Coulombs Law, Electrostatic Field & Electric Dipole

1 Mark Questions

1.Why do the electrostatic field lines not form closed loop?[All India 2014, Delhi 2012]
Ans.The electrostatic field lines do not form closed loop because no electric field lines exist inside the charged body

2.Why do the electric field lines never cross each other?[All India 2014]

Ans

Ans.At the intersection point, there would be two directions of electric field which is not possible so lines of forces never cross each other

3.Why must electrostatic field at the surface of a charge every point? Give reason. [Foreign 2014, Delhi 2012]

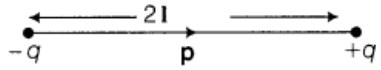
Ans.As, electric field inside a conductor is always zero. The electric lines of forces exert lateral pressure on each other leads to explain repulsion between like charges. Thus, in order to stable spacing, the lines are normal to the surface.

4.Two point charges g_x and q_2 are placed at a distance d apart as shown in the figure. The electric field intensity is zero at the point P on the line joining them as shown. Write two conclusions that you can draw from this. [Delhi2014c]

Ans.(i) The two point charges (q^ and q_2) should be of opposite nature.
(ii) Magnitude of charge q_1 must be greater than magnitude of charge q_2.

5.Define dipole moment of an electric dipole. Is it a scalar quantity or a vector quantity? [Foreign 2012; All India 2011]

Ans.Electric dipole moment of an electric dipole is equal to the product of its charges and the length of the electric dipole.It is denoted by p. Its unit is coulomb-metre.

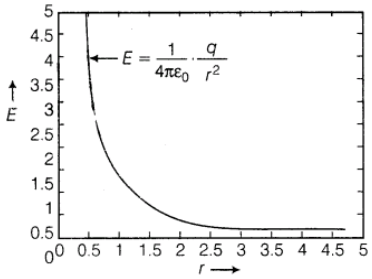


$$\mathbf{p} = q \times 2\mathbf{l}$$

It is a vector quantity and its direction is from negative charge towards positive charge

6.Draw a plot showing the variation of electric field (E) with distance r due to a point charge Q. [Delhi 2012]

Ans. The plot showing the variation of electric field and electric potential with distance r due to a point charge q is shown as below



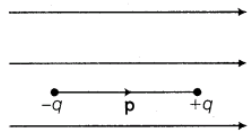
7.A proton is placed in a uniform electric field directed along the position X-axis. In which direction will it tend to move? [Delhi 2011 c]

Ans. Proton will tend to move along the X-axis in the direction of a uniform electric field.

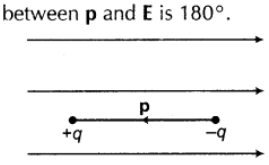
8. In which orientation, a dipole placed in a uniform electric field is in (i) stable (ii) unstable equilibrium?[Delhi 2011; All India 2008]

Ans.

(*i*) For stable equilibrium, the angle between **p** and **E** is 0°. **(1/2)**



(*ii*) For unstable equilibrium, the angle between **p** and **E** is 180°.



(1/2)

9.Two point charges having equal charges separated by lm distance experience a force of 8 N. What will be the force experienced by them if they are held in water at the same distance? (Given, K_{water} = 80).[Ail India 2010 C]

Ans.Two point charges system is taken from air to water keeping other variable (e.g., distance, magnitude of charge) unchanged. So, only factor which may affect the interacting force is dielectric constant of medium

Force acting between two point charges

$$F = \frac{1}{4\pi \varepsilon_0 K}\frac{q_1 q_2}{r^2} \quad \text{or} \quad F \propto \frac{1}{K}$$

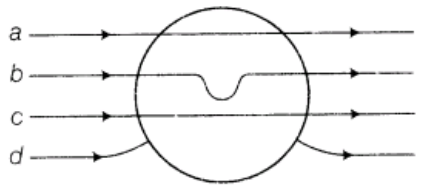
$$\Rightarrow \quad \frac{F_{air}}{F_{medium}} = K$$

$$\Rightarrow \quad \frac{8}{F_{water}} = 80$$

$$\Rightarrow \quad F_{water} = \frac{8}{80}$$

$$F_{water} = \frac{1}{10}\,\text{N}$$

10.A metallic shpere is placed in a uniform electric field as shown in the figure. Which path is followed by electric field lines and why?[HOTS; Foreign 2010]



Ans. Path d is followed by electric field lines. Electric field intensity inside the metallic sphere will be zero, therefore, no electric lines of force exist inside the sphere, also lines fall normally on the surface. Electric field lines are always perpendicular to the surface of the conductor.

11.Point out right or wrong for the following statement.The mutual forces between two charges do not get affected by the presence of other charges.

Ans.Right, because mutual force acting between two point charges is proportional to the product of magnitude of charges and inversely proportional to the square of the distance between them, i.e. independent of the other charges.

12.A dipole of dipole moment p is present in a uniform electric field E . Write the value of the

angle between p and E for which the torque experienced by the dipole, is minimum. [Delhi 2009 c]

Ans. Since, torque (x) on the dipole in electric field E is

$$\tau = \mathbf{p} \times \mathbf{E}$$

$$\Rightarrow \quad |\tau| = pE \sin\theta$$

For minimum torque,

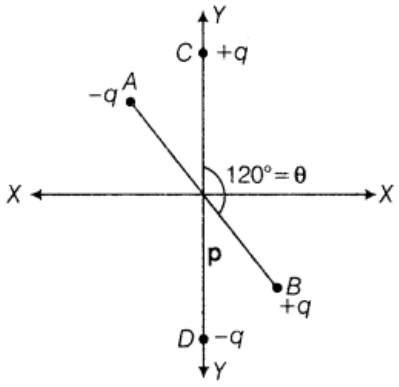
$$|\tau| = 0$$

$$\Rightarrow \quad pE \sin\theta = 0$$

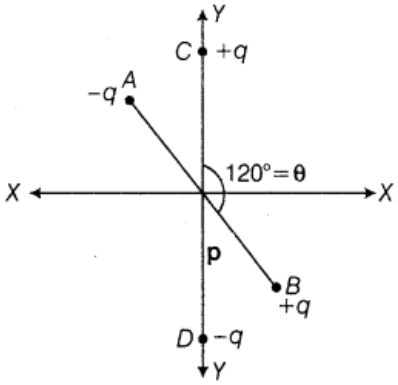
$$\sin\theta = 0$$

$$\Rightarrow \quad \theta = 0°, 180°$$

13.Two small identical dipoles AB and CD, each of dipole moment p are kept at an angle of 120° as

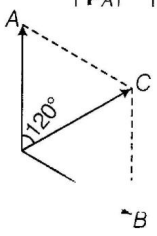


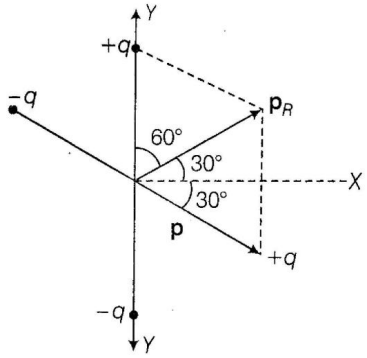
shown in the figure. What is the resultant dipole moment of this combination? If this system is subjected to electric field (E) directed along + X-direction, what will be the magnitude and direction of the torque acting on this? [Delhi 2008]



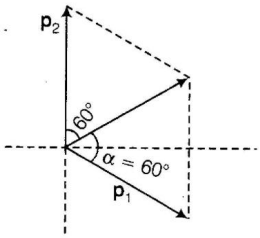
Ans.

$|\mathbf{p}_A| = |\mathbf{p}_C| = p$





The resultant p_R is a magnitude.



$$p_R = \sqrt{p_1^2 + p_2^2 + 2p_1 p_2 \cos\theta}$$

$$= \sqrt{p^2 + p^2 + 2p^2 \cos\theta} = \sqrt{2p^2(1+\cos\theta)}$$

$$[\because p_1 = p_2 = p]$$

$$= \sqrt{2p^2 \times 2\cos^2\frac{\theta}{2}} = 2p\cos\frac{\theta}{2}$$

$$\tan\alpha = \frac{p_2 \sin\theta}{p_1 + p_2\cos\theta} = \frac{p\sin 120°}{p + p\cos 120°}$$

$$= \frac{p\sqrt{3}/2}{p - \frac{p}{2}} = \sqrt{3}$$

$$|\mathbf{p}_R| = 2p\cos\frac{\theta}{2} = 2p\cos\frac{120°}{2} = p$$

$\mathbf{p}_R$ will subtend an angle of 30° with X-axis.
Now, torque acting on the system

$$\tau = \mathbf{p}_R \times \mathbf{E} = p_R E \sin\theta = \frac{1}{2}pE$$

Torque will work to align the dipole in the direction of electric field **E**. **(1/2)**

2 Marks Questions

14.An electric dipole of length 4 cm when placed with its axis making an angle of 60° with a uniform electric field, experiences a torque of $4\sqrt{3}$ Nm. Calculate the potential energy of the dipole if it has charge ± 8 nC.[Delhi 2014]

Ans.

Given, length $2a = 4\,cm = 4 \times 10^{-2}$ m

Angle, $\theta = 60°$

Torque, $\tau = 4\sqrt{3}$ Nm

We know that, $\tau = Q(2a)\,E \sin\theta$

Electric field, $E = \dfrac{\tau}{Q(2a)\sin\theta}$

$$= \frac{4\sqrt{3}}{8 \times 10^{-9} \times 4 \times 10^{-2} \times \sin 60°}\ \text{N/C} \quad \textbf{(1)}$$

$$= 2.5 \times 10^{10}\ \text{N/C}$$

$\therefore$ Potential energy, $C = -pE\cos\theta$

$$= -Q(2a)\,E\cos\theta$$

$$U = -8 \times 10^{-9} \times 4 \times 10^{-2} \times \frac{4\sqrt{3} \times \cos 60°}{8 \times 10^{-9} \times 4 \times 10^{-2} \times \sin 60°}$$

$$= \frac{-4\sqrt{3}}{\sqrt{3}}\ \text{J} = -4\ \text{J} \quad \textbf{(1)}$$

15.An electric dipole of length 2 cm when placed with its axis making an angle of 60° with a uniform of electric field,experiences a torque of $8\sqrt{3}$ Nm. Calculate the potential energy of the dipole if it has charge of ± 4 nC.[Delhi 2014]

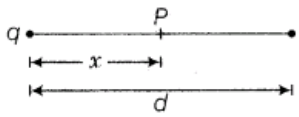
Ans.Refer to ans. 14 (Ans. 8J).

16.An electric dipole of length 1cm which placed with its axis making an angle of 60° with a uniform electric field,experiences a torque of $6\sqrt{3}$ Nm. Calculate the potential energy of the dipole if it has charge ± 2 nC. [Delhi 2014]

Ans.Refer to ans. 14 (Ans. -6J).

17.Two point charges q and – 2 q are kept d distance apart, find the location of the point relative to charge to q at which potential due to this system is zero.[All India 2014]

Ans.



(1)

Let P be the required point at distance x from charge q

$$\therefore \quad \frac{1}{4\pi\varepsilon_0}\frac{q}{x} + \frac{1(-2q)}{4\pi\varepsilon_0(d-x)} = 0$$

$$\Rightarrow \quad \frac{1}{x} = \frac{2}{d-x}$$

$$x = \frac{d}{3} \quad \textbf{(1)}$$

So, required point is at a distance $d/3$ from charge q.

18.An electric dipole is placed in a uniform electric field E with its dipole moment p parallel to the field. Find

(i)the work done in turning the dipole till its dipole moment points in the direction opposite to E.

(ii)the orientation of the dipole for which the torque acting on it becomes maximum.[All India 2014 C]

Ans.

(*i*) We have $W = \int_{\theta_1}^{\theta_2} \tau d\theta$

$$\therefore \quad W = \int_0^{\pi} pE \sin\theta \, d\theta$$

$$= pE\,[-\cos\theta]_0^{\pi}$$

$$= 2pE$$

(*ii*) We know that,

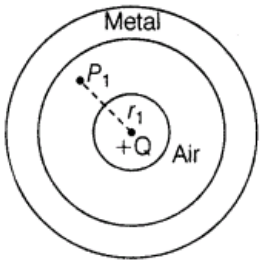
$$\tau = pE \sin\theta$$

If $\theta = \frac{\pi}{2}$, then τ is maximum

i.e. $\quad \tau = pE \sin\frac{\pi}{2}$

$$\tau = pE \quad \text{(maximum)}$$

19.A small metal sphere carrying a charge +0 is located at the centre of a spherical cavity in a large uncharged metallic spherical shell. Write the charges on the inner and outer surfaces of the shell. Write the expression for the electric field at the point P_x. [Delhi 2014 c]



Ans.

According to question, the charge on inner surface = $-Q$ **(1)**

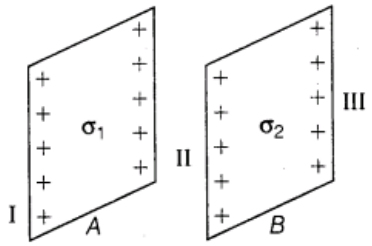
According to question, the charge on outer surface = $+Q$

Electric field at point P_1 is given by **(1)**

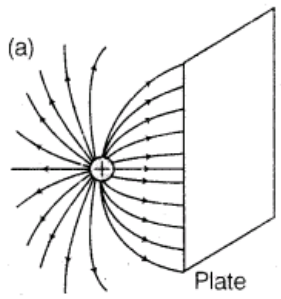
$$E = \frac{Q}{4\pi\varepsilon_0 r_1^2}$$

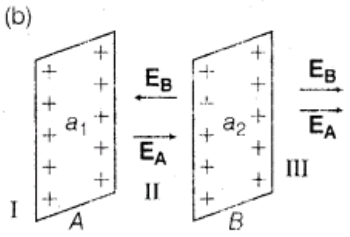
20.(i) Point charge (+Q) is kept in the vicinity of and uncharged conducting plate. Sketch electric field lines between the charge and the plate.

(ii)Two infinitely large plane thin parallel sheets having surface charge densities sigma1 and sigma2 (sigma1>sigma2) are shown in the figures. Write the magnitude and directions of net fields on the marked II and III. [Foreign 2014]



Ans.





In region II

The electric field due to the sheet of charge A will be from left of right (along the positive direction) and that due to the sheet of charge B will be from right to left (along the negative direction). Therefore, in region II we have

$$E = \frac{\sigma_1}{\varepsilon_0} + \left(-\frac{\sigma_2}{\varepsilon_0}\right)$$

$$\Rightarrow \quad E = \frac{1}{\varepsilon_0}(\sigma_1 - \sigma_2)$$

In region II

The electric fields due to both the charged sheets will be from left to right, i.e, along the positive direction. Therefore, in region III we have

$$E = \frac{\sigma_1}{\varepsilon_0} + \frac{\sigma_2}{\varepsilon_0} = \frac{1}{\varepsilon_0}(\sigma_1 + \sigma_2)$$

21.Calculate the amount of work done in turning an electric dipole of dipole moment 3×10^{-8} C-m from its position of unstable equilibrium to the position of stable equilibrium in a uniform electric field of intensity 10^3 N/C. [Foreign 2011]

Ans.

According to question,

For unstable equilibrium, the angle between **p** and **E** is $\theta_1 = 180°$

Finally, for stable equilibrium, $\theta_2 = 0°$ **(1/2)**

Required work done

$W = pE(\cos\theta_1 - \cos\theta_2)$ **(1/2)**

$= 3 \times 10^{-8} \times 10^3(\cos 180° - \cos 0°)$

$[\because \cos 180° = -1, \cos 0° = +1]$

$W = -6 \times 10^{-5}$ J **(1)**

22. Plot a graph showing the variation of Coulomb force (F) *versus* $1/r^2$, where r is the distance between the two charges of each pair of charges (1 μC, 2 μC) and (1 μC, −3 μC). Interpret the graphs obtained.

[All India 2011C]

Ans.

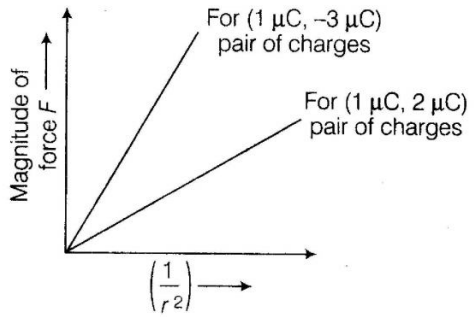
According to Coulomb's law, the magnitude of force acting between two stationary point charges is given by $F = \left(\frac{q_1 q_2}{4\pi\varepsilon_0}\right)\left(\frac{1}{r^2}\right)$

For given $q_1 q_2$, $F \propto \left(\frac{1}{r^2}\right)$

The slope of F *versus* $\frac{1}{r^2}$, graph depends on $q_1 q_2$.

Magnitude of $q_1 q_2$ is higher for second pair.

$\therefore$ Slope of F *versus* $\frac{1}{r^2}$ graph. **(1)**



Corresponding to second pair (1 μC, − 3 μC) is greater.

Higher the magnitude of product of charges q_1 and q_2, higher the slope. **(1)**

23.Two identical metallic spherical shells A and B having charges + 40 and -10Q are kept a certain distance apart. A third identical uncharged sphere C is first placed in contact with sphere A and then with sphere B, then spheres A and B are brought in contact and then separated. Find the charge on the spheres A and B.[All India 2011 c]

Ans.When two identical conducting charged spheres are brought in contact, then redistribution of charge takes place, i.e. the charge is equally divided on both the spheres. When C and A are placed in contact, charge of A equally divides in two spheres. Therefore, charge on each A and C = + 2Q

Now, C is placed in contact with B, then charge on each A and C becomes

$$\frac{2Q + (-10\,Q)}{2} = -4Q$$

When A and B are placed in contact, then charge on each A and B becomes

$$\frac{2Q + (-4\,Q)}{2} = -Q$$ **(1)**

24.A dipole with a dipole moment of magnitude p is in stable equilibrium in an electrostatic field of magnitude E. Find the work done in rotating this dipole to its position of unstable equilibrium. [All India 2010c]

Ans.

For stable equilibrium, the angle between **p** and **E** $\theta_1 = 0°$.

For unstable equilibrium, $\theta_2 = 180°$. **(1)**

Work done in rotating the dipole from angle θ_1 to θ_2

$$W = pE(\cos\theta_1 - \cos\theta_2)$$
$$= pE(\cos 0° - \cos 180°)$$
$$W = 2pE \quad \textbf{(1)}$$

25.A dipole is present in an electrostatic field of magnitude 10^6N/C. If the work done in rotating it from its position of stable equilibrium to its position of unstable equilibrium is 2×10~23J, then find the magnitude of the dipole moment of this dipole.[All India 2010 C]

Ans.

Electric field intensity, $E = 10^6$ N/C

Work done, $W = 2 \times 10^{-23}$ J

Work done in rotating the dipole from stable equilibrium position to unstable equilibrium position.

$$W = pE(\cos 0° - \cos 180°) = 2pE \quad \textbf{(1)}$$

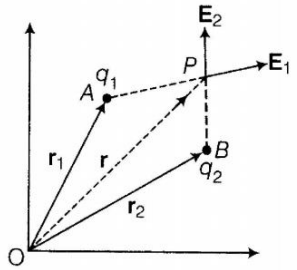
$$\therefore \quad p = \frac{W}{2E} = \frac{2 \times 10^{-23}}{2 \times 10^6} = 10^{-29} \text{ C-m} \quad \textbf{(1)}$$

26.Deduce the expression for the electric field E due to a system of two charges q_x and q_2 with position vectors i1 and r_2 at a point r with respect to common origin. [Delhi 2010c]

Ans.

Let two point charges q_1 and q_2 situated at points *A* and *B* have position vectors $\mathbf{r}_1$ and $\mathbf{r}_2$.

$\because$ $\mathbf{AP} = \mathbf{r} - \mathbf{r}_1$ and $\mathbf{BP} = \mathbf{r} - \mathbf{r}_2$



Electric field intensity at point *P* due to q_1,

$$\mathbf{E}_1 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1}{|\mathbf{BP}|^3} \mathbf{AP}$$

Similarly, $\mathbf{E}_2 = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_2}{|\mathbf{AP}|^3} \mathbf{BP}$ **(1)**

$\therefore$ Net electric field intensity at point *P*,

$$\mathbf{E} = \mathbf{E}_1 + \mathbf{E}_2$$
$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{|\mathbf{r} - \mathbf{r}_1|^3}(\mathbf{r} - \mathbf{r}_1) + \frac{q_2}{|\mathbf{r} - \mathbf{r}_2|^3}(\mathbf{r} - \mathbf{r}_2)\right] \quad \textbf{(1)}$$

27.The sum of two point charges is 7 microC. They repel each other with a force of 1 N when

kept 30 cm apart in free space. Calculate the value of each charge. [Foreign 2009]

Ans.

Let one of two charges is x μC. Therefore, other charge will be $(7 - x)$ μC.

By Coulomb's law, $F = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{r^2}$ **(1)**

$$1 = 9 \times 10^9 \times \frac{(x \times 10^{-6})(7 - x) \times 10^{-6}}{(0.3)^2}$$

$$9 \times 10^{-2} = 9 \times 10^{9-12} \, x(7 - x)$$

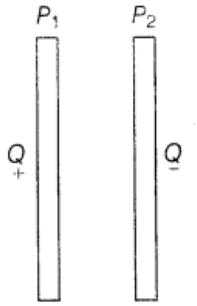
$$10 = x(7 - x)$$

$$\therefore x^2 - 7x + 10 = 0 \quad \Rightarrow \quad (x - 2)(x - 5) = 0$$

$$x = 2 \text{ μC or } 5 \text{ μC} \qquad \textbf{(1)}$$

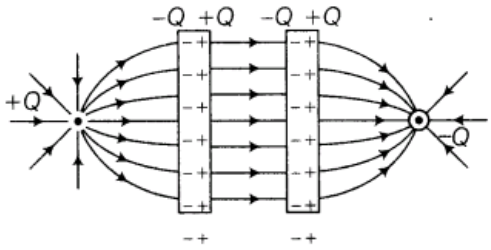
Therefore, charges are 2 μC and 5 μC.

28.Figure shows two large metal plates and P_2 tightly held against each other and placed between two equal and unlike point charges perpendicular to the line joining them.
(i)What will happen to the plates when they are released?
(ii)Draw the pattern of the electric field lines for the system.[HOTS; Foreign 2009]



Ans.(i) By electrostatic induction, charge induces on the plates and opposite nature of charge appears on the surface facing each other. Therefore, they start attracting towards each other.

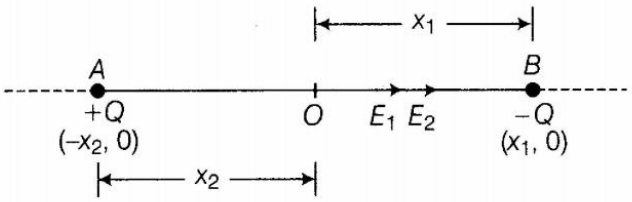
(*ii*) **(1)**



Field lines must be perpendicular to the plates. Also, equispaced field lines exist between two plates as electric field between, them is uniform.

29.Two charges + Q and -Q are kept at points ($-x_2$,0) and (x_t, 0) respectively, in the XY-plane. Find the magnitude and direction of the net electric field at the origin (0,0). [All India 2009 C]
Ans.

To find the electric field intensity at a point due to two charges, first of all find the individual electric fields due to both charges and then find the resultant field using vector addition.



Electric field intensity at O due to $+Q$ charge,

$$E_1 = \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{(x_2)^2} \quad \text{(towards } B\text{)} \quad \ldots(i)$$

Electric field intensity at O due to $-Q$ charge,

$$E_2 = \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{(x_1)^2} \quad \text{(towards } B\text{)} \quad \ldots(ii)$$

(1)

$\because$ E_1 and E_2 act along the same direction.

$\therefore$ Net electric field intensity at O,

$$E = E_1 + E_2 \quad \text{(towards } B\text{)}$$

$$= \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{(x_2)^2} + \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{(x_1)^2}$$

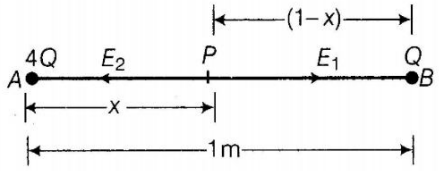
$$E = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{x_2^2} + \frac{1}{x_1^2}\right]$$

(1)

30.Two point charges 4Q and Q are separated by 1 m in air. At what point on the line joining of charges, is the electric field intensity zero? [All India 2008]

Ans.

Let electric field intensity at any point P which lies at a distance x metre from $4Q$ be zero.



$\therefore$ Electric field intensity (E_1) due to $4Q$ at P

= Electric field intensity (E_2) due to $+Q$ at P

As directions of $\mathbf{E}_1$ and $\mathbf{E}_2$ are in opposite directions.

$$\Rightarrow \quad \frac{1}{4\pi\varepsilon_0} \times \frac{4Q}{x^2} = \frac{1}{4\pi\varepsilon_0} \times \frac{Q}{(1-x)^2} \qquad \textbf{(1)}$$

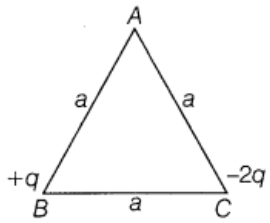
$$\text{or} \quad \frac{4}{x^2} = \frac{1}{(1-x)^2} \Rightarrow \left(\frac{1-x}{x}\right)^2 = \frac{1}{4} \Rightarrow \frac{1-x}{x} = \frac{1}{2}$$

$$\frac{1}{x} - 1 = \frac{1}{2} \quad \Rightarrow \quad \frac{1}{x} = \frac{3}{2} \quad \therefore \quad x = \frac{2}{3}\text{m}$$

Electric field intensity is zero at a point which lies at a distance $x = \frac{2}{3}$ m from $+4Q$ charge on the line joining two charges. **(1)**

3 Marks Questions

31.Two point charges + q and -2q are placed at the vertices B and C of an equilateral triangle ABC of side a as given in the figure. Obtain the expression for (i) the magnitude and (ii) the direction of the resultant electric field at the vertex A due to these two charges.



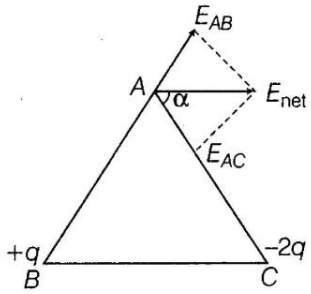
[All India 2014 C]

Ans.

(*i*) The magnitude,

$$|\mathbf{E}_{AB}| = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{a^2} = E \qquad \textbf{(1/2)}$$

$$|\mathbf{E}_{AB}| = \frac{1}{4\pi\varepsilon_0} \times \frac{2q}{a^2} = 2E \qquad \textbf{(1/2)}$$



$$E_{net} = \sqrt{(2E)^2 + E^2 + 2 \times 2E \times E \times \left(-\frac{1}{2}\right)}$$

$$= \sqrt{4E^2 + E^2 - 2E^2} = E\sqrt{3} \qquad \ldots(i) \quad \textbf{(1/2)}$$

We know that, $E = \dfrac{q}{4\pi\varepsilon_0 a^2}$

So, $E_{net} = \dfrac{q\sqrt{3}}{4\pi\varepsilon_0 a^2}$

(*ii*) Direction of resultant electric field at vertex **(1/2)**

$$\tan\alpha = \frac{E_{AB}\sin 120^\circ}{E_{AC} + E_{AB}\cos 120^\circ} = \frac{E \times \frac{\sqrt{3}}{2}}{2E + E \times \left(-\frac{1}{2}\right)}$$

$$\tan\alpha = \frac{1}{\sqrt{3}}$$

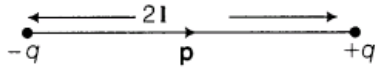
$$\alpha = \tan^{-1}\left(\frac{1}{\sqrt{3}}\right) \qquad \textbf{(1)}$$

$$\alpha = 30^\circ \text{ (with side } AC)$$

32.Define the term electric dipole moment. Is it a scalar or vector? Deduce an expression for the electric field at a point on the equatorial plane of an electric dipole of length 2a.[All India 2013; Foreign 2009]

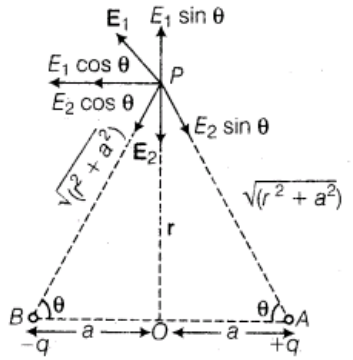
Ans.For electric dipole moment

Electric dipole moment of an electric dipole is equal to the product of its charges and the length of the electric dipole.It is denoted by p. Its unit is coulomb-metre.



$$\mathbf{p} = q \times 2\mathbf{l}$$

It is a vector quantity and its direction is from negative charge towards positive charge
Consider an electric dipole AB consists of two charges +q and -q separated by a distance 2a. We have to find electric field at point P on equipotential line separated by a distance



Electric field at point P due to charge $+q$

$$\mathbf{E}_1 = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{[\sqrt{(r^2 + a^2)}]^2}$$

$$= \frac{1}{4\pi\varepsilon_0} \times \frac{q}{(r^2 + a^2)} \text{ along } \mathbf{AP}$$

Electric field at point P due to charge $-q$

$$\mathbf{E}_2 = \frac{1}{4\pi\varepsilon_0} \times \frac{q}{r^2 + a^2} \text{ along } \mathbf{PB}$$

$$E = E_1 \cos\theta + E_2 \cos\theta$$

$$= \frac{1}{4\pi\varepsilon_0} \times \frac{q}{(r^2 + a^2)} \cos\theta + \frac{1}{4\pi\varepsilon_0} \times \frac{q}{(r^2 + a^2)} \cos\theta$$

$$= 2 \times \frac{1}{4\pi\varepsilon_0} \times \frac{q}{(r^2 + a^2)} \times \frac{a}{\sqrt{(r^2 + \quad ^2)}}$$

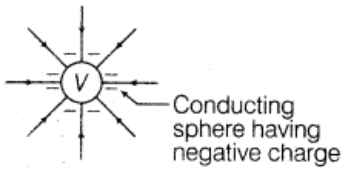
$$= \frac{1}{4\pi\varepsilon_0} \times \frac{q2a}{(r^2 + a^2)^{3/2}}$$

But $q \times 2a = P \quad \therefore \quad E = \frac{1}{4\pi\varepsilon_0} \times \frac{P}{(r^2 + a^2)^{3/2}}$

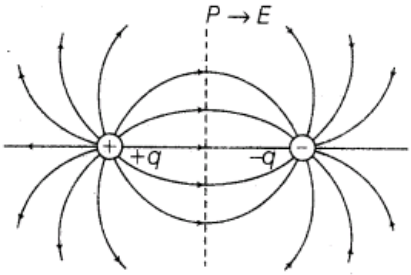
If $r >> a$, then $\quad E = \frac{1}{4\pi\varepsilon_0} \times \frac{P}{r^3}$ **(1)**

33.Sketch the pattern of electric field lines due to
(i) a conducting sphere having negative charge on it.
(ii) an electric dipole.[All India 2011 C]

Ans.(i) Electric field lines due to a conducting sphere are shown in figure

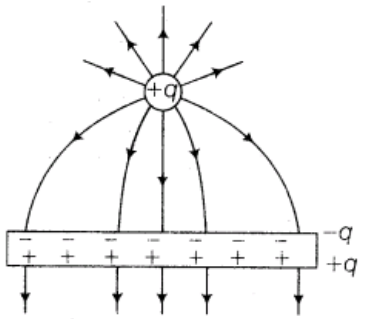


(ii) Electric field lines due to an electric dipole are shown in figure



34.A positive point charge (+ q) is kept in the vicinity of an uncharged conduction plate. Sketch electric field lines originated from the point on to the surface Of the plate. [All India 2009; HOTS]

Ans.Equal charge of opposite nature induces in the surface of conductor nearer to the source charge



Electric lines of forces should fall/normally 90° away on/from the conducting plate. **(1)**

4 Marks Questions

35.Deduce the expression for the torque acting on a dipole of dipole moment p in the presence of a uniform electric field E.[All India 2014; Delhi 2008]

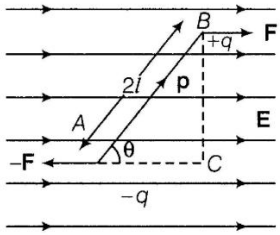
Ans. Torque on an Electric Dipole in a Uniform Electric Field Consider an electric dipole consisting of two charges – q and + q placed in a uniform external electric field of intensity The length of the electric dipole is 21.The dipole moment p makes an angle 0 with the direction of the electric field.

Two forces F and – F which are equal in magnitude and opposite in direction act on the dipole.

$$|\mathbf{F}| = |-\mathbf{F}| = qE$$

The net force is zero. Since, the two forces are equal in magnitude opposite in direction and act at different points, therefore, they constitute a couple.

A net torque x acts on the dipole about an axis passing through the mid-point of the dipole



Dipole in a uniform electric field

Now,

τ = either force × perpendicular distance BC between parallel forces

$= qE(2l \sin\theta)$

$\tau = (q \times 2l)E \sin\theta$ or $\tau = pE \sin\theta$

In vector notation,

$\tau = \mathbf{p} \times \mathbf{E}$

SI unit of torque is newton-metre (N-m) and its dimensional formula is $[ML^2T^{-2}]$.

***Case* 1** If $\theta = 0°$, then $\tau = 0$

The dipole is in stable equilibrium. **(1/2)**

***Case* 2** If $\theta = 90°$, then $\tau = pE$ (maximum value)

The torque acting on dipole will be maximum.

***Case* 3** If $\theta = 180°$, then $\tau = 0$ **(1)**

The dipole is in unstable equilibrium. **(3)**

36.While travelling back to his residence in the car, Dr. Pathak was caught up in a thunderstorm. It became very dark. He stopped driving the car and waited for thunderstorm to stop. Suddenly, he noticed a child walking alone on the road. He asked the boy to come inside the car till the thunderstorm stopped Dr.Pathak dropped the boy at his residence. The boy insisted that Dr. Pathak should meet his parents. The parents expressed their gratitude to Dr. Pathak for his concern for safety of the child.

Answer the following questions based on the above information

(i)Why is it safer to sit inside a car during a thunderstorm?

(ii)Which two values are displayed by Dr. Pathak in his action?

(iii)Which values are reflected in parents response to Dr. Pathak?

(iv)Give an example of similar action on your part in the past from everyday life.[Delhi 2013; VBQ]

Ans.(i)It is safer to be set inside a car during thunderstorm because the car acts like a Faraday cage. The metal in the car will shield you from any external electric fields and thus prevent the lightning from travelling within the car.

(ii) Awareness and humanity

(iii) Gratitude and obliged

(iv) I once came across to a situation where a puppy was stuck in the middle of a busy road during rain and was not able to go cross due to heavy flow, so I quickly rushed and helped him.

37.An electric dipole moment p is held in a uniform electric field E.

(i)Prove that no translation force acts on the dipole.

(ii)Hence, prove that the torque acting on the dipole is given by pE sin 0 indicating the direction along which it acts. [Foreign 2008]

Ans.(i)When dipole is placed in a unifrom electric field, then force on +q charge due to electric field E

$$\mathbf{F}_1 = q\mathbf{E} \text{ (along } \mathbf{E})$$

Force on $-q$ charge

$$\mathbf{F}_2 = -q\mathbf{E} \text{ (opposite to } \mathbf{E})$$

$\therefore$ Net force on dipole $F_{net} = \mathbf{F}_1 + \mathbf{F}_2$

$$= e\mathbf{E} + (-q\mathbf{E}) = 0$$

$$F_{net} = 0 \qquad \textbf{(2)}$$

Net translating force on dipole is zero.

(ii)It is safer to be set inside a car during thunderstorm because the car acts like a Faraday cage. The metal in the car will shield you from any external electric fields and thus prevent the lightning from travelling within the car.

(a) Awareness and humanity

(b) Gratitude and obliged

(c) I once came across to a situation where a puppy was stuck in the middle of a busy road during rain and was not able to go cross due to heavy flow, so I quickly rushed and helped him.