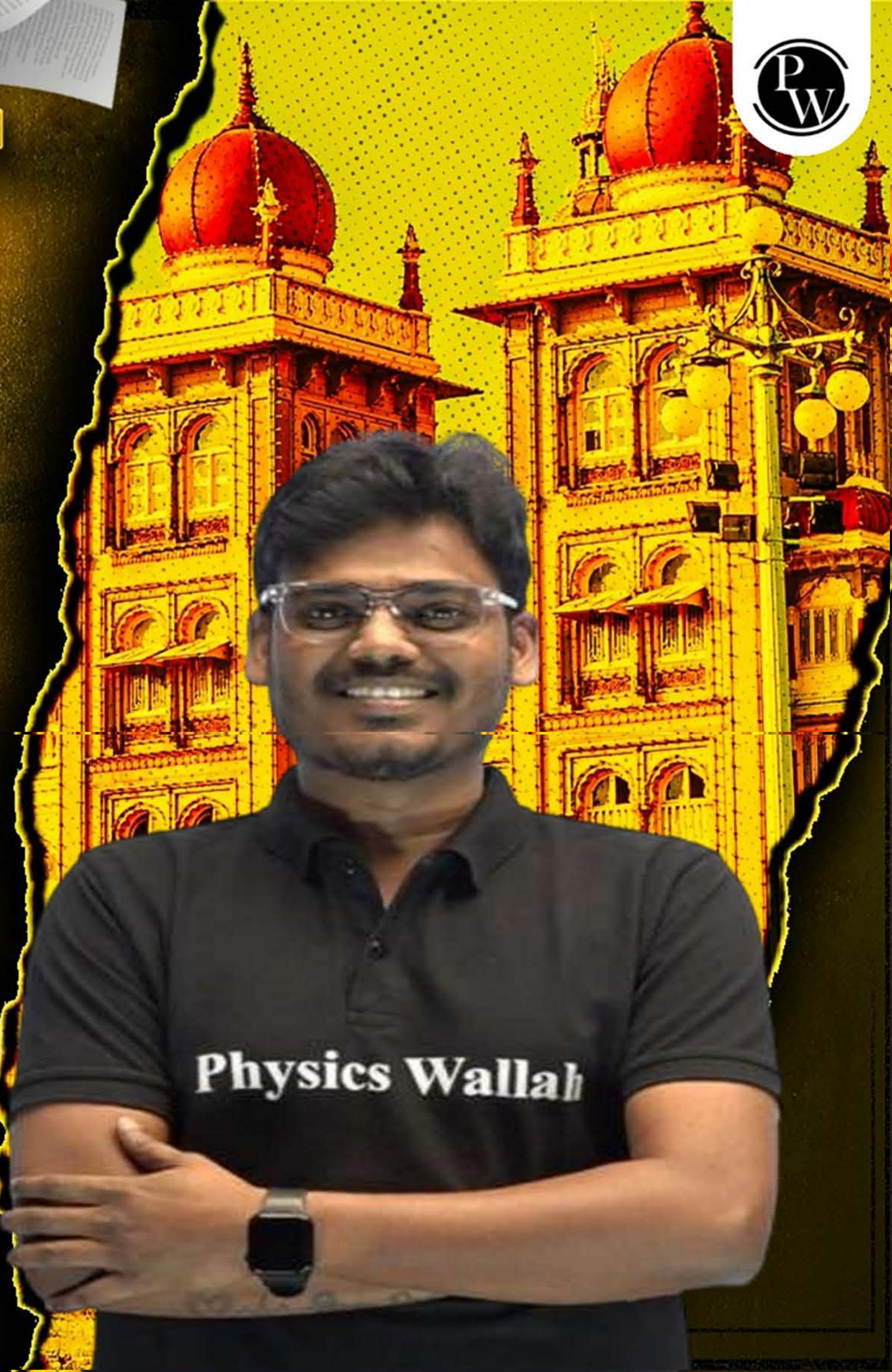
ULTIMATE KCET

CRASH COURSE 2026

PHYSICS | Lecture - 02

ELECTRIC CHARGES AND FIELDS

By – AK SIR



Recap *of previous lecture*

1. CHARGE AND ITS PROPERTIES
2. COULOMB'S LAW
3. ELECTRIC FIELD AND FIELD LINES
4. QUESTIONS

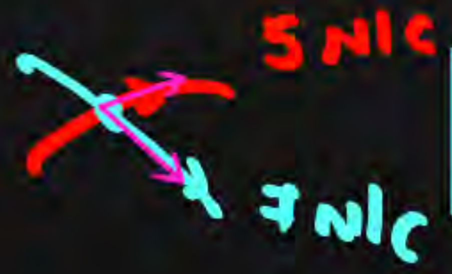
Topics *to be covered*

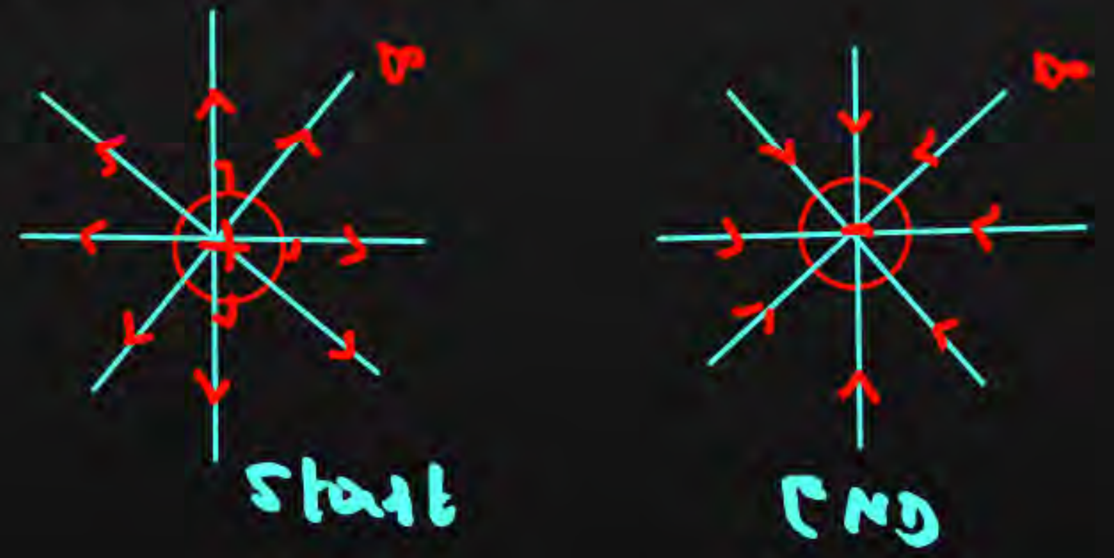
1. ELECTRIC DIPOLE AND DIPOLE MOMENT
2. FORCE AND TORQUE ON A ELECTRIC DIPOLE
3. ELECTRIC FLUX AND ITS CALCULATIONS
4. GAUSS'S LAW AND ITS APPLICATIONS

Electric field lines or Lines of forces

Properties: These are the imaginary lines of force in electric field of charge.

1. Electric field lines are geometrical representation of strength of electric field.
2. Electric field lines originate from positive charge and terminate on the negative charge.
3. Electric field lines are always perpendicular to the surface of the conductor.
4. Electric field lines do not pass through the conductor.
5. Electric field lines do not intersect.
6. They do not form any closed loops.





Question

Which of the electrostatic lines of forces are correct drawn?

(A) 

(B) 

(C) 

(D) All of these

Question

Electric field lines about a negative point charge are

A. Circular, anticlockwise

B. Circular, clockwise

C. Radial, inwards

D. Radial, outwards

Question

The figure shows some of the electric field lines corresponding to an electric field. The figure suggests

(A) $E_A > E_B > E_C$ ✗

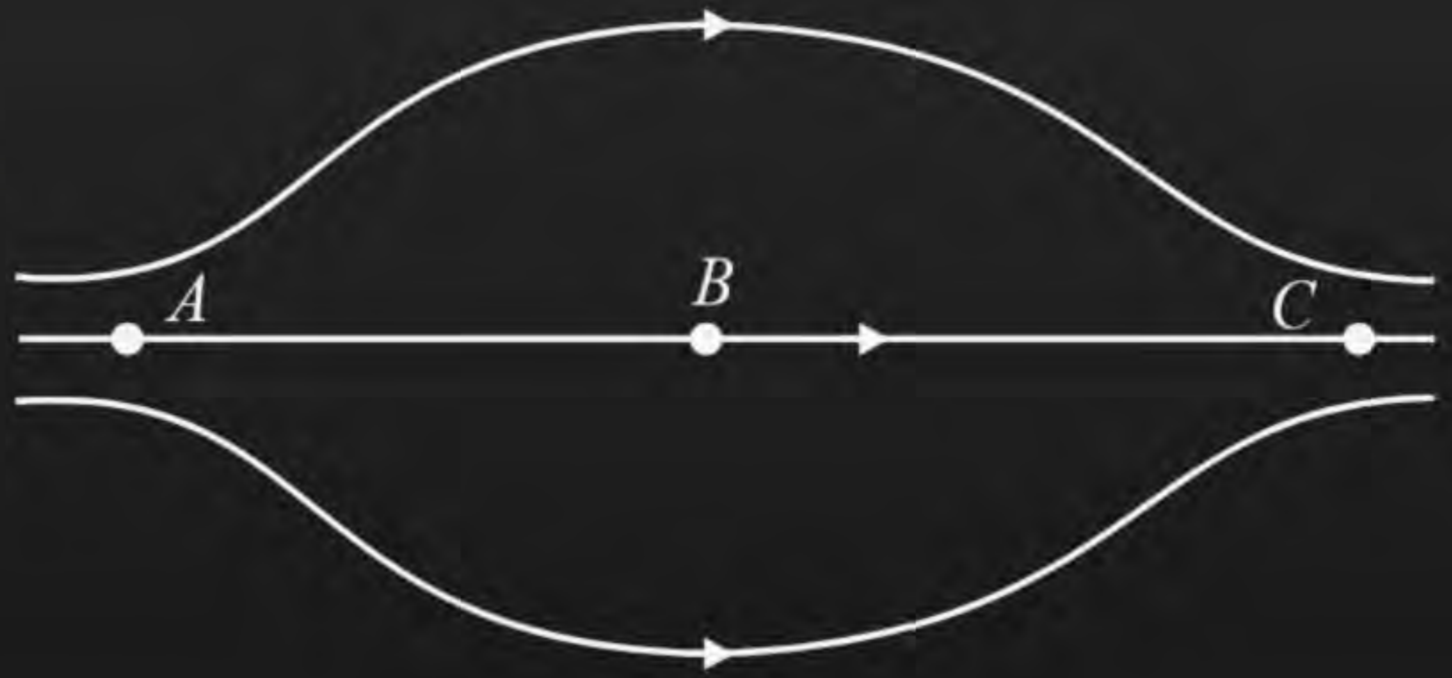
(B) $E_A = E_B = E_C$ ✗

(C) $E_A = E_C > E_B$ ✓

(D) $E_A = E_C < E_B$

$E.F \propto \frac{1}{\text{spacing}}$

$E_A = E_C > E_B$



Question

$E = \frac{Kq}{r^2}$ due to point charge

$\downarrow E \propto \frac{1}{r^2}$

The electric field lines on the left have twice the separation on those on the right as shown in figure. If the magnitude of the field at A is 40 vm^{-1} what is the force on 20 μC charge kept at *B*

$r_B = 2r_A$

(A) 4×10^{-4} N

(B) 8×10^{-4} N

(C) 16×10^{-4} N

(D) 1×10^{-4} N

E.F $\propto \frac{1}{\text{Spacing}}$

$\frac{E_B}{E_A} = \frac{r_A}{r_B} = \frac{r_A}{2r_A} = \frac{1}{2}$

$E_B = \frac{E_A}{2} = \frac{40}{2}$

$E_B = 20\ V/m$

$F_B = qE_B$

$F_B = 20 \times 10^{-6} \times 20 = 400 \times 10^{-6}$

$F_B = 4 \times 10^{-4}$ N

Question

Pick out the statement which is incorrect?

(A) A negative test charge experiences a force opposite to the direction of the field ✓

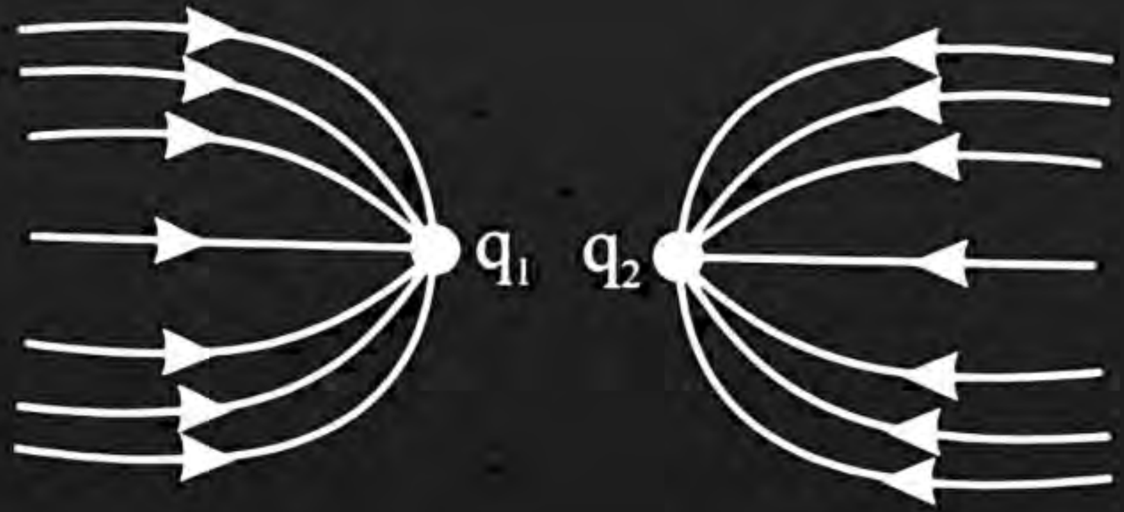
(B) The tangent drawn to a line of force represents direction of electric field ✓

(C) Field lines never intersect ✓

(D) The electric field lines forms closed loop ✗

Question

The given figure gives electric lines of force due to two charges q_1 and q_2. What are the signs of the two charges?



A. q_1 is positive but q_2 is negative

B. q_1 is negative but q_2 is positive

C. Both are negative

D. Both are positive

Question

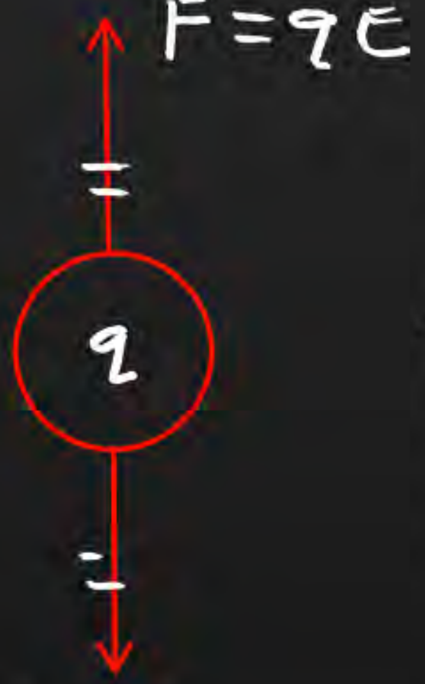
Calculate the magnitude of an electric field which can just suspend a deutron of mass $3.2 \times 10^{-27} kg$ freely in air

Rest

H_1^1, H_1^2, H_1^3

$\alpha \rightarrow He_2^4$

X_Z^A, $Z \rightarrow$ No. of proton



$w = mg$

$F = w$

$qE = mg$

$E = \frac{mg}{q} = \frac{3.2 \times 10^{-27} \times 10}{1.6 \times 10^{-19}}$

$E = 20 \times 10^{-8}$

$E = 2 \times 10^{-7} N/C$

H_1^2 $q_d = q$ ✓

$m_d = 2m$ ✓

Question

$u = 0$

A charged particle of mass m and charge q is released from rest in an uniform electric field E. Neglecting the effect of gravity, the kinetic energy of the charged particle after t seconds is

(A) $\frac{Eq^2m}{2t^2}$

(B) $\frac{Eqm}{t}$

(C) $\frac{E^2q^2t^2}{2m}$

(D) $\frac{2E^2t^2}{mq}$

$K = \frac{1}{2}mv^2$

$v = 0 + at = \frac{qE}{m}t$

$K = \frac{1}{2}m \times \frac{q^2E^2t^2}{m^2}$

$K = \frac{q^2E^2t^2}{2m}$

From class-11

$v = u + at$ ✓

$s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

Question

A particle of mass m and charge q is placed at rest in uniform electric field E and then released. The kinetic energy attained by the particle after moving a distance y is

(A) qEy^2

(B) qE^2y

(C) qEy

(D) q^2Ey

$u = 0$

$K = \frac{1}{2}mv^2 = \frac{1}{2} m \times \frac{2qEy}{m}$

$K = qEy$

$s = ut + \frac{1}{2}at$

$v^2 = u^2 + 2as$

$v^2 = 0^2 + 2\frac{qE}{m}y$

$v^2 = \frac{2qEy}{m}$

Question

The magnitude of point charge due to which the electric field 30 cm away has the magnitude 2 NC^{-1} will be

(A) 2×10^{-11} C

(B) 3×10^{-11} C

(C) 5×10^{-11} C

(D) 9×10^{-11} C

$$E = \frac{Kq}{r^2}$$

$$q = \frac{Er^2}{K}$$

$$q = \frac{2 \times (30 \times 10^{-2})^2}{9 \times 10^9}$$

$$q = \frac{2 \times 900 \times 10^{-4}}{9 \times 10^9} = 2 \times 10^2 \times 10^{-4-9} = 2 \times 10^{-11}$$

$$q = 2 \times 10^{-11}\ C$$

Question

$u = 0$

In the uniform electric field of $E = 1 \times 10^4$ NC^{-1} an electron is accelerated from rest. The velocity of the electron when it has travelled a distance of 2×10^{-2} m is nearly

s

$\frac{e}{m}$ *of electron* $\approx 1.8\times10^{11}\ C\ kg^{-1}$

A $8.5 \times 10^6\ \text{ms}^{-1}$

B $1.6 \times 10^6\ \text{ms}^{-1}$

C $0.85 \times 10^6\ \text{ms}^{-1}$

D $0.425 \times 10^6\ \text{ms}^{-1}$

$v^2 = u^2 + 2as$

$v^2 = 0^2 + 2\frac{qE}{m}s$

$v^2 = 2\left(\frac{e}{m}\right)Es = 2\times1.8\times10^{11}\times1\times10^4\times2\times10^{-2}$

$v^2 = 7.2\times10^{13} = 72\times10^{12}$

$v = \sqrt{72\times10^{12}} = 8.5\times10^6$ m/s

Question

$u=0$

An electron of mass m, charge e falls through a distance h metre in a uniform electric field E. Then, time of fall

(A) $t = \sqrt{\dfrac{2hm}{eE}}$

(B) $t = \dfrac{2hm}{eE}$

(C) $t = \sqrt{\dfrac{2em}{hE}}$

(D) $t = \dfrac{2eE}{hm}$

$S = ut + \frac{1}{2}at^2$

$h = 0(t) + \frac{1}{2}\frac{qE}{m} \cdot t^2$

$h = \frac{1}{2}\frac{eE}{m}t^2$

$t^2 = \frac{2hm}{eE}$

$t = \sqrt{\frac{2hm}{eE}}$

Question

Acceleration of a charged particle of charge q and mass m moving in a uniform electric field of strength E is

A. $\frac{q}{mE}$

B. $\frac{qE}{m}$

C. $\frac{m}{qE}$

D. mqE

Question

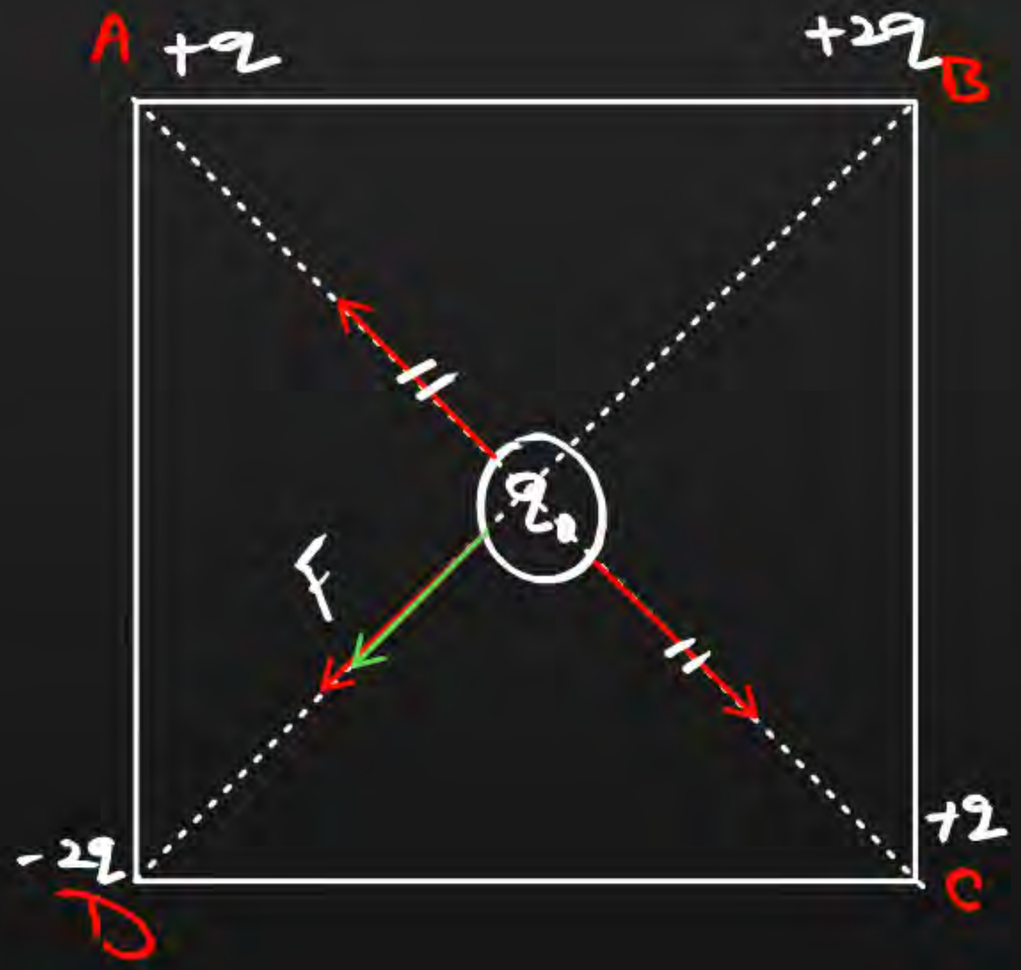
Four charges $+q, +2q$, $+q$ and $-2q$. are placed at the corners of a square ABCD respectively. The force on a unit positive charge kept at the centre O is

(A) Along the diagonal BD

(B) Along the diagonal AC

(C) Perpendicular to AD

(D) Zero



Question

A 2 g object, located in a region of uniform electric field $E = (300\ NC^{-1})\ \hat{i}$ carries a charge Q. The object released from rest at $x = 0$ has a kinetic energy of 0.12 J at x = 0.5m Then, Q is

(A) 400 μC

(B) – 400 μC

(C) 800 μC

(D) – 800 μC

$u = 0$

$K_i = 0$

$W = \Delta K = K_f - K_i$

$W = K_f$

$Fx = K_f$

$qEx = K_f$

$Q \times 300 \times 0.5 = 0.12$

$Q = \frac{0.12}{300 \times 0.5} = 0.0008 = 800\ \mu C$

Different types of charge density

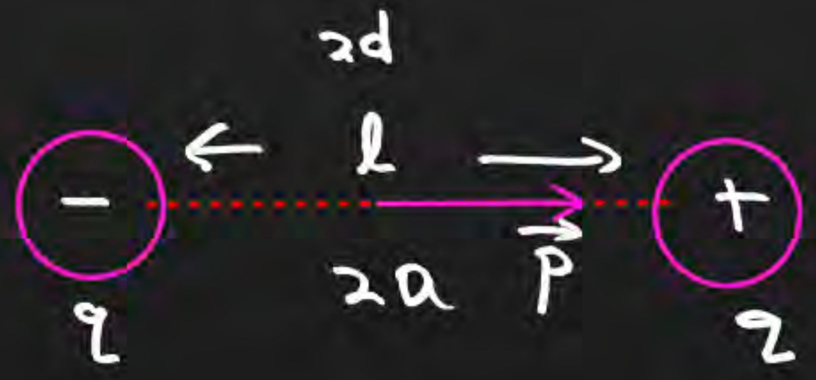
$D = \frac{m}{V}$

CONTINUOUS CHARGE DISTRIBUTION

LINEAR	SURFACE	VOLUME
C/m	C/m²	C/m³
Q or q	q	q
← L →		
$\lambda = \frac{q}{L} \Rightarrow \boxed{\lambda = \frac{dq}{dL}}$	$\sigma = \frac{q}{A}$	$\rho = \frac{q}{V}$
	$\sigma = \frac{dq}{dA}$	$\rho = \frac{dq}{dv}$

Electric Dipole

An electric dipole is a set of two equal and opposite point charges separated by a small distance.



Expression - $\vec{P} = q \times 2d$

Unit - C-m

Quantity - Vector direction is from -ve to +ve charge

Direction -

Dimension - $[A^1 T^1 L^1]$

$= [LAT]$

Question

An electric dipole is formed by $+4\mu C$ and $-4\mu C$ charges at 5 mm distance. Calculate the dipole moment and give its direction.

$2d$

$-4\mu C$ to $+4\mu C$

$$P = q \times 2d$$

$$P = 4\times10^{-6} \times 5\times10^{-3}$$

$$P = 20\times10^{-9}$$

$$P = 2\times10^{-8}\ C\cdot m$$

Question

Three point charges of $+2q$, $+2q$ and $-4q$ are placed at the corners A,B and C of an equilateral triangle ABC of side x. The magnitude of the electric dipole moment of this system is

(A) $2qx$

(B) $3\sqrt{2}qx$

(C) $3qx$

(D) $2\sqrt{3}qx$

$$P_1 = P_2 = P = (2q)x = 2qx$$

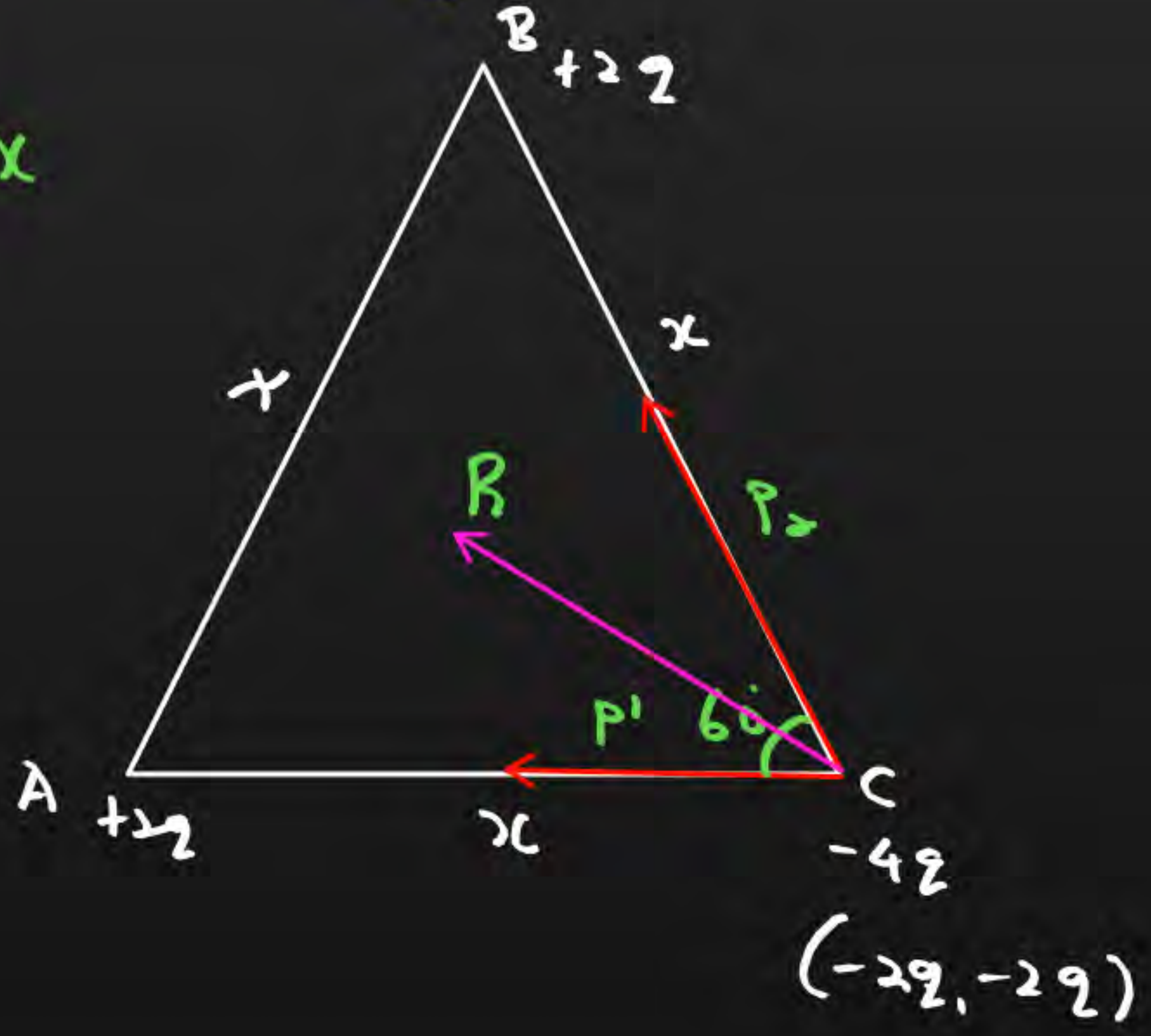
$$A = B, \quad R = 2A\cos\left(\frac{\theta}{2}\right)$$

$$R = 2P \times \cos\left(\frac{60°}{2}\right)$$

$$R = 2P \times \frac{\sqrt{3}}{2} = \sqrt{3}P$$

$$R = \sqrt{3} \times 2qx$$

$$R = 2\sqrt{3}qx$$



Question

An HCl molecule has a dipole moment Of 3.2×10^{-30} Cm. Assuming that equal and opposite charges lie on the two atoms forming the dipole, what will be the magnitude Of the charge? (The separation distance between the two atoms of HCl is 2×10^{-11} m)

(A) 2.4×10^{-20} C

(B) 1×10^{-20} C

(C) 3.2×10^{-18} C

(D) 1.6×10^{-19} C

$P = q \times 2d$

$3.2 \times 10^{-30} = q \times 2 \times 10^{-11}$

$q = \frac{3.2 \times 10^{-30}}{2 \times 10^{-11}} = 1.6 \times 10^{-19}$ C

Question

Determine the electric dipole moment of the system of three charges, placed on the vertices of an equilateral triangle as shown in the figure

(A) $\frac{(\sqrt{3}ql)(\hat{j}-i)}{\sqrt{2}}$

(B) $2ql\hat{j}$

(C) $-\sqrt{3}ql(\hat{j})$

(D) $\frac{(ql)(\hat{i}-j)}{\sqrt{2}}$

$P_1 = q \times l \quad P_2 = q \times l$

$P_1 = P_2 = P = ql$

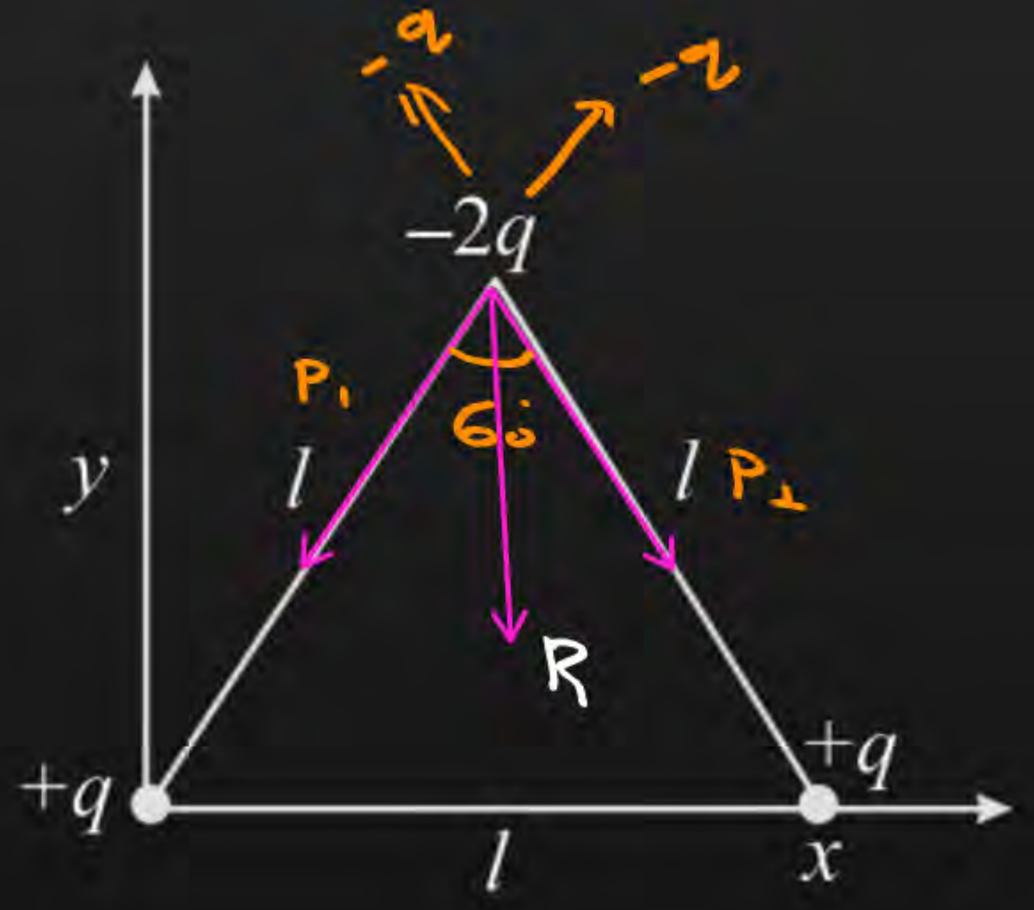
$R = 2P\cos\left(\frac{\theta}{2}\right)$

$R = 2 \times ql \times \cos\left(\frac{60}{2}\right)$

$R = 2ql \times \frac{\sqrt{3}}{2}$

$R = \sqrt{3}ql$

$\vec{R} = \sqrt{3}ql(-\hat{j})$



Question

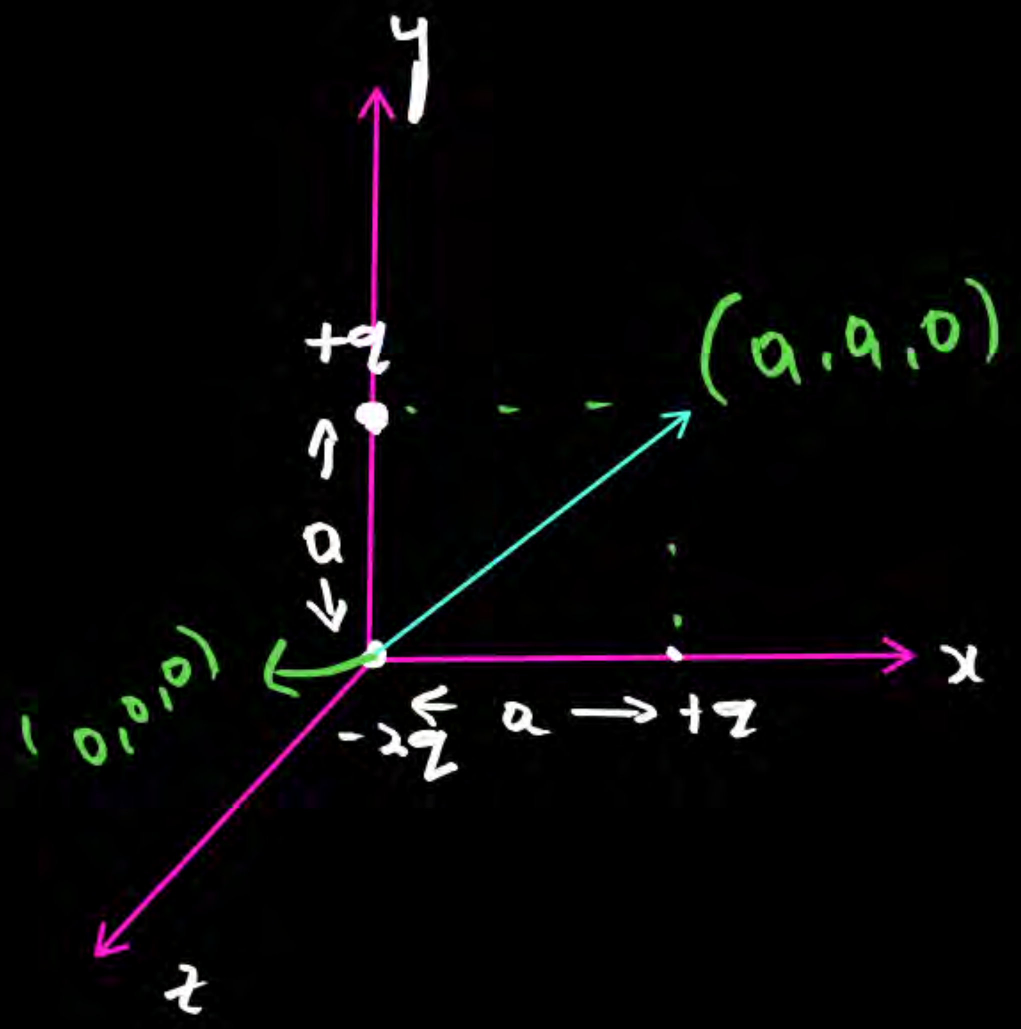
Three point charges +q, −2q and +q are placed at points $(x = 0, y = a, z = 0)$, $(x = 0, y = 0, z = 0)$ and $(x = a, y = 0, z = 0)$ respectively. The magnitude and direction of the electric dipole moment vector of this charge assembly are:

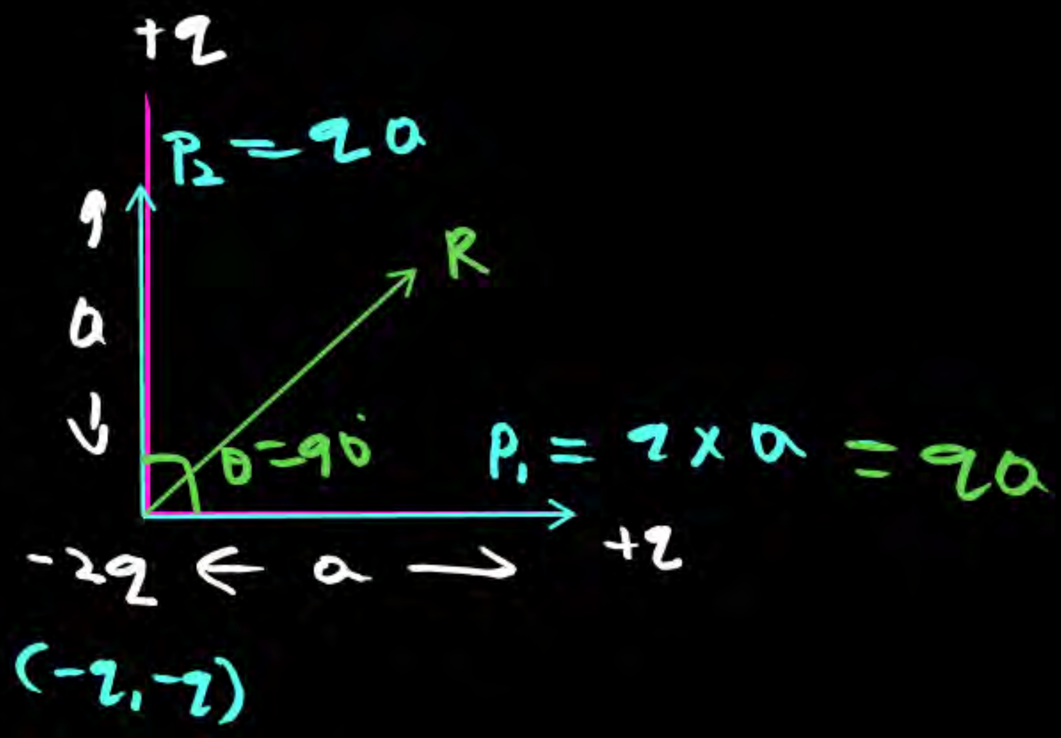
(A) $\sqrt{2}qa$ along the line joining points $(x = 0, y = 0, z = 0)$ and $(x = a, y = a, z = 0)$

(B) qa along the line joining points $(x = 0, y = 0\ z = 0)$ and $(x = a, y = a, z = 0)$

(C) $\sqrt{2}qa$ along $+ve$ x direction

(D) $\sqrt{2}qa$ along $+ve$ y direction





$$R = 2p\cos\left(\frac{\theta}{2}\right)$$

$$R = 2 \times qa \times \cos\left(\frac{90^\circ}{2}\right)$$

$$R = 2qa \times \frac{1}{\sqrt{2}}$$

$$R = \sqrt{\frac{4}{2}}\, qa = \boxed{\sqrt{2}\, qa}$$

Electric field due to an Electric Dipole

$P = q \times 2d$

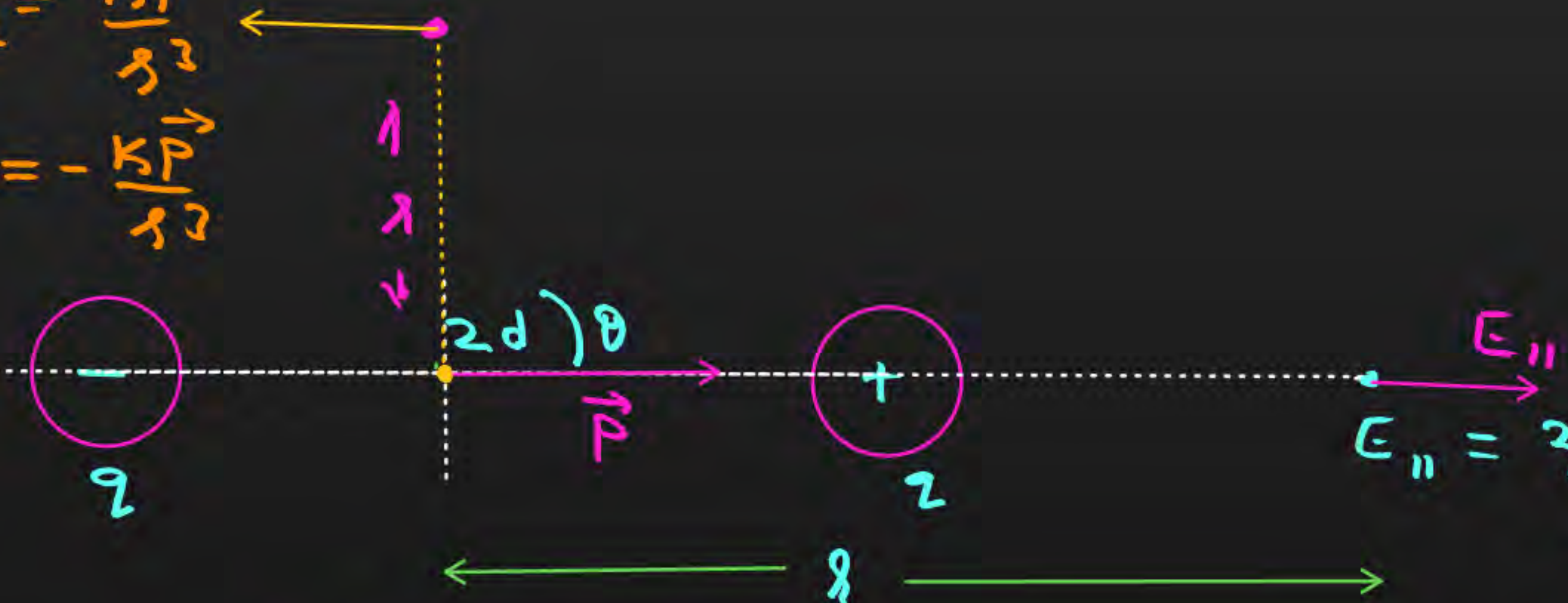
$K = \frac{1}{4\pi\epsilon_0}$

$E_\perp = \frac{KP}{r^3}$

$\vec{E}_\perp = -\frac{K\vec{P}}{r^3}$

$\theta = 180^\circ$

Antiparallel



$E_\parallel = \frac{2KP}{r^3}$

$\vec{E}_\parallel = \frac{2K\vec{P}}{r^3} \Rightarrow \theta = 0^\circ$ parallel

$\Downarrow$

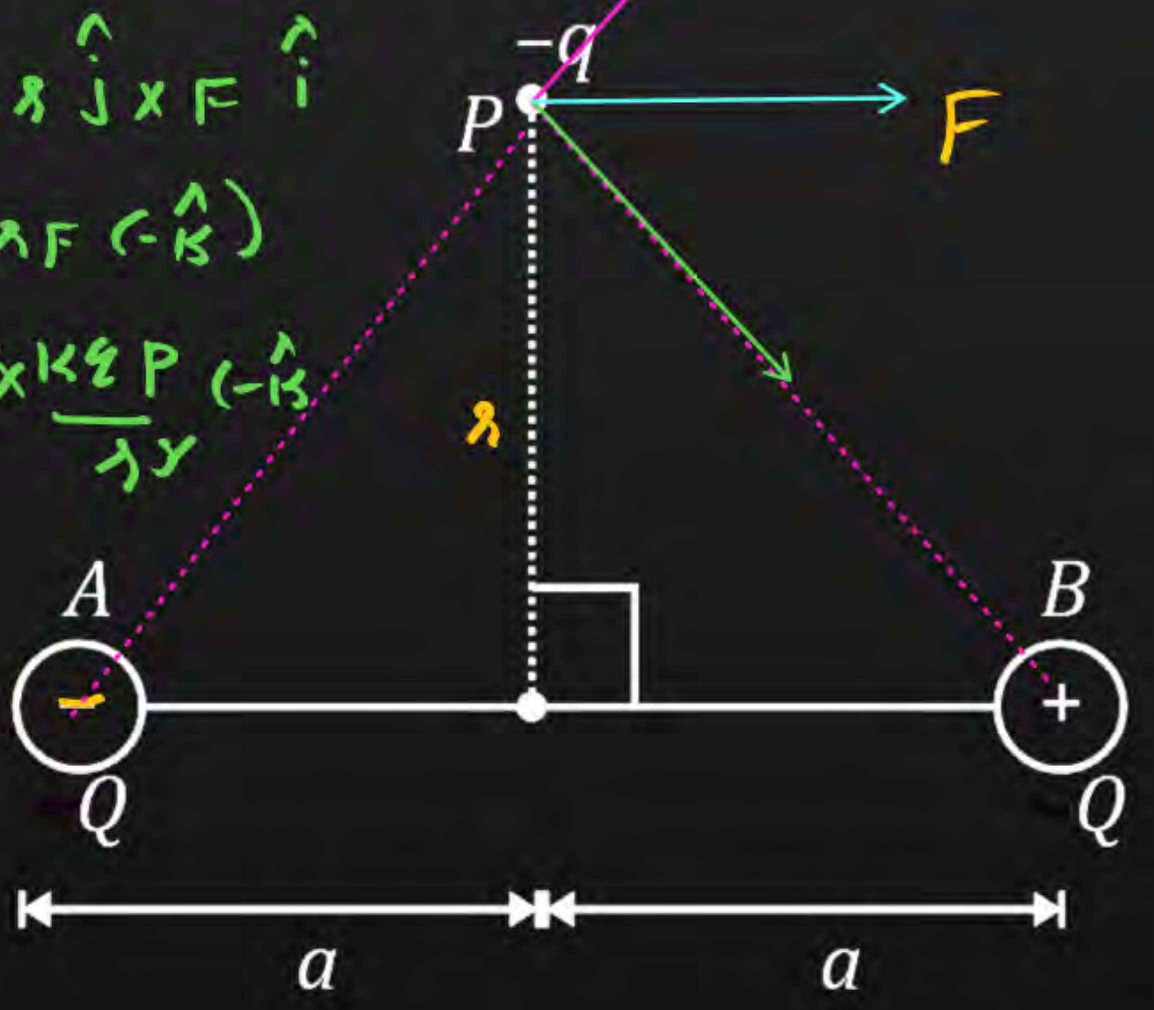
$\vec{E}$ & $\vec{P}$

$\vec{E}_\parallel = 2(-E_\perp)$

$E_\parallel = 2E_\perp$

Question

In the situation shown in the diagram, if q << |Q| and r >>a The net force on the free charge -q and net torque on it about O at the instant shown are respectively ($p = 2aQ$ is the dipole moment)



(A) $\frac{1}{4\pi\varepsilon_o}\frac{pq}{r^3}\hat{\imath}, -\frac{1}{4\pi\varepsilon_o}\frac{pq}{r^2}\hat{k}$

(B) $\frac{1}{4\pi\varepsilon_o}\frac{pq}{r^2}\hat{k}, \frac{1}{4\pi\varepsilon_o}\frac{pq}{r^3}\hat{\imath}$

(C) $-\frac{1}{4\pi\varepsilon_o}\frac{pq}{r^2}\hat{k}, -\frac{1}{4\pi\varepsilon_o}\frac{pq}{r^3}\hat{\imath}$

(D) $\frac{1}{4\pi\varepsilon_o}\frac{pq}{r^3}\hat{\imath}, \frac{1}{4\pi\varepsilon_o}\frac{pq}{r^2}\hat{k}$

Question

$\tau = F r.$ $\vec{\tau} = \vec{r} \times \vec{F}$

If E_{ax} and E_{eq} represents electric field at a point on the axial and equatorial line of a dipole. If points are at a distance r from the centre of the dipole, for r >>a

(A) $E_{ax} = E_{eq}$

(B) $E_{ax} = -E_{eq}$

(C) $E_{ax} = -2E_{eq}$

(D) $E_{eq} = 2E_{ax}$

Question

The angle between the dipole moment and electric field at any point on the equatorial plane is

(A) 180°

(B) 0°

(C) 45°

(D) 90

Question

$F \propto \frac{1}{r^2}$, $E = \frac{F}{q} \propto \frac{1}{r^2}$

Dipole axis : $E \propto \frac{1}{r^3}$

The force on a charge situated on the axis of a dipole is F, If the charge is shifted to double the distance, The force acting will be

(A) Zero

(B) F/2

(C) F/4

(D) F/8

(1)

$F = qE$

$F \propto E$

$E \propto \frac{1}{r^3}$

$E_{\parallel} = \frac{2KP}{r^3}$

$E_{\perp} = \frac{KP}{r^3}$

$E \propto \frac{1}{r^3}$

$\frac{E'}{E} = \frac{r'^3}{r^3}$

$\frac{E'}{E} = \frac{(2r)^3}{r^3} = \frac{8r^3}{r^3}$

$E' = 8E$

$F' = \frac{F}{8}$

(2)

$F = \frac{q \times 2KP}{r^3}$ — (1)

$F' = \frac{q \times 2KP}{r'^3}$

$F' = \frac{q \times 2KP}{(2r)^3} = \frac{q \times 2KP}{8r^3}$

$F' = \frac{F}{8}$

Question

If the magnitude of intensity of electric field at a distance 'x' on the axial line and at a distance 'y' on equatorial line on a given dipole are equal, then x:y is

(A) 1:1

(B) $1:\sqrt{2}$

(C) 1:2

(D) $\sqrt[3]{2}:1$

$E_{\perp} = E_{\parallel}$

$E_{\parallel} = \frac{2KP}{x^3}$

$E_{\perp} = \frac{KP}{y^3}$

$E_{\perp} = \frac{KP}{r^3}$ $= \frac{2KP}{r^3}$

$E_{\parallel} = E_{\perp}$

$\frac{2KP}{x^3} = \frac{KP}{y^3}$

$\frac{x^3}{y^3} = 2 \Rightarrow \frac{x}{y} = (2)^{1/3} = \sqrt[3]{2}$

Question

Consider two charges each of 10 μC but opposite in sign separated by 5 mm. Find the electric field at a point 0.2 m away from the midpoint on a line that is passing through the midpoint and at an angle of 60° to the axis of the dipole.

(A) $2.6 \times 10^7\ \mathrm{NC^{-1}}$

(B) $7.4 \times 10^4\ \mathrm{NC^{-1}}$

(C) $1.3 \times 10^8\ \mathrm{NC^{-1}}$

(D) $5.2 \times 10^8\ \mathrm{NC^{-1}}$

$$E = \frac{kp}{r^3}\sqrt{3\cos^2\theta + 1} = \frac{9\times10^9 \times 5\times10^{-8}}{(0.2)^3}\sqrt{3\cos^2(60^\circ)+1}$$

$p = q \times 2d$

$p = 10\times10^{-6} \times 5\times10^{-3}$

$p = 50\times10^{-9}$

$p = 5\times10^{-8}$ C-m

$$= \frac{45\times10^1}{8\times10^{-3}}\sqrt{3\times\left(\frac{1}{2}\right)^2+1}$$

$$= 5.625\times10^4\sqrt{\frac{3}{4}+1} = 5.625\times10^4 \times \frac{\sqrt{7}}{2}$$

$E = 7.4\times10^4$ N/C

Question

Consider two charges each of 10 μC but opposite in sign separated by 5 mm. Find the electric field at a point 0.2 m away from the midpoint on a line that is passing through the midpoint and the normal to the axis of the dipole.

(A) $5.6 \times 10^{8}\ \mathrm{NC^{-1}}$

(B) $7.8 \times 10^{4}\ \mathrm{NC^{-1}}$

(C) $5.6 \times 10^{4}\ \mathrm{NC^{-1}}$

(D) $8.9 \times 10^{-8}\ \mathrm{NC^{-1}}$

Dipole in a uniform external field

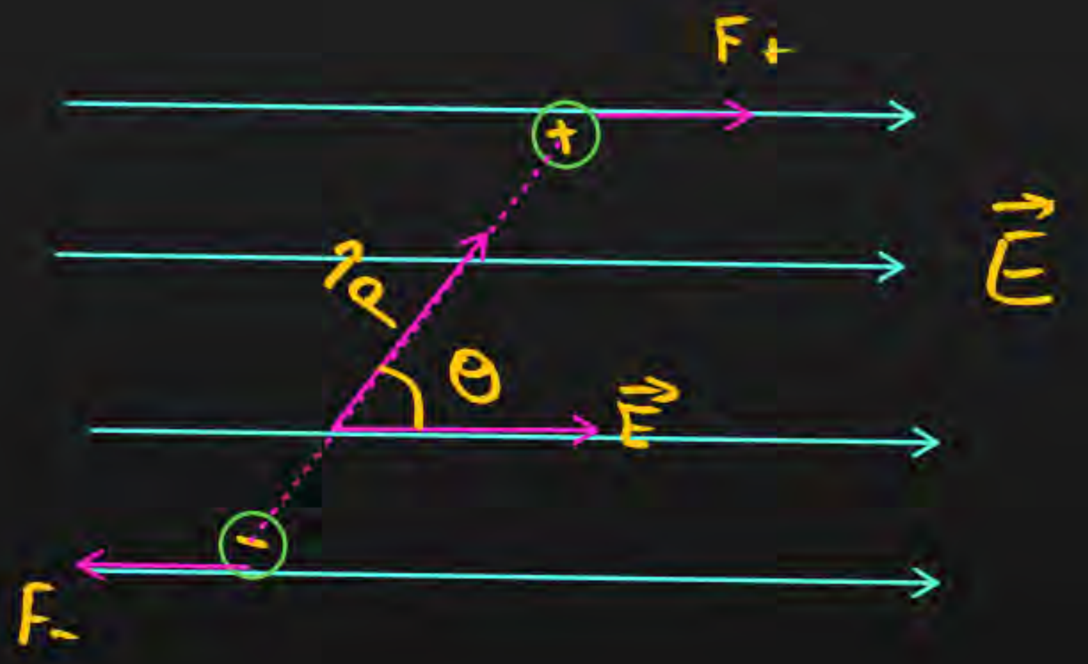
An electric dipole placed in a uniform electric field $\vec{E}$ and θ is the angle between $\vec{P}$ and $\vec{E}$.

Net force on a Dipole is given by

$$\vec{F} = \vec{F}_+ + \vec{F}_-$$

$$\vec{F} = qE(\hat{i}) + qE(-\hat{i})$$

$$\boxed{\vec{F} = 0}$$ Always -



Dipole in a uniform external field

An electric dipole placed in a uniform electric field $\vec{E}$ and θ is the angle between $\vec{P}$ and $\vec{E}$.

Torque on a dipole :Torque is a twisting force that causes rotation around an axis.

$$\vec{\tau} = \vec{r} \times \vec{F}$$

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

Expression - $\vec{\tau} = \vec{p} \times \vec{E}$

Quantity- Vector.

Unit- N-m

Dipole in a uniform external field

Electrostatic potential energy of a dipole placed in a uniform field is defined as the Work done in rotation of dipole from direction to another.

$$U = -PE\cos\theta$$

$$U = -\vec{P}\cdot\vec{E}$$

$$\vec{A}\cdot\vec{B} = AB\cos\theta$$

$$\vec{A}\times\vec{B} = AB\sin\theta\,\hat{n}$$

Work done in rotation of dipole in a uniform electric field from θ_1 to θ_2

$$W = \Delta U = U_f - U_i = -PE(\cos\theta_2 - \cos\theta_1)$$

Equilibrium of charge system

$U = mgh$

$U = -pE\cos\theta$

$U = -pE(1)$

$\theta = 0^\circ$

$F_{net} = 0$

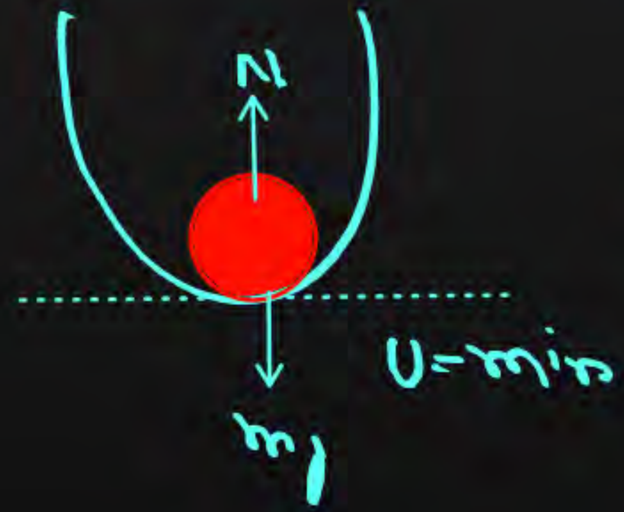
$a_{net} = 0$

TYPES OF EQUILIBRIUM

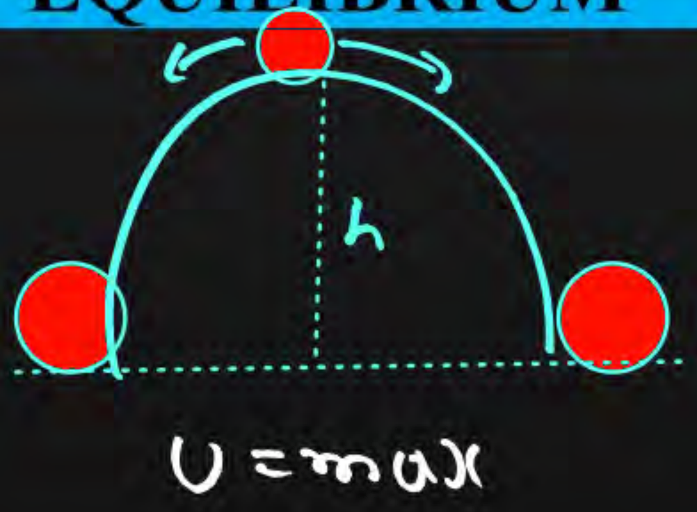
$U = +pE$

$\theta = 180$

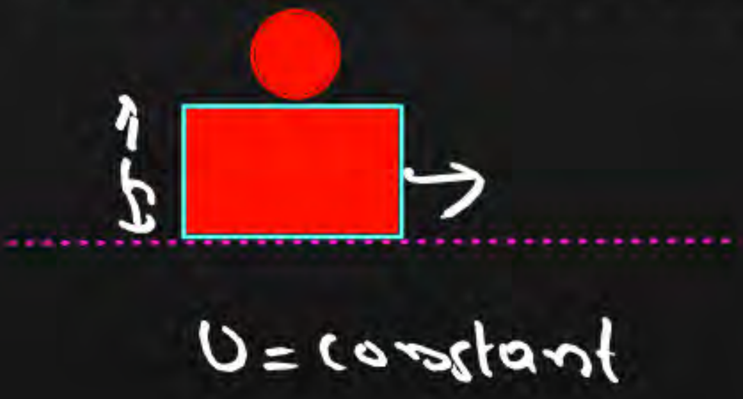
STABLE EQUILIBRIUM



UNSTABLE EQUILIBRIUM



NEUTRAL EQUILIBRIUM



Question

An electric field of 1000 V/m applied to an electric dipole at an angle of 45^0. The value of electric dipole moment is $10^{-29} C - m$,What is the potential energy of electric dipole?

(A) $-9 \times 10^{-20} J$

(B) $-10 \times 10^{-29} J$

(C) $-20 \times 10^{-18} J$

(D) $-7 \times 10^{-27} J$

$U = -pE\cos\theta$

$U = -10^{-29} \times 10^{3} \times \cos 45^\circ$

$U = -10^{-26} \times \frac{1}{\sqrt{2}}$

$U = -0.707 \times 10^{-26}$

$U = -7.07 \times 10^{-27} J$

Question

Net charge on electric dipole:

$Q = +q - q$

$Q = 0$

(A) one

(B) zero

(C) two

(D) infinite

Question

A dipole of dipole moment $\vec{p}$ is placed in uniform electric field $\vec{E}$ then torque acting on it is given by:

(A) $\vec{\tau} = \vec{p} \cdot \vec{E}$

(B) $\vec{\tau} = \vec{p} \times \vec{E}$

(C) $\vec{\tau} = \vec{p} + \vec{E}$

(D) $\vec{\tau} = \vec{p} - \vec{E}$

Question

Electric field at the equator of a dipole is E. If strength and distance is now doubled then the electric field will be:

(A) E/2

(B) E/8

(C) E/4

(D) E

$$E_\perp = \frac{KP}{r^3}$$

$$E_\perp' = \frac{KP'}{r'^3}$$

$$E_\perp' = \frac{K(2P)}{(2r)^3} = \frac{2KP}{8r^3} = \frac{1}{4}\frac{KP}{r^3}$$

$$E_\perp' = \frac{1}{4} \times E_\perp = \frac{E}{4}$$

Question

An electric dipole with dipole moment 4×10^{-9} C–m is aligned at 30° with the direction of a uniform electric field of magnitude 5×10^{4} NC^{-1}, the magnitude of the torque acting on the dipole is

(A) $\sqrt{3} \times 10^{-4}$ N-m

(B) 10^{-5} N-m

(C) 10×10^{-3} N-m

(D) 10^{-4} N-m

$\tau = pE\sin\theta$

$\tau = 4 \times 10^{-9} \times 5 \times 10^{4} \times \sin 30°$

$\tau = 20 \times 10^{-5} \times \frac{1}{2}$

$\tau = 10 \times 10^{-5}$

$\tau = 10^{-4}$ N-m

Question

An electric dipole is kept in non-uniform electric field. It generally experiences

(A) A force and torque

(B) A force but not a torque

(C) A torque but not a force

(D) neither a force nor a torque

Question

An electric dipole is kept in uniform electric field. It generally experiences

A A force and torque

B A force but not a torque

C A torque but not a force

D neither a force nor a torque

$F = 0$

$\tau =$ may or not be zero

$\tau = pE \sin\theta$

$\tau \propto \theta$

$\theta = 0°$ — $\tau = 0$ ⇓ stable

$\theta = 180°$ — $\tau = 0$ ⇓ unstable

$\theta = 90°$ — $\tau = pE$

Question

Two charges of each magnitude 0.01 C and separated by a distance of 0.4 mm constitute an electric dipole. If the dipole is placed in an uniform electric field $\vec{E}$ of 10 $\text{dyne} \cdot \text{C}^{-1}$ making 30° angle with $\vec{E}$, the magnitude of torque acting on dipole is:

(A) 4.0×10^{-10} N m

(B) 1.0×10^{-8} N m

(C) 1.5×10^{-9} N m

(D) 2.0×10^{-10} N m

Question

An electric dipole with dipole moment 5×10^{-6} Cm aliened with the direction of a uniform electric field of magnitude 4×10^5 N/C. The dipole is then rotated through an angle of 60° with respect to the electric field. The change in the potential energy of the dipole is

(A) 0.8 J

(B) 1.0 J

(C) 1.2 J

(D) 1.5 J

$\theta_1 = 0^\circ$, θ_2

$$W = \Delta U = -pE(\cos\theta_2 - \cos\theta_1)$$

$$\Delta U = -5\times10^{-6}\times4\times10^{5}\,[\cos 60^\circ - \cos 0^\circ]$$

$$= -20\times10^{-1}\,[\tfrac{1}{2} - 1]$$

$$= -2 \times -\tfrac{1}{2}$$

$$= +1$$

$$\Delta U = 1\,J$$

Question

An electric dipole is placed at an angle of 30° (θ) with an electric field of intensity 2×10^5 NC^{-1}. It experiences a torque equal to 4 N-m. If the dipole length is 2 cm, calculate the magnitude of the charge on the dipole.

(A) 2 mC

(B) 8 mC

(C) 6 mC

(D) 4 mC

$\tau = pE\sin\theta$

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

$4 = q \times 2 \times 10^{-2} \times 2 \times 10^5 \times \sin 30°$

$4 = q \times 4 \times 10^3 \times \frac{1}{2}$

$q = 2 \times 10^{-3}$ C

$q = 2$ mC

Question

The electric field at a point on the equatorial plane at a distance r from the center of a dipole having dipole moment $\vec{P}$ is given by:
($r \gg$ separation of two charges forming the dipole, ε_0 = permittivity of free space)

(A) $\vec{E} = \frac{\vec{P}}{4\pi\varepsilon_0 r^3}$

(B) $\vec{E} = \frac{2\vec{P}}{\pi\varepsilon_0 r^3}$

(C) $\vec{E} = \frac{\vec{P}}{4\pi\varepsilon_0 r^2}$

(D) $\vec{E} = -\frac{\vec{P}}{4\pi\varepsilon_0 r^3}$

Electric Flux

→ scalar.

Electric flux: It is measure of amount of Electric field lines passing perpendicular to a surface.

$$\phi = \vec{E}\cdot\vec{A} = \frac{N}{C} \times m^2 = N m^2 C^{-1}$$

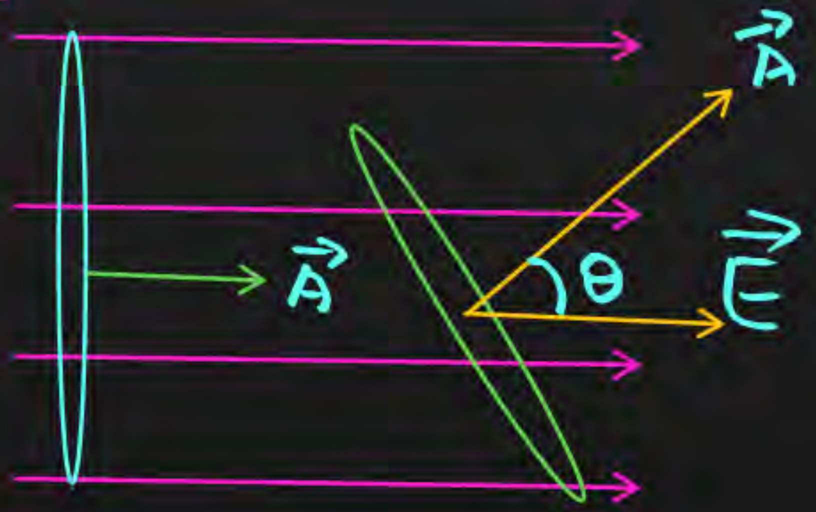
$$\phi = E A \cos\theta$$

OR

$$\frac{V}{m} \times m^2$$

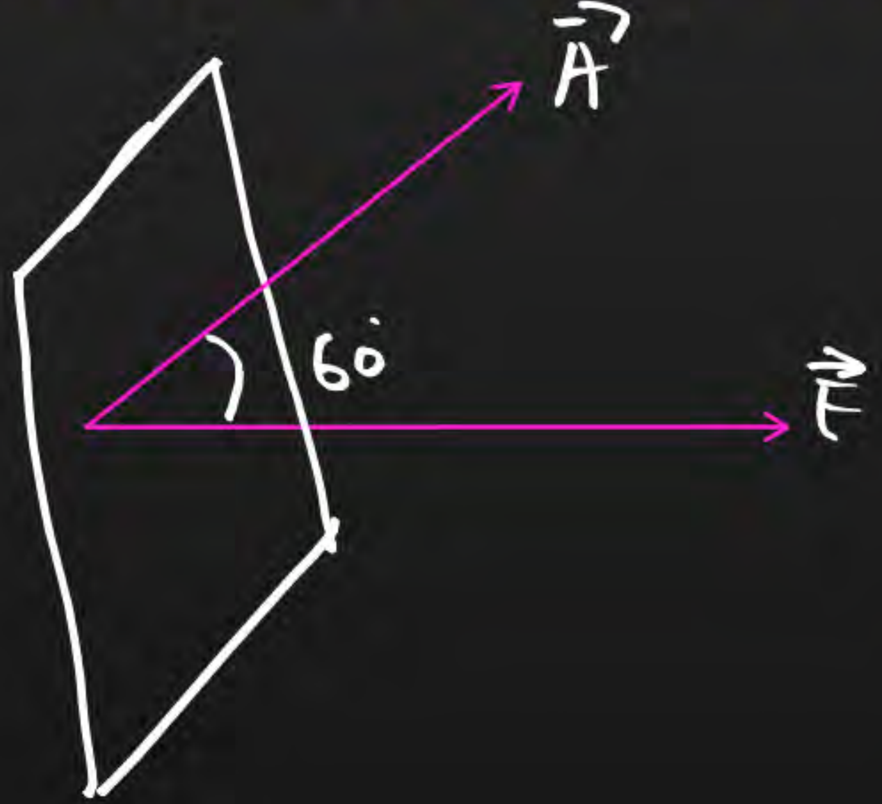
$$V m$$

$$\phi = E \cdot A \cdot \cos\theta$$



Question

A rectangular surface of sides 10 cm and 15 cm is placed inside a uniform electric field of 25 N/C, such that normal to the surface makes an angle of 60^0 with the direction of electric field. Find the flux of electric field through the rectangular surface.



$\phi = EA\cos\theta$

$\phi = E \times l \times b \times \cos\theta$

$\phi = 25 \times 10 \times 10^{-2} \times 15 \times 10^{-2} \times \cos 60^\circ$ ($\cos 60^\circ \to \frac{1}{2}$)

$\phi = 1875 \times 10^{-4}$

$\phi = 0.1875$ V-m

Question

If $\vec{E} = (2\hat{\imath} + 3\hat{\jmath} - 5\hat{k})$ and $\vec{A} = (2\hat{\imath} - \hat{\jmath} - \hat{k})$ then find electric flux.

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

$$\phi = (2\hat{i} + 3\hat{j} - 5\hat{k})(2\hat{i} - \hat{j} - \hat{k})$$

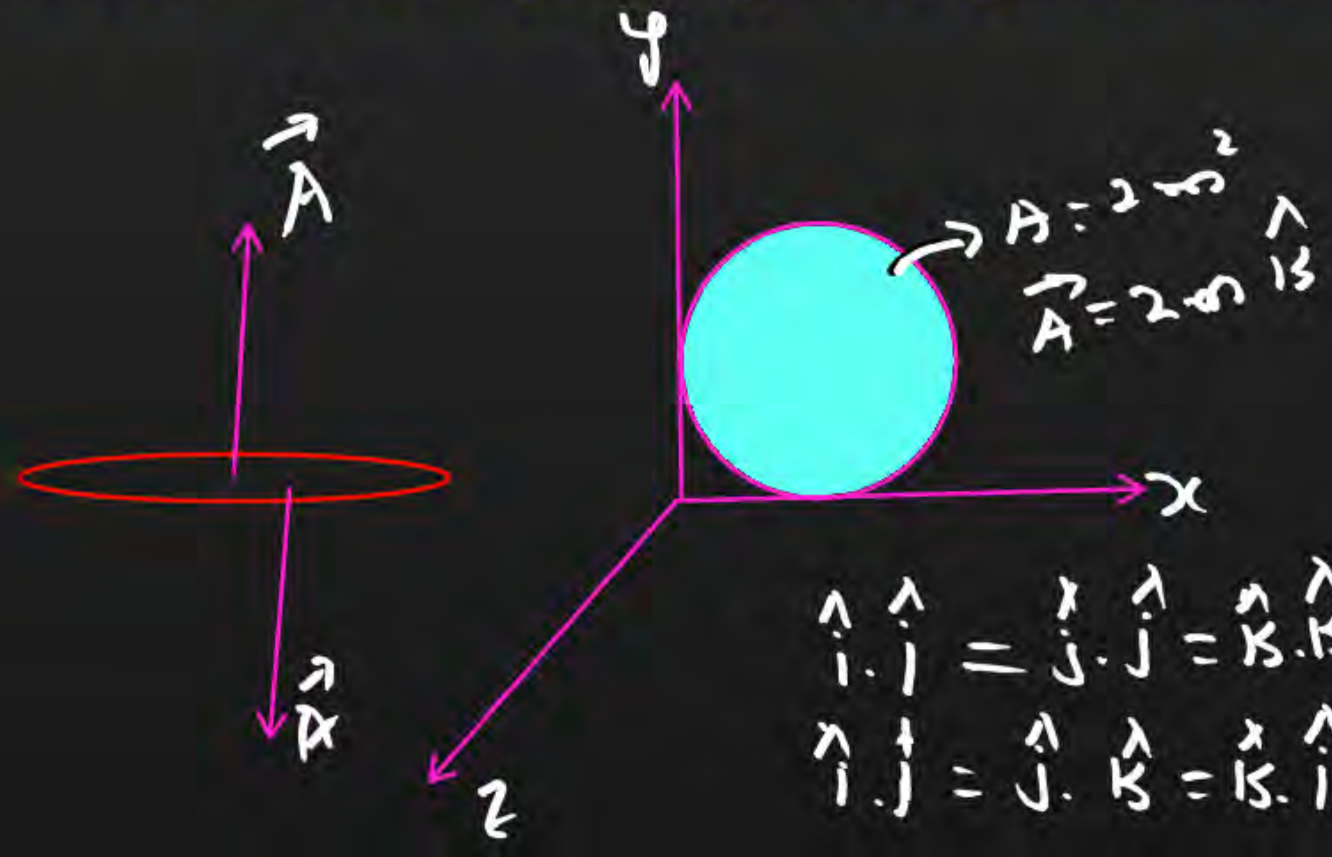
$$\phi = 4(1) - 3(1) + 5$$

$$\phi = 4 + 5 - 3 = 9 - 3$$

$$\boxed{\phi = 6 \text{ V-m}}$$

Question

A thin disc of area $2m^2$ is placed in x-y plane in a uniform field of strength $\vec{E} = (2\hat{\imath} - \hat{\jmath} + 4\hat{k})$, find flux of the field passing through the disc.



$\hat{i}\cdot\hat{i} = \hat{j}\cdot\hat{j} = \hat{k}\cdot\hat{k} = 1$

$\hat{i}\cdot\hat{j} = \hat{j}\cdot\hat{k} = \hat{k}\cdot\hat{i} = 0$

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

$\phi = (2\hat{i} - \hat{j} + 4\hat{k})\cdot(2\hat{k})$

$\phi = 0 - 0 + 8(1)$

$\phi = 8\ V\text{-}m$

Question

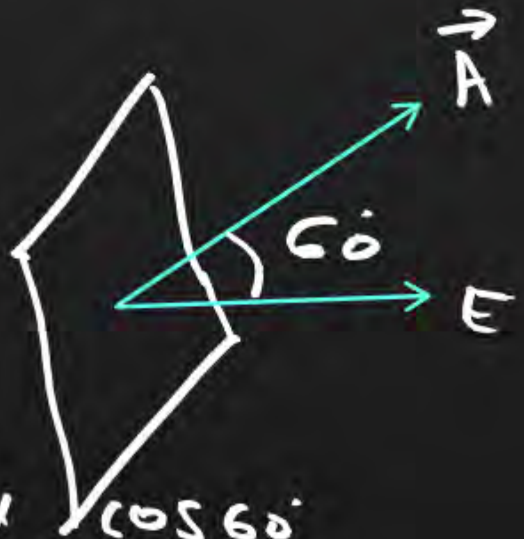
Consider an electric field $\vec{E} = (3 \times 10^3)\hat{\imath}(N/C)$. What is the flux (Nm^2/C) through the square of 10 cm side, if the normal to its plane makes 60^0 angle with the x-axis?

(A) 10

(B) 15

(C) 20

(D) 25



$\phi = EA\cos\theta$

$\phi = 3 \times 10^3 \times (10 \times 10^{-2})^2 \times \cos 60^\circ$

$\phi = 3 \times 10^3 \times 100 \times 10^{-4} \times \frac{1}{2}$

$\phi = 1.5 \times 10^5 \times 10^{-4}$

$\phi = 15$ V-m

Question

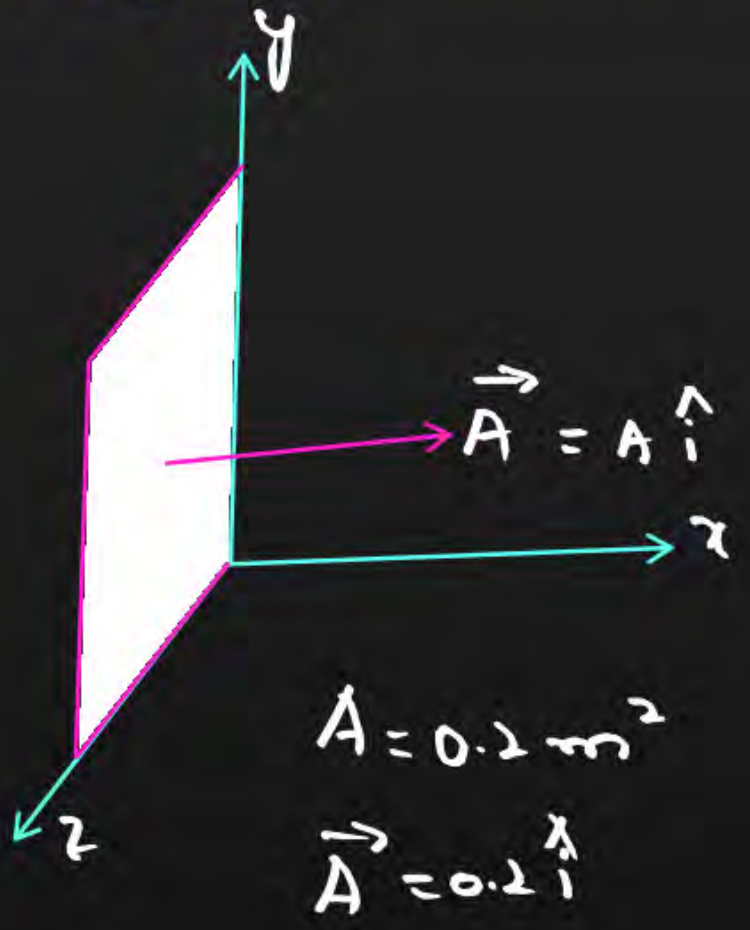
The electric field in a region $\vec{E} = \frac{3}{5}E_0\hat{\imath} + \frac{4}{5}E_0\hat{\jmath}(N/C)$. Where $E_0 = (2 \times 10^3)\,(N/C)$. Find the flux due to electric field through a rectangular surface of area $0.2\,m^2$ parallel to the Y-Z plane.

A 210

B 250

C 240

D 255



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

$\phi = \left(\frac{3}{5}\times 2\times 10^3\,\hat{i} + \frac{4}{5}\times 2\times 10^3\,\hat{j}\right)\cdot 0.2\,\hat{i}$

$\phi = \frac{6}{5}\times 10^3 \times 0.2\,(1)$

$\phi = 0.24\times 10^3$

$\phi = 240\ V\cdot m$

Question

H.W

A uniform electric field $E = 3 \times 10^5\ NC^{-1}$ is acting along the positive Y-axis. The electric flux through a rectangle of area 10 cm x 30 cm whose plane is parallel to the Z-X plane is:

A. 12×10^3 Vm

B. 9×10^3 Vm

C. 15×10^3 Vm

D. 18×10^3 Vm

Question

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

The scalar product of electric field and the surface area is:

(A) Electric flux

(B) Magnetic flux

(C) Dipole moment

(D) Mobility

Gauss's theorem

$\phi = \frac{q_1 + q_2 \cdot q_3}{\varepsilon_0}$ ✓

E.F. due to all the charges present

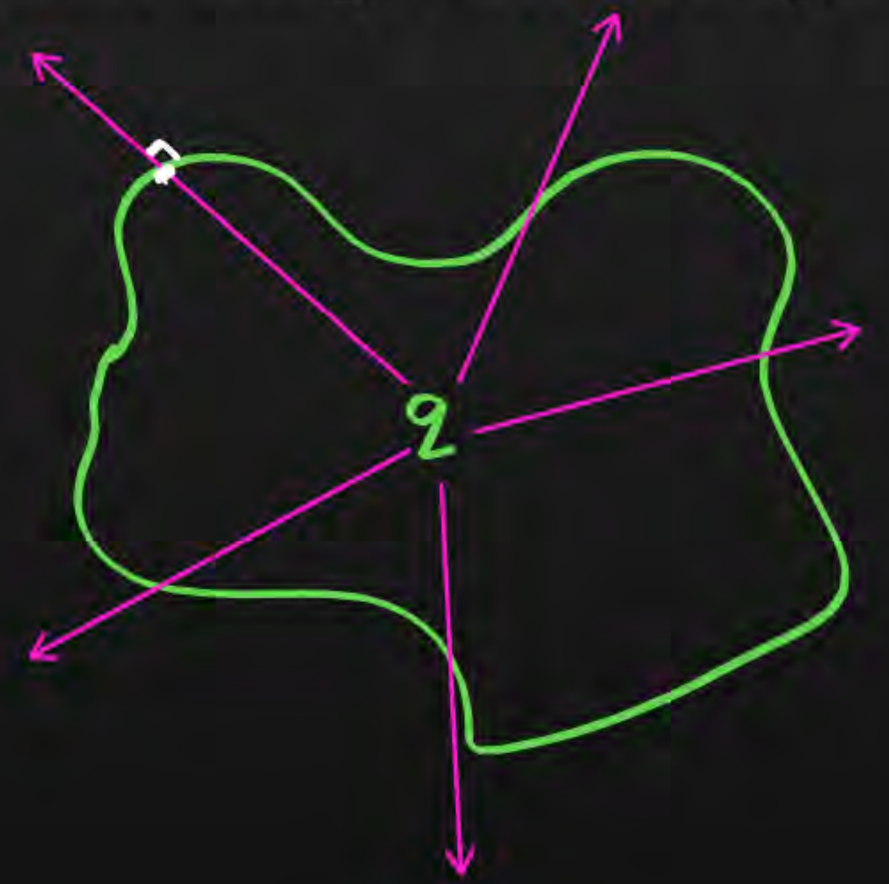
Gauss' theorem statement:

"Electric flux through any closed loop surface is $\frac{1}{\varepsilon_0}$ times the charge enclosed by it"

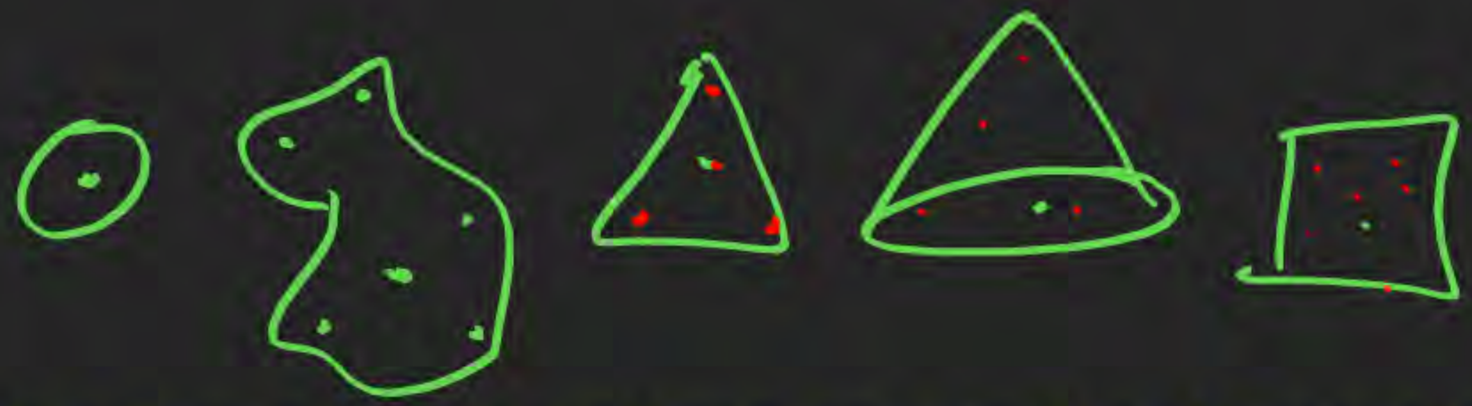
$$\phi = \frac{q}{\varepsilon_0}$$

$\phi = \vec{E} \cdot \vec{A} = \frac{q}{\varepsilon_0}$ → Definite shapes

$\phi = \int \vec{E} \cdot d\vec{A} = \frac{q}{\varepsilon_0}$ → small Area



Gauss's theorem



Characteristics of Gaussian surface and its important points regarding Gauss's law.

1. Flux through Gaussian surface is independent of its shape.
2. Flux through Gaussian surface depends only on charges present inside it.
3. Flux through Gaussian surface is independent of position of charges inside it.
4. In a Gaussian surface $\emptyset = 0$ does not imply E=0 but E=0 implies $\emptyset = 0$

Gauss's theorem

The value of Electric Flux is zero in the following circumstances:

1. If a dipole is (or many dipoles are) enclosed by a closed surface
2. Magnitude of (+ve) and (–ve) charges are equal inside a closed surface
3. If no charge is enclosed by closed surface
4. Incoming flux (-ve) = Out going flux (+ve)

Calculation of Flux

Steps to follow

1. Complete the symmetrical system i.e charge at the centre

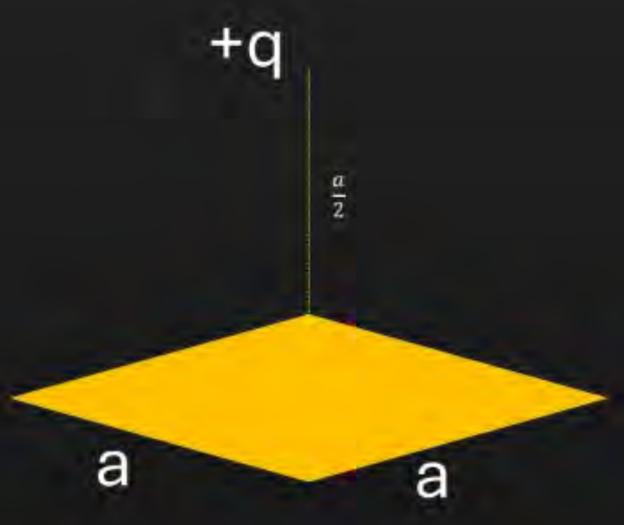
2. Total flux, $\varnothing_{Total} = \frac{q_{inside}}{\varepsilon_0}$

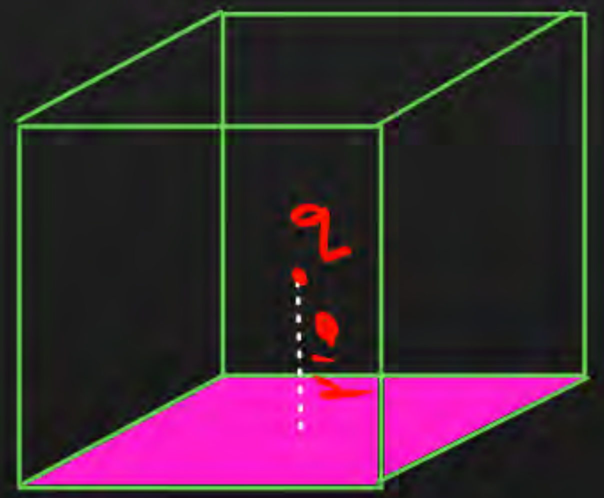
3. Flux through 1 face or 1 sheet, $\varnothing_{1face} = \varnothing_{1sheet} = \frac{q_{inside}}{n\,\varepsilon_0}$

   where, n – No.of faces or sheets

Calculation of Flux

Find electric flux of charge 'q' through the surfaces shown





1. ✓

2. $\phi = \frac{q}{\varepsilon_0}$ ✓

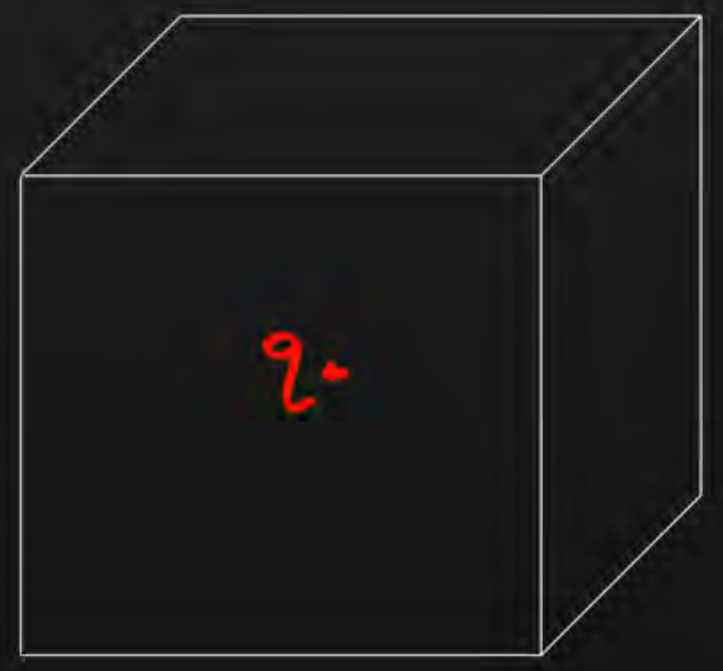
3. $6 \times \phi_{1face} = \frac{q}{\varepsilon_0}$

$$\phi_{1face} = \frac{q}{6\varepsilon_0}$$

Calculation of Flux

Find electric flux of charge 'q' through the surfaces shown

1. Charge at body centre



$\phi_T = \frac{q}{\epsilon_0}$

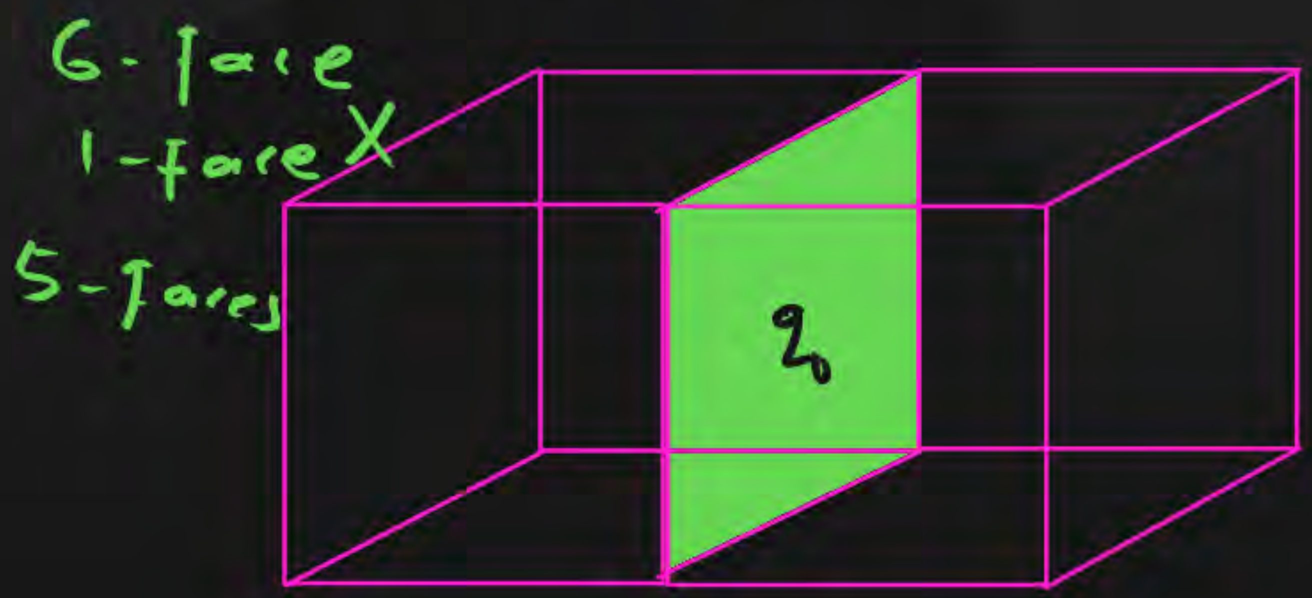
$\phi_{1\,face} = \frac{q}{6\epsilon_0}$

Calculation of Flux

Find electric flux of charge ‘q’ through the surfaces shown

1. Symmetry ✓
   If not → Add extra cubes to make it symmetry

2. Charge at face centre/surface

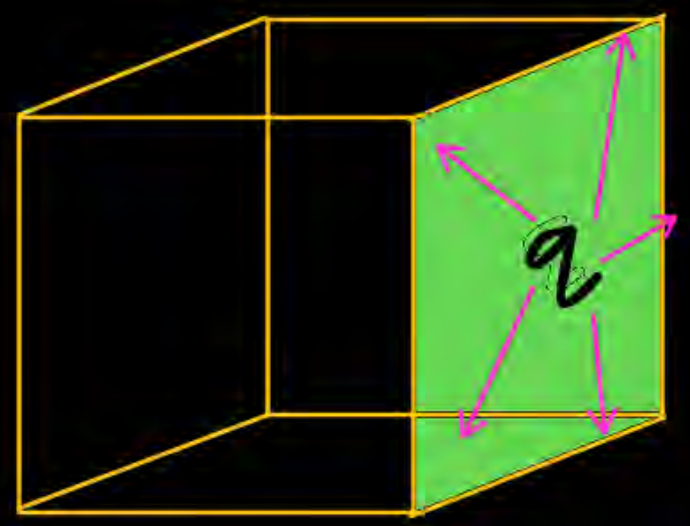


$$\phi_T = \frac{q}{\varepsilon_0}$$

$$2 \times \phi_{1cube} = \frac{q}{\varepsilon_0}$$

$$\phi_{1cube} = \frac{q}{2\varepsilon_0}$$

$$\phi_{1face} = \frac{q}{5 \times 2\varepsilon_0} = \frac{q}{10\varepsilon_0}$$

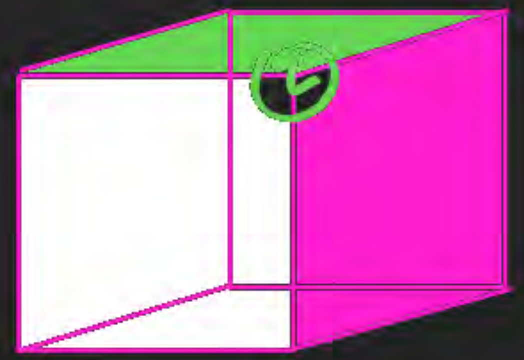


6 face ✓

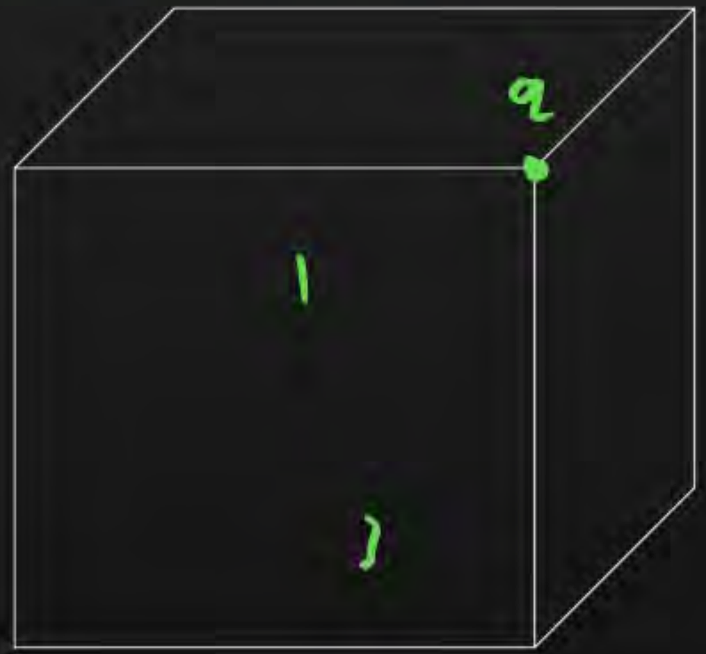
5 face ⇒ φ link ✓

Calculation of Flux

Find electric flux of charge 'q' through the surfaces shown



3. Charge at corner/vertex



Flux linked with only 3 faces.

Adding 7 cubes more to make it symmetry

8 cubes $= \frac{q}{\varepsilon_0}$

$8 \times \phi_{1cube} = \frac{q}{\varepsilon_0}$

$$\phi_{1cube} = \frac{q}{8\varepsilon_0}$$

$3 \times \phi_{1face} = \frac{q}{8\varepsilon_0}$

$$\phi_{1face} = \frac{q}{24\varepsilon_0}$$

Question

According to Gauss's law in electrostatics, the electric flux through a closed surface depends on:

(A) the area of the surface

(B) the quantity of charges enclosed by the surface

(C) the shape of the surface

(D) the volume enclosed by the surface

Question

A metallic sphere of radius R carrying a charge q is kept at a certain distance from another metallic sphere of radius $\frac{R}{4}$ carrying a charge Q. What is the electric flux at any point inside the metallic sphere of radius R due to the sphere of radius $\frac{R}{4}$?

(A) $\frac{Q}{4\pi \epsilon_o R^2}$

(B) $\frac{Q}{\epsilon_o}$

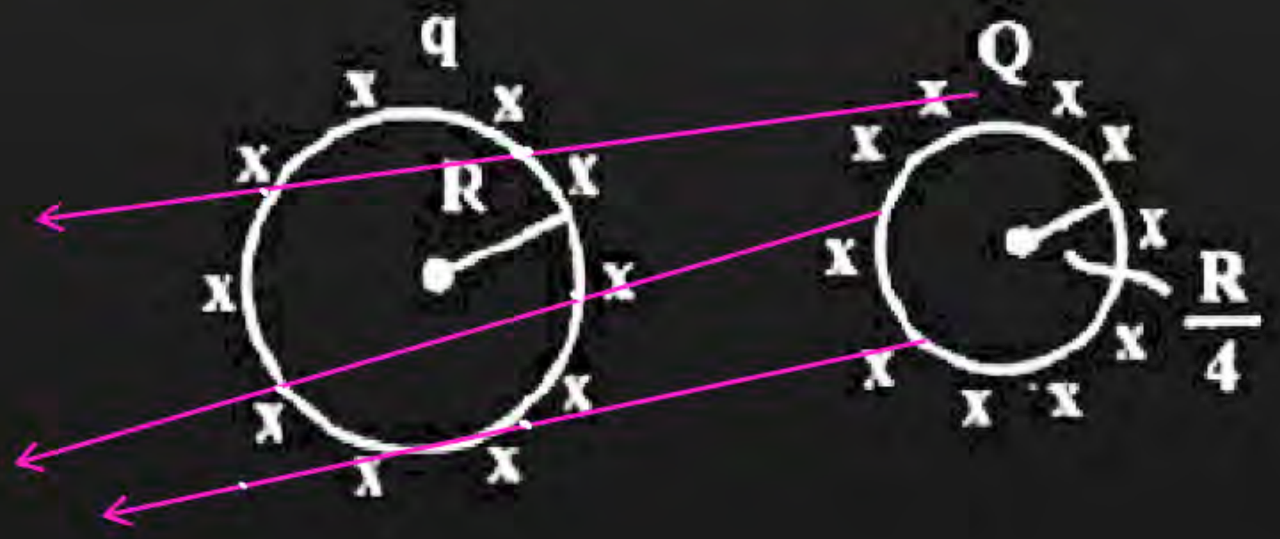
(C) $\frac{Q}{4\pi \epsilon_o R_4^2}$

(D) Zero

$\phi = 0$

$\phi_{in} = \phi_{out}$

$Q = 0$



Question

You are given a dipole of charge $+q$ and $-q$ separated by a distance $2R$. A sphere 'A' of radius R passes through the centre of the dipole as shown below and another sphere 'B' of radius $2R$ passes through the charge $+q$. Then the electric flux through the sphere A is

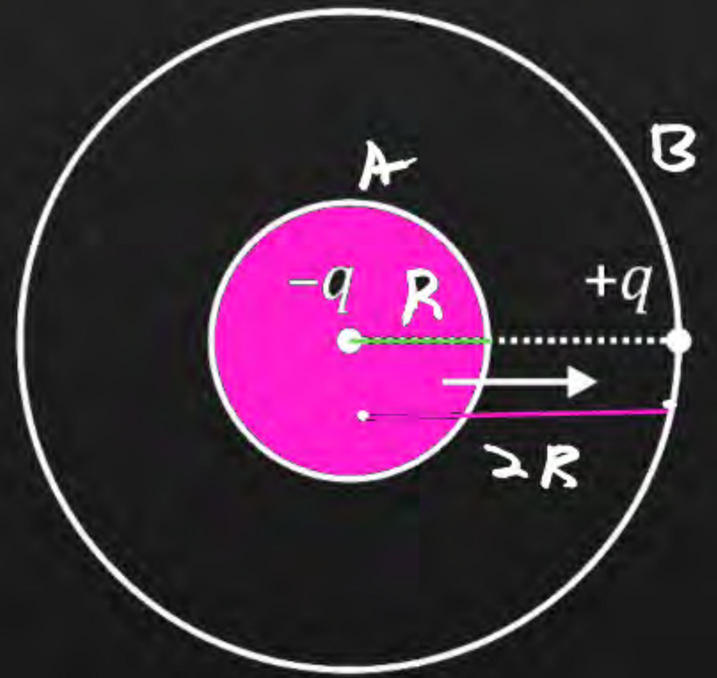
(A) $\frac{-q}{\epsilon_0}$

(B) $\frac{q}{\epsilon_0}$

(C) $\frac{q}{2\epsilon_0}$

(D) Zero

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



Question

Match Column-I with Column-II related to an electric dipole of dipole moment $\vec{p}$ that is placed in a uniform electric field $\vec{E}$: The potential energy

(a) Angle between $\vec{p}$ and $\vec{E}$	**i) $-pE\cos\theta$**
(b) 180 °	(ii)+pE
(c) 90°	(iii)Zero

$\cos 180° = -1$

$U = -pE(-1)$

$U = +pE$

$U = -pE\cos 90° = 0$

(A) $a \rightarrow$ iii, $b \rightarrow$ i, $c \rightarrow$ ii

(B) $a \rightarrow$ ii, $b \rightarrow$ iii, $c \rightarrow$ i

(C) $a \rightarrow$ i, $b \rightarrow$ ii, $c \rightarrow$ iii

(D) $a \rightarrow$ ii, $b \rightarrow$ i, $c \rightarrow$ iii

Question

If $\oint \vec{E}.d\vec{S} = 0$ over a surface, then:

$E \neq 0$ $\quad \phi = 0$

(A) the electric field inside the surface is necessarily uniform

(B) the number of flux lines entering the surface must be equal to the number of flux lines leaving it

(C) the magnitude of electric field on the surface is constant

(D) all the charges must necessarily be inside the surface

Question

The electric field in a certain region is acting radially outward and is given by $E = Ar$. A charge contained in a sphere of radius a centered at the origin of the field will be given by:

(A) $4\pi\varepsilon_0 Aa^2$

(B) $\pi\varepsilon_0 Aa^2$

(C) $4\pi\varepsilon_0 Aa^3$

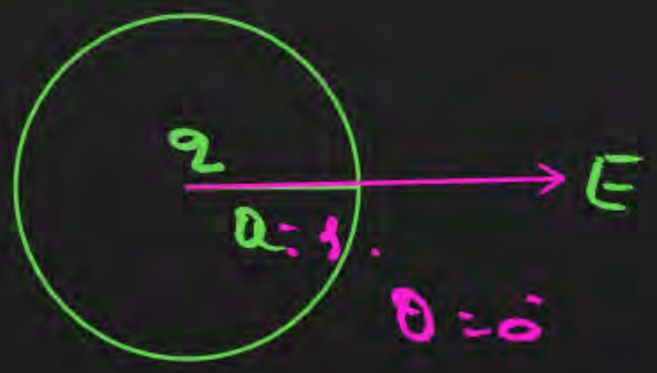
(D) $\varepsilon_0 Aa^2$

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

$$E \cdot A\cos\theta = \frac{q}{\varepsilon_0}$$

$$Ar \cdot 4\pi a^2 (1) = \frac{q}{\varepsilon_0}$$

$$4\pi a^3 A = \frac{q}{\varepsilon_0} \Rightarrow q = 4\pi\varepsilon_0 a^3 A$$



Question

The total electric flux through a closed spherical surface of radius 'r' enclosing an electric dipole of dipole moment 2aq is (Given ε_0= permittivity of free space)

↳ Q = 0

(A) Zero

(B) $\frac{q}{\varepsilon_o}$

(C) $\frac{2q}{\varepsilon_o}$

(D) $\frac{8\pi r^2 q}{\varepsilon_o}$

Question

A charge Q is enclosed by a Gaussian spherical surface of radius R. If the radius is doubled, then the outward electric flux will

A. Be reduced to half

B. Remain the same

C. Be doubled

D. Increase four times

Question

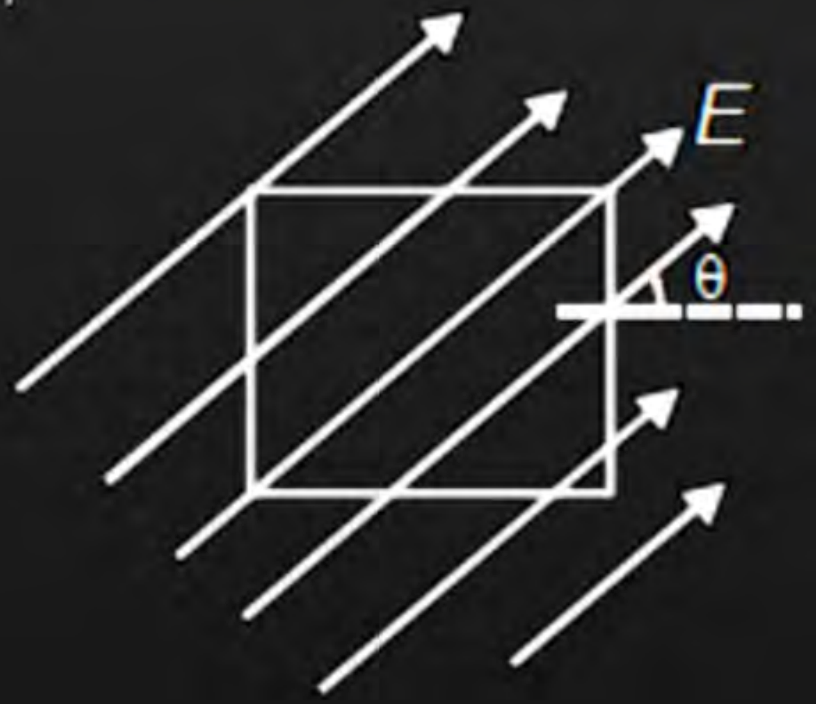
A surface of side L metre in the plane of the paper is placed in a uniform electric field E(volt/m) acting along the same plane at an angle θ with the horizontal side of the square as shown in figure. The electric flux linked to the surface in unit of V-m, is

(A) EL^2

(B) $EL^2\cos\theta$

(C) $EL^2\sin\theta$

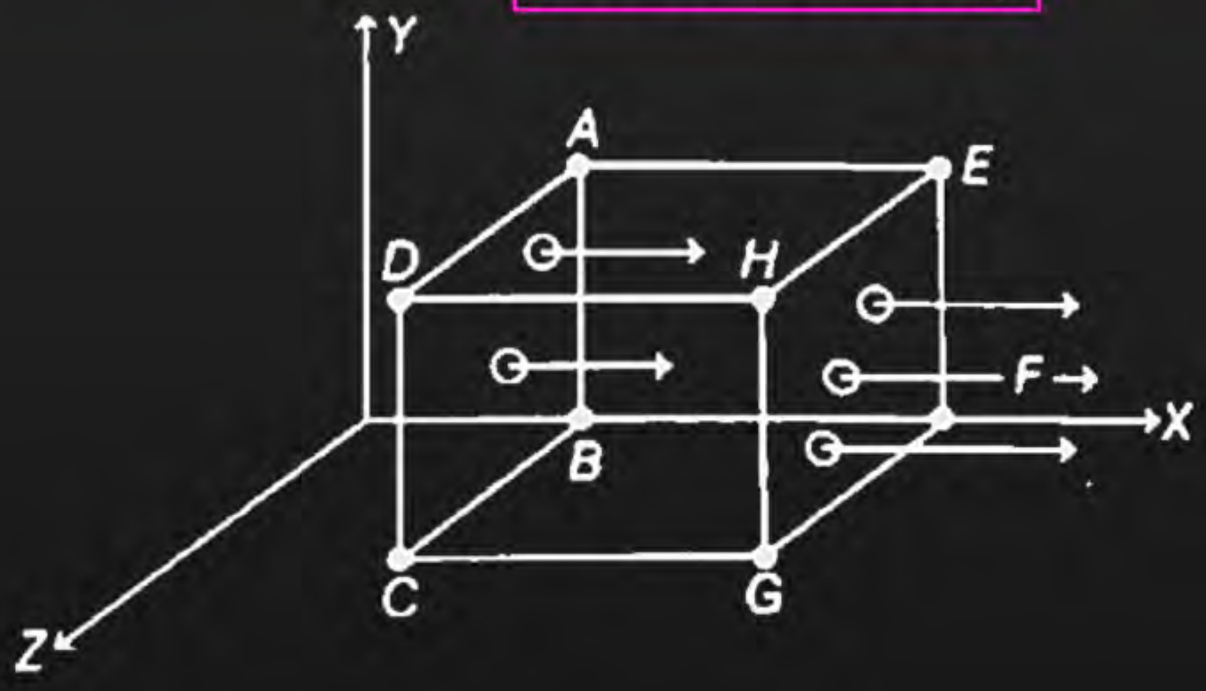
(D) 0



Question

A cubical Gaussian surface has side of length $a = 10$ cm. Electric field lines are parallel to X-axis as shown in figure. The magnitudes of electric fields through surfaces ABCD and EFGH are 6 kN C^{-1} and 9 kN C^{-1} respectively. Then, the total charge enclosed by the cube is [Take, $\varepsilon_0 = 9 \times 10^{-12}\ Fm^{-1}$]

[Home Work]



(A) –0.27 nC

(B) 1.35 nC

(C) –1.35 nC

(D) 0.27 nC

Question

A hollow cylinder has a charge q coulomb within it (at the geometrical centre). If ϕ is the electric flux in units of Volt-meter associated with the curved surface B, the flux linked with the plane surface A in units of volt-meter will be:

(A) $\frac{1}{2}\left(\frac{q}{\varepsilon_0} - \phi\right)$

(B) $\frac{q}{2\varepsilon_0}$

(C) $\frac{\phi}{3}$

(D) $\frac{q}{\varepsilon_0} - \phi$

$$\phi = \phi_A + \phi_B + \phi_C$$

$$\frac{q}{\varepsilon_0} = 2\phi_A + \phi$$

$$2\phi_A = \frac{q}{\varepsilon_0} - \phi$$

$$\phi_A = \frac{1}{2}\left(\frac{q}{\varepsilon_0} - \phi\right)$$

$\phi_A = \phi_C$

Question

A sphere encloses an electric dipole with charges $\pm 3 \times 10^{-6}$C. What is the total electric flux through the sphere?

A. -3×10^{-6} N-m^2/C

B. Zero

C. 3×10^{-6} N-m^2/C

D. 6×10^{-6} N-m^2/C

Question

Figure shows a spherical Gaussian surface and a charge distribution. When calculating the flux of electric field through the surface, The flux will be due to

(A) $+q_3$ alone

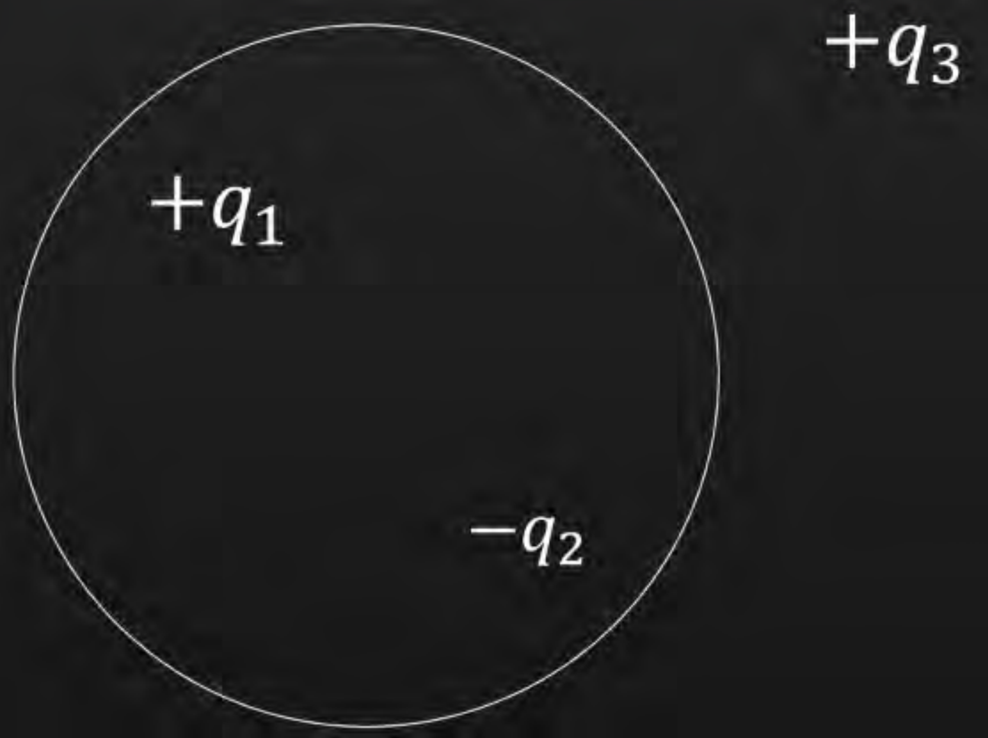
(B) $+q_1$ and $+q_3$

(C) $+q_1, -q_2$ and $+q_3$

(D) $+q_1$ and $-q_2$

$$\phi = \frac{q_{enc}}{\varepsilon_0}$$

$$\phi = \frac{+q_1 - q_2}{\varepsilon_0}$$



Question

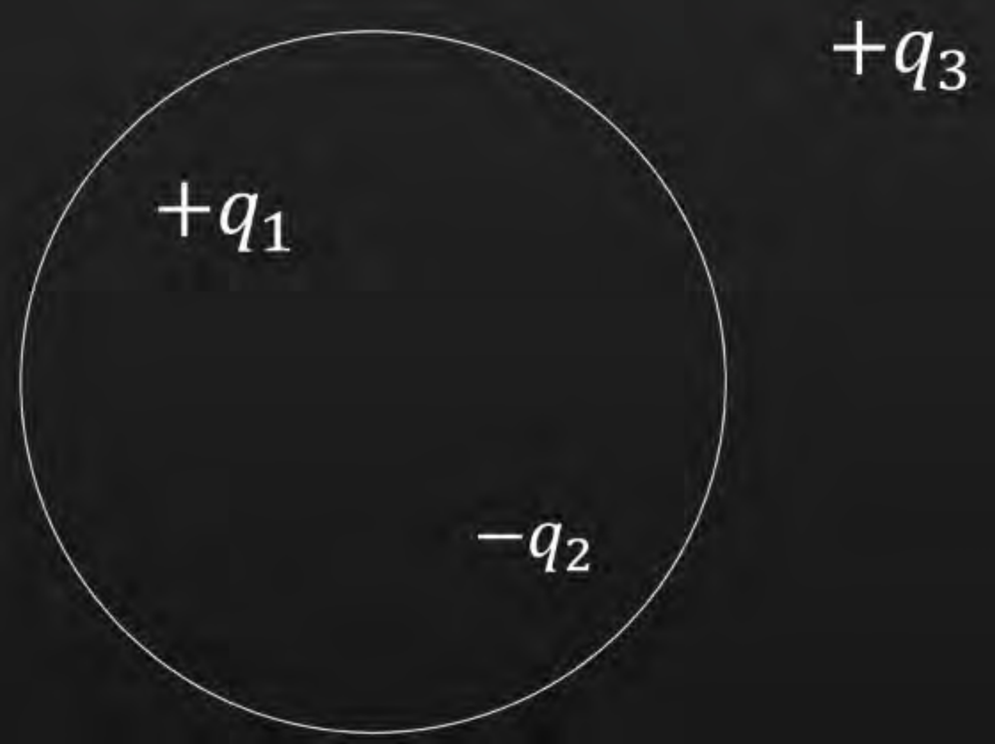
Figure shows a spherical Gaussian surface and a charge distribution. When calculating the flux of electric field through the surface, The electric field will be due to

(A) $+q_3$ alone

(B) $+q_1$ and $+q_3$

(C) $+q_1, -q_2$ and $+q_3$

(D) $+q_1$ and $-q_2$



Question

If there are only one type of charge in the universe, then ($E \rightarrow$ Electric field, $dS \rightarrow$ Area vector)

(A) $\oint E.ds \neq 0$ on any surface

(B) $\oint E.ds$ Could not be defined

(C) $\oint E.ds \neq \infty$ If charge is inside

(D) $\oint E.ds = 0$ on if charge is outside, $\oint E.ds = \frac{q}{\varepsilon_0}$ if charges is inside

Question

A charge $Q\,\mu C$ is placed at the centre of a cube. The flux coming out from any one of its faces will be (in SI units):

(A) $\frac{Q}{\varepsilon_0} \times 10^{-6}$

(B) $\frac{2Q}{3\varepsilon_0} \times 10^{-3}$

(C) $\frac{Q}{6\varepsilon_0} \times 10^{-3}$

(D) $\frac{Q}{6\varepsilon_0} \times 10^{-6}$

Question

What is the flux through a cube of side 'a' if a point charge q is at one of its corners?

A) $\frac{2q}{\varepsilon_0}$

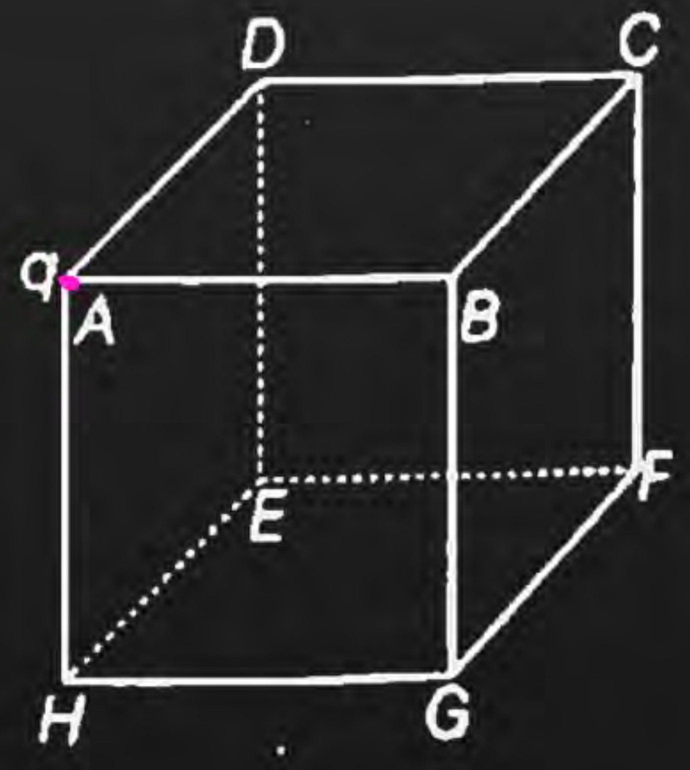
B) $\frac{q}{8\varepsilon_0}$

C) $\frac{q}{\varepsilon_0}$

D) $\frac{q}{2\varepsilon_0}$

Question

A point charge q is placed at the corner of a cube of side a as shown in the figure. What is the electric flux through the face ABCD ?



(A) 0

(B) $\frac{q}{24\varepsilon_o}$

(C) $\frac{q}{6\varepsilon_o}$

(D) $\frac{q}{72\varepsilon_o}$

Flux is not linked with

ABCD
ABGH
ADEH

} $\phi = 0$

Applications of Gauss Law

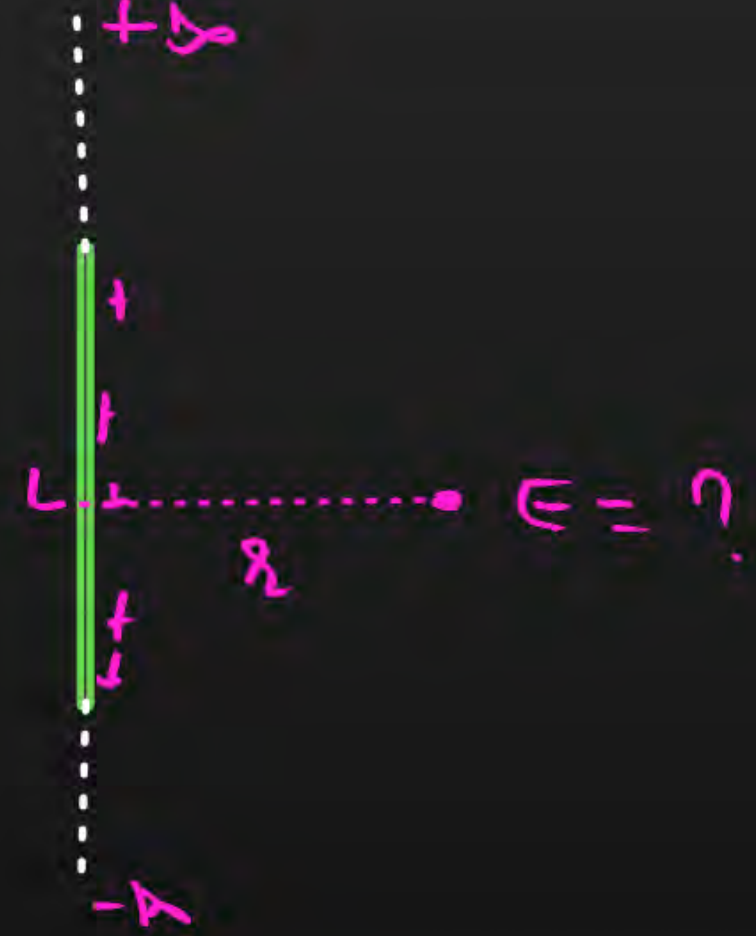
1. Electric field due to infinite charged wire.

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

$$\lambda = \frac{q}{L}$$

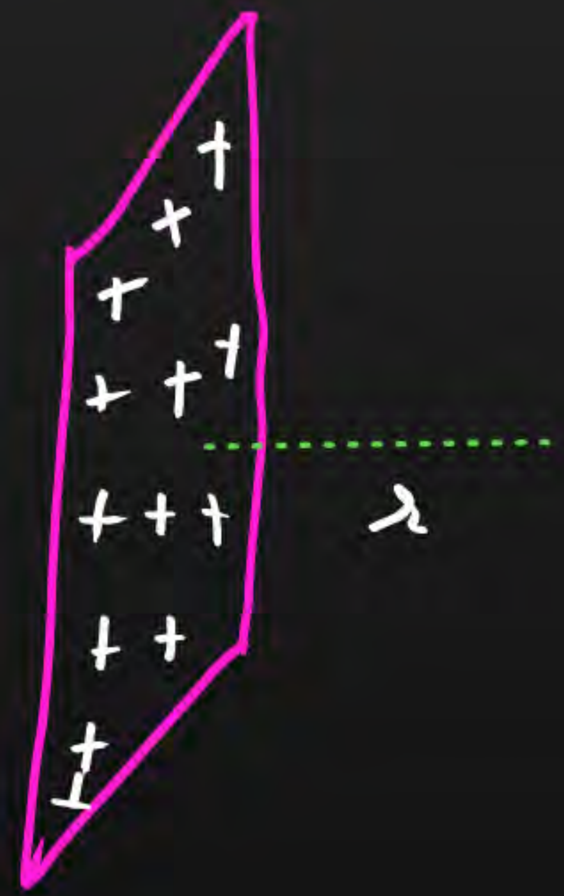
$$E = \frac{2}{r} \times \frac{1}{4\pi\varepsilon_0}\lambda$$

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



Applications of Gauss Law

2. Electric field due to an infinite plane sheet of charge



$E = \frac{\sigma}{2\varepsilon_0}$ → Non-conducting

$E = \frac{\sigma}{\varepsilon_0}$ → conducting

Applications of Gauss Law

3. Electric field intensity just outside a charged conductor.

$$E = \frac{\sigma}{\epsilon_0}$$

Applications of Gauss Law

Next class

4. Electric field due to a uniformly charged thin spherical shell OR conducting sphere OR Hollow sphere.

Thank You