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Electro Magnetic Theory

CHAPTER 1

Unit 1.1: Coulomb's Law

[NET JUNE 2020]

1. Three-point charges q are placed at the corners of an equilateral triangle. Another point charge $-Q$ is placed at the centroid of the triangle. If the force on each of the charges q vanishes, then the ratio Q/ q is

(a) $\sqrt{3}$ (b) $\frac{1}{\sqrt{3}}$

(c) $\frac{1}{3\sqrt{3}}$ (d) $\frac{1}{3}$

[NET JUNE 2016]

2. Four equal charge of $+Q$, each are kept at the vertices of a square of side R. A particle of mass m and charge $+Q$ is placed in the plane of the square at a short distance $a(\ll R)$ from the centre. If the motion of the particle is confined to the plane, it will undergo small oscillations with an angular frequency

(a) $\sqrt{\frac{Q^2}{2\pi\varepsilon_0 R^3 m}}$ (b) $\sqrt{\frac{Q^2}{\pi\varepsilon_0 R^3 m}}$

(c) $\sqrt{\frac{\sqrt{2}Q^2}{\pi\varepsilon_0 R^3 m}}$ (d) $\sqrt{\frac{Q^2}{4\pi\varepsilon_0 R^3 m}}$

[NET DEC. 2016]

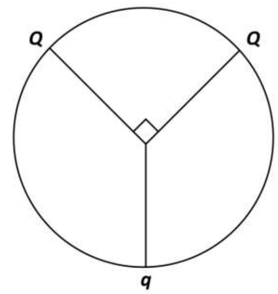
3. The charge per unit length of a circular wire of radius a in the $xy-$plane, with its centre at the origin, is $\lambda = \lambda_0 \cos\theta$, where λ_0 is a constant and the angle θ is measured from the positive $x-$axis. The electric field at the center of the circle is

(a) $\vec{E} = -\frac{\lambda_0}{4\epsilon_0 a}\hat{\imath}$ (b) $\vec{E} = \frac{\lambda_0}{4\epsilon_0 a}\hat{\imath}$

(c) $\vec{E} = -\frac{\lambda_0}{4\epsilon_0 a}\hat{\jmath}$ (d) $\vec{E} = \frac{\lambda_0}{4\epsilon_0 a}\hat{k}$

[NET DEC. 2012]

4. Three charges are located on the circumference of a circle of radius $'R'$ as shown in the figure below. The two charges Q subtend an angle 90˚ at the centre of the circle. The charge 'q' is symmetrically placed with respect to the charges Q. If the electric field at the centre of the circle is zero, what is the magnitude of Q?



(a) $\frac{q}{\sqrt{2}}$ (b) $\sqrt{2}q$

(c) $2q$ (d) $4q$

[NET DEC. 2011]

5. Four equal point charges are kept fixed at the four vertices of a square. How many neutral points (i.e. points where the electric field vanishes) will be found inside the square?

(a) 1 (b) 4

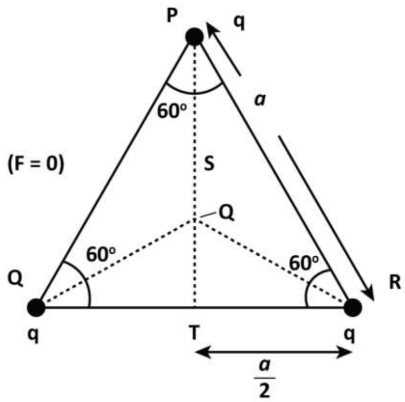
(c) 5 (d) 7

Answer Key				
1	**2**	**3**	**4**	**5**
b	c	a	a	c

:: Solutions ::

1. Solution:- (b)

Force on q should be zero $(F = 0)$



$PT = \sqrt{a^2 - \left(\frac{a}{2}\right)^2} \Rightarrow \sqrt{a^2 - \frac{a^2}{4}} \Rightarrow \sqrt{\frac{3a^2}{4}} \Rightarrow \frac{\sqrt{3}a}{2}$

$PS \Rightarrow \frac{2}{3}$ of PT

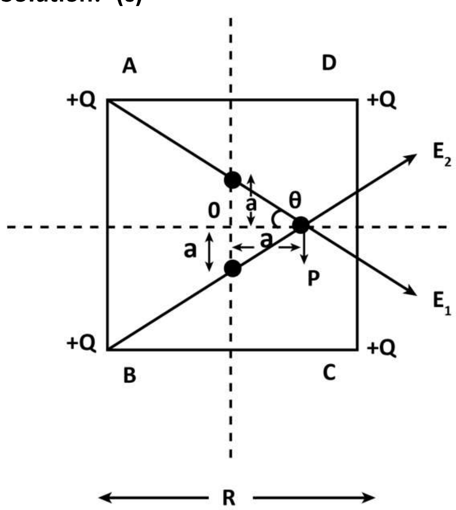
$PS = \frac{2}{3} \times \frac{\sqrt{3}a}{2} \Rightarrow \frac{a}{\sqrt{3}}$

Angle of equilateral triple is 60°. So

Force on q due to all 3 charpes q, q & $-Q$.

$$\frac{kq^2 \cos 30°}{a^2} + \frac{kq^2 \cos 30°}{a^2} \Rightarrow k\frac{qQ}{\left(\frac{Q}{\sqrt{3}}\right)^2}$$

2. Solution:- (c)



Consider particle is at point P which is at a distance (a) from the centre O.

E_1 & E_2 be the electric field due to charges present at A & B resp.

$E_1 = E_2$ because distance & charges are equal due to which we calculate electric field at point P.

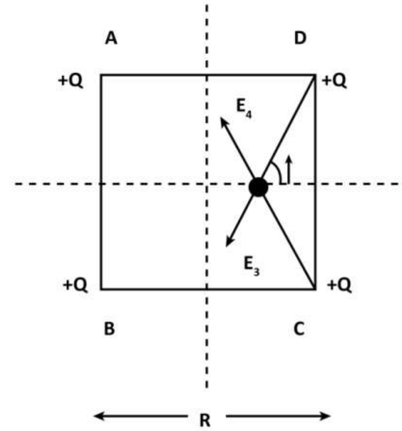
$E_1 = E_2 = \frac{k\,Q}{\left[\left(\frac{R}{2}\right)^2 + \left(\frac{R}{2}+\frac{a}{2}\right)^2\right]}$

Resultant of electric field's present at point P due to charges present at A & B are.

$E_{2,y} = 2\,E_1 \cos\theta$

$E_{12,,y} = \frac{2k\theta}{\left[\left(a+\frac{R}{2}\right)^2 + \left(\frac{R}{2}\right)^2\right]^{\frac{3}{2}}}\left[a + \frac{R}{2}\right) \frac{2k\theta}{\left[\frac{R^2}{2}\right]^{\frac{3}{2}}}\left(a + \frac{R}{2}\right)$

$E_{12,y} \Rightarrow \frac{4\sqrt{2}k\theta}{R^3}\left[a + \frac{R}{2}\right]$ ...... (1)



Similarly, $E_3 = E_4 = \frac{k\theta}{\left[\left(\frac{R}{2}-a\right)^2 + \left(\frac{R}{2}\right)^2\right]}$

Resultant $E_{3\,4,y} = 2E_3 \cos d = \frac{2k\theta}{\left[\left(\frac{R}{2}-a\right)^2 + \frac{R^2}{4}\right]^{\frac{3}{2}}}\left(\frac{R-a}{2}\right)$

$E_{34,y} = \frac{4\sqrt{2}k\theta}{R^3}\left[\frac{R}{2} - a\right]$ ... (2)

Now, add equation (1) & (2)

Resultant $E \Rightarrow \frac{4\sqrt{2}k\theta}{R^3}\left[\left(\frac{R}{2} - a\right) - \left(\frac{R}{2} + a\right)\right] \Rightarrow -\frac{8\sqrt{2}k\theta}{R^3}$

$E \Rightarrow \frac{-8\sqrt{2}}{R^3}\frac{\theta a}{4\pi\epsilon}$

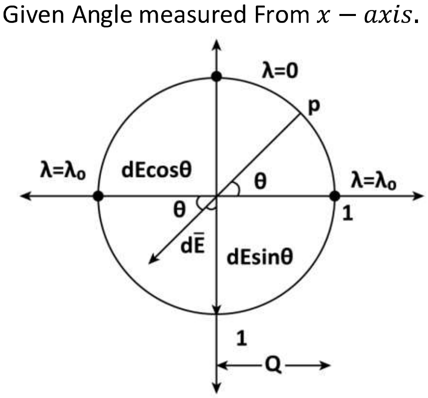
$E \Rightarrow \frac{-2\sqrt{2}\theta}{\pi\epsilon_0 R^3}$

Force on that charge present at point P is $F \Rightarrow QE\ F \Rightarrow \frac{-2\sqrt{2}Qa}{\pi\epsilon_0 R^3}$

$$w \Rightarrow \sqrt{\frac{2\sqrt{2}Q^2}{\pi\,\epsilon_0\,m\,R^3}}$$

3. Solution:- (a)

Given Angle measured From $x - axis$.



Correct option is from a & b.

Electric field due to a charged element at P is.

$dE = -dE\cos\theta\,\hat{\imath} - dE\sin\theta\ \hat{\jmath}$

So, the total electric field at at the centre is.

$\vec{E} = -i\ \int \frac{\lambda\, dl}{4\pi\epsilon_0 a^2}\cos\theta\ - \hat{\jmath}\int \frac{\lambda\, dl}{4\pi\epsilon_0 a^2}\ \sin\theta$

Given :- $\lambda = \lambda_0\cos\theta$

$\vec{E} = -\hat{\imath}\ \int_0^{2\pi} \frac{\lambda_0 cos^2\theta}{4\pi\epsilon_0 a^2}(a\ d\theta)\ -$

$\hat{\jmath}\ \int \frac{\lambda_0\cos\theta(a\ d\ \theta)\sin\theta}{4\pi\epsilon_0 a^2}$ $[dl = a\ d\theta]$

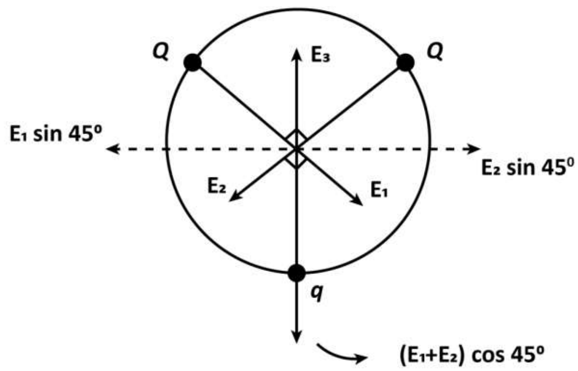
$\vec{E}\ \Rightarrow \frac{-\hat{\imath}\,\lambda_0}{4\pi\epsilon_0 a}\ \int_0^{2\pi} cos^2\theta\ d\ \theta - \hat{\jmath}\ \int \frac{\lambda_0}{4\pi\epsilon_0 a}\cos\theta\sin\theta\ d\theta$

$\vec{E}\ \Rightarrow\ -\hat{\imath}\left(\frac{\lambda_0}{4\pi\epsilon_0 a}\right)\left(\frac{2\pi}{2}\right)\quad = -\frac{\lambda_0}{4\epsilon_0 a}\ \hat{\imath}$

$$\vec{E}\ = \frac{-\lambda_0\ \hat{\imath}}{4\ \epsilon_0\ a}$$

4. Solution: (a)

Electric field due to the two equal charges Q will be



$E_1 = E_2 = \frac{1}{4\pi\varepsilon_0}\frac{Q}{R^2}$

Electric field due to the charge q will be $E_3 = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}$

Resultant of E_1 and E_2 is $= \sqrt{E_1^2 + E_2^2} = \sqrt{2}E_1$,

$E_1 = E_2 = \frac{\sqrt{2}Q}{4\pi\epsilon_0 R^2}\ = \frac{q}{4\pi\epsilon_0 R^4}$

$\Rightarrow Q = \frac{q}{\sqrt{2}}$

5. Solution:- (c)

Inside the square, there is only five points where the field vanishes due to symmetry one at the centre and other 4 also present due to the 4 charges present at the vertices.