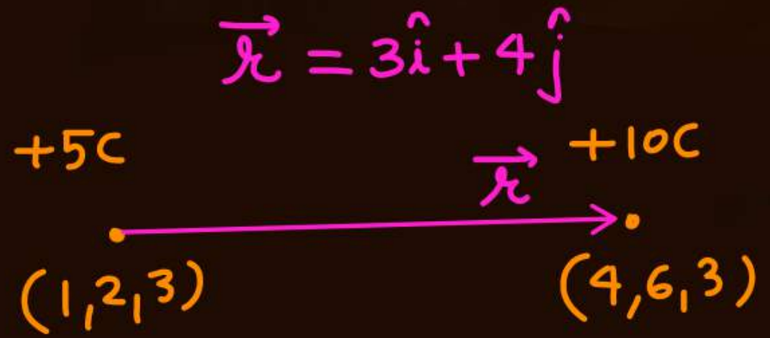
q_1 q_2

force applied by q_1 on q_2 $= \frac{Kq_1q_2}{r^2}\hat{r}$

① $\vec{r}$ की मुंडी (head) वहाँ रखना है जिसपर force निकालना है

② q_1 q_2 with sign रखना है

Q

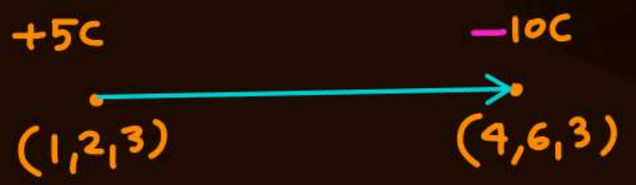


find force applied by

+5c on +10 c $= \frac{Kq_1q_2}{r^2}\hat{r}$

$= \frac{9\times10^9 \times 5\times10}{25} \times \left(\frac{3\hat{i}+4\hat{j}}{5}\right)$

$= 36\times10^8\left(3\hat{i}+4\hat{j}\right)$



$\vec{r} = 3\hat{i} + 4\hat{j}$

find force applied by

+5c on −10 c =

$= \frac{9\times10^9 \times 5\times(-10)}{25} \times \left(\frac{3\hat{i}+4\hat{j}}{5}\right)$

$= -36\times10^8\left(3\hat{i}+4\hat{j}\right)$

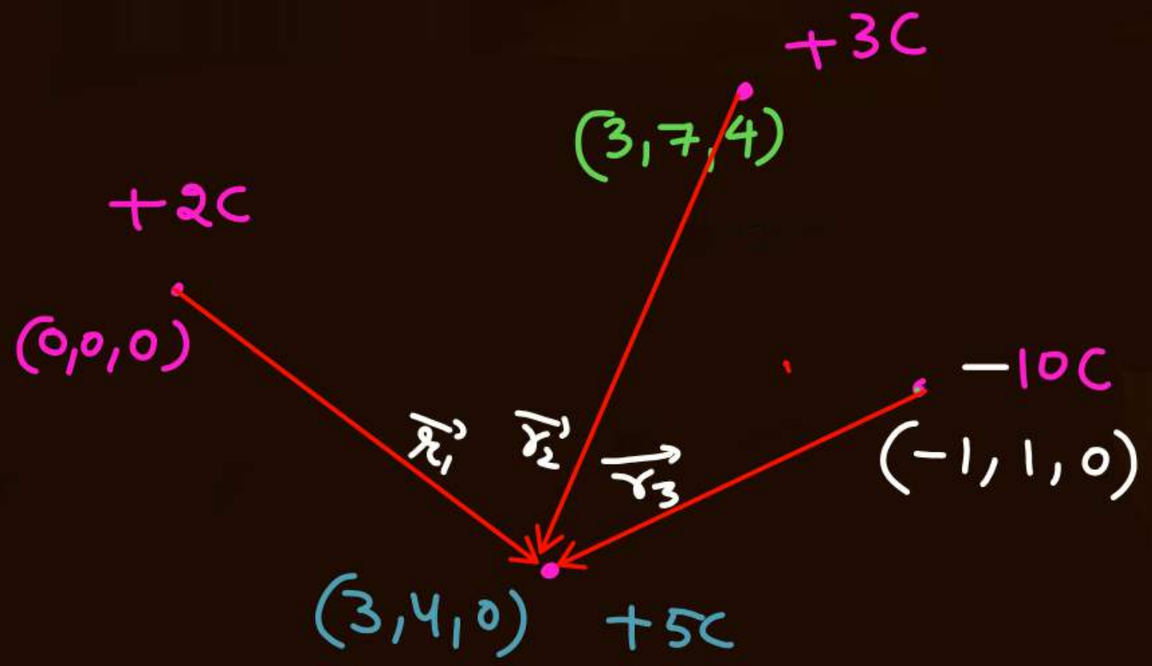
Q

$$\vec{r} = 4\hat{i} + 3\hat{j}$$

force applied by $-5C$ on $-20\,C$

$$= \frac{9\times10^{9}\times(-5)(-20)}{5^{2}}\left(\frac{4\hat{i}+3\hat{j}}{5}\right)$$

Q



$\vec{r_1} = 3\hat{i} + 4\hat{j}$

$\vec{r_2} = -3\hat{j} - 4\hat{k}$

$\vec{r_3} = 4\hat{i} + 3\hat{j}$

find net force on +5C

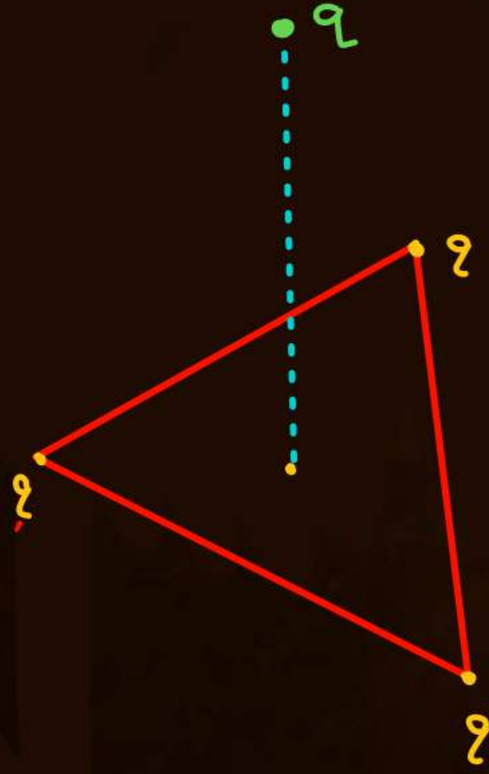
$$= \frac{K(2\times5)}{5^2}\frac{(3\hat{i}+4\hat{j})}{5}$$

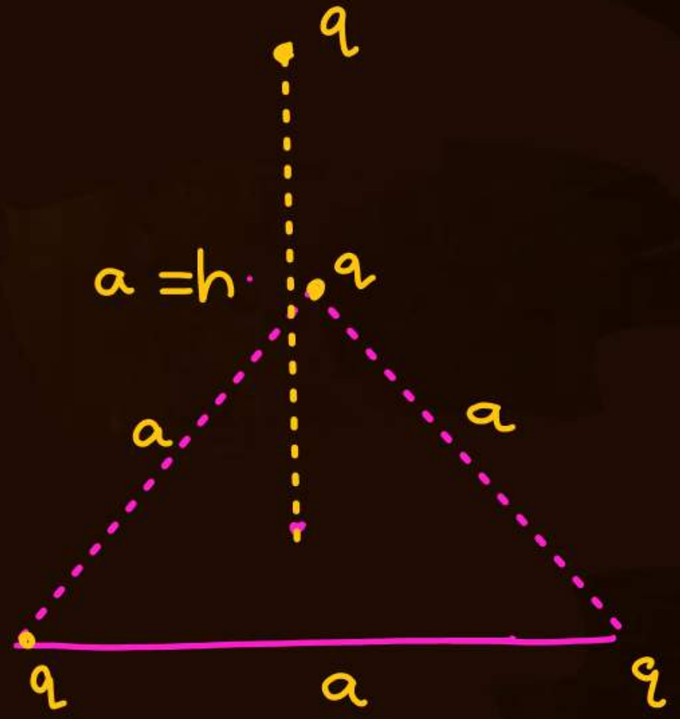
$$+ \frac{K\times3\times5}{5^2}\left(\frac{-3\hat{j}-4\hat{k}}{5}\right)$$

$$+ \frac{K(-10)\times5}{5^2}\left(\frac{4\hat{i}+3\hat{j}}{5}\right)$$

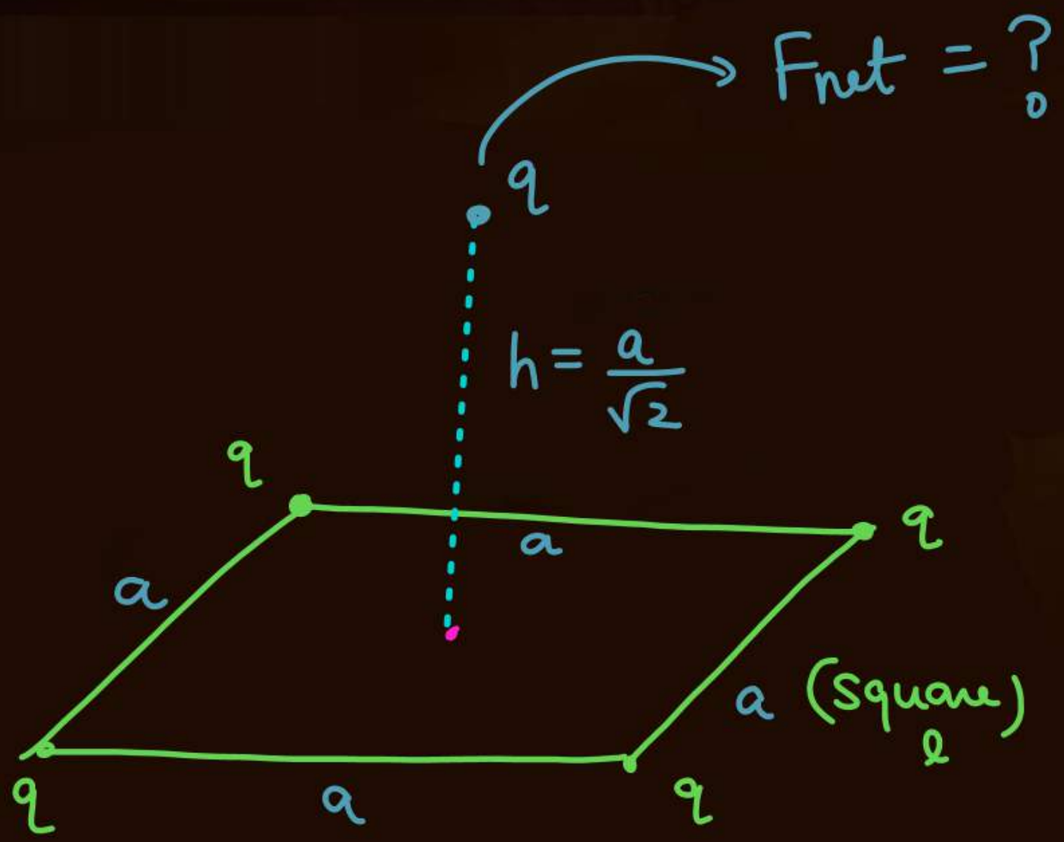
Q2 H/W

Three charges (+q) are placed at vertices of a equil. triangle as shown in daigram. Find net force on 4th charge particle at a height $h = a$ above the centroid of triangle.





Q



SHM $\vec{F} = -(k)\vec{x}$

↳ SHM वाला Const

$F = \dfrac{(k) q_1 q_2}{r^2}$

$k = \dfrac{1}{4\pi\epsilon_0}$

SHM ≡ ① mp पता करो $F_{net} = 0$

② particle को x- displace करो mp से

③ F_{net} ✓

④ $\vec{F}_{net} = -k\vec{x} \equiv$ SHM ✓ $T = 2\pi\sqrt{\frac{m}{k}}$

Electric field

- The region sorrounding a charge (or charge distribution) in which its electrical effects, electric forces can be experienced.
- Electric field strength or Electric field intensity $\vec{E}$, it measure how strong is the Electric field at that particular point.

$\Longrightarrow$. Electric field intensity is defined as force on unit test charge

E.F. due to point charge

$(E\cdot F)_{\text{at A due to } +Q} = \dfrac{\vec{F}}{q_0}$

$+Q$ is fix

force experienced per unit test charge

$$E_A = \lim_{q_0 \to 0} \frac{F}{q_0} = \frac{kQq_0}{r^2 q_0} = \frac{kQ}{r^2}$$

$$\vec{E} = \lim_{q_0 \to 0} \frac{\vec{F}}{q_0}$$

QUESTION

Two electrons each are fixed at a distance '2d'. A third charge proton placed at the midpoint is displaced slightly by a distance x (x << d) perpendicular to the line joining the two fixed charges. Proton will execute simple harmonic motion having angular frequency : (m = mass of charged particle)

[JEE Mains 2021]

1. $\left(\frac{2q^2}{\pi\varepsilon_0 md^3}\right)^{\frac{1}{2}}$
2. $\left(\frac{\pi\varepsilon_0 md^3}{2q^2}\right)^{\frac{1}{2}}$
3. $\left(\frac{q^2}{2\pi\varepsilon_0 md^3}\right)^{\frac{1}{2}}$
4. $\left(\frac{2\pi\varepsilon_0 md^3}{q^2}\right)^{\frac{1}{2}}$

Ans. (3)

QUESTION

Two small spheres each of mass 10 mg are suspended from a point by threads 0.5 m long. They are equally charged and repel each other to a distance of 0.20 m. The charge on each of the sphere is $\frac{a}{21} \times 10^{-8}$C. The value of 'a' will be _____.

[Given g = 10 ms^{-2}]

[JEE Mains 2021]

Ans. 20

QUESTION

A certain charge Q is divided into two parts q and (Q – q). How should the charges Q and q be divided so that q and (Q – q) placed at a certain distance apart experience maximum electrostatic repulsion? [JEE Mains 2021]

1. $\frac{q}{2}$
2. Q = 2q
3. Q = 4q
4. Q = 3q

Ans. (2)

QUESTION

A particle of mass 1 mg and charge q is lying at the mid-point of two stationary particles kept at a distance '2 m' when each is carrying same charge 'q'. If the free charged particle is displaced from its equilibrium position through distance 'x' ($x << 1$ m). The particle executes SHM. Its angular frequency of oscillation will be ____ $\times 10^5$ rad/s if $q^2 = 10\ C^2$.

[JEE Mains 2021]

Ans. 6000

QUESTION

Two identical tennis balls each having mass 'm' and charge 'q' are suspended from a fixed point by threads of length 'l'. What is the equilibrium separation when each thread makes a small angle 'θ' with the vertical ?

[JEE Mains 2021]

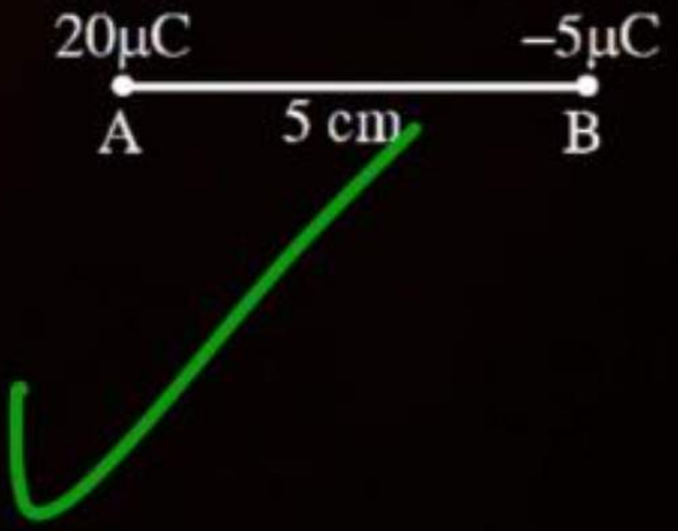
1. $x = \left(\frac{q^2 l}{2\pi\varepsilon_0 mg}\right)^{\frac{1}{2}}$
2. $x = \left(\frac{q^2 l}{2\pi\varepsilon_0 mg}\right)^{\frac{1}{3}}$
3. $x = \left(\frac{q^2 l^2}{2\pi\varepsilon_0 m^2 g}\right)^{\frac{1}{3}}$
4. $x = \left(\frac{q^2 l^2}{2\pi\varepsilon_0 m^2 g^2}\right)^{\frac{1}{3}}$

Ans. (2)

QUESTION

Two particles A and B having charges 20 μc and –5 μC respectively are held fixed with a separation of 5 cm. At what position a third charged particle should be placed so that it does not experience a net electric force? [JEE Mains 2021]

1. At 5 cm from 20 μC on the left side of system
2. At 5 cm from – 5 μC on the right side
3. At 1.25 cm from – 5 μC between two charges
4. At midpoint between two charges



Ans. (2)

QUESTION

Three point charges of magnitude 5μC, 0.16 μC and 0.3 μC are located at the vertices A, B, C of a right angled triangle whose sides are AB = 3cm, BC = $3\sqrt{2}$ cm and CA = 3 cm and point A is the right angle comer. Charge at point A experiences _____ N of electrostatic force due to the other two charges. **[JEE Mains 2022]**

Ans. 17

QUESTION

A chage of 4μC is to be divided into two. The distance between the two divided charges is constant. The magnitude of the divided charges so that the force between them is maximum, will be:

[JEE Mains 2022]

1. 1 μC and 3 μC
2. 2 μC and 2 μC
3. 0 μC and 4 μC
4. 1.5 μC and 2.5 μC

Ans. (2)

QUESTION

Two identical charged particles each having a mass 10 g and charge 2.0×10^{-7} C area placed on a horizontal table with a separation of L between then such that they stay in limited equilibrium. If the coefficient of friction between each particle and the table is 0.25, find the value of L.

(Use $g = 10ms^{-2}$)

[JEE Mains 2022]

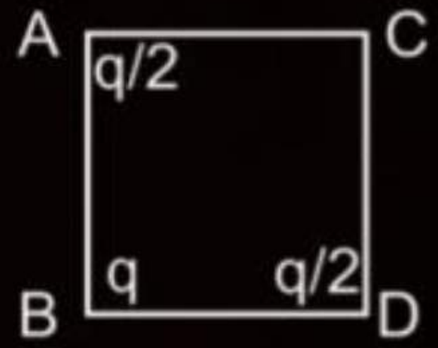
1. 12 cm
2. 10 cm
3. 8 cm
4. 5 cm

Ans. (1)

QUESTION

The three charge q/2, q and q/2 are placed at the corners A, B and C of a square of side 'a' as shown in figure. The magnitude of electric field (E) at the comer D of the square, is :

[JEE Mains 2022]



1. $\frac{q}{4\pi \epsilon_0 a^2}\left(\frac{1}{\sqrt{2}}+\frac{1}{2}\right)$
2. $\frac{q}{4\pi \epsilon_0 a^2}\left(1+\frac{1}{\sqrt{2}}\right)$
3. $\frac{q}{4\pi \epsilon_0 a^2}\left(1-\frac{1}{\sqrt{2}}\right)$
4. $\frac{q}{4\pi \epsilon_0 a^2}\left(\frac{1}{\sqrt{2}}-\frac{1}{2}\right)$

Ans. (1)

QUESTION

A point charge $q_1 = 4q_0$ is placed at origin. Another point charge $q_2 = -q_0$ is placed at $x = 12$ cm. Charge of proton is q_0. The proton is placed on x-axis so that the electrostatic force on the proton in zero. In this situation, the position of the proton from the origin is _____cm.

[29 January 2023 - Shift 1]

Ans : (24)

QUESTION

A 10 μC charge is divided into two parts and placed at 1 cm distance so that the repulsive force between them is maximum. The charges of the two parts are:

[13 April 2023 - Shift 2]

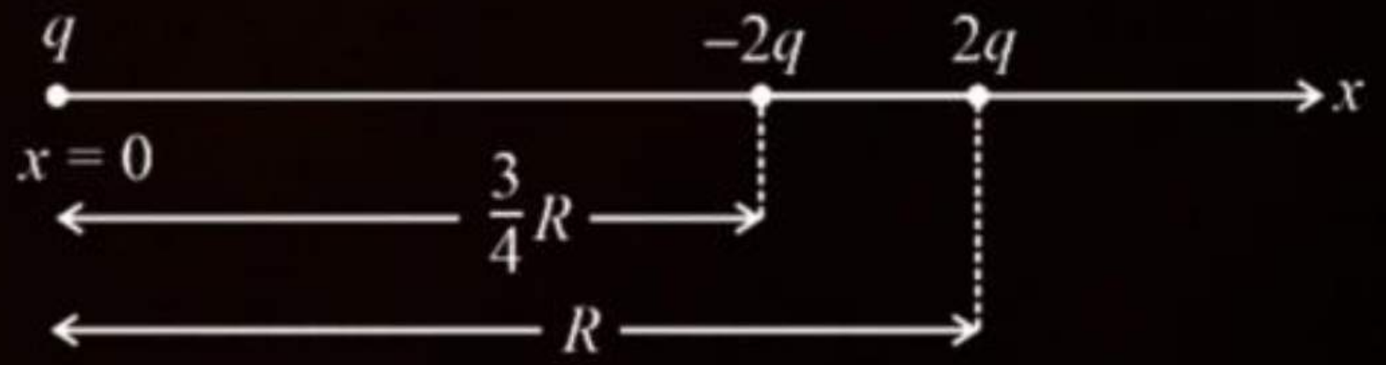
1. 7 μC, 3 μC
2. 8 μC, 2 μC
3. 5 μC, 5 μC
4. 9 μC, 1 μC

Ans : (3)

QUESTION

Three point charges q, −2q and 2q are placed on x axis at a distance x = 0, x = $\frac{3}{4}$ R and x = R respectively from origin as shown. If q = 2 × 10^{-6} C and R = 2 cm, the magnitude of net force experienced by the charge −2q is _____ N.

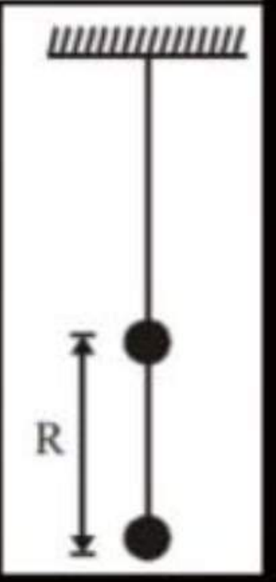
[13 April 2023 - Shift 2]



Ans : (5440)

QUESTION

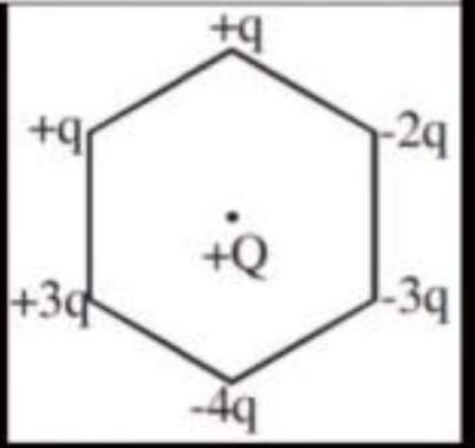
Two identical balls of mass m = 0.9 g each are charged by the same charges, joined by a thread and suspended from the ceiling (figure). Find the charge (in μC) that each ball should have so that the tension in both the threads are same? The distance between the centers of balls is R = 3m.



Ans : 03

QUESTION

Six charges are kept at the vertices of a regular hexagon as shown in the figure. If magnitude of force applied by +Q on +q charge is F, then net electric force on the +Q is nF. Find the value of n.



Ans : 9

QUESTION

Two charges, each equal to q, are kept at x = –a and x = a on the x-axis. A particle of mass m and charge $q_0 = \frac{q}{2}$ is placed at the origin. If charge q_0 is given a small displacement (y << a) along the y-axis, the net force acting on the particle is proportional to **[JEE-Main-2013]**

(1) y (2) –y (3) $\frac{1}{y}$ (4) $-\frac{1}{y}$

Ans : (1)

HCV

17. Four equal charges 2.0×10^{-6} C each are fixed at the four corners of a square of side 5 cm. Find the Coulomb force experienced by one of the charges due to the rest three.

Ans. 27.5 N at 45° with the extended sides of the square from the charge under consideration

HCV → will discuss in KPP (dont panic)

20. Ten positively charged particles are kept fixed on the x-axis at points $x = 10$ cm, 20 cm, 30 cm, ..., 100 cm. The first particle has a charge $1{\cdot}0 \times 10^{-8}$ C, the second 8×10^{-8} C, the third 27×10^{-8} C and so on. The tenth particle has a charge 1000×10^{-8} C. Find the magnitude of the electric force acting on a 1 C charge placed at the origin.

Ans. $4{\cdot}95 \times 10^{5}$ N

HCV

27. Two particles A and B having charges q and $2q$ respectively are placed on a smooth table with a separation d. A third particle C is to be clamped on the table in such a way that the particles A and B remain at rest on the table under electrical forces. What should be the charge on C and where should it be clamped ?

Ans. $-(6-4\sqrt{2})\,q$, between q and $2q$ at a distance of $(\sqrt{2}-1)\,d$ from q

HCV

32. Two particles A and B, each carrying a charge Q, are held fixed with a separation d between them. A particle C having mass m and charge q is kept at the middle point of the line AB. (a) If it is displaced through a distance x perpendicular to AB, what would be the electric force experienced by it. (b) Assuming $x \ll d$, show that this force is proportional to x. (c) Under what conditions will the particle C execute simple harmonic motion if it is released after such a small displacement ? Find the time period of the oscillations if these conditions are satisfied.

Ans. (a) $\dfrac{Qqx}{2\pi\varepsilon_0\left(x^2+\dfrac{d^2}{4}\right)^{3/2}}$ (c) $\left[\dfrac{m\pi^2\varepsilon_0 d^3}{Qq}\right]^{\frac{1}{2}}$

HCV

33. Repeat the previous problem if the particle C is displaced through a distance x along the line AB.

Ans. time period $= \left[\frac{\pi^3 \varepsilon_0 m d^3}{2Qq}\right]^{\frac{1}{2}}$

Home work

- DPP - 03
- H.W ques from PYQ & other ques are attached
  - → जो अच्छे/tough ques होंगे I will discuss them in separate vedio

just try them....

Thank You