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Electro Magnetic Theory

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) $\sqrt{\frac{Q^2}{2\pi\epsilon_0 R^3 m}}$ (b) $\sqrt{\frac{Q^2}{\pi\epsilon_0 R^3 m}}$
(c) $\sqrt{\frac{\sqrt{2}Q^2}{\pi\epsilon_0 R^3 m}}$ (d) $\sqrt{\frac{Q^2}{4\pi\epsilon_0 R^3 m}}$

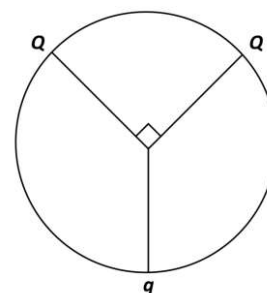
[NET DEC. 2016]

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

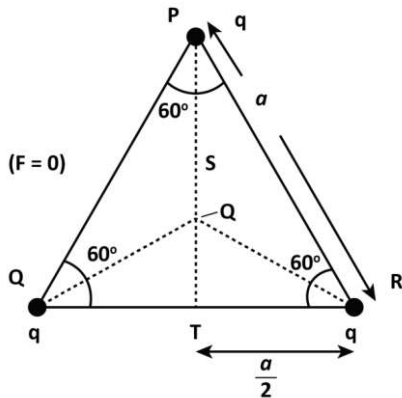
Answer Key

1	2	3	4	5
b	c	a	a	c

:: Solutions ::

1. Solution:- (b)

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



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

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

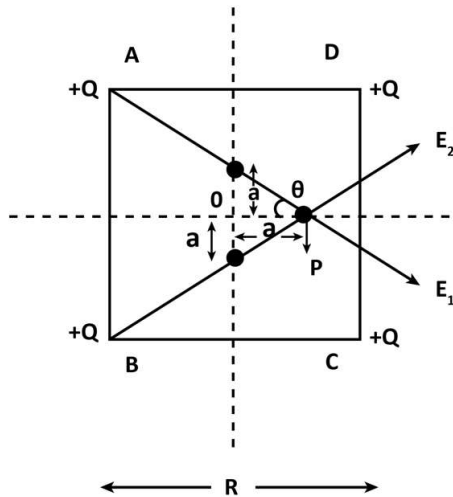
$$PS = \frac{2}{3} \times \frac{\sqrt{3}a}{2} \Rightarrow \frac{a}{\sqrt{3}}$$

Angle of equilateral triangle is 60° . So

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

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

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.

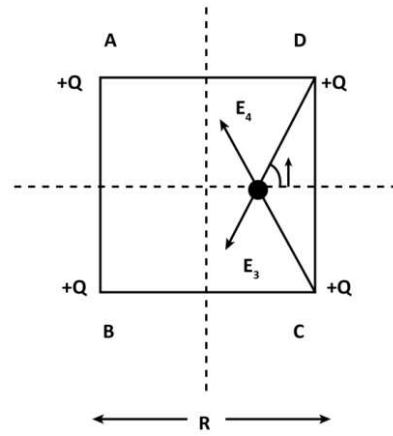
$$E_1 = E_2 = \frac{kQ}{\left[\left(\frac{R}{2}\right)^2 + \left(\frac{R+a}{2}\right)^2\right]}$$

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

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

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

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



$$\text{Similarly, } E_3 = E_4 = \frac{k\theta}{\left[\left(\frac{R-a}{2}\right)^2 + \left(\frac{R}{2}\right)^2\right]^{\frac{3}{2}}}$$

$$\text{Resultant } E_{34,y} = 2E_3 \cos d = \frac{2k\theta}{\left[\left(\frac{R-a}{2}\right)^2 + \left(\frac{R}{2}\right)^2\right]^{\frac{3}{2}}} \left(\frac{R-a}{2}\right)$$

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

Now, add equation (1) & (2)

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

$$E \Rightarrow \frac{-8\sqrt{2} \theta a}{R^3 4\pi\epsilon_0}$$

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

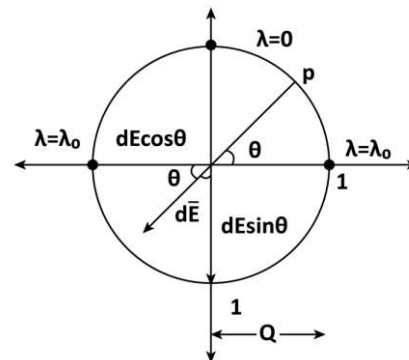
Force on that charge present at point P is $F \Rightarrow QE \Rightarrow$

$$\frac{-2\sqrt{2}Qa}{\pi\epsilon_0 R^3}$$

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

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.

$$dE = -dE \cos \theta \hat{i} - dE \sin \theta \hat{j}$$

So, the total electric field at the centre is.

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

$$\text{Given :- } \lambda = \lambda_0 \cos \theta$$

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

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

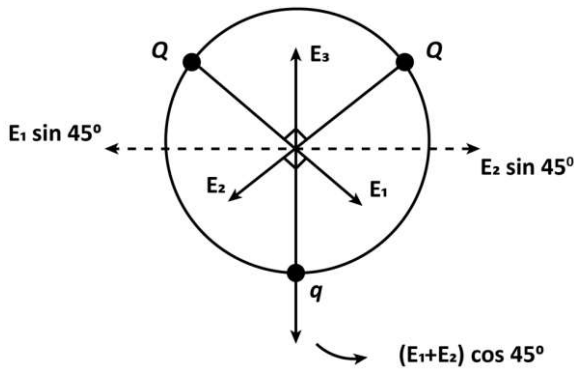
$$\vec{E} \Rightarrow \frac{-\hat{i} \lambda_0}{4\pi\epsilon_0 a} \int_0^{2\pi} \cos^2 \theta d\theta - \hat{j} \int \frac{\lambda_0}{4\pi\epsilon_0 a} \cos \theta \sin \theta d\theta$$

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

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

4. Solution: (a)

Electric field due to the two equal charges Q will be



$$E_1 = E_2 = \frac{1}{4\pi\epsilon_0} \frac{Q}{R^2}$$

$$\text{Electric field due to the charge } q \text{ will be } E_3 = \frac{1}{4\pi\epsilon_0} \frac{q}{R^2}$$

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

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

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

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.