DRGP Institute

Chapter 1

Electric Charges And Fields

Chapter 1
Electric Charges And Fields

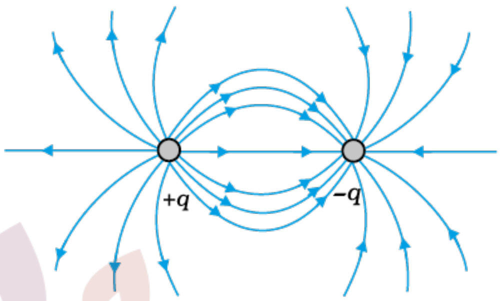
BOARD- 2013

1. write two properties of electric field line. (1 Marks)

Ans:- 1. Field line start from +ve charges and end at -ve charges. If there is a single charge, they may start or end at ∞.

2. Two field lines can never cross each other.

3. They don't form any closed loops.



2. (i) write the statement of Gauss's Law for electrostatics. (1/2)

(ii) Draw a diagram & derive an expression for electric field due to a uniformly charged ∞ plane sheet at a point near the sheet. (1/2+2)

(iii) In a given diagram write the value of electric flux passing from the surface.

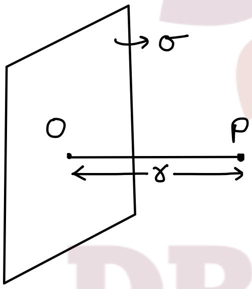
- $q_1 = 2\mu C$
- $q_2 = -1\mu C$

(1/2)

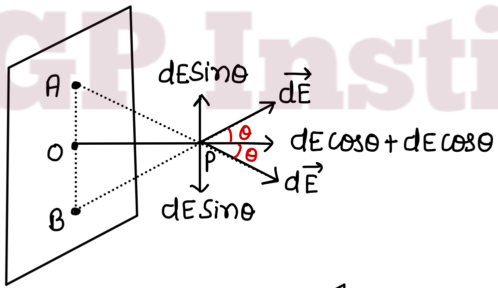
Ans. (i) Gauss's Law - Electric flux through a closed surface is $1/\varepsilon_0$ times of total charge enclosed in surface.

$$\phi = \frac{\Sigma q}{\varepsilon_0}$$

(ii)

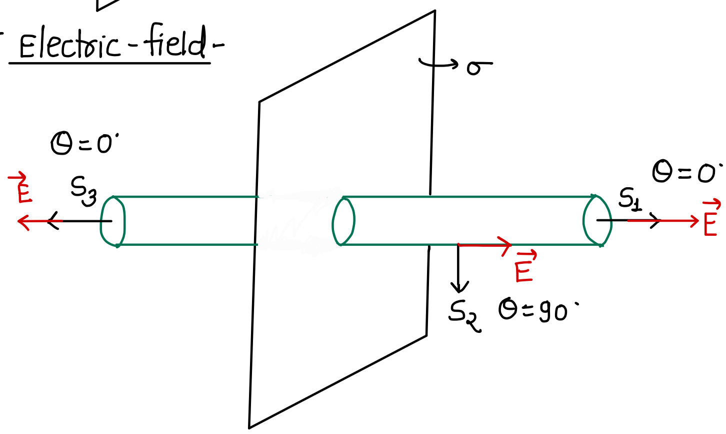


Suppose there is uniformly charged ∞ plane sheet with σ surface charge density. There is a point P at r ⊥ distance from sheet.



→ By the direction of components it is clear that net electric field is in direction of $\vec{OP}$.

Calculation of Electric-field-



→ Take a cylindrical gausian surface passing through sheet.

→ According to gauss Law -

$$\oint \vec{E}\cdot\vec{ds} = \frac{\Sigma q}{\varepsilon_0}$$

$$\int_{S_1} E ds \cos\theta + \int_{S_2} E ds \cos\theta + \int_{S_3} E ds \cos\theta = \frac{\Sigma q}{\varepsilon_0}$$

$$\int_{S_1} E ds \cos 0^\circ + \int_{S_2} E ds \cos 90^\circ + \int_{S_3} E ds \cos 0^\circ = \frac{\Sigma q}{\varepsilon_0}$$ { $\cos 0^\circ = 1$, $\cos 90^\circ = 0$ }

$$\int_{S_1} E ds + \int_{S_3} E ds = \frac{\sigma S}{\varepsilon_0}$$ { $\sigma = \frac{\Sigma q}{S}$ }

$$E\int_{S_1} ds + E\int_{S_3} ds = \frac{\sigma S}{\varepsilon_0}$$

$$ES + ES = \frac{\sigma S}{\varepsilon_0}$$

$$2ES = \frac{\sigma S}{\varepsilon_0}$$

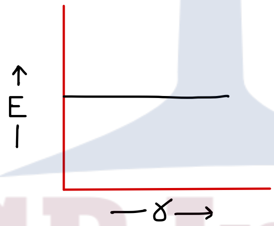
$$\boxed{E = \frac{\sigma}{2\varepsilon_0}}$$

in vector form

$$\boxed{\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{n}}$$

$\hat{n}$ is the unit vector (⊥ to charged surface)

Graph b/w $\vec{E}$ & r -



E not depends on r.

(iii)

- $q_1 = 2\mu C$
- $q_2 = -1\mu C$

$$\phi = \frac{\Sigma q}{\varepsilon_0} = \frac{(2\times10^{-6}) + (-1\times10^{-6})}{8.85\times10^{-12}}$$

$$\phi = \frac{10^{-6}}{8.85\times10^{-12}} = \frac{10^{6}}{8.85} = 1.13\times10^{5}\ V\times m$$

or Nm^2/C

BOARD- 2013 (Supp.)

No Question asked

BOARD- 2014

3. Define electric flux. Apply Gauss' Law to obtain an expression for the electric field intensity at a point due to an infinitely long uniformly charged straight wire. Draw the necessary diagram. [1+2+1=4]

Ans- Electric flux- Dot product of electric field intensity and area vector is called electric flux.

$$\phi = \vec{E}\cdot\vec{S}$$

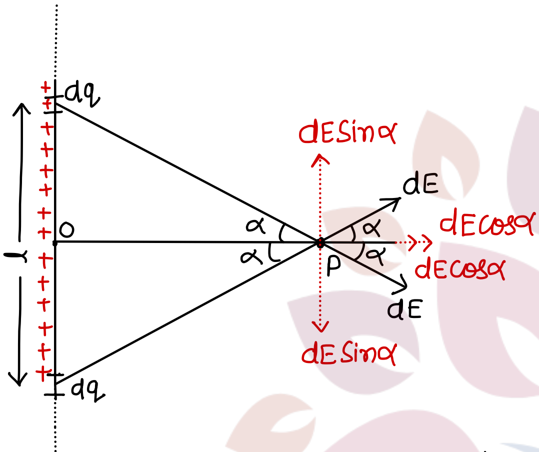
or

$$\phi = \oint \vec{E}\cdot\vec{ds}$$

SI Unit - Nm^2/C or $V \times m$

Electric field intensity ∞ long uniform charged straight wire-

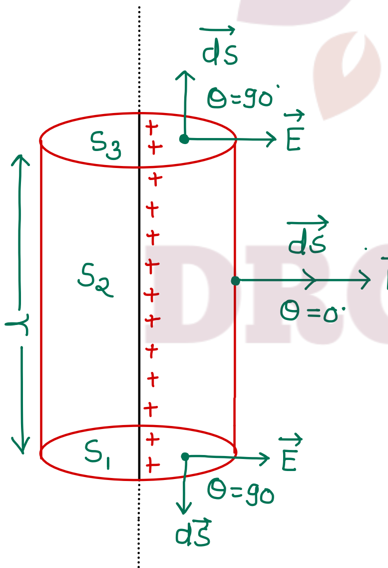
Suppose there is uniformly charged ∞ plane sheet with λ linear charge density. There is a point P at r ⊥ distance from sheet. On this point we want to calculate Electric field.



→ $dE\sin\alpha$ component of electric field are equal in magnitude and opposite in direction so they cancel each other.

→ $dE\cos\alpha$ component of Electric field are in same direction. So direction of E.F is ⊥ to the wire.

→ To calculate Electric field we assume a cylindrical gaussian surface around wire.



according to gauss Law -

$$\oint \vec{E}\cdot\vec{ds} = \frac{\Sigma q}{\varepsilon_0}$$

$$\int_{S_1} Eds\cos\theta + \int_{S_2} Eds\cos\theta + \int_{S_3} Eds\cos\theta = \frac{\Sigma q}{\varepsilon_0}$$

$$\int_{S_1} Eds\cos 90^\circ + \int_{S_2} Eds\cos 0^\circ + \int_{S_3} Eds\cos 90^\circ = \frac{\Sigma q}{\varepsilon_0}$$

$$0 + \int_{S_2} Eds + 0 = \frac{\Sigma q}{\varepsilon_0} \qquad \left\{ \begin{matrix} \cos 90^\circ = 0 \\ \cos 0^\circ = 1 \end{matrix} \right\}$$

$$E\int ds = \frac{\lambda l}{\varepsilon_0} \qquad \{ \lambda = \Sigma q / l \}$$

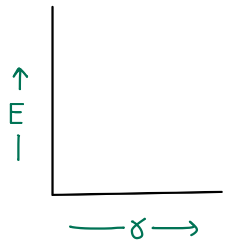
$$E(2\pi r l) = \frac{\lambda l}{\varepsilon_0}$$

$$\boxed{E = \frac{\lambda}{2\pi\varepsilon_0 r}}$$

or

$$E = \frac{2\lambda}{4\pi\varepsilon_0 r}$$

$$E = \frac{2K\lambda}{r}$$



In vector form-

$$\vec{E} = \frac{2K\lambda}{r}\hat{n}$$

where $\hat{n}$ is a unit vector in ⊥ direction of wire

BOARD- 2015

4. Write Gauss law.

Ans- According to this law " Flux linked with any closed surface is always $1/\varepsilon_0$ time of total charge enclosed by Closed Surface"

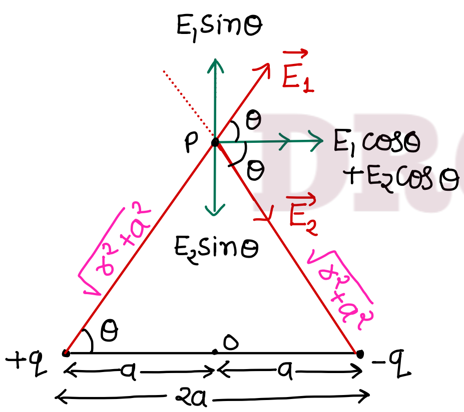
$$\phi = \frac{\Sigma q}{\varepsilon_0}$$

or

$$\oint \vec{E}\cdot\vec{ds} = \frac{\Sigma q}{\varepsilon_0}$$

5. (a) Derive a relation for electric field due to an electric dipole at a point on the equatorial plane of the electric dipole. Draw necessary diagram.
(b) An electric dipole of charge ± 1μc exists inside a spherical Gaussian surface of radius 1 cm. Write the value of outgoing flux from the Gaussian surface.

Ans- (a) Electric field due to electric dipole at equatorial point -



Suppose we have electric dipole of P dipole moment. ($P = q\,2a$). we want to calculate electric field intensity at r ⊥ distance from mid point of O.

→ Electric field at point P due to +q charge-

$$E_1 = \frac{Kq}{(\sqrt{r^2+a^2})^2}$$

$$E_1 = \frac{Kq}{r^2+a^2}$$

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

$$E_2 = \frac{Kq}{(\sqrt{r^2+a^2})^2}$$

$$E_2 = \frac{Kq}{r^2+a^2}$$

$$E_1 = E_2 = E = \frac{Kq}{r^2+a^2}$$

→ $E_1 \sin\theta$ & $E_2 \sin\theta$ component of electric field are equal in magnitude & opposite in direction so they cancel each other.

→ So Net electric field at point P –

$$E_{eq} = E_1 \cos\theta + E_2 \cos\theta$$
$$E_{eq} = E\cos\theta + E\cos\theta$$
$$E_{eq} = 2E\cos\theta$$

$$E_{eq} = \frac{2Kq}{r^2+a^2}\cos\theta \quad -① $$

$$\cos\theta = \frac{B}{H} = \frac{a}{\sqrt{r^2+a^2}}$$

put in eq^n ①

$$E_{eq} = \frac{2Kq}{r^2+a^2} \times \frac{a}{\sqrt{r^2+a^2}}$$

$$E_{eq} = \frac{2Kqa}{(r^2+a^2)^{3/2}}$$

$\{ r >> a$ so $r^2+a^2 \simeq r^2$, $2qa = P \}$

$$E_{eq} = \frac{KP}{(r^2)^{3/2}}$$

$$\boxed{E_{eq} = \frac{KP}{r^3}}$$

vector form $\vec{E} = -\frac{K\vec{P}}{r^3}$

{direction opposite to $\vec{P}$ +ve to -ve}

(b) Total charge enclosed by the spherical Gaussian Surface-

$$\Sigma q = 1\mu C - 1\mu C = 0$$

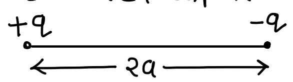
$$\phi = \frac{\Sigma q}{\varepsilon_0}$$

$$\boxed{\phi = 0}$$

BOARD- 2016

6. write the definition of dipole moment.

Ans- Product of magnitude of any one charge and distance b/w both charges is called dipole moment.



$\vec{P} = q(2\vec{a})$

Unit - Cm

Direction - $-q$ to $+q$

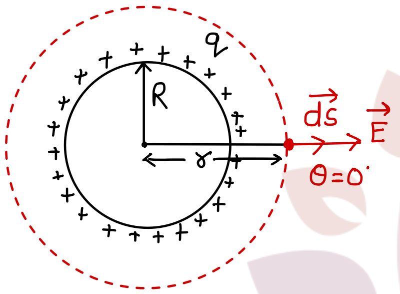
7. write Gauss's Law. Determine the electric field at the points which are situated outside and inside of a uniform charged thin spherical

Shell. Draw Necessary diagrams of Gaussian surfaces.

Ans- Uniformly charged thin spherical shell (Conducting sphere)

Suppose we have a uniformly charged sphere of a radius R and charged q. we want to calculate electric field at r distance from centre.

(i) Electric field intensity outside the shell ($r>R$) - According to gauss Law -



$$\oint \vec{E}\cdot\vec{ds} = \frac{\Sigma q}{\varepsilon_0}$$

$$\int E\,ds\cos 0° = \frac{\Sigma q}{\varepsilon_0}$$

$$E\oint ds = \frac{q}{\varepsilon_0} \qquad \left\{ \begin{array}{l} \cos 0° = 1 \\ \Sigma q = q \end{array} \right\}$$

$$E(4\pi r^2) = \frac{q}{\varepsilon_0}$$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$$

$$\boxed{E_{out} = \frac{Kq}{r^2}}$$

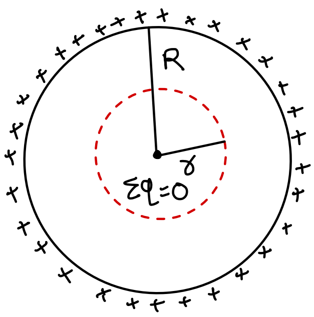
(ii) Electric field intensity surface of the shell ($r=R$) -

$$\oint \vec{E}\cdot\vec{ds} = \frac{\Sigma q}{\varepsilon_0}$$

$$E(4\pi R^2) = \frac{q}{\varepsilon_0}$$

$$\boxed{E_{surface} = \frac{Kq}{R^2}}$$

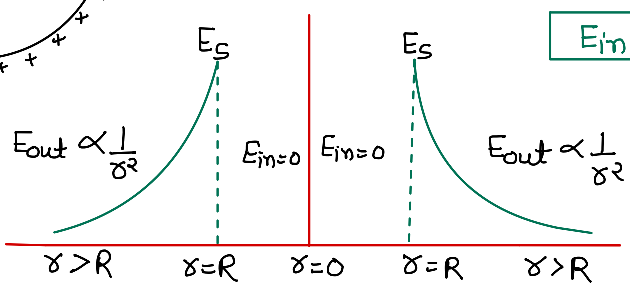
(iii) Electric field intensity inside the shell ($r<R$) -



Total charge enclosed by gaussian surface is zero. So, electric field intensity inside the shell will be zero.

$$\Sigma q = 0$$

$$\boxed{E_{in} = 0}$$



BOARD - 2017

8. State Gauss law in electrostatics. Derive an expression of electric field due to an infinitely long straight uniform charged wire. Draw necessary diagram. [1+2+1 Marks]

BOARD - 2017 (Supp.)

NO Question asked

BOARD - 2018

9. Define electric field intensity. [1 MARKS]

Ans - Electric field intensity at any point in the electric field is equal to the force acting on a unit positive test charge at that point.

$$\vec{E} = \frac{\vec{F}}{q_0} \qquad \text{unit - N/C}$$

BOARD - 2018 (Supp)

10. What will be the value of electrostatic force b/w two point charges when a conducting medium is present b/w them? [1]

Ans - In presence of medium electrostatic force b/w two point charges are -

$$F_m = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{q_1q_2}{r^2}$$

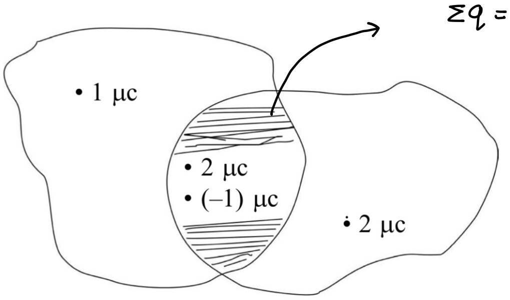
ε_r of conducting medium is ∞

So, $F_m = 0$

11. (a) Define dipole moment.
(b) Derive expression to find electric field intensity at a point on equitorial line of an electric dipole. Draw necessary diagram. [1+2+1]

BOARD - 2019

12. (a) Write statement of gauss law. Derive expression of electric field due to uniformely charged ∞ non-conducting sheet at a point near to it.
(b) find flux in shaded area -



$\Sigma q = 2 - 1 = 1\mu C$

$$\phi = \frac{\Sigma q}{\varepsilon_0}$$

$$\phi = \frac{1\times10^{-6}}{\varepsilon_0} \ Vxm$$

13. Define electric dipole moment.

BOARD-2020

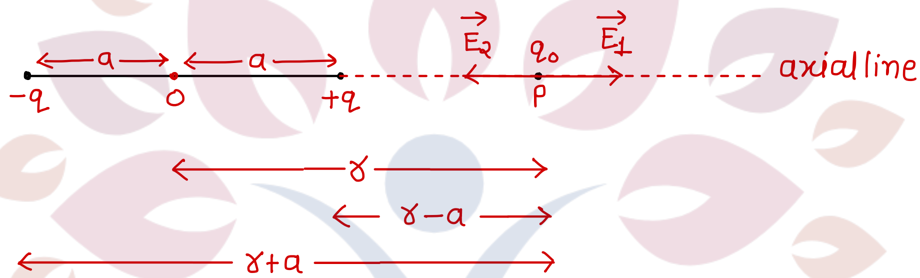
No question asked

BOARD-2020 (Supp)

14. what is electric dipole? obtain the expression of the electric field at a point on the axial line due to electric dipole. Draw necessary diagram.

Ans:- Pair of two equal and opposite point charge separated by very small distance is called electric dipole.

Expression of electric field at axial line -



$\vec{E_1}$ is electric field intensity at point p, due to +q-

$$E_1 = \frac{Kq}{(r-a)^2}$$

$\vec{E_2}$ is electric field intensity at point P, due to -q-

$$E_2 = \frac{Kq}{(r+a)^2}$$

$\vec{E_1}$ & $\vec{E_2}$ are in opposite direction

& $E_1 > E_2$

So, Net electric field-

$$E = E_1 - E_2$$

$$E = \frac{Kq}{(r-a)^2} - \frac{Kq}{(r+a)^2}$$

$$E = Kq\left[\frac{(r+a)^2-(r-a)^2}{(r-a)^2(r+a)^2}\right]$$

$$E = Kq\left[\frac{(r^2+a^2+2ra)-(r^2+a^2-2ra)}{\{r^2-a^2\}^2}\right]$$

$$E = Kq\left[\frac{r^2+a^2+2ra-r^2-a^2+2ra}{(r^2)^2}\right] \quad \left\{\begin{matrix} r>>a \\ r^2-a^2 \simeq r^2\end{matrix}\right\}$$

$$E = Kq\left[\frac{4ra}{r^4}\right]$$

$$E = \frac{Kq(4a)}{r^3}$$

$$E = \frac{2Kq(2a)}{r^3}$$

$$\boxed{E = \frac{2Kp}{r^3}}$$

vector form

$$\vec{E} = \frac{2K\vec{p}}{r^3}$$ {direction:- along direction of dipole moment [$-q$ to $+q$]}

15. What is electric flux? Derive an expression of intensity of electric field at any point due to an ∞ linear charged wire by Gauss Law. Draw necessary diagram.

BOARD-2021

16. There are 'n' electric dipole situated inside a closed surface. The value of net electric flux leaving from the closed surface will be- (1 Mark)

(a) nq/ε_0 (b) q/ε_0 (c) $q/n\varepsilon_0$ (d) zero

Ans - zero

17. Define intensity of electric field. Obtain the formula for the intensity of electric field at a point on the axial line due to the electric dipole. Draw necessary diagram. (1+2+1=4)

BOARD-2022

18. The SI unit of electric flux- [1 Marks]

(a) $NC^{-1}m^2$ (b) $NC^{-1}m^{-2}$ (c) $N^{-1}C^{-1}m^{-2}$ (d) $N^{-1}C^{1}m^2$

Ans- $NC^{-1}m^2$

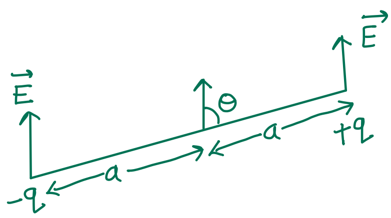
19. In Millikan's experiment, the charge found on a charged droplet was $-6.4\times10^{-19}C$, then write the number of electrons in that charged droplet. [1 Marks]

Ans-

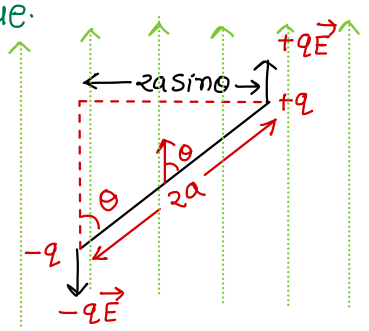
$$q = ne$$
$$n = q/e$$
$$n = \frac{6.4\times10^{-19}}{1.6\times10^{-19}} = 4e^-$$

20. Write the definition of electric dipole. An electric dipole placed in uniform external field. Calculate torque. [1+2 Marks]

Ans -



⇒



Suppose an electric dipole is placed in uniform electric field E. Dipole moment of dipole is $\vec{p}$ and angle b/w dipole moment $\vec{p}$ and $\vec{E}$ is θ.

→ Force on both end of dipole is equal and opposite so, net force is zero and due to it no translatory motion in dipole.

→ But line of action of both force is different so, Due to which torque is produced. So, there is rotational motion occur in dipole.

Torque = Force × ⊥ distance b/w line of action of force

$$\tau = F \times 2a\sin\theta$$
$$\tau = qE(2a\sin\theta)$$
$$\tau = (q\cdot 2a)E\sin\theta$$
$$\tau = PE\sin\theta$$
$$\boxed{\vec{\tau} = \vec{p}\times\vec{E}}$$

direction of τ will be ⊥ to the both $\vec{p}\times\vec{E}$ according to Right hand thumb rule.

BOARD - 2023

21. The SI value of permitivity of free space of vaccum is -

a. 9×10^{9} Nm^2/C^2 b. 9×10^{-9} Nm^2/C^2

c. 8.85×10^{-12} C^2/Nm^2 d. 8.85×10^{12} C^2/Nm^2

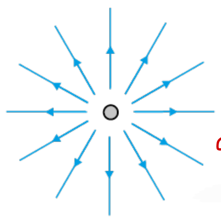
Ans - 8.85×10^{-12} C^2/Nm^2

22. A uniformly thin charged spherical shell has an electric field at all points .... inside it.

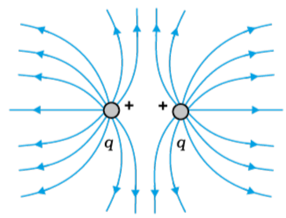
Ans - Zero

23. Show electric field line due to a single charge (q>0).

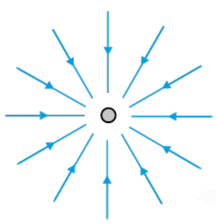
Ans -



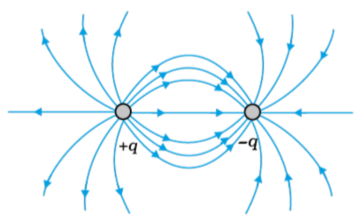
q>0



Same charge



q<0



Opposite charge

Board-2024

24. The electric flux on a Gaussian spherical surface of radius 15cm, drawn with a point charge as the centre is ϕ. If the radius of this surface is tripled then electric flux passing through the surface will be-

a. zero b. ∞ c. 3ϕ d. ϕ

Ans- ϕ

25. The field lines of a single +ve charge are radially ....

Radially outward.

26. Derive formula for the electric field due to electric dipole at any point on the equatorial plane. Draw necessary diagram.

27. obtain an expression for the electric field at any point due to a uniformly charged infinite plane sheet with the help of Gauss's Law. Draw necessary diagram.

Additional

Properties of Field Lines

1. Field line start from +ve and end at -ve charge. If there is a single charge, they may start or end at infinity.
2. Electric field lines do not form any closed loop.
3. Tangent drawn on a point on field line denotes direction of electric field.
4. Two field line can never cross each other.
   If they did, there will be 2 directions of electric field at intersection point, which is not possible.

Best of Luck for Exam