# PHYSICS

for IIT-JEE, AIEEE, PMT, I.Sc., XI & XII

at

# TOP TUTORIALS

NIRMALA DEVI CHARITABLE TRUST द्वारा संचालित

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BORING ROAD, PATNA-1

ELECTROSTATICS

ENGLISH

Director : SHEKHAR PRASAD

Imagination is more powerful than knowledge-EINSTEIN

# SYMBOL

| | PHYSICAL QUANTITIES | SYMBOL |
|---|---|---|
| 1. | Charge | Q or q |
| 2. | Electron | e |
| 3. | Proton | p |
| 4. | Charge of electron | – e |
| 5. | Charge of proton | +e |
| 6. | Number of Electrons or Protons | n |
| 7. | Electric force | $\vec{F}_e$ |
| 8. | Coulombian force | $\vec{F}_c$ |
| 9. | Electric field | $\vec{E}$ |
| 10. | Electric potential | V |
| 11. | electric potential energy | U |
| 12. | Dielectric constant | K |
| 13. | Distance between two charges | r or d |
| 14. | Very small displacement | $d\vec{r}$ |
| 15. | Very small potential difference | dV |
| 16. | Length of electric dipole | d |
| 17. | Electric dipole moment | $\vec{p}$ |
| 18. | Area vector | $\vec{A}$ or $\vec{S}$ |
| 19. | Very small area vector | $d\vec{A}$ or $d\vec{S}$ |
| 20. | electric flux | $\phi$ (fy) |
| 21. | Very small electric flux | $d\phi$ |
| 22. | Internal charge | $Q_{in}$ |
| 23. | Charge density | $\lambda$ (lembda) |
| 24. | Absolute permittivity of free space | $\varepsilon_o$ (epsillion knot) |
| 25. | Relative permittivity of the medium | $\varepsilon_r$ (epsillion r) |
| 26. | Capacitance | C |
| 27. | Electric potential energy in unit volume | u |

# UNIT

| | Symbol | Unit |
|---|---|---|
| 1- | Q or q or e | coulomb (C) |
| 2- | $\vec{F}_e$ or $\vec{F}_c$ | Newton (N) |
| 3- | $\vec{E}$ | $\frac{\text{Newton}}{\text{coulomb}}\left(\frac{N}{C}\right)$ or $\frac{\text{volt}}{\text{metre}}\left(\frac{V}{m}\right)$ |
| 4- | V | Volt (V) or $\frac{\text{Joule}}{\text{coulomb}}\left(\frac{J}{C}\right)$. |
| 5- | $\vec{p}$ | coulomb-metre (C-m) |
| 6- | $\vec{A}$ or $\vec{S}$ or $d\vec{A}$ or $d\vec{S}$ | metre$^2$ ($m^2$) |

| | | |
|---|---|---|
| 7- | $\phi$ or $d\phi$ | $\frac{\text{Newton}-\text{metre}^2}{\text{coulomb}}\left(\frac{N-m^2}{C}\right)$ or volt-metre (V-m) |
| 8- | $\lambda$ | $\frac{\text{coulomb}}{\text{metre}}\left(\frac{C}{m}\right)$ or $\frac{\text{coulomb}}{\text{metre}^2}\left(\frac{C}{m^2}\right)$ or $\frac{\text{coulomb}}{\text{metre}^3}\left(\frac{C}{m^3}\right)$ |
| 9- | $\varepsilon_o$ | or $\frac{\text{Farad}}{\text{metre}}\left(\frac{F}{m}\right)$ |
| 10- | $Q_{in}$ | coulomb (C) |
| 11- | C | farad (F) or $\frac{\text{coulomb}}{\text{volt}}\left(\frac{C}{v}\right)$ |
| 12- | K | unitless |
| 13- | u | $\frac{\text{Joule}}{\text{metre}^3}\left(\frac{J}{m^3}\right)$ |

## DIMENSIONAL FORMULA

| | **Symbol** | **Dimensional Formula** |
|---|---|---|
| 1- | Q or q or e or $Q_{in}$ | IT |
| 2- | $\vec{E}$ | $MLI^{-1}T^{-3}$ |
| 3- | V | $ML^2I^{-1}T^{-3}$ |
| 4- | U | $ML^2T^{-2}$ |
| 5- | u | $ML^{-1}T^{-2}$ |
| 6- | k | LTI |
| 7- | A or $\vec{S}$ or $d\vec{A}$ or $d\vec{S}$ | no dimensional formula |
| 8- | $\phi$ or $d\phi$ | $ML^3I^{-1}T^{-3}$ |
| 9- | $\lambda$ | $L^{-1}IT$ or $L^{-2}IT$ or $L^{-3}IT$ |
| 10- | $\varepsilon_o$ or $\varepsilon_r$ | $M^{-1}L^{-3}I^2T^4$ |
| 11- | C | $M^{-1}L^{-2}I^{-2}T^4$ |

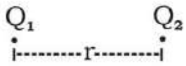
## FORMULA

**1.** The value of charge in n electrons or in n protons will be :-

$$Q = n.(\pm e)$$

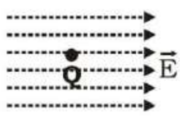
'—' is used for electron and '+' is used for protons.

**2.** When two point charges are at some distance, then magnitude of the forces acting on each other :-



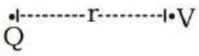

$$F = \frac{1}{4\pi\varepsilon_o}\cdot\frac{|Q_1|\cdot|Q_2|}{r^2}$$

**3.** When a point charge is placed in an electric field, then electric force acting on the charge:-



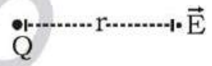

$$\vec{F} = Q\vec{E}$$

**4.** The electric potential due to a point charge at some distance :-



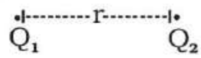

$$V = \frac{1}{4\pi\varepsilon_o}.\frac{Q}{r}$$

**5.** The magnitude of the electric field due to a point charge at some distance :-



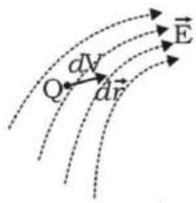

$$E = \frac{1}{4\pi\varepsilon_o}.\frac{|Q|}{r^2}$$

**6.** When two point charges are placed at some distance, then the electrical potential energy of the system will be :-



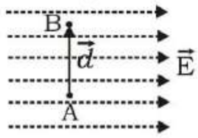

$$U = \frac{1}{4\pi\varepsilon_o}.\frac{Q_1, Q_2}{r}.$$

**7.** The relation between electric field and small change in electric potential when a charge displaces in the electric field is :-



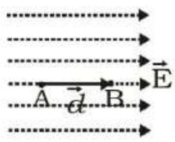

$$dV = -\vec{E}.d\vec{r}.$$

**8.** When we move perpendicularly in a uniform electric field then change in electric potential is :-



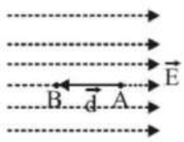

$$V_B - V_A = 0$$

**9.** When we move along a uniform electric field then change in electric potential is :-



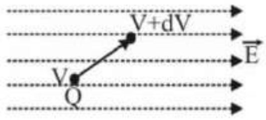

$$V_B - V_A = -Ed.$$

**10.** When we move opposite to a uniform electric field then change in electric potential is :-



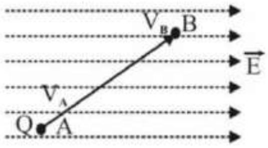

$$V_B - V_A = Ed.$$

**11.** If a charge q displaces in an electric field so that its electric potential changes by a very small amount dV, than the change in its electric potential energy dU will be :-



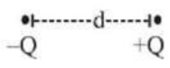

$$dU = Q\,dV$$

**12.** If electric potentials at points A and B in an electric field are respectively $V_A$ and $V_B$ and a charge Q moves from A to B than change in its electric potential energy $U_B - U_A$ will be -




$$U_B - U_A = Q\,(V_B - V_A).$$

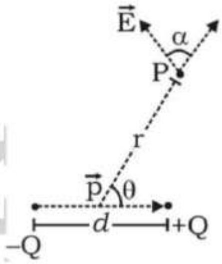
**13.** If the charge of an electric dipole is q and the distance between the charges is d, than its electric dipole moment $\vec{p}$ will be :-




$$\vec{p} = Q\vec{d}$$

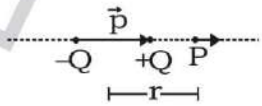
Th direction of electric dipole moment is from the negative charge to the positive charge of the electric dipole.

**14.** The electric field due to an electric dipole at an arbitrary point is:-



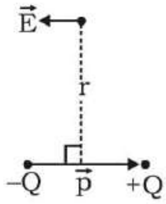

$$E = \frac{1}{4\pi\varepsilon_o} \cdot \frac{p\sqrt{3\cos^2\theta + 1}}{r^3} \quad \text{and,} \quad \alpha = \tan^{-1}\left(\frac{\tan\theta}{2}\right)$$

**15.** The electric field due to an electric dipole at an end on position is :-



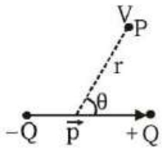

$$\vec{E} = \frac{1}{4\pi\varepsilon_o} \cdot \frac{2\vec{p}}{r^3}.$$

**16.** The electric field due to an electric dipole at a proadside on position is :-



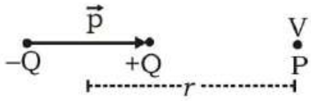

$$\vec{E} = -\frac{1}{4\pi\varepsilon_o} \cdot \frac{\vec{p}}{r^3}.$$

**17.** The electric potential due to an electric dipole at an arbitrary point is :-



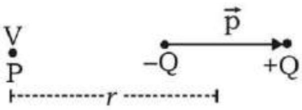

$$V = \frac{1}{4\pi\varepsilon_o} \cdot \frac{p\cos\theta}{r^2}.$$

**18.** The electric potential due to an electric dipole at an end on position near the positive charge is :-



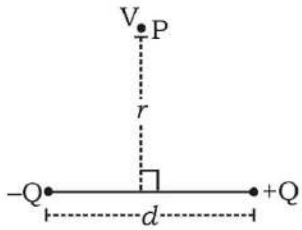

$$V = \frac{1}{4\pi\varepsilon_o} \cdot \frac{p}{r^2}.$$

**19.** The electric potential due to an electric dipole at an end on position near the negative charge is :-



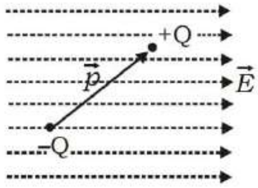

$$V = -\frac{1}{4\pi\varepsilon_o} \cdot \frac{p}{r^2}.$$

**20.** The electric potential due to an electric dipole at a proadside on position is :-




V = 0.

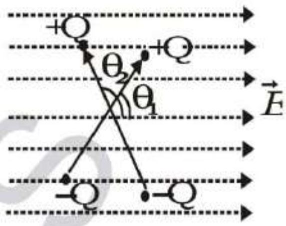
**21.** When an electric dipole is placed in a uniform electric field, then the torque acting on the dipole is :-




$$\vec{\tau} = \vec{p} \times \vec{E}.$$

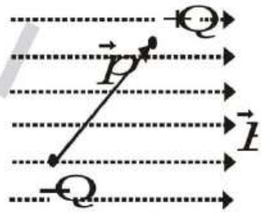
**22.** In an electric dipole is rotated in a uniform electric field, then change in electric potential energy of the system is :-

$$\Delta U = -pE\left(\cos\theta_2 - \cos\theta_1\right).$$



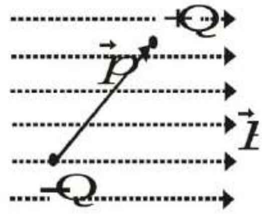

**23.** When an electric dipole is placed in a uniform electric field, then the electric potential energy of the system is :-

$$U = -\vec{p}.\vec{E}.$$



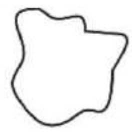

**24.** When an electric dipole is placed in a uniform electric field then the force acting on the dipole is :-

$$\vec{F} = 0.$$

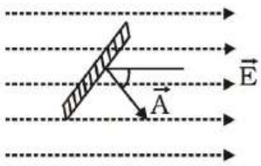



**25.** The area vector of a three dimensional closed surface is zero. So,

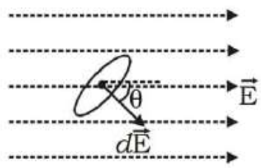
$$\vec{A} = 0$$



**26.** The magnitude of area vector of a plane surface is equal to the area of the surface and its direction is along the perpendicular to the surface and in that direction which makes smaller angle with electric field.



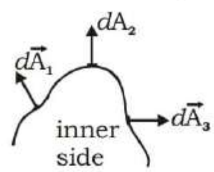

**27.** If a surface is very small of every type, then it is treated as a plane surface and it is explained about it just above.




**28.** If a surface is curved, then its area vector is vector sum of all the small-small area vectors. Example :-

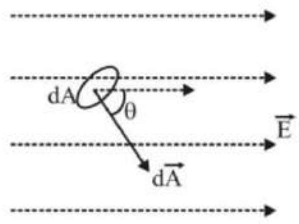
$$\vec{A} = d\vec{A}_1 + d\vec{A}_2 + d\vec{A}_3 + .......$$

The direction of all these small area vectors on this curved surface are along perpendicular outward of the surface.

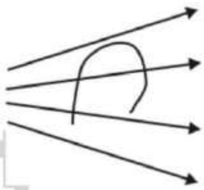



**29.** If a very small area vector $d\vec{A}$ is laying in an electric field $\vec{E}$ and the angle between $d\vec{A}$ and $\vec{E}$ is θ, then the value of very small electric flux dϕ made on the surfacfe will be :-

$d\phi = \vec{E}.d\vec{A}$ $\Rightarrow d\phi = E.dA.\cos\theta$

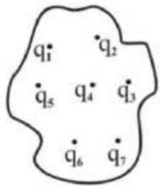


**30.** When a curved surface is laying in an electric field $\vec{E}$, then the electric flux made on the whole surface will be :-



$$\phi = \int d\phi \qquad \Rightarrow \phi = \int \vec{E}.d\vec{A}$$

**31.** To know the internal charge $Q_{in}$ of a three dimensional closed surface, all the charges inside the surface are added according to simple algebric method.

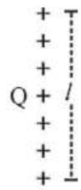


$$Q_{in} = q_1 + q_2 + q_3 + \ldots\ldots$$

**32.** If internal charge of a three dimensional closed surface is $Q_{in}$, then the value of electric flax $\phi$ will be :-

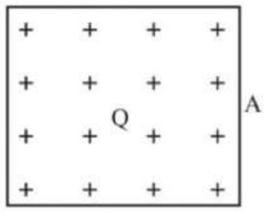

$$\phi = \frac{Q_{in}}{\varepsilon_o}$$

**33.** If charge Q is distributted uniformly in a length $l$, then the value of charge density $\lambda$ will be :-



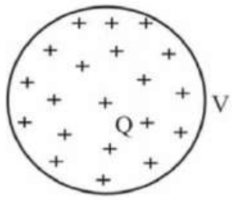

$$\lambda = \frac{Q}{\ell}$$

**34.** If charge Q is distributted uniformly in an area A, then the value of charge density $\lambda$ will be :-




$$\lambda = \frac{Q}{A}$$

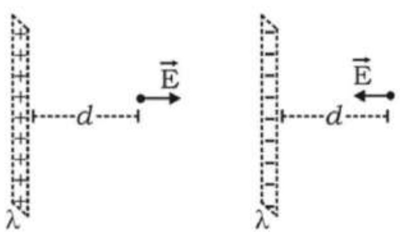
**35.** If charge Q is distributted uniformly in the volume V, then the value of charge density $\lambda$ will be :-




$$\lambda = \frac{Q}{V}$$

**36.** If charge is distributted uniformly on a very large plane surface such that the charge density is $\lambda$, then the value of electric field created by this plane surface at a point which is near to it will be :-

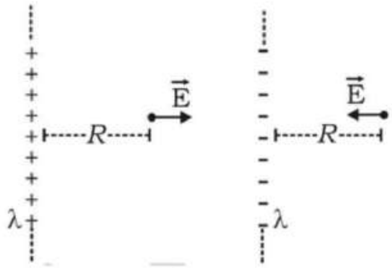
The direction of electric field is just opposite to the surface, if charge is positive but the direction of electric field is towards the surface, if charge is negative.




$$E = \frac{\lambda}{2\varepsilon_o}$$

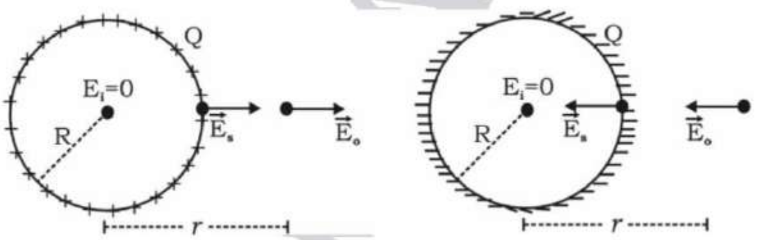
**37.** If charge is distributted uniformly on a very long line such that the charge density is $\lambda$, then the value of electric field created by this linear charge at a distance R from it will be:-

The direction of electric field is just opposite to the linear charge, if charge is positive but the direction of electric field is towards the surface, is charge is negative.




$$E = \frac{1}{4\pi\varepsilon_o} \cdot \frac{2\lambda}{R}$$

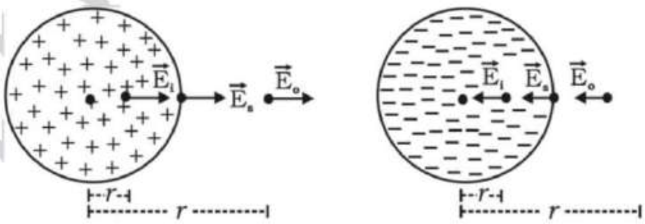
**38.** If charge Q is distributted uniformly on the whole surface of a sphere of radius R, then the value of electric field is zero at every point inside the sphere. The value of electric field $E_s$ at a point on the surface of the sphere and the value of electric field $E_o$ at a point which is outer side of the sphere at a distance r from the centre will be :-




The direction of electric field is just opposite to the centre of the sphere, if charge is positive but the direction of electric field is towards the centre of the sphere, if charge is negative.

$$E_i = 0 \qquad E_s = \frac{1}{4\pi\varepsilon_o} \cdot \frac{Q}{R^2} \qquad \text{and} \qquad E_o = \frac{1}{4\pi\varepsilon_o} \cdot \frac{Q}{r^2}$$

**39.** If charge Q is distributted uniformly in the whole volume of a sphere of radius R, the value of electric field $E_i$ at a point inside the sphere at a distance r from the centre, the value of electric field $E_s$ at a point on the surface of the sphere and the value of electric field $E_o$ at a point which is outside of the sphere at a distance r from the centre will be :-

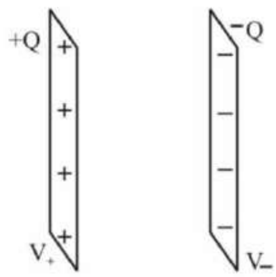



The direction of electric field is just opposite to the centre of the sphere, if charge is positive but the direction of electric field is towards the centre of the sphere, if charge is negative.

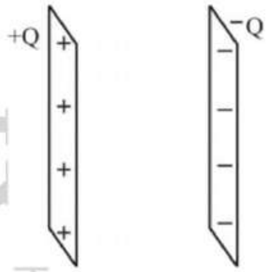
$$E_i = \frac{1}{4\pi\varepsilon_o} \cdot \frac{Qr}{R^3} \qquad E_s = \frac{1}{4\pi\varepsilon_o} \cdot \frac{Q}{R^2} \qquad \text{and} \qquad E_o = \frac{1}{4\pi\varepsilon_o} \cdot \frac{Q}{r^2}$$

**40.** If the potential of the positive plate of a capacitor is $V_+$ and of the negative plate of the capacitor is $V_-$, then the potential V of the capacitor will be :-

$$V = V_+ - V_-$$

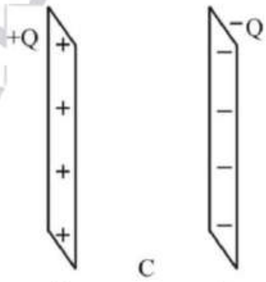


**41.** If the charge on the positive plate of a capacitor is +Q and on the negative plate of the capacitor is –Q, then the charge Q of the capacitor will be :-



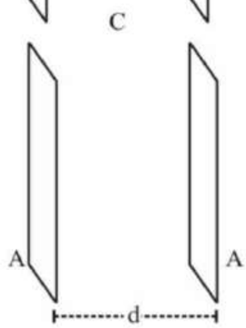

$$Q = +Q$$

**42.** The relation among capacitance C of a capacitor, its potential V and its charge Q is known by the formula :-



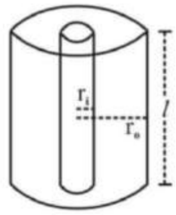

$$Q = CV$$

**43.** Suppose that there is a parallel plate capacitor having plate area A and the distance between the plates d. So, the capacitance C of a parallel plate capacitor will be :-



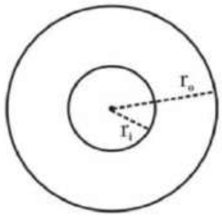

$$C = \frac{\varepsilon_0 A}{d}$$

**44.** Suppose that there is a cylindrical capacitor of length $l$ and the radii of the inner and outer cylinderical plates are $r_i$ and $r_0$ respectively. So, the capcacitance C of a cylinderical capacitor will be :-



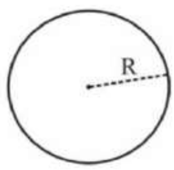

$$C = \frac{2\pi\varepsilon_o \ell}{\log\left(\frac{r_o}{r_i}\right)}$$

**45.** Suppose that there is a spherical capacitor having the radius of inner plate $r_i$ and the radius of outer plate $r_0$. So, the capacitance C of a spherical capacitor will be :-



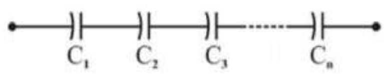

$$C = \frac{4\pi\varepsilon_o r_i r_o}{r_o - r_i}$$

**46.** Suppose that there is an isolated spherical capacitor having radius r, then the capacitance C of an isolated spherical capacitor will be :-



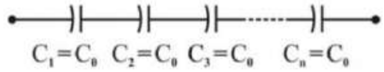

$$C = 4\pi\varepsilon_o R$$

**47.** When some capacitors $C_1$, $C_2$, $C_3$,..... and $C_n$ are connected in a series combination between any two terminals (A and B as shown in the figure), then the equivalent capacitance C will be :-



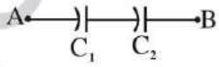

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots\ldots\ldots\ldots + \frac{1}{C_n}$$

**48.** When n identical capacitors $C_0$ each are connected in a series combination between any two terminals (A and B as shown in the figure), then the equivalent capacitance C will be:-



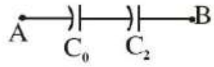

$$C = \frac{C_0}{n}$$

**49.** When two capacitors $C_1$ and $C_2$ are connected in a series combination between two terminals (A and B as shown in the figure), then the equivalent capacitance C will be :-



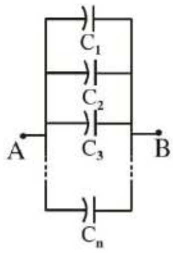

$$C = \frac{C_1C_2}{C_1 + C_2}$$

**50.** When two identical capacitors $C_0$ each are connected in a series combination between two terminals (A and B as shown in the figure), then the equivalent capacitance C will be:-



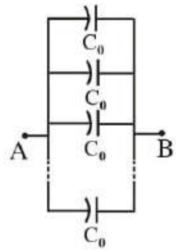

$$C = \frac{C_0}{2}.$$

**51.** When some capacitors $C_1$, $C_2$, $C_3$.............. and $C_n$ are connected in a parallel combination between any two terminals (A and B as shown in the figure), then the equivalent capacitance C will be :-



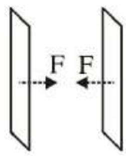

$$C = C_1+C_2+C_3+.......+C_n$$

**52.** When n identical capacitors $C_0$ each are connected in aparallel combination between any two terminals (A and B as shown in the figure), then the equivalent capacitance C will be:-



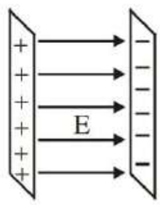

$$C = nC_0$$

**53.** If a parallel plate capacitor of plate area A is charged to Q then both the plates of the capacitor will attract each-other by the force F :-



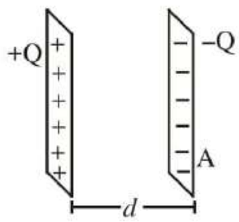

$$F = \frac{Q^2}{2\varepsilon_0 A}$$

**54.** If a parallel plate capacitor of plate area A is charged to Q, then the electric field E between the plates from the positive plate to the negative plate is known by the formula:-




$$E = \frac{Q}{\varepsilon_0 A}$$

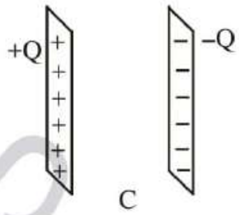
**55.** If a parallel plate capacitor of plate area A and the distance between the plate d is charged to Q, then the electric potential energy U in the capacitor will be :-




$$U = \frac{Q^2 d}{2A\varepsilon_o}$$

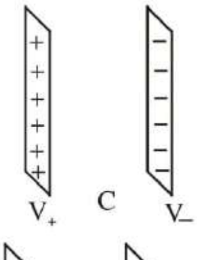
**56.** If a parallel plate capacitor of capacitance C is charged to Q, then the electric potential energy U in the capacitor will be :-

$$U = \frac{Q^2}{2C}$$



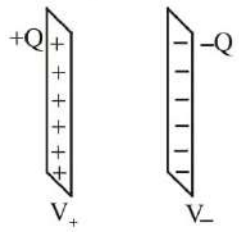

**57.** If a parallel plate capacitor of capacitance C is charged to the potential V, then the electric potential energy U in the capacitor will be :-

$$U = \frac{1}{2}CV^2$$



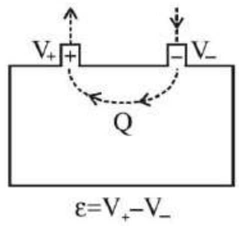

**58.** If a parallel plate capacitor is charged by applying a potential difference V and the charge developed in it is Q, then the electric potential energy U in the capacitor will be :-

$$U = \frac{1}{2}QV$$



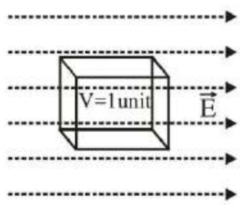

**59.** If charge Q passes through the battery of terminal potential difference $V=V_+ - V_-$ from the negative terminal to the positive terminal, then the work done W by the battery is known by the formula :-

$$W = QV$$



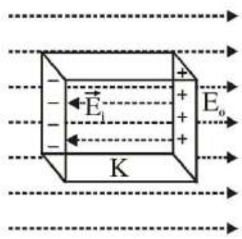

**60.** The electric potential energy per unit volume u in a uniform electric field $\vec{E}$ is known by the formula :-

$$u = \frac{1}{2}\varepsilon_0 E^2$$




**61.** When a body of dielectric material of dielectric constant k is placed inside a uniform electric field $E_0$, then the resultant electric field $E_R$ inside the body is along the external applied electric field $\vec{E}_0$ and its value is known by the formula:-

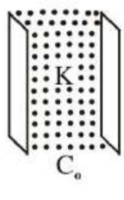
$$E_R = E_0 - E_i = \frac{E_0}{K}$$



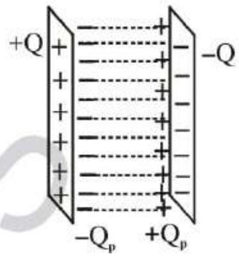

where, $E_i$ is the induced electric field in the body of dielectric material.

**62.** When a dielectric material of dielectric constant k is filled in the whole space between the plates of every type of capacitors of capacitance then the new capacitance C of the capacitor is :-

$$C=kC_o.$$

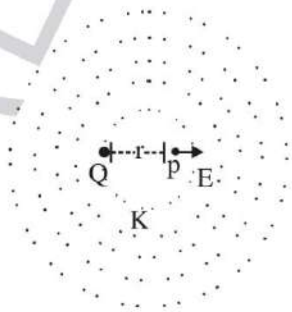


**63.** When a dielectric material of dielectric constant K is filled in the whole space between the plates of a capacitor have been charged to Q then the magnitude of polarised charge $Q_p$ on side of the dielectric material is known by the formula :-



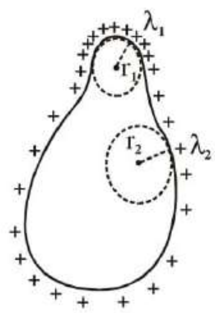

$$Q_p = Q\left(1 - \frac{1}{k}\right)$$

**64.** When a charge Q is placed in the region of a dielectric material of dielectric constant k, then the magnitude of the electric field E at a distance r from the point charge is known by the formula




$$E = \frac{1}{k}.\frac{1}{4\pi\varepsilon_0}.\frac{Q}{r^2}.$$

**65.** When charge is placed on a nonuniform conducting material, then it is distributed nonuniformly on the outer surface of the conductor having charge density λ greater at that portion, which radius of curvature r is small. And, the relation between these two quantity is known by the formula :-




$$\lambda \propto \frac{1}{r} \quad \Rightarrow \quad \frac{\lambda_1}{\lambda_2} = \frac{r_2}{r_1}$$

## COULOMB'S LAW

**1.** What is electrostatics ?

**Ans.** That branch of physics in which we study about stationary charges and properties related with it is called electrostatics.

**2.** What is charge ?

**Ans.** That property related with an electron or a proton, due to which they apply electric forces on each. Other is called charge.

**3.** What is electric force ?

**Ans.** Two or more than two charges always apply forces on each-other and this force is called electric force. It is also called electrostatics force.

**4.** Lightning and thundering of cloudes in the sky happen due to ............ .

**Ans.** Electric discharge.

**5.** Give some examples of electric discharge.

**Ans.** These are examples of electric discharge :-

(i) Lightening and thundering of cloudes in the sky.

(ii) Sparkling with crackling when a blanket is rubbed with the front portion of nails in a dry weather of winter.

(iii) Sparkling with crackling when a sinthetic cloth or a sweater put off in a dry weather of winter.

(iv) Crackling when we but our hand near a television or a computer screen etc.

**6.** Which equipment performs on the theory of electrostatics :-

(a) xerox machine | (b) capacitor

(c) van de Graff generator | (d) spray painting

**Ans.** (a), (b), (c), (d)

**7.** Charge has ............... type. One type is called ................. charge and other type is called .............. charge.

**Ans.** Two, positive, Negative.

**8.** What is the cavendish's law of attraction and repulsion in electrostatics ?

**Ans.** Cavendish's law of attraction and repulsion in electrostatics states that, "charges of same nature repel each-other, while charges of opposite nature attract each-other."

**9.** The charge on an electron is imagined of ............ type and the charge on a proton is imagined of ........... type.

**Ans.** Negative, Positive

**10.** The charge on an electron is imagined ............. and the charge on a proton is imagined ................ .

**Ans.** $-1.6\times10^{-19}C$ , $+1.6\times10^{-19}C$

**11.** All type of charges can attract an uncharged object.

**Ans.** True.

**12.** All type of charges can repel an uncharged object

**Ans.** False

**13.** When some charges are given to a conductor, then this charge spread out on the whole surface of the conductor immediately.

**Ans.** True.

**14.** When some charges are given to an insulator, then this charge will be laying at that place where it was placed.

**Ans.** True.

**15.** Statement-I : An object is electrically neutral generally.

Statement- II : The number of negative charges (electrons) and the number of positive charges (protons) are equal generally.

**Ans.** a

**16.** An object is called charged when number of negative charges (electrons) and positive charges (protons) are ........... in it.

**Ans.** not equal.

**17.** An object is ........... charged, in which number of positive charges (protons) is greater than negative charges (electrons)

**Ans.** positively.

**18.** An object is ............ charged, in which number positive charges (electrons) is greater than positive charges (protons)

**Ans.** negatively.

**19.** Some negative charges (electrons) are ................ an object, to make it negatively charged.

**Ans.** Put on

**20.** Some negative charges (electrons) are ........... an object, to make it positively charged.

**Ans.** removed from

**21.** Statement- I : When an object is negatively charged then its mass increases and when an object is positively charged then its mass decreases.

Statement - II : electrons are put on an object to make it negatively charged and electrons are removed from an object to make it positively charged and electron has mass.

**Ans.** a

**22.** How can an uncharged solid conductor can be charged :-

(a) By touching a charged conductor with an uncharged solid conductor.

(b) By rubbing an uncharged solid conductor with another solid conductor.

(c) By bringing a charged conductor near to an uncharged solid conductor.

(d) none of these.

**Ans.** (a), (c)

**23.** 'Two objects are charged when they are rubbed against each other : About which type of objects, this statement is true :-

(a) a conductor and an insulator (b) Both conductors

(c) Both insulators (d) All of the above.

**Ans.** (c)

**24.** What happens when an uncharged solid conductor is touched with a charged solid conductor ?

**Ans.** When an uncharged solid conductor is touched with a charged solid conductor, then the uncharged solid conductor becomes charged. The nature of charge on the earlier uncharged solid conductor is same which was the nature of charge on the earlier charged solid conductor. The developed charge on the earlier uncharged solid conductor remains when the earlier charged solid conductor is removed.

**25.** Write a note on frictional charging.

**Ans.** When two insulated objects are rubbed against each-other, then charges of equal magnitude and opposite nature are developed in both the objects and such type charging is called frictional charging. It happens so because some electrons are transferred during rubbinbg from the object which has less electron effinity to the object which has larger electron effinity. That object becomes positively charged from which electrons emit and that object becomes negatively charged in which electrons enject.

Example :- Electron effinity of ebonite is greater than fur. Due to this, when both are rubbed against each-other, then some electrons are transferred from fur to ebonite and due to this ebonite becomes negatively charged and fur becomes positively charged.

**26.** If the pairs of following objects are rubbed against each-other, then which will be negatively charged and which will be positively charged :-

(a) rod of ebonite and fur (b) rod of glass and cloth of silk

(c) dry hair and comb (d) wool and rubber

(e) rubber or umber and fur or wool

**Ans.** By rubbing these pairs against each-other they are charged negatively and positively so as :-

| Negatively charged | Positively charged |
|---|---|
| (a) rod of ebonite | fur |
| (b) cloth of silk | rod of glass |
| (c) comb | dry hair |
| (d) rubber | wool |
| (e) rubber or umber | fur or wool |

**27.** Statement- I : When two objects made of conductor are rubbed against each other, then they are charged.

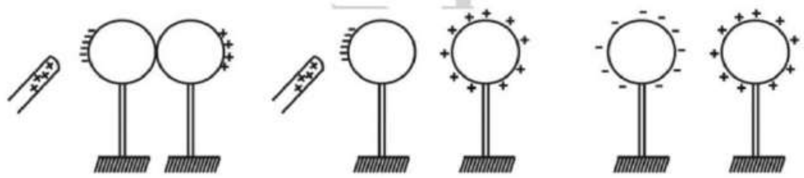
Statement- II : When two objects are rubbed against each-other then generally some electrons are transferred from one object to the other object.

**Ans.** d

**28.** How can a conducting object be charged by induction ?

**Ans.** When a charged object is brought near to an uncharged conducting object, then charge of opposite nature is developed on the uncharged object near to the charged object and charge of the same nature, which was on the earlier charged object is also developed on the earlier uncharged object on the opposite portion. These both charges developed in the earlier uncharged conductor have equal magnitude and opposite nature. That charge is called _________charge which developed near to the earlier charged object and that charge is called free charge which developed opposite to the earlier charged object. When this charged object due to induction is touched with another conductor, then free charge goes to this conductor. Now, if the earlier charged object and this another conductor are removed, then only______charge remains in the object having induced charge. Which spread over the whole surface of the conductor. In such a way, a conducting object is charged due to induction.

$29_A \rightarrow$ You are given a rod of glass which has been rubbed with silk and two metallic spheres put on isolated stands. How will you charge these spheres having equal magnitude and opposite nature.

Ans. 

When a glass-rod is rubbed with slik then it becomes positively charged. Now both the metallic spheres put on isolated stands are put in contact with each-other and the positively charged glass-rod is brought near to one of the sphere according to the given first figure. Negative charge will induct in the nearer sphere and positive charge will induced in the distinct sphere due to this. Now according to the second figure, both the spheres are seperated without seperating the glass-rod. At last when the glass rod is removed as shown in the third figure, then negative charge is distributted uniformly on the whole surface of the nearer sphere and positive charge is distributted uniformly on the whole surface of the distinct sphere.

**30.** Write the fundamental laws of electric charge.

**Ans.** These are properties of electric charge :-

(i) Charge has two type :- negative charge and positive charge.

(ii) Charge of same nature repel each-other, while charges of opposite nature attract each-other.

(iii) Charge of opposite nature have a tendency to cancel each-other.

(iv) The value of total charge on an object is equal to the algebric sum of all the charges situated in different parts of the object.

(v) The algebric sum of electric charges in an isolated system remains constant always ........... It is called the theory of conservation of electric charge.

(vi) The value of charge in all objects is an intigeral multiple of charge in an electron or a proton always. It is called quantization of electric charge.

(vii) The value of electric charge does not depent on frame of reference.

**31.** What do you mean by quantization of electric charge ?

**Ans.** We know that electrons are put on an object to make an uncharged object negatively charged and electrons are removed from it to make it positively charged. If n electrons are put on an object to make it negatively charged, then the vlaue of negative charge on it will be –ne and when if n electrons are removed from an object to make it positively charged, then the value of positive charge on it will be +ne, where e is the magnitude of charge on an electron or on a proton. So, the vlaue of charge on all objects will always be an integral multiple of $e = \pm 1.6 \times 10^{-19}$ C. Charginig of an object in such a way is called quantization of electric charge.

## QUANTIZATION OF CHARGES

### INTRODUCTORY

**1.** If there are 20 electrons then, what is the amount of charge.

**Ans.**

**2.** Find the total value of charge in $5 \times 10^4$ protons

**Ans.**

**3.** Find the number of protons in a charge of $+2\mu C$.

**Ans.**

**4.** What is the number of electrons in the charge of $-5 \times 10^{-4} C$.

**Ans.**

### ZERO LEVEL

**1.** If an object has 200 electrons and 250 protons, then how much charge has that object?

**Ans.** $8 \times 10^{-18} C$

**2.** If 20 electrons transfer from an object A to another object B, when they are rubbed with each-other, then find the charges in both the objects.

**Ans.** $Q_A = +3.2 \times 10^{-18} C$; $Q_B = -3.2 \times 10^{-18} C$

**3.** How much electrons should be put on an object to develope a negative charge of $2\mu C$ on this object ?

**Ans.** $1.25 \times 10^{13}$

### LEVEL - 1

**1.** If $10^9$ electrons move out of a body to another body every second, how much time is required to get a total charge of 1 C on the other body ? **(N.C.E.R.T)**

**Ans.** 198 years

**2.** Estimate the number of electrons in 100 g of water. How much is the total negative charge on these electrons ? **(H.C. Verma)**

**Ans.** $3.35 \times 10^{25}, 5.35 \times 10^6 C$

**3.** How much positive and negative charge is there in a cup of water ? **(N.C.E.R.T)**

**Ans.** $Q_+ = Q_- = 1.34 \times 10^7 C$

**4.** $H_2SO_4$ is used as electrolyte in a battery. A charge of $+5\mu C$ is on the positive terminal and a charge of $-5\mu C$ is on the negative terminal of the battery in equilibrium situation. Find the numbers of ions on each the terminals.

**Ans.** $n_- = 1.56 \times 10^{13}$; $n_+ = 3.12 \times 10^{13}$

♦♦♦

**32.** Statement- I : The vlaue of electric charge on an object will never be $3 \times 10^{-19}$ C.
Statement - II : The value of electric charge on an object will be intigeral multiple of charge on an electron or a proton only.

**Ans.** a

**33.** Write the differences between mass and electric charge.

**Ans.** Following are differences between mass and electric charge :-

| Mass | Electric Charge |
|---|---|
| (i) Mass is positive always. | (i) Electric charge is negative and positive both |
| (ii) Only attractive forces act among masses always. | (ii) Both type of forces, attractive and repulsive, act among electric charges. |
| (iii) Properties of quantization is not found in mass. | (iii) Properties of quantization is found in electric charge. |
| (iv) Mass is not conserve always, because mass can convert into energy and energy can also convert into mass according to the formula $E=mc^2$. | (iv) Charge is conserved always. |
| (v) Mass exists without resultant charge. | (v) Charge does not exist without mass. |
| (vi) The mass of an object changes with the speed of the object. | (vi) The charge on an object does not depends with the speed of the object. |

**34.** Write the coulomb's law.

**Ans.** According to coulomb's law, "The magnitude of electric force actinig between two point charges is directly proportional to the magnitude of both charges and inversely proportional to the square of the distance between them".

**35.** Discribe the coulomb's law in detail.

**Ans.** We know that two charges always apply electric forces on each-other. This electric force repel each-other if the nature of both the charges are same and this electric force attract each-other if the nature of both the charges are opposite. Both the charges apply electric forces of equal magnitude on each-other in every condition.

Coulomb's law states that the magnitude of electric force acting between two point charges is directly proportional to the magnitude of both charges and inversely proportional to the square of the distance between them. So, when two point charges $Q_1$ and $Q_2$ are are laying at a seperation of r, the according to coulomb's law, the magnitude of electric force F acting between them will be :-

$$F \propto |Q_1|.|Q_2| \quad \text{...... (i)} \quad \text{and,} \quad F \propto \frac{1}{r^2} \quad \text{....... (ii)}$$

Now, after combining both the equatin,

$$F \propto \frac{|Q_1|.|Q_2|}{r_2} \qquad \therefore F = k.\frac{|Q_1|.|Q_2|}{r_2} \quad \text{.......... } (\propto)$$

Where, k is a proportionality constant, which is called electrostatic force constant or coulomb constant. The vlaue of k depends on the used unit system and the medium between the charges.

If both the charges are placed in air or vaccum and the used unit system is SI, then the value of k is $\frac{1}{4\pi\varepsilon_o}$, where $\varepsilon_o$ (          ) is called the absolute permittivity free space and its value is $8.854\times10^{-12}\frac{C^2}{N-m^2}$. When the vlaue of $\varepsilon_o$ is put in $\frac{1}{4\pi\varepsilon_o}$, then its value is $9\times10^9\frac{N-m^2}{C^2}$. so, when both the charges are placed in air or vacuum and calculation is made in SI system, then coulomb's law will be written as :-

$$F = \frac{1}{4\pi\varepsilon_o} \cdot \frac{|Q_1| \cdot |Q_2|}{r^2}$$

But, when both the charges are placed in a medium and calculation is made in SI system, then coulomb's law will be written as :-

$$F = \frac{1}{4\pi\varepsilon_o\varepsilon_r} \cdot \frac{|Q_1| \cdot |Q_2|}{r^2}$$

where, $\varepsilon_r$ is the relative permittivity of the medium or dielectric constant and its value is different for different media.

**36.** What is called permittivity ?

**Ans.** The permittivity of a medium is that property of the medium, which states that how greater force will apply the charges on each other which are placed in that medium.

**37.** "Coulomb's force is a two-charge interaction." What is the meaning of this sentence ?

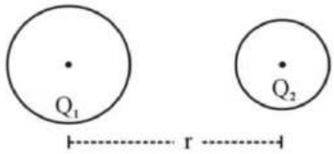
**Ans.** Coulomb's force acting between two charges does not depent on the presentation of other charges near them and due to this property of coulomb's force, it is called a two-charge interaction.

**38.** In which conditions, coulomb's force can be used ? Explain in detail.

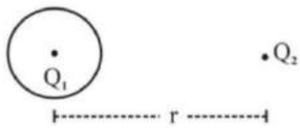
**Ans.** Coulomb's force is used in the following conditions.

(i) When both the charges are just like points, then coulomb's force is used.

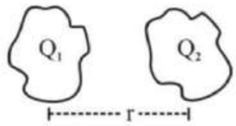

(ii) when shape of both the charges are spherical, then coulomb's law is used also. It can be used in both the conditions :- charge is distributted uniformly on the whole surface of the sphere only or distributed in its whole volume uniformly. The meaning of r in this condition is the distance between the centres of both the charged spheres.




(iii) Coulomb's law can also be used when the shape of a charge is spherical and the spape of the other charge is just like a point. Coulomb's force can be used in both the conditions, when charge is distributted uniformly on the whole surface of the sphere only or distributted in its whole volume uniformly. The meaning of r in this condition is the distance from the centre of the sphere to the point charge.




(iv) Coulomb's law can be used when the distance between the charges is very large than their shapes.




## COLUMB'S LAW
## INTRODUCTORY

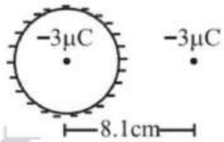
**1.** Two point charges of $+2\mu C$ and $-3\mu C$ are placed at a distance of 3 cm from each other. How much electric forces are applied by them on each other.

**Ans.**

**2.** A charge of $+4\times10^{-4}C$ is distributted uniformly on the surface of a sphere of radius 3 cm and another charge of $+2\times10^{-4}C$ is also distributted in the whole volume of a sphere of radius 2 cm uniformly. If the distance between centres of both the spheres is 6 cm, then find electric force acting between them.

**Ans.**

**3.** A charge of $-3\mu C$ is distributted uniformly on the whole surface of a sphere as shown in the figure and there is also a point charge outside of the sphere. Find the value of electric forces applied on each other.




**Ans.**

**4.** Two objects of irregular shape are placed at a distance of 4 m from each other. The thickness of one objective 4 cm and 3 cm of the other. There is a charge of $-2\mu C$ on the first object and a charge of $+2\mu C$ on the other object. How much electric force are applied by them on each other.

**Ans.**

**5.** What is the force between two small charged spheres having charges of $2\times10^{-7}C$ and $3\times10^{-7}C$ placed 30 cm apart in air ? **(N.C.E.R.T)**

**Ans.**

## ZERO LEVEL

**1.** Find the electric force acting between both the charges in a hydrogen atom. The radius of a hydrogen atom is 0.53 Å.

**Ans.**

**2.** A positive point charge of $2\mu C$ is placed at a point (3, 0)m and another positive point charge of $3\mu C$ is placed at a point (0, 4) m. Find the electric force acting between them.

**Ans.**

**3.** There are two identical hollow spheres and their radii are 4 cm and a charge of $3\mu C$ of positive nature is distributted uniformly on the surfaces of each spheres. If both the spheres are placed so that they are touching each-other, then how so that they are touching each-other, then how much repulsive electric force with they apply on each-other.

**Ans.**

**4.** Dielectric constant of water is 80. If both the ions of NaCl are situated at a distnace of 4mm in water, then find the magnitude of electric force acting between them.

**Ans.**

**5.** The electrostatic force on a small sphere of charge $0.4\ \mu C$ due to another small sphere of charge $-0.8\mu C$ in air is 0.2 N. (a) What is the distance between the two spheres ? (b) What is the force on the second sphere due to the first ? **(N.C.E.R.T)**

**Ans.**

**6.** dFind the electric force between two protons separated by a distance of 1 fermi (1 fermi $=10^{-15}m$). The protons in a nucleus remain at a separation of this order. **(H.C. Verma)**

**Ans.** 230 N

## LEVEL - 1

**1.** A charge of 1.0 C is placed at the top of the your college building and another equal charge at the top of your house. Take the separation between the two charges to be 2.0 km. Find the force exerted by the charges on each other. How many times of your weight is this force ? **(H.C. Verma)**

**Ans.** $2.25\times10^{3}N$

**2.** At what separation should two equal charges, 1.0 C each, be placed so that the force between them equals the weight of a 50 kg person ? **(H.C. Verma)**

**Ans.** $4.3\times10^{3}\,m$

**3.** Two equal charges are placed at a separation of 1.0 m. What should be the magnitude of the charges so that the force between them equals the weight of a 50 kg person ?

**Ans.** $2.3\times10^{-4}\,C$ **(H.C. Verma)**

**4.** Two charged particles are placed at a distance 1.0 cm apart. What is the minimum possible magnitude of the electric force acting on each charge ? **(H.C. Verma)**

**Ans.** $2.3\times10^{-24}\,N$

**5.** Suppose all the electrons of 100 g water are lumped together to form a negatively charged particle and all the nuclei are lumped together to form a positively charged particle. If these two particles are placed 10.0 cm away from each other, find the force of attraction between them. Compare it with your weight. **(H.C. Verma)**

**Ans.** $2.56\times10^{25}\,N$

**6.** Consider a gold nucleus to be a sphere of radius 6.9 fermi in which protons and neutrons are distributed. Find the force of repulsion between two protons situated at largest separation. Why do these protons not fly apart under this repulsion ? **(H.C. Verma)**

**Ans.** 1.2 N

**7.** Two insulating small spheres are rubbed againist each other and placed 1 cm apart. If they attract each other with a force of 0.1 N, how many electrons were transferred from one sphere to the other during rubbing ? **(H.C. Verma)**

**Ans.** $2\times10^{11}$

**8.** NaCl molecule is bound due to the electric force between the sodium and the chlorine ions when one electron of sodium is transferred to chlorine. Taking the separation between the ions to be $2.75\times10^{-8}\,cm$, find the force of attraction between them. State the assumptions (if any) that you have made. **(H.C. Verma)**

**Ans.** $3.05\times10^{-9}\,N$

**9.** Find the ratio of the electric and gravitational forces between two protons. **(H.C. Verma)**

**Ans.** $1.23\times10^{36}$

**10.** A hydrogen atom contains one proton and one electron. It may be assumed that the electron revolves in a circle of radius 0.53 angstrom (1 angstrom = $10^{-10}\,m$ and is abbreviated as Å) with the proton at the centre. The hydrogen atom is said to be in the ground state in this case. Find the magnitude of the electric force between the proton and the electron of a hydrogen atom in its ground state. **(H.C. Verma)**

**Ans.** $8.2\times10^{-8}\,N$

♦♦♦

**39.** Write the properties of coulomb's law.

**Ans.** Coulomb's law has following properties :-

(i) Coulomb's law is a practical law.

(ii) Coulomb's law can not be used when the distance between two charges is $10^{-15}$ or less than it.

(iii) Coulomb's law is used directly between point charges or charges distributted uniformly on a sphere.

(iv) Coulomb's force is a two-charge interaction.

**40.** Which statement(s) is/are true for electric force acting between two charges :-

(a) both charges apply equally electric forces on each-other.

(b) larger charge applies larger force on a smaller charge and smaller charge applies smaller force on a larger charge.

(c) It obeyes newtons third law of motion.

(d) none of these.

**Ans.** (c)

**41.** Define relative permittivity and dielectric constant.

**Ans.** The ratio of electric force acting between two point charges when they are placed at a particular distance in air or vacuum and electric force acting between these two point charges when they are placed at the same distance in a medium is called the relative permittivity or dielectric constant of this medium.

If electric force acting between two point charges $Q_1$ and $Q_2$ when they are placed in air or vacuum at a particular distnace is F and the electric force acting between these charges when they are placed in a medium at the same distance is $F_m$, then the relative permittivity of this medium $(\varepsilon_r)$ or its dielectric constant (k) will be :-

$$\varepsilon_r \text{ or } k = \frac{F}{F_m}$$

**42.** The relative permittivity of a metal is ................ .

**Ans.** Infinite.

**43.** Define coulomb.

**Ans.** When two point charges of equal magnitude are placed in air or vaccum at a distance of 1 m and the electric force acting between them is $9 \times 10^9$N, then the magnitude of electric force is one coulomb.

**44.** Write the differences between electrostatic force and gravitational force.

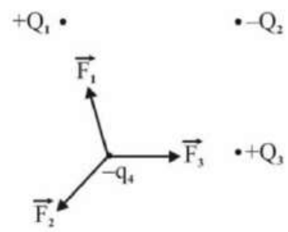
Ans. The differences between electrostatic force and gravitational force are following :-

| Electrostatic force | Gravitational force |
|---|---|
| (i) It acts between charges | (i) It acts between masses. |
| (ii) It has both type :- attractive and repulsive | (ii) It is attractive only. |
| (iii) It depends on medium. | (iii) It does not depend on medium |

**45.** Express with example "principle of superposition".

Ans. The principle of superposition states that the net electric force acting on a charge due to a number of charges situated near this charge, is equal to the vector sum of all the electric forces applied by the number of charges on this charge individually.

Exmple :- Suppose that there are four point charges $+Q_1, -Q_2, +Q_3$ and $-Q_4$, which are placed as shown in the figure. If, you want to know total electric force acting on the charge $-Q_4$ , then you will have to find the electric force $\vec{F}_1$ applied by $+Q_1$ on $-Q_4$ at first, then the electric force $\vec{F}_2$ applied by $-Q_2$ and then the electric force $\vec{F}_3$ applied by $+Q_3$. Then, these all the electric forces will be added and due to this the total electric force $\vec{F}$ acting on the charge $-Q_4$ will be obtained. So,

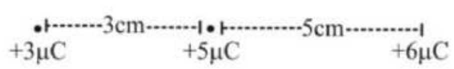



$$\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + ..........$$

**ELECTRIC FORCES AMONG CHARGES**

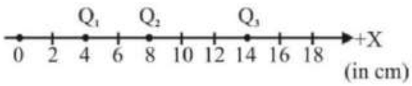
**INTRODUCTORY**

**1.** Find total electric force acting on the point charge of $+6\mu C$ as shown in the figure.



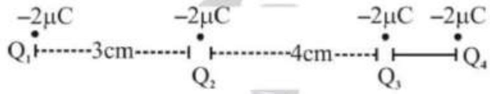

**Ans.**

2. If $Q_1 = +1\mu C, Q_2 = +2\mu C$ and $Q_3 = -3\mu C$ , then find total electric force acting on the charge $Q_2$ .




**Ans.**

3. Find total electric force on the point charge $Q_2$ as shown in the figure.




**Ans.**

**ZERO LEVEL**

1. If a point charge of $+2\mu C$ is placed at the point $A \equiv (2,0)$ cm and another point charge of $4\mu C$ is also placed at the point $B \equiv (4,0)$ cm, then find the total electric force acting on a point charge $Q \equiv +6\mu C$ which is placed at point $P \equiv (7,0)$ cm.

**Ans.**

2. Three point charges having value $+5\mu C$ each have been placed at the points (0,–3)cm, (0,0) and (0,5) cm. Find total electric force acting on the charge which is placed at the origin.

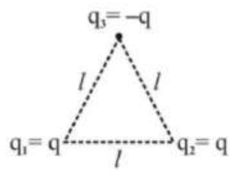
**Ans.**

3. Four point charges are placed on X-axis. $Q_1 = +1\mu C$ has been placed at the point (–7,0)cm, $Q_2 = -2\mu C$ has been placed at the point (–3,0)cm, $Q_3 = -3\mu C$ has been placed at the point (2,0) cm and a charge $Q_4 = +4\mu C$ has been placed at the point (4,0) cm. Find total electric force acting on the charge $Q_3$ .

**Ans.**

**LEVEL - 1**

1. Consider the charges q, q and –q placed at the vertices of an equilateral triangle, as shown in the figure. What is the force on each charge ?




**Ans.**

2. Three equal charges, $2.0 \times 10^{-6}$ C each, are held fixed at the three corners of an equilateral triangle of side 5 cm. Find the Coulomb force experienced by one of the charges due to the rest two. **(H.C. Verma)**

**Ans.** 24.9 N at 30° with the extended sides of the square from the charge under consideration.

3. Four equal charges $2.0 \times 10^{-6}$ C each are fixed at the four corners of a square of side 5 cm. Find the Coulomb force experienced by one of the charges due to the rest three.

**Ans.** 27.5 N at 45° with the extended sides of the square from the charge under consideration **(H.C. Verma)**

4. Ten positively charged particles are kept fixed on the X-axis at points x=10 cm, 20 cm, 30 cm, ...., 100 cm. The first particle has a charge $1.0 \times 10^{-8}$ C, the second $8 \times 10^{-8}$ C, the third $27 \times 10^{-8}$ C and so on. The tenth particle has a charge $1000 \times 10^{-8}$ C . Find the magnitude of the electric force acting on a 1 C charge placed at the origin. **(H.C. Verma)**

**Ans.** $4.95 \times 10^5$ N

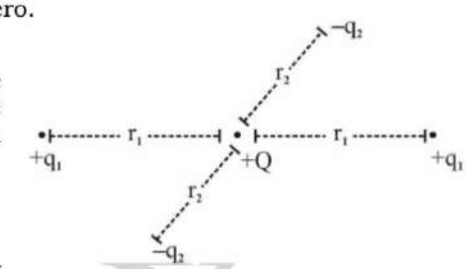
♦♦♦

46. If there are two or more than two charges in a region, then magnitudes of resultant electric forces acting on each charges are equal.

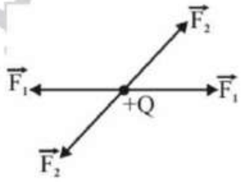
Ans. False.

**47.** Explain that if a charge is surrounded uniformly by identical charges, then resultant electric force acting on this charge is equal to zero.

Ans. Suppose that a charge +Q is surrounded by some charges as shown in the figure. So, the electric forces acting on it can be shown in the given figure.




So, the repulsive electric forces applied by both the charges having value $q_1$ each on it are equal in magnitude and opposite in direction and so both cancel the effects of each-other or the resultant of these both electric forces is equal to zero. Similarly, the attractive electric forces applied by both the charges having value $q_2$ each on it are also equal in magnitude and opposite in direction and so the resultant of these both electric forces is also equal to zero.




So, if a charge is surrounded uniformly by identical charges, then resultnat electric force acting on this charge is equal to zero.

## SYMETRICALLY DISTRIBUTION OF CHARGES

### INTRODUCTORY

**1.** Two protons are laying at equal distances from an electron in opposite directions at same distances. How much total electric force is acting on this charges.

**Ans.** Zero

### ZERO LEVEL

**1.** There is a hexagon of side a. Six identical point charges, each having vlaue q, are placed at all the six vertices of the hexagon. If a point charge Q is placed at the centre of this hexagon, then how much electric force will act on this charge.

**Ans.** Zero.

**2.** Four point charges $q_A = 2\mu C$, $q_B = -5\mu C$, $q_C = 2\mu C$ and $q_D = -5\mu C$ are located at the corners of a square ABCD of side 10 cm. What is the force on a charge of $1\mu C$ placed at the centre of the square ? **(N.C.E.R.T)**

**Ans.** Zero

### LEVEL - 1

**1.** A positive charge of $6\mu C$ is distributted uniformly on a circle of radius 4 cm. If a proton is placed at the centre of this circle then how much electric force will act on this proton?

**Ans.** Zero.

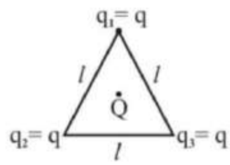
**2.** There is a pentagon of side a. Five identical point charges, each having value q, are placed at all the five vertices of the pentagon. If a charge Q is placed at the centre of this pentagon, then how much electric force will act on this charge ?

**Ans.** Zero.

**3.** There is a square of side a. Four identical point charges are placed at all the four vertices of a square. The value of each charge is q. If one of these charges is moved to the cnetre of the square from its vertex, then find the electric force acting on this charge.

**Ans.** $\frac{1}{4\pi\varepsilon_o} \cdot \frac{2Q^2}{a^2}$ towards the vacant vertex.

**4.** Consider three charges $q_1, q_2, q_3$ each equal to q at the vertices of an equilateral triangle of side t. What is the force on a charge Q placed at the centroid of the triangle, as shown in the figure.




**Ans.** Zero

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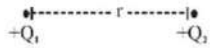
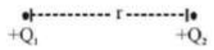
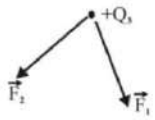
## LEVEL - II

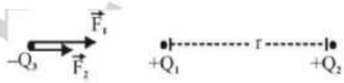



Suppose that two point charges $+Q_1$ and $+Q_2$ of the same nature are laying at rest at a distance r from each-other as shown in the figure.

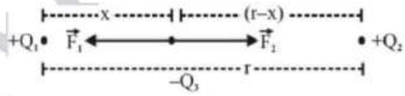



when a third point charge of any nature $\pm Q_3$ is placed anywhere near these two charges of same nature, then both charges will apply electric forces on it. But we know that the resultant of two vectors becomes zero, when directions of both vectors are just opposite and magnitudes are equal. So, to make the resultant electric force equal to zero on this third charge, it should be placed on the line joining the two fixed charges at a point between the charges.




Example : When the third charge $-Q_3$ is placed at a distance x from $+Q_1$ between both the charges then the electric forces $\vec{F_1}$ and $\vec{F_2}$ applied by both the charges +Q, and $+Q_2$ will be along opposite directions and the magnitudes of $\vec{F_1}$ and $\vec{F_2}$ should also be equal to make the resultant zero. So,




$$F_1 = F_2 \qquad \Rightarrow \frac{1}{4\pi\varepsilon_o}\cdot\frac{|+Q_1|\cdot|-Q_3|}{x^2} = \frac{1}{4\pi\varepsilon_o}\cdot\frac{|-Q_3|\cdot|+Q_2|}{(r-x)^2}$$

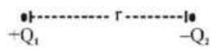
$$\Rightarrow \frac{|+Q_1|}{x^2} = \frac{|+Q_2|}{(r-x)^2}$$

And, after knowing the value of x in such a way, at last the position of the third charge will be obtained.

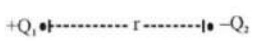
**1.** Two charges $2\times10^{-6}$C and $1\times10^{-6}$C are placed at a separation of 10cm. Locate the position where a third charge be placed such that it experiences no net force due to these charges?

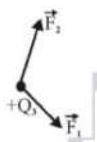
**Ans.** 5.9 cm from the larger charge in between the two charges. **(H.C. Verma)**

♦♦♦

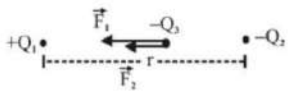



Suppose that two point charges $+Q_1$ and $-Q_2$ of opposite nature are laying at rest at a distance r from each-other as shown in the figure.

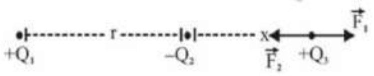


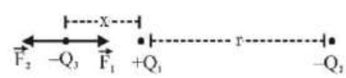

When a third point charge of any nature $\pm Q_3$ is placed anywhere near these two charges of opposite nature, then both charges will apply electric forces on it as in the previous situation. And, again to make the resultant of these two electric forces equal to zero, the directions of both the electric forces should be just opposite and their magnitudes should be equal. So, to make the resultant electric force equal to zero on this third charge, it should be placed on the line joining the two fixed charges at a point outside of the charges near one of the charges.




Example :- When the third charge $\pm Q_3$ is placed at a point on the line joining the two fixed charges and outside of the charges then the electric force $\vec{F_1}$ and $\vec{F_2}$ applied by both the charges $+Q_1$ and $-Q_2$ will be along opposite directions.




And, if the magnitudes of both the electric forces $\vec{F_1}$ and $\vec{F_2}$ are equal acting on the third charge



$\pm Q_3$, then the total electric force acting on this charge wil be equal to zero. So, suppose that this situation is obtained by placing $\pm Q_3$ towards $-Q_2$ at a distance x from it, then :-

$$F_1 = F_2 \qquad \Rightarrow \frac{1}{4\pi\varepsilon_o}\cdot\frac{|+Q_1|\cdot|\pm Q_3|}{(r+x)^2} = \frac{1}{4\pi\varepsilon_o}\cdot\frac{|-Q_2|\cdot|\pm Q_3|}{x^2}$$

$$\Rightarrow \frac{|+Q_1|}{(r+x)^2} = \frac{|-Q_2|}{x^2}.$$

So, it is clear that $(r+x)^2 > x^2$, so to be balanced this equation $|+Q_1| > |-Q_2|$ must be followed. So, the third charge will be placed towards that charge, which has less magnitude in this situation and the value of x will be obtained from the above equation.

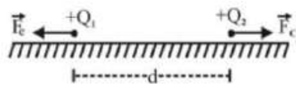
**2.** Two charges $2\times10^{-6}C$ and $-1\times10^{-6}C$ are placed at a separation of 10 cm. Locate the position where a third charge will not experience a net force. **(H.C. Verma)**

**Ans.** 34.1 cm from the larger charge on the line joining the charge in the side of the smaller charge.

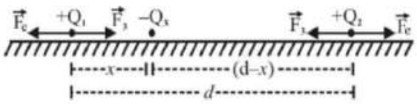
♦♦♦

When two charges of same nature are placed at some separation from each-other on a horizontal smooth surface, then both will start to repel each other. When a third charge of opposite nature and a particular value is placed on the line joining both the charges and between them at a particular position, then both the initial charges can remain in rest.

Two charges $+Q_1$ and $+Q_2$ are placed on a smooth horizontal surface in this figure and both are applying repulsive forces on each other. If a negative charge $-Q_3$ is placed anywhere between them, then it will apply forces on these both charges along opposite to these forces.




So, according to this figure, the magnitudes of both electric forces $\vec{F}_e$ and $\vec{F}_3$ acting on the charge $+Q_1$ must be equal. So, $Fe = F_3$




$$\Rightarrow \frac{1}{4\pi\varepsilon_o}\cdot\frac{|+Q_1|\cdot|+Q_2|}{d^2} = \frac{1}{4\pi\varepsilon_o}\cdot\frac{|+Q_1|\cdot|-Q_3|}{x^2}. \qquad \Rightarrow \frac{|+Q_2|}{d^2} = \frac{|-Q_3|}{x^2} \quad \ldots (\alpha)$$

Similarly, the magnitudes of both electric forces $\vec{F}_e$ and $\vec{F}_3$ acting on the charge $+Q_2$ must be equal also. So,

$$F_e = F_3 \qquad \Rightarrow \frac{1}{4\pi\varepsilon_o}\cdot\frac{|+Q_1|\cdot|+Q_2|}{d^2} = \frac{1}{4\pi\varepsilon_o}\cdot\frac{|-Q_3|\cdot|+Q_2|}{(d-x)^2}$$

$$\Rightarrow \frac{|+Q_1|}{d^2} = \frac{|-Q_3|}{(d-x)^2} \quad \ldots (\beta)$$

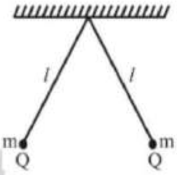
Now, by solving these two equations, the magnitude of the third charge and its position will be obtained.

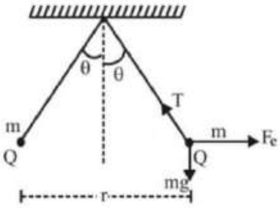
**3.** Two particles A and B having charges q and 2q respectively are placed on a smooth table with a separation d. A third particle C is to be clamped on the table in such a way that the particle A and B remain at rest on the table under electrical forces. What should be the charge on C and where should it be clamped ? **(H.C. Verma)**

**Ans.** $-\left(6-4\sqrt{2}\right)q$, between q and 2q at a distance of $\left(\sqrt{2}-1\right)d$ from q.

♦♦♦

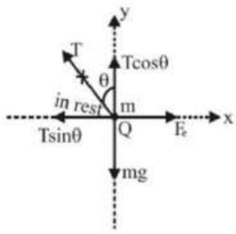
When two identical charges are tied at one end of two insulating strings of equal length and the other ends of both the strings are fixed to a common point of a ceiling then both the charges are get separated from each other to obtain equilibrium position.




Now suppose that the distance between both the charges is r in equilibrium and each string is making an angle $\theta$ with the vertical line.

Now, if Newton's first law of motion is applied on any one of the charged massive particle, then unknown quantities are obtained. Example:- For X-axis :-




$T \sin \theta = F_e$ $\Rightarrow T\sin\theta = \frac{1}{4\pi\varepsilon_o}\frac{|Q|.|Q|}{r^2}$ ... (α)

and, for Y-axis :-

$T\cos\theta = mg$ ... (β)

Now, both the equations will be solved.

**4.** Two identical balls, each having a charge of $2\times10^{-7}C$ and a mass of 100 gm, are suspended from a common point by two insulating strings each 50 cm long. The balls are held at a separation 5 cm apart and then released. Find **a.** the electric force on one of the charged balls, **b.** the components of the resultant force on it along and perpendicular to the string, **c.** the tension in the string, **d.** the acceleration of one of the balls. Answers are to be obtained only for the instant just after the release. **(H.C. Verma)**

**Ans. a.** 0.144 N; **b.** zero, 0.095 N away from the other charge; **c.** 0.986 N and **d.** 0.95 $m/s^2$ perpendicular to the string and going away from the other charge.

**5.** Two small spheres, each having a mass of 20 gm, are suspended from a common point by two insulating strings of length 40 cm each. The spheres are identically charged and the separation between the balls at equilibrium is found to be 4 cm. Find the charge on each sphere. **(H.C. Verma)**

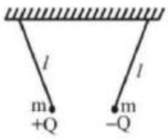
**Ans.** $4.17\times10^{-8}$ C.

**6.** Two identical pith balls, each carrying a charge q, are suspended from a common point by two strings of equal length *l*. Find the mass of each ball if the angle between he strings is $2\theta$ in equilibrium. **(H.C. Verma)**

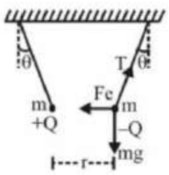
**Ans.** $\frac{q^2\cot\theta}{16\pi\varepsilon_o g\ell^2\sin^2\theta}$.

♦♦♦

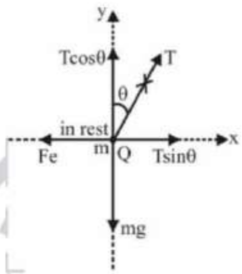
When two charges of equal magnitude and opposite nature are tied at one end of two insulating strings of equal length and the other ends of both the strings are fixed to two different points on a common ceiling at some separation, then both the charges come closer to obtain equilibrium position.




Now suppose that the distance between both the charges is r and both the strings are making angle $\theta$ with the vertical line in equilibrium.



If now Newton's first law of motion is applied on any one charged massive particle, then the unknown quantities will be obtained as earlier.




Example :- For X-axis :-

$$T\sin\theta = Fe \qquad \Rightarrow \quad T\sin\theta = \frac{1}{4\pi\varepsilon_o}\cdot\frac{|+Q|.|-Q|}{r^2} \qquad \dots (\alpha)$$

and, for Y-axis :-

$$T\cos\theta = mg \qquad \dots (\beta)$$

Now, both the equations will be solved.

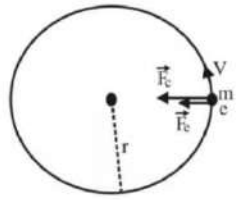
**7.** Two identical balls, each having a charge of $2.00\times10^{-7}C$ and a mass of 100 g, are suspended from a common point by two insulating strings each 50 cm long. The balls are held at a separation 5.0 cm apart and then released. Find (a) the electric force on one of the charged balls (b) the components of the resultant force on it along and perpendicular to the string (c) the tension in the string (d) the acceleration of one of the balls. Answers are to be obtained only for the instant just after the release. **(H.C. Verma)**

**Ans.** 8.2 gm; $8.2\times10^{-2}N$

♦♦♦

The motion of electrons in every atom is circular. The centripetal force dimanded by these electrons is full-filled by the electric force applied be the protons situated in the nucleus to these electrons.

Now, Suppose that there are z protons in the nucleus of an atom and an electron is revolving in an orbit of radius r. If the value of its speed is V, of its mass is m and of its charge is e then the value of centripetal force $F_c$ will be :-




$$F_C = \frac{mV^2}{r} \qquad \dots . (\alpha)$$

Now, because the number of protons is z, so the total positive charge of the nucleus will be ze. So the vlaue of electric force applied by the protons of the nucleus on the electron $F_e$ will be :-

$$F_e = \frac{1}{4\pi\varepsilon_o}\cdot\frac{|ze|.|e|}{r^2} \qquad \dots . (\beta)$$

But, the centripetal force is full-filled by electric force at this place. So, from the equation (α) and (β) :- $F_c = F_e$

$$\Rightarrow \frac{mV^2}{r} = \frac{1}{4\pi\varepsilon_o}\cdot\frac{|ze|.|e|}{r^2} \qquad \Rightarrow mV^2 = \frac{1}{4\pi\varepsilon_o}\cdot\frac{|ze|.|e|}{r}$$

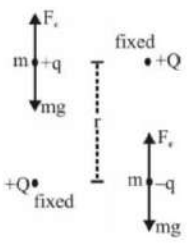
The unknown quantities can be obtained by the using of this equation.

**8.** A hydrogen atom contains one proton and one electron. It may be assumed that the electron revolves in a circle of radius 0.53 angstrom (1 angstrom = $10^{-10}$ m and is abbreviated as Å) with the proton at the centre. The hydrogen atom is said to be in the ground state in this case. Find the magnitude of the electric force between the proton and the electron of a hydrogen atom in its ground state. **(H.C. Verma)**

**Ans.** $8.2\times10^{-8}N$

♦♦♦

Suppose that a charged particle is tied at a place. If another charged massive particle is placed anywhere near this tied charged particle, then two forces will act on this charged massive particle :- first electric force and the second weight. This charged massive particle will be in equilibrium if the magnitudes of both the forces are equal and their directions are opposite.



If the nature of the charged massive particle is just like the nature of the tied charge, then it will be in equilibrium at a point just above the tied charge and if the nature of the charged massive particle is just opposite to the nature of the tied charge, then it will be in equilibrium at a point just below the tied charge. These situations are shown clearly in this figure. And the magnitudes of the forces acting on it will also be equal in equilibrium. So,

$$F_e = mg \qquad \therefore \frac{1}{4\pi\varepsilon_o}.\frac{|+Q|.|\pm Q|}{r^2} = mg$$

**9.** A particle having a charge of $2.0\times10^{-4}C$ is placed directly below and at a separation of 10 cm from the bob of a simple pendulum at rest. The mass of the bob is 100 g. What charge should the bob be given so that the string becomes loose. **(H.C. Verma)**

**Ans.** $5.4\times10^{-9}C$

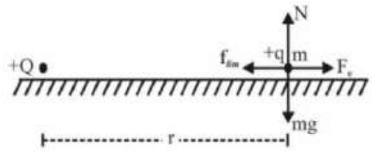
**10.** A particle A having a charge of $2.0\times10^{-6}C$ and a mass of 100 g is placed at the bottom of a smooth inclined plane of inclination 30°. Where should another particle B, having same charge and mass, be placed on the incline so that it may remain in equilibrium ?

**Ans.** 27 cm from the bottom. **(H.C. Verma)**

♦♦♦

If a massive charged particle is placed on a rough surface and it has a tendency to slip then friction will also act on it. If another charge is brought near it then electric force will also act on it as well as friction is acting. If the value of this electric force becomes at least the value of the limiting friction, then the object will come in motion.

If this charge +q has to be brought in motion from rest, then the value of $F_e$ should be equal to $f_{lim}$ at least. So,




$$f_{lim} = F_e \qquad \Rightarrow \mu N = \frac{1}{4\mu\varepsilon_o}.\frac{|+Q|.|+q|}{r^2} \qquad \therefore \mu mg = \frac{1}{4\pi\varepsilon_o}.\frac{|+Q|.|+q|}{r^2}.$$

**11.** A particle A having a charge of $2.0\times10^{-6}C$ is held fixed on a horizontal table. A second charged particle of mass 80 g stays in equilibrium on the table at a distance of 10 cm from the first charge. The coefficient of friction between the table and this second particle is $\mu = 0.2$. Find the range within whoich the charge of this second particle may lie.

**Ans.** between $\pm 8.71 \times 10^{-8}$ C **(H.C. Verma)**

♦♦♦

vxj ,d gh idfr oky nk vko'kk dk ,d /kxk d nkuk fljk l ck/ fn;k tk;] rc nkuk vko'k ifrd"k.k d dkj.k ,d&nlj l nj tku dk dkf'k'k djxkA bld dkj.k /kxk ruko e pyk tk;xk rFkk nkuk vko'k lkE;koLFkk e vk tk,xA

bl fLFkfr e pfd nkuk vko'k vrr% lkE;koLFkk e jgr g] ftl dkj.k fdlh Hkh vko'k ij dke djuoky nkuk cyk T rFkk $F_e$ dk ifjek.k Hkh cjkcj gkxkA vFkkr


$$T = F_e \qquad \therefore T = \frac{1}{4\pi\varepsilon_o}.\frac{|+Q_1|.|+Q_2|}{r^2}$$

**12.** Two charged particles having charge $2.0\times10^{-8}$ C each are joined by an insulating string of length 1 m and the system is kept on a smooth horioznatl table. Find the tension in the string. **(H.C. Verma)**

**Ans.** $3.6\times10^{-6}$ N

**13.** Two identically charged particles are fastened to the two ends of a spring of spring constant 100 N/m and natural length 10 cm. The system rests on a smooth horizontal table. If the charge on each particle is $2.0\times10^{-8}$ C, find the extension in the length of the spring. Assume that the extension is small as compared to the natural length. Justify this assumption after you solve the problem. **(H.C. Verma)**

**Ans.** $3.6\times10^{-6}$ m

tc nk vko'kk dk ,d&nlj I dN njh ij j[k dj eDr dj fn;kA tk;] rc nkuk d chp dk njh ;k rk c<xk ;k ?kVxkA bld dkj.k nkuk vko'kk ij ,d&nlj d }kjk yxk; tkuoky fon;r cy dk eku Hkh ifjoÙku'khy gkxkA rFkk ge tkur g] fd vxj cy ifjoÙku'khy g] rk Roj.k Hkh ifjoÙku'khy gkxkA vr%] bl fLFkfr e vko'kk dk Roj.k Hkh ifjoÙku'khy gkxkA

14. nk vkof'kr d.kk dk n0;eku rFkk vko'k Øe'k% 2 mg vkj 4 mg rFkk $+3\mu C$ vkj $-6\mu C$ gA nkuk dk ,d&nlj I 17cm dh njh I eDr fd;k x;k gA tc nkuk d chp dh njh 12cm gkxh] rc nkuk d Roj.k dk ifjek.k Kkr djA

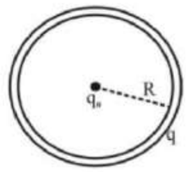
**Ans.**

**LEVEL - III**

1. Two particles A and B, each having a charge Q, are placed a distance d apart. Where should a particle of charge q be placed on the perpendicular bisector of AB so that it experiences maximum force ? What is the magnitude of this maximum force ?

**Ans.** $\frac{d}{2\sqrt{2}};\frac{3.08Qq}{4\pi\varepsilon_o d^2}$ **(H.C. Verma)**

2. A ring of radius R with a uniformly distributed charge q as shown in figure. A charge $q_0$ is now placed at the centre of the ring. Find the increment in the tension in ring.




**Ans.** $\frac{qq_o}{8\pi^2\varepsilon_o R^2}$

3. Three small balls, each of mass 10 gm are suspended separately from common point by silk threads, each one meter long. The balls are identically charged and hang at the corners of an equilateral triangle of side 0.1 metre. What is the charge on each ball ?

**Ans.** $6.2\times10^{-8}$C

4. Two particles A and B, each carrying a charge Q, are held fixed with a separation d between them. A particle C having mass m and charge q is kept at the middle point of the line AB. (a) If it is displaced through a distance x perpendicular to AB, what would be the electric force experienced by it. (b) Assuming x << d, show that this force is proportional to x. (c) Undere what conditions will the particle C execute simple harmonic motion if it is released after such a small displacement ? Find the time period of the oscillations if these conditions are satisfied. **(H.C. Verma)**

**Ans.** (a) $\frac{Qqx}{2\pi\varepsilon_o\left(x^2+\frac{d^2}{4}\right)^{3/2}}$ ; (c) $\sqrt{\frac{m\pi^3\varepsilon_o d^3}{Qq}}$.

5. Repeat the previous problem if the particle C is displaced through a distance x along the line AB. **(H.C. Verma)**

**Ans.** $\sqrt{\frac{m\pi^3\varepsilon_o d^3}{2Qq}}$

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## ELECTRIC POTENTIAL ENERGY

48. What do you mean by electric potential energy ?

Ans. If a system has more than one charges, then the system has potential energy, which is called electric potential energy.

49. Electric potential energy is a .......... quantity, its dimensional formula is ............ and its SI unit is .................

Ans. Scalar; $ML^2T^{-2}$; Joule (J)

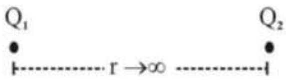
50. The symbol of electric potential energy is ............ .

Ans. U.

51. If a system has two charges, then in which condition the system has no electric potential energy ?

Example:-

Ans. If a system has two charges and the distance between the charges is infinity, then the system has no electric potential energy. According to coulomb's law, in this situation, there is no electric force act between the charges, so there is no electric potential energy of the system.




52. If the seperation between two charges is ....... then the electric potential energy of the system is zero.

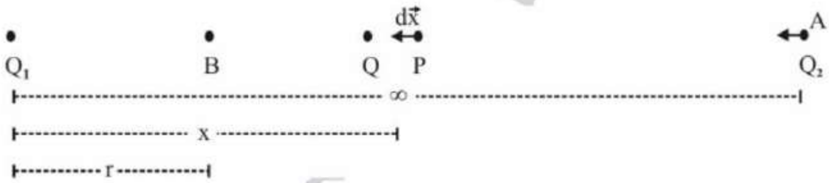
Ans. infinity.

53. The work done to bring two charges from infinite separation to a particular distance with negligible speed is called the .......... of the system in final case.

Ans. Electric potential energy.

54. Obtain an expression for electric potential energy of a two charged particle system, when the separation between them is finite.

Ans.




Suppose that there are two charged particles $Q_1$ and $Q_2$. The initial seperation between them is $\infty$. Then charge $Q_1$ is fixed and the other $Q_2$ is moved from A to B with a very slow speed. So, when the distance between them will be x then the electric force acting between them will be :-

$$F_e = \frac{1}{4\pi\varepsilon_o}.\frac{|Q_1|.|Q_2|}{x_2} \qquad \Rightarrow F_e = \frac{1}{4\pi\varepsilon_o}.\frac{Q_1.Q_2}{x^2} \quad ....... \text{(i)}$$

And, the direction of electric force applied by $Q_1$ on $Q_2$ is away of $Q_1$. So, to move the charge $Q_2$ with negligible speed :-

$$\because \quad v \approx 0 \qquad \Rightarrow a \approx 0 \qquad \Rightarrow F_R \approx 0$$

So, the external force should be applied on $Q_2$ towards $Q_1$ and its value will be :-

$$F_{ext} = F_e \qquad \Rightarrow F_{ext} = \frac{1}{4\pi\varepsilon_o}\frac{Q_1.Q_2}{x^2} \quad \text{\{from (i)\}} \quad \text{- (ii)}$$

so, the small work done to move $Q_2$ from P to Q by $d\vec{x}$ will be :-

$$dw = \vec{F}.d\vec{x} \qquad \Rightarrow dw = F(-dx)\cos 0^o \qquad \Rightarrow dw = \frac{-1}{4\pi\varepsilon_o}.\frac{Q_1Q_2}{x^2}.dx.1 \quad \text{\{from (ii)\}}$$

$(\because x \text{ is decreasing})$ $\Rightarrow dw = \frac{-1}{4\pi\varepsilon_o}.Q_1Q_2.x^{-2}.dx.$ ..... (iii)

So, the work done to move it from A to B will be :-

$w = \int dW$ $\Rightarrow w = \int_{\infty}^{r} \frac{-1}{4\pi\varepsilon_o}.Q_1Q_2.x^{-2}dx$ {from (iii)}

$\Rightarrow w = \frac{-1}{4\pi\varepsilon_o}.Q_1Q_2\int_{\infty}^{r} x^{-2}dx$ $\Rightarrow w = \frac{-1}{4\pi\varepsilon_o}.Q_1Q_2\left[\frac{x^{-1}}{-1}\right]_{\infty}^{r}$

$\Rightarrow w = \frac{-1}{4\pi\varepsilon_o}.Q_1Q_2\left[-\frac{1}{x}\right]_{\infty}^{r}$ $\Rightarrow w = \frac{1}{4\pi\varepsilon_o}Q_1Q_2\left[\frac{1}{x}\right]_{\infty}^{r}$

$\Rightarrow w = \frac{1}{4\pi\varepsilon_o}.Q_1Q_2\left[\frac{1}{r}-\frac{1}{\infty}\right]$ $\Rightarrow w = \frac{1}{4\pi\varepsilon_o}.Q_1Q_2\left[\frac{1}{r}-O\right]$

$\Rightarrow w = \frac{1}{4\pi\varepsilon_o}.\frac{Q_1Q_2}{r}.$

So, the electric potential energy of the system will be :-

U= W $\therefore U = \frac{1}{4\pi\varepsilon_o}.\frac{Q_1Q_2}{r}$

55. When we use the formula $U = \frac{1}{4\pi\varepsilon_o}.\frac{Q_1Q_2}{r}$ to obtain electric potential energy of a system, then the value of charges is used with their sign.

Ans. True.

56. When their are two charges in a system, then the electric potential energy of the system may be :-

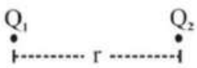
*a.* +ve *b.* –ve *c.* zero *d.* all

Ans. *d.*

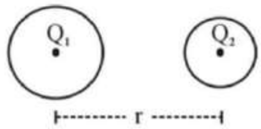
57. In which conditions, the formula $U = \frac{1}{4\pi\varepsilon_o}.\frac{Q_1Q_2}{r}$ is used to obtain the electric potential energy of a system ? Example in detail.

Ans. The formula $U = \frac{1}{4\pi\varepsilon_o}.\frac{Q_1Q_2}{r}$ is used to obtain the electric potential energy of a system in the following conditions :-

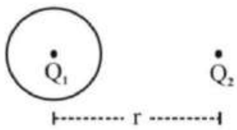
i. When both the charges are just like points, then the formula is used.



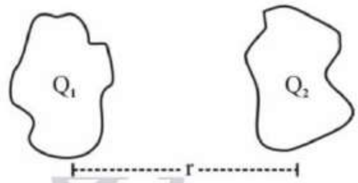

ii. When shape of both the charges are spherical, then the formula is used also. It can be used in both the cases :- charge is distributted uniformly on the whole surface of the sphere only or distributted in its whole volume uniformly. The meaning of r in this condition is the distance between the centres of both the charged spheres.




iii. This formula can also be used when the shape of a charge is spherical and the shape of the other charge is just like a point. This formula can be used in both the conditions, when charge is distributted uniformly on the whole surface of the sphere only or distributted in its whole volume uniformly. The meaning of r in this condition is the distance from the centre of the sphere to the point charge.



iv. This formula can be used when the distance between the charges is very large than their spheres.

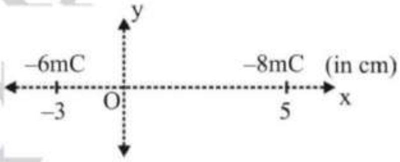



## INTRODUCTORY

1. There are two spherical charges, where charges are distributted uniformly on the surface of the spheres. The first sphere has a charge of $+2\times10^{-5}$C and the second sphere has a charge of $-4\times10^{-5}$ C. If the distance between their centres is 8 cm, then find the electric potential energy of the system.

   Ans.

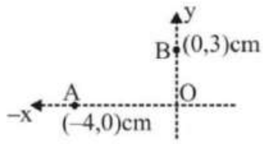
2. Two point charges are placed on x-axis as shown in the figure. Find electric potential energy of the system.




   Ans.

## ZERO LEVEL

3. Two point charges are placed at the points A and B. Charge at A is $+5\mu C$ and the charge at B is $-5\mu C$. Find the electric potential energy of the system.




   Ans.

4. A charge of $+6\mu C$ is distributted uniformly in the whole volume of a sphere of radius 3 cm. A point charge of $+2\mu C$ is placed at the surface of the sphere. Find electric potential energy of the system.

   Ans.

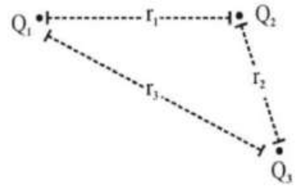
## LEVEL - I

5. A point charge of $4\mu C$ is 8 m north of the observer and another point charge of $6\mu C$ is 6m west of the observer. Find electric potential of the system.

   Ans.

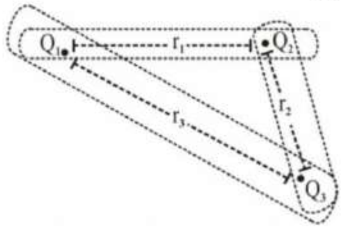
58. How will you obtain electric potential energy of a system, if the system has more than two charges ?

Ans. If a system has more than two charges, then each pair of two charges has electric potential energy. So, to obtain total electric potential energy of the system, we obtain electric potential energies of each pair of two charges and then add these all the electric potential energy is by scalar method.




So, according to the first figure, there are three pair of two charges.

So, according to the second figure, electric potential energies of each will be :-



$$U_1 = \frac{1}{4\pi\varepsilon_o}.\frac{Q_1Q_2}{r_1} \quad ..... (i) \qquad U_2 = \frac{1}{4\pi\varepsilon_o}.\frac{Q_2Q_3}{r_2} \quad ..... (ii)$$

$$U_3 = \frac{1}{4\pi\varepsilon_o}.\frac{Q_3Q_1}{r_3} \quad ...... (iii) \qquad ......................................$$

...................................... ......................................

So, the total electric potential energy of the system will be :-

$$U = U_1 + U_2 + U_3 + ....................$$

$$\Rightarrow \quad U = \frac{1}{4\pi\varepsilon_o}.\frac{Q_1Q_2}{r_1} + \frac{1}{4\pi\varepsilon_o}.\frac{Q_2Q_3}{r_2} + \frac{1}{4\pi\varepsilon_o}.\frac{Q_3Q_1}{r_3} + ..........$$

$$\Rightarrow \quad U = \frac{1}{4\pi\varepsilon_o}.\left[\frac{Q_1Q_2}{r_1} + \frac{Q_2Q_3}{r_2} + \frac{Q_3Q_1}{r_3} + .......\right]$$

**INTRODUCTORY**

1. Three point charges having value Q each have been placed at all the three vertices of an equilateral triangle of side *a*. Find electric potential energy of the system.

   Ans. $3.\frac{1}{4\pi\varepsilon_o}.\frac{Q^2}{a}$.

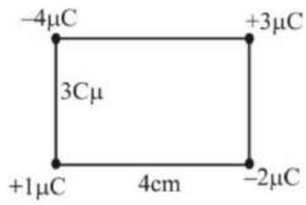
**ZERO LEVEL**

2. Four identical point charges having value Q each have been placed at all the vertices of a square of side *a*. Find electric potential energy of the system.

   Ans.

3. Four point charges have been placed at the vertices of a rectangle as shown in the figure. Find electric potential energy of the system.

   Ans.



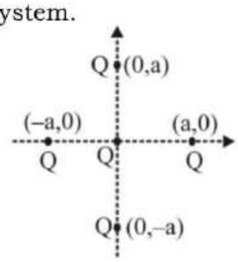

**LEVEL - I**

4. A charge of +6μC is distributted uniformly in the whole volume of a sphere of radius 3 cm. Two another point charges of −2μC each have been placed on the surface of the sphere dimetrically opposite. Find electric potential energy of the system.

   Ans.

5. Five identical point charges have been placed as shown in the figure. Find electric potential energy of the system.

   Ans.




59. When electric potential energy of a system changes ?

Ans. When seperation among charges change, then electric potential energy of the system changes.

60. What will you do to obtain change in electric potential energy of a system ?

Ans. To obtain change in electric potential energy of a system, at first we obtain the electric potential energy of the system $U_i$ in the initial stage. Then we obtain the electric potential energy of the system $U_f$ in the final stage. Then the subtraction of initial electric potential energy $U_i$ of the system from the final electric potential energy $U_f$ of the system will be change in electric potential energy $\Delta U$ of the system.

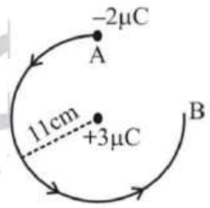
$$\therefore \ \Delta U = U_f - U_i$$

## INTRODUCTORY

1. Two identical point charges Q each were placed at a seperation d. If the seperation is decreased to d/2, then find change in electric potential energy of the system.

   Ans.

2. A point charge of $+3\mu C$ is fixed at the centre of a circle and another point charge of $-2\mu C$ moves from A to B as the path shown in the figure. Find change in electric potential energy of the system.



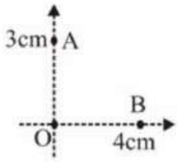

   Ans.

## ZERO LEVEL

3. Three $\alpha$-particles are placed at all the three vertices of an equilateral triangle of side 2 cm. If the side of the triangle is increased to 3 cm, then find the change in electric potential energy of the system.

   Ans.

4. A point charge of $+3\times10^{-4}C$ is fixed at the origin and an electron is moved from A to B along a straight line. Find change in electric potential energy of the system.




   Ans.

## LEVEL - I

5. How much electric potential energy of a system will change to construct an equilateral triangle of side 2 cm having three identical point charges of $-5\mu C$ each.

   Ans.

6. There is a rectangle of side 4cm×3 cm. Four identical point charges of $+1\mu C$ each have been placed at all of its four vertices. Find the change in electric potential energy of the system if the rectangle is converted into a square of side 2 cm.

   Ans.

61. What is the relation between change in electric potential energy of a system and externally work done on the system ?

Ans. If all the other type energies are constant, then work done by an external agent is equal to the change in electric potential energy of the system. So, it can be written as :-

$W_{ext} = \Delta U$ {if all other energies are constant}

62. What is the relation between change in electric potential energy of a system and internal work done by the system ?

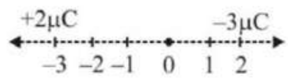
Ans. The work done by the system (which is called internal work done) is equal to the negativ eof change in electric potential energy of the system. So, it can be written as :-

$$W_{int} = -\Delta U$$

## INTRODUCTORY

1. How much work will be done to decrease the distance between two electrons from 5 cm to 2 cm ?

2. Two point charges are placed on X-axis. The first charge of $+2\mu C$ is placed at x=–3cm and other charge of $-3\mu C$ is placed at x=2cm. How much work will be done by the system if the charge of $-3\mu C$ is displaced from x=2 cm to x=–1 cm.



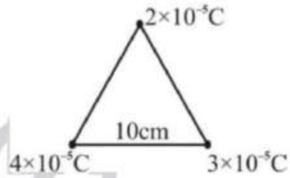

   Ans.

## ZERO LEVEL

3. Three particles, each having a charge of $10\mu C$, are placed at the vertices of an equilateral triangle of side 10 cm. Find the work done by a person in pulling them apart to infinite separations. **(H.C. Verma)**

   Ans. –27 J

4. How much work has to be done is assembling three charged particles at the veretices of an equilateral triangle as shown in figure ? **(H.C. Verma)**




Ans. 234 J.

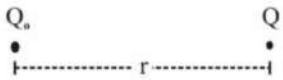
**LEVEL - I**

5. Two equal charges, $2\times10^{-7}$ C each, are held fixed at a separation of 20 cm. A third charge of equal magnitude is placed midway between the two charges. It is now moved to a point 20 cm from both the charges. How much work is done by the electric field during the process ? **(H.C. Verma)**

Ans. $3.6\times10^{-3}$ J.

63. Obtain a relation between electric potential and electric potential energy.

Ans. Suppose that there are two point charges $Q_o$ and Q at a separation r. So, electric potential created by the charge $Q_o$ at the place of the charge Q will be :-




$$V = \frac{1}{4\pi\varepsilon_o}.\frac{Q_o}{r} \qquad ....... (\alpha)$$

and, electric potential energy of this system will be :-

$$U = \frac{1}{4\pi\varepsilon_o}.\frac{Q_oQ}{r} \qquad ...... (\beta)$$

So, from (i)/(ii) :- $\frac{V}{U} = \frac{\frac{1}{4\pi\varepsilon_o}.\frac{Q_o}{r}}{\frac{1}{4\pi\varepsilon_o}.\frac{Q_o.Q}{r}} \Rightarrow \frac{V}{U} = \frac{1}{Q}$ $\qquad \therefore U = Q.V$

So, if we know electric potential at a particular point and another point charge is placed at that particular point, then the product of that charge and electric potential at that poinit will be electric potential energy of the system.

**INTRODUCTORY**

1. The electric potential at a point is 20V. If a point charge of $-3\mu C$ is placed at that point, then find electric potential energy.

Ans. $-6\times10^{-5}$ J.

2. A point charge is placed in an electric field at a particular point, where the value of electric poential is –60V. If electric potential energy is $-120\mu J$, then find the value of charge.

Ans.

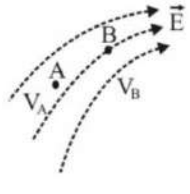
**ZERO LEVEL**

3. There is a hexagone of side a. Six identical point charges Q each have been placed at its vertices. If a point charge q is placed at the centre of the hexagone then find electric potential energy associated with this point charge.

Ans.

64. How will you obtain change in electric potential energy, when a charged particle goes from one point to the other point in an electric field ?

Ans. Suppose that there are two poinits A and B in an electric field. The electric potentials at A and B are $V_A$ and $V_B$ respectively. A point charge Q moves from A to B. So, change in electric potential energy will be :-




$$\Delta U = U_B = U_A \qquad \Rightarrow \Delta U = QV_B - QV_A$$

$\Rightarrow \Delta U = Q(V_B - V_A)$ $\therefore \Delta U = Q.\Delta V$

**INTRODUCTORY**

1. A point charge of $+2\mu C$ moves from A to B. If electric potentials at A and B are 5V and 8V respectively, then find change in electric potential energy.

   Ans.

2. A point charge moves in an electric field from one place to the other so that electric potential changes by 6V. If electric potential energy changes by $-18\mu J$, then find the vlaue of charge.

   Ans.

3. A point charge of $+5\mu C$ moves in an electric field and electric potential energy changes by $6\times10^{-4} J.$. Find change in electric poential.

   Ans.

65. What do you mean by natural tendency of movement of objects of a system having more than one object ?

Ans. When a system has more than one object and these objects apply forces on each other, then if these objects are released to move, then these will move and due to this their seperation will decrease or increase. Such type of decreasing seperation or increasing seperation between the objects is called natural tendency of movement.

66. How will you know that electric potential energy of a system is increasing or decreasing without calculation ?

Ans. If charged particles of a system move towards their natural tendency, then electric potential energy of the system decreases, but if these charged particles of the system move opposite to their natural tendency, then electric potential energy of the system increases.

**INTRODUCTORY**

1. If the seperation between two electrons are increased, then electric potential energy of the system :-

   *a.* increases  *b.* decreases.

   *c.* remains constant  *d.* may increase or may decrease

   Ans. b

2. A proton is placed at origin. And, another proton is moved from x=6cm to x=2cm. The electric potential energy of the system will :-

   *a.* increases  *b.* decreases

   *c.* remains constant  *d.* may increase or may decrease.

   Ans. *a.*

**ZERO LEVEL**

3. An $\alpha$ – particle is placed at origin. If another $\alpha$ – particle is moved from the point (–8,–6)m, to the point (3, 4)m, then electric potential energy of the system will :-

   *a.* increase  *b.* decrease

   *c.* remains constant  *d.* may increase or may decrease.

   Ans. *a*

67. What do you mean by electric dipole ?

Ans. When two point charges of equal magnitude and opposite nature are placed at a very small seperation, then this system is called electric dipole.

68. Give some examples of electric dipole.

Ans. These are some examples of electric dipole :-

## ELECTRIC POTENTIAL

1. Define electric potential.

Ans. The work done to bring one unit positive charge from infinity to a particular point is called the electric potential at that particular point.

2. The symbol of electric potential is ......, it is ......... quantity and its dimensional formula is ........ .

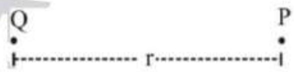
Ans. V; scalar; $ML^2 I^{-1} T^{-3}$.

3. The SI unit of electric potential is ........

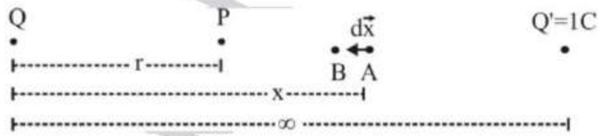
Ans. Joule/Columb which is also called volt (V)

4. Derive an expression to obtain electric potential due to a point charge at a point near to this charge.

Ans. Suppose that, there is a point charge Q and we have to obtain electric potential at the point P, which is at a distance r from this point charge.




Now, suppose that there is a poiint charge $Q' = 1C$ at infinite distance from the first charge, which is brough nearer to the first charge with negligable speed. So, when the distance between them will be x, then the electric force actinig between them will be :-




$$F_C = \frac{1}{4\pi\varepsilon_o} \cdot \frac{|Q| \cdot |Q'|}{x^2} \qquad \Rightarrow F_e = \frac{1}{4\pi\varepsilon_o} \cdot \frac{Q.1}{x^2}$$

$$\Rightarrow \quad F_e = \frac{1}{4\pi\varepsilon_o} \cdot \frac{Q}{x^2} \qquad ..... \text{(i)}$$

And, the direction of electric force applied by Q on $Q' = 1C$ is away of Q. So, to move the charge $Q' = 1C$ with negligable speed :-

$$\because \ v \approx 0 \qquad \Rightarrow a \approx 0 \qquad \Rightarrow F_R \approx 0$$

So, external force should be applied on $Q' = 1C$ towards Q and its value will be :-

$$F_{ext} = F_e \qquad \Rightarrow F_{ext} = \frac{1}{4\pi\varepsilon_o} \cdot \frac{Q}{x^2} \qquad \text{\{from (i)\}}$$

So, the small work done to move $Q' = 1C$ from A to B by $d\vec{x}$ will be :-

$$dW = \vec{F}_{ext} . d\vec{x} \qquad \Rightarrow dW = F_{ext}(-dx).\cos O^o \quad \{\because \text{ x is decreasing}\}$$

$$\Rightarrow \quad dW = -F_{ext}.dx.1 \qquad \Rightarrow dW = -\frac{1}{4\pi\varepsilon_o} \cdot \frac{Q}{x^2}.dx \qquad \text{\{from (ii)\}}$$

$$\Rightarrow \quad dW = -\frac{Q}{4\pi\varepsilon_o}.x^{-2}.dx \qquad .... \text{(iii)}$$

So, the work done to move it from $\infty$ to P will be :-

$$w = \int dW \qquad \Rightarrow W = \int_{\infty}^{r} -\frac{Q}{4\pi\varepsilon_o}.x^{-2}dx \qquad \text{\{from (iii)\}}$$

$$\Rightarrow \quad W = -\frac{Q}{4\pi\varepsilon_o} \int_{\infty}^{r} x^{-2}dx \qquad \Rightarrow W = -\frac{Q}{4\pi\varepsilon_o} \cdot \left[\frac{x-1}{-1}\right]_{\infty}^{r}$$

$$\Rightarrow \quad W = \frac{Q}{4\pi\varepsilon_o} \cdot \left[\frac{1}{x}\right]_{\infty}^{r} \qquad\qquad \Rightarrow W = \frac{1}{4\pi\varepsilon_o} \cdot Q\left[\frac{1}{r} - \frac{1}{\infty}\right]$$

$$\Rightarrow \quad W = \frac{1}{4\pi\varepsilon_o} \cdot Q\left[\frac{1}{r} - 0\right] \qquad\qquad \Rightarrow W = \frac{1}{4\pi\varepsilon_o} \cdot \frac{Q}{r}$$

So, the electric potential due to a point charge Q at a distance r from it will be :-

$V = W \qquad\qquad \Rightarrow V = \frac{1}{4\pi\varepsilon_o} \cdot \frac{Q}{r}$.

5. A charge modifies its surrounding and when we study this modified surrounding without direction (as a scalar quantity), then it is called ........ .

Ans. Electric potential.

6. When we use the formula $V = \frac{1}{4\pi\varepsilon_o} \cdot \frac{Q}{r}$ to obtain electric potential, then the value of charge is used with its sign.

Ans. True.

7. Electric potential may be :-

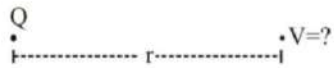
a. +ve    b. –ve    c. zero    d. none of these.

Ans. a,b, c.

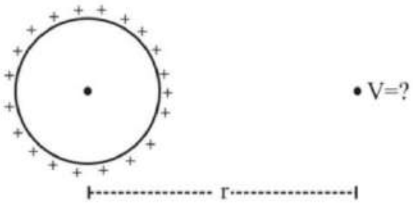
8. In which conditions, the formula $V = \frac{1}{4\pi\varepsilon_o} \cdot \frac{Q}{r}$ is used to obtain the electric potential by a charge. Explain in detail.

Ans. The formula $V = \frac{1}{4\pi\varepsilon_o} \cdot \frac{Q}{r}$ can be used to know the value of electric potential created by an electric charge in the following conditions :-

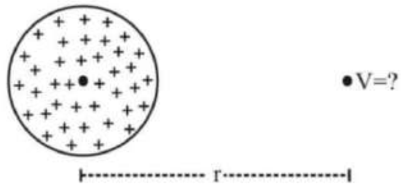
i. This formula can be used, when the charge is just like a point.



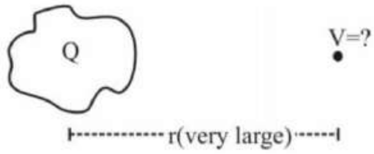

ii. This formula is also used when charge is distributted uniformly on the surface of a sphere. The distance of the poinit is measured from the centre of the sphere in this case.




iii. This formula is also used when charge is distributted uniformly in the whole volume of a sphere. The distance of the point is measured from the centre of the sphere in this case.




iv. This formula is also used when the distance of that point, where we have to find the value of electric potential, is very large with respect to the size of the charge and shape of the charge is not any factor in this case.

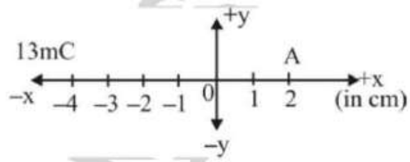


## INTRODUCTORY

1. A charge of $50\mu C$ is distributted nonuniformly on the whole body of a man standing in a playground. Find electric potential at the point which is 200 m away from the man.

   Ans.

2. A point charge of 12 mC is placed on X-axis at x=–4 cm. Find the electric potential at the poiint A as shown in the figure at x=2cm.



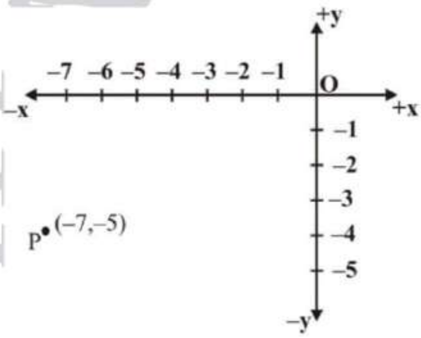

   Ans.

## ZERO LEVEL

3. A charge of $4\times10^{-7}C$ is distributted uniformly on the whole surface of a football of radius 9 cm. Find electric potential at its surface.

   Ans.

4. A point charge of $-2\sqrt{74}\,\mu C$ is placed at the origin. Find the electric potential at the point P as shown in the figure.



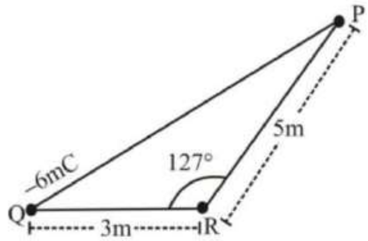

   Ans.

## LEVEL - I

5. The position vector of a point charge of $8\times10^{-4}C$ is (2, 3, 4)m. Find the electric potential at the origin.

   Ans.

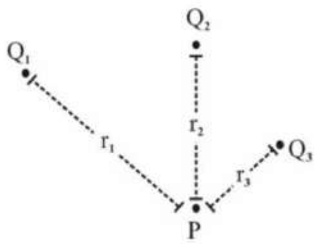
6. A point charge of –6mC is placed at one vertex of a triangle as shown in the figure. Find the electric potential at the point P.




   Ans.

9. If there are more than one charges in a region, then how will you obtain electric potential at a point in that surrounding ?

Ans. If there are more than one charges in a region, then every charges will create electric potential at every point of that region and the total electric potential at a particular point will be sum of all the electric potentials created by all the charges at that point.




Suppose that there are some point charges $Q_1$, $Q_2$, $Q_3$... in the surrounding. And, we have to obtain electric potential at the point P, which distances from the charges $Q_1$, $Q_2$, $Q_3$,.... are $r_1$, $r_2$, $r_3$...... respectively. Let, electric potentials at P due to $Q_1$, $Q_2$, $Q_3$..... are $V_1$, $V_2$, $V_3$,.... respectively. So,

$$V_1 = \frac{1}{4\pi\varepsilon_o}.\frac{Q_1}{r_1} \quad ...\text{(i)} \qquad V_2 = \frac{1}{4\pi\varepsilon_o}.\frac{Q_2}{r_2} \quad ....\text{(ii)}$$

$$V_3 = \frac{1}{4\pi\varepsilon_o}.\frac{Q_3}{r_3} \quad ...\text{(ii)} \qquad ..............................$$

.............................. ..............................

So, electric potentials at the point P due to whole charges will be :-

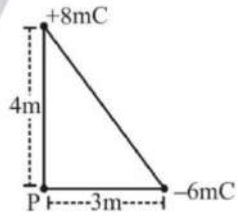
$$V = V_1 + V_2 + V_3 + \ldots\ldots$$

$$\Rightarrow \quad V = \frac{1}{4\pi\varepsilon_o}.\frac{Q_1}{r_1} + \frac{1}{4\pi\varepsilon_o}.\frac{Q_2}{r_2} + \frac{1}{4\pi\varepsilon_o}.\frac{Q_3}{r_3} + \ldots.. \quad \{\text{from (i),(ii), (iii)}\ldots..\}$$

$$\Rightarrow \quad V = \frac{1}{4\pi\varepsilon_o}.\left(\frac{Q_1}{r_1} + \frac{Q_2}{r_2} + \frac{Q_3}{r_3} + \ldots\ldots\ldots\right) \quad \ldots\ldots (\alpha)$$

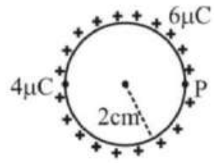
**INTRODUCTORY**

1. Two point charges are placed at two vertices of an equilateral triangle as shown in the figure. Find electric potential at the vertex P.




Ans. Zero.

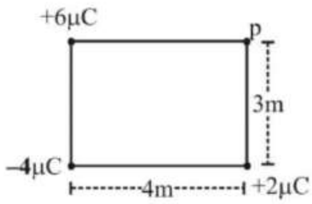
2. There is a sphere of radius 2 cm. A charge of $+6\mu C$ is distributted uniformly on the whole surface of the sphere. Another point charge of $+4\mu C$ is also placed at a point on its surface. Find electric potential at the point P, which is diagnolly opposite to the poiint charge of $4\mu C$.




Ans.

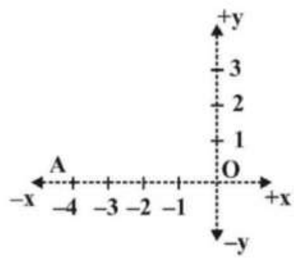
**ZERO LEVEL**

3. Find the electric potential at the point P as shown in the figure.




Ans.

4. There is a point charge of $-30\mu C$ at the point P. Find electric potentials at the points A, B and O.



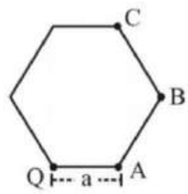

Ans.

**LEVEL - I**

5. A point charge of $+5\mu C$ is placed at the point $A \equiv (-4, -3, 2)\,\text{cm}$. Find electric potential at the point $B \equiv (1, -1, -2)\,\text{cm}$.

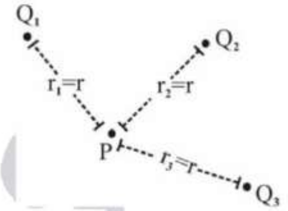
Ans.

6. There is a hexagon of side a as shown in the figure. Find electric potentials at the points A, B and C.




Ans.

10. How will you obtain electric potential at a point if the distances of all the charges particles are equal from the point?




Ans. Suppose that some point charges $Q_1$, $Q_2$, $Q_3$ ... are placed in a region such that their distances are same from the point P, where we have to obtain electric potential. So, the electric potential at the point P from the equation $(\alpha)$ of the question –9 will be :-

$$V=\frac{1}{4\pi\varepsilon_o}.\left(\frac{Q_1}{r_1}+\frac{Q_2}{r_2}+\frac{Q_3}{r_3}+........\right) \qquad \Rightarrow V=\frac{1}{4\pi\varepsilon_o}\left[\frac{Q_1}{r}+\frac{Q_2}{r}+\frac{Q_3}{r}+....\right]$$

$$\{\because r_1=r_2=r_3=......=r \text{ (left)}\} \quad \Rightarrow V=\frac{1}{4\pi\varepsilon_o}.\frac{Q_1+Q_2+Q_3+......}{r} \quad \Rightarrow \quad V=\frac{1}{4\pi\varepsilon_o}.\frac{Q_{total}}{r}$$

$$Q_{total}=Q_1+Q_2+Q_3+......$$

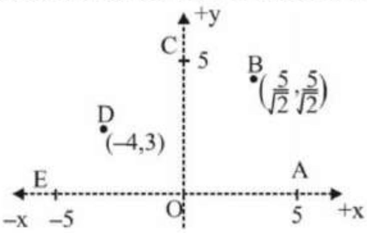

So, when the distances of all the charges are same from a particular point, where we have to obtain electric potential, then all the point charges will be placed at the same point at the given common distance.

## INTRODUCTORY

1. There is a square of side 5 cm. Four identical point charges having value $-4\mu C$ each have been placed at all its four vertices. Find electric potential at its centre.
   Ans.
2. There is a rectangle of length 6 cm and width 4 cm. Four identical point charges having value $-12\mu C$ each have been placed at all its four vertices. Find the electric potential at its centre.
   Ans.

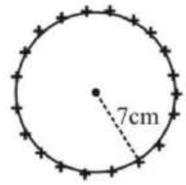
## ZERO LEVEL

3. There is an equilateral triangle of side a. Three identical point charges having value Q each have been placed at all of its three vertices. Find electric potential at its centre.
   Ans.
4. Five point charges having values $+1\mu C$, $+2\mu C$, $+3\mu C$, $+4\mu C$ and $+5\mu C$ have been placed at the points A, B, C, D and E as shown in the figure. Find electric potential at the origin.
   Ans. $2.7\times10^6$ V



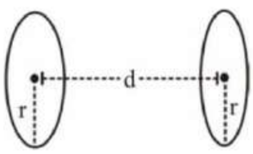

[illegible]

[illegible] $^{9}$ V.




## LEVEL - I

6. A charge of $-20\mu C$ is distributted non-uniformly on the surface of a sphere of radius 5 cm. Find electric potential at its surface.
   Ans. $-3.6\times10^6$ V.
7. There are two identical circular rings of radii r each. They are placed parallel to each-other, such that their axes are common. If each ring has a charge Q distributted uniformly on it, then find electric potential at one of the centre of the ring.




   Ans. $\frac{1}{4\pi\varepsilon_o}.Q\left(\frac{1}{r}+\frac{1}{\sqrt{r^2+d^2}}\right)$.

## ELECTRIC FIELD

**67.** What is electric field ?

Ans. A region, in which if a charge is placed and this charge experiences an electric force, is called electric field.

**68.** A charge modifies its surroundings and this modified region is called _______

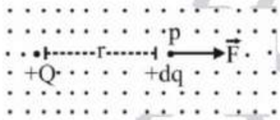
Ans. Electric field.

**69.** What is electric field intensity ?'

Ans. When a unit positive point charge (+1 C) is placed in an electric field at a point, then the electric force experienced by this charge is called the electric field intensity at that point in this electric field. Electric field intensity is also called electric field only.

**70.** How will be find electric field intensity at a point in an electric field created by a point charge in its surroundings ?

Ans. Suppose that there is a point charge +Q which is developing electric field in its surroundings and we want to know the value of electric field at a point P which is at a distance r from the charge.




Now, a very small positive point charge +dq is placed at that point. The value of electric force acting on this positive charge +dq will be :-

$$F = \frac{1}{4\pi\varepsilon_o} \cdot \frac{|Q| \cdot |dq|}{r^2} \quad \text{....... (i)}$$

But if dq = 1 C, then from the equation ....... (i) :-

$$F = \frac{1}{4\pi\varepsilon_o} \cdot \frac{|Q| \cdot |+1|}{r^2} \Rightarrow F = \frac{1}{4\pi\varepsilon_o} \cdot \frac{|Q|}{r^2}$$

and we know that the electric force acting on a charge of +1C, when it is placed at a point in an electric field, is called the electric field intensity at that point in the electric field. So, the magnitude of electric field intensity at a distance r from a point charge +Q and created by it is $E = \frac{1}{4\pi\varepsilon_o} \cdot \frac{|Q|}{r^2}$ and its direction is just opposite to the charge.

Similarly, the magnitude of electric field intensity at a distance r from a point charge –Q and created by it is $E = \frac{1}{4\pi\varepsilon_o} \cdot \frac{|-Q|}{r^2}$ and its direction is towards the charge.

**71.** What do you mean by a source charge ?

Ans. A charge which creates a measurable electric field is called a source charge.

**72.** What do you mean by a test charge ?

Ans. A very small positive point charge, which is used to measure the intensity at a point in an electric field is called a test charge.

**73.** Why the value of a test charge is selected always very small ?

Ans. If the vlaue of a test charge is not selected very small, then it will create an electric field of a large value itself, which will change the value of that electric field which has to be measured and due to this that electric field can not be measured.

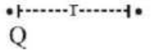
**74.** The direction of electric field created by a positive charge is ______ to the charge and the direction of electric field created by a negative charge is _______ to the charge.

Ans. Opposite, towards

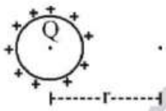
**75.** In which conditions, the formula $E = \frac{1}{4\pi\varepsilon_o} \cdot \frac{|Q|}{r^2}$ can be used to know the value of electric field created by an electric charge ?

Ans. The formula $E = \frac{1}{4\pi\varepsilon_o} \cdot \frac{|Q|}{r^2}$ can be used to know the value of electric field created by an electric charge in the following conditions :-

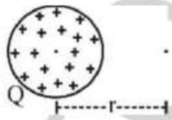
(i) This formula can be used, when the charge is just like a point.



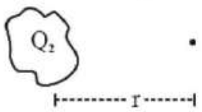

(ii) This formula is also used, when charge is distributted uniformly on the surface of a sphere. The distance of the point is measured from the centre of the sphere in this case.




(iii) This formu;la is also used, when charge is distributted uniformly in the whole volume of a sphere. The distance of the point is meausred from the centre of the sphere in this case.




(iv) this formula is also used when the distance of that point, where we have to find the value of electric field, is very large with respect to the size of the charge and shape of the charge is no any factor in this case.




## ELECTRIC FIELD DUE TO CHARGE

### INTRODUCTORY

**16.** An α-particle is placed at the point (–2, 0) cm. Find the electric field created by it at the point (3, 0) cm.

**Ans.**

**17.** Find the electric field created by a negative point charge of 4μC at a point 5 cm above the point charge.

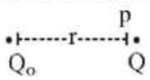
**Ans.**

**18.** Positive charge of 5μC is distributted uniformly in the whole value of a sphere of radius 2 cm. Find the value of electric field at the surface of the sphere.

**Ans.**

♦♦♦

**76.** What happens when a charge is placed in an electric field ? Explain in detail.




Ans. Suppose that there is a point charge $Q_o$ and there is a point P at a distance r from it. So, the magnitude of electric field created by this charge $Q_o$ at this point will be :-

$$E = \frac{1}{4\pi\varepsilon_o} \cdot \frac{|Q_o|}{r^2} \qquad \text{........... } (\alpha)$$

When another point charge Q is placed at this point P, then magnitude of electric force F acting on this point charge Q according to the coulomb's law will be :-

$$F = \frac{1}{4\pi\varepsilon_o} \cdot \frac{|Q| \cdot |Q|}{r^2} \qquad \text{............ } (\beta)$$

So, by dividing the equation (α) by the equation (β) :-

$$\frac{E}{F} = \frac{\frac{1}{4\pi\varepsilon_o} \cdot \frac{|Q_o|}{r^2}}{\frac{1}{4\pi\varepsilon_o} \cdot \frac{|Q_o| \cdot |Q|}{r^2}} \qquad \Rightarrow \frac{E}{F} = \frac{1}{|Q|}$$

$$\therefore F = |Q|E \qquad \text{.............} (\gamma)$$

So, it can be said that if a charge is placed in an electric field, then electric force acts on it, which magnitude is equal to the product of the magnitude of charge and the magnitude of electric field.

Now, suppose that the charge $Q_o$ is positive. So, it will create an electric field at the point P in the direction just opposite to itself. And if charge Q is also positive, then electric force will act on it by the charge $Q_o$ along the direction just opposite to the charge $Q_o$. So, the direction of electric field at the place of the position of the charge Q and the direction of electric force acting on it are same. So, the equation (α) can be written in vector form in this way :-

$$\vec{F} = Q\vec{E}$$

So, if there is a positive charge in an electric field then electric force will act on it along the direction of electric field and if that charge is negative, then electric force will act on it in just opposite direction of electric field.

**77.** If there is a positive charge in an electric field then electric force will act on it in the direction just opposite to the electric field and if there is a negative charge then electric force will act on it along the direction of the electric field.

Ans. False.

**78.** Statement- I When a charge is placed in an electric field, then electric force acts on it always along the direction of electric field.

Statement- II : If a charge Q is placed in an electric field $\vec{E}$, then electric force $\vec{F}$ acting on that charge is obtained by the formula $\vec{F} = Q\vec{E}$.

Ans. d

**ELECTRIC FORCE DUE TO ELECTRIC FIELD**

**INTRODUCTORY**

**19.** There is a uniform electric field of '5 N/C along east. Find electric forces acting on an electron and an α-particle which are placed in the electric field.

**Ans.**

**20.** A force of $6\times10^{-3}$ N is acting on a point charge of $-2\mu C$ along -Y-axis. Find the electric field at that place.

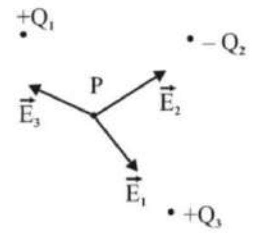
**Ans.**

♦♦♦

**79.** Explain with example of principle of superposition for electric field.

Ans. The principle of superposition for electric field states that, if there are more than one charge in a region, then the net electric field at a point in that region is equal to the sum (vector sum) of all the electric fields created by all the charges.

Example that there are three point charges which are placed as shown in the figure. There is a point P in this region, where we have to know electric field. So, at first the electric field $\vec{E}_1$, created by charge $+Q_1$ at P, is obtained, then the electric field $\vec{E}_2$, created by charge $-Q_2$ and then the electric field $\vec{E}_3$, created by charge $+Q_3$ are obtained. After now, all these electric fields are added and due to this the net electric field $\vec{E}$ created at point P is obtained so,




$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \_\_\_\_.$$

**ELECTRIC FIELD DUE TO CHARGES**

**INTRODUCTORY**

**19.** A positive point charge of 2μC is placed at the point (–2, 0) cm and another positive point charge of 4μC is also placed at the point (2, 0) cm. Find electric fields at points (0, 0) and (4, 0) cm due to these charges.

**Ans.**

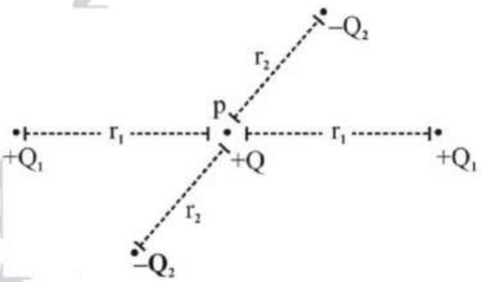
**20.** Find the value of electric field at the centre of the rectangle due to the point charges placed at all the four vertices of the rectangle.H

**Ans.**

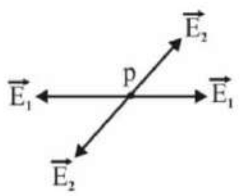
♦♦♦

**80.** Express that the vlaue of electric field at a point is zero, if this point is surrounded by identical charges identically.

Ans. Suppose that a point P is surrounded identically by some charges as shown in the figure. So, the electric fields developed at this point can be shown in another figure.




The electric fields created at this point due to both the charges having value $+Q_1$ each are equal in magnitude and opposite in direction and due to this both cancel the effects of each-other or the resultant of these two electric fields is equal to zero. Similarly, the electric fields created at this point due to both the charges having value $-Q_2$ each are equal in magnitude and opposite in direction also and due to this both cancel the effects of each-other or the resultant of these two electric fields is equal to zero also.



So, the value of electric field at a point is zero, if this point is surrounded be identical charges identically.

## ELECTRIC FIELD DUE TO CHARGES DISTRIBUTTED UNIFORMALY

### INTRODUCTORY

**21.** When two protons are placed at some distance with each other, then what will be electric field at the middle point of the charges.

**Ans.** Zero.

**22.** Negative charge of $5\mu C$ is distributted uniformly on the surface of a hollow sphere of radius 3 cm. Find electric field at its centre.

**Ans.**

**23.** A charge of $720\mu C$ is distributted uniformly on a circle of radius 2 cm. If an arc of $1^{o}$ is cut out from the circle then find the electric field at the centre of the circle due to the rest part of the circle.

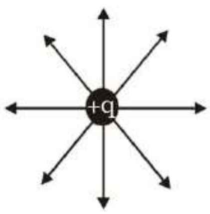
**Ans.**

♦♦♦

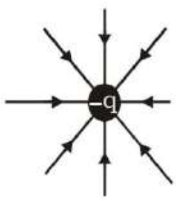
**81.** What do you mean by electric field line ?

Ans. When a positive point charge is released from a poinit in an electric field, then the path travelled by this charge is called on electric field line.

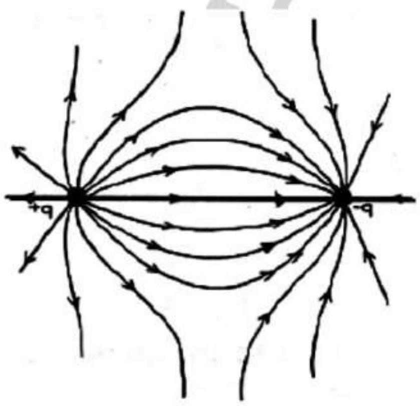
**82.** Show the electric field lines created by a positive point charge.

Ans. 

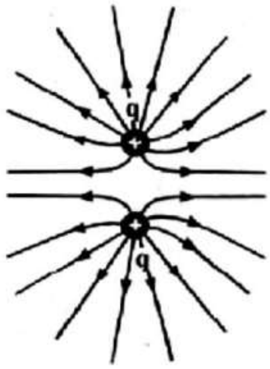

83. Show the electric field lines created by a negative point charge.

Ans. 

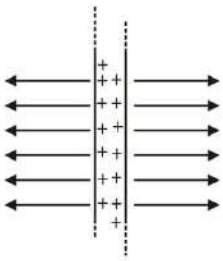

**84.** Show the electric field lines created by two point charges of equal magnitude and opposite nature placed at some separation.

Ans. 

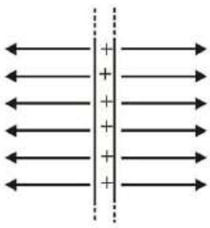
**85.** Show the electric field lines created by two identical point charges placed at some separation.

Ans. 

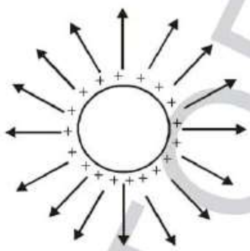

**86.** Show the electric field lines created by a plane infinite large surface on which positive charge is distributted uniformly.

Ans. 

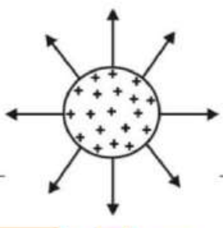
**87.** Show the electric field lines created by a straight line of infinite length on which positive charge is distributted uniformly.

Ans. 

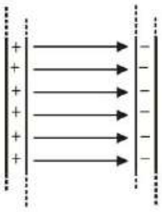
**88.** Show the electric field lines created by a hollow sphere on which positive charge is distributted uniformly on the whole surface of the sphere.

Ans. 

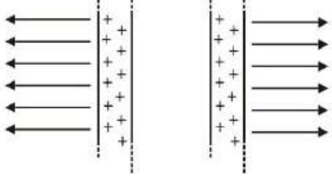
**70.** Show the electric field lines created by a sphere in which positive charge is distributted uniformly in the whole volume of the sphere.

Ans. 

**71.** Infinite large two place surfaces are placed parallel to each-other. Positive charge on one surface and negative charge on other surface are distributted uniformly. Show the electric field lines, if the magnitudes of densities of charges are equal on both the plates.

Ans. 

**72.** Infinite large two plane surfaces are placed parallel to each-other. Positive charges are distributted uniformly on both the surfaces such that the charge densities are equal on both the surfaces. Show electric field lines.

Ans. 

**73.** Write the properties of electric field lines.

Ans. Electric field lines have following properties :-

(i) Electric field lines go away from a positive charge and go towards a negative charge.

(ii) Electric field lines are perpendicular to the surface of a charge or on the xsurface of a uniformly charged body or on the surface of a metalic uncharged objects.

(iii) When a positive charge is released in an electric field, then it moves along an electric field line.

(iv) Electric field lines are imaginary.

(v) The direction of electric field at a point on an electric field line is along the tangent drawn through that poiint on the electric field linie.

(vi) Two electric field lines never cut each-other.

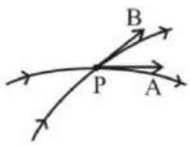
(vii) The electric field lines have large separation among them where electric field has small magnitude and the electric field lines have small separation among them where electric field has great magnitude.

(viii) The density of electric field lines is smaller at that region where the magnitude of electric field is smaller and the density of electric field lines is greater at thatg region where the magnitude of electric field is greater.

(ix) Electric field lines passes through materials of every type.

**74.** Why do electric field lines not cut each-other ?

Ans. We know that the direction of electric field at any point in an electric field is along the tangent drawn on electric field line passing through that point. So, if two electric field lines cut each-other at a point P as shown in the figure then there are two tangents PA and PB at point P as shown in the figure. So, the direction of electric field at point P is along $\overrightarrow{PA}$ and also along $\overrightarrow{PB}$. But a vector has only one direction and because electric field is a vector, so it can not has two direction. So, electric field lines can not cut each-other.




**75.** What is uniform electric field ? Write its important features.

Ans. An electric field which has equal magnitude and same direction at every place is called a uniform electric field. It has following properties :-

(i) The magnitudes of electric field are equal to every place.

(ii) The directions of electric field are also same at every place.

(iii) Electric field lines are straight, parallel to each-other and in same direction.

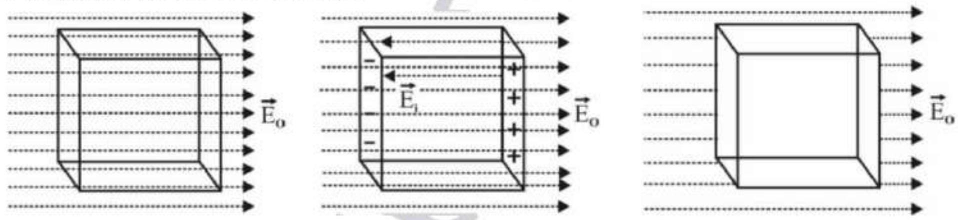
(iv) It is generated by those charged objects whose shape are plane and infinite or the charged object is very far away.

**76.** A point electric charge creates a uniform electric field.

Ans.

**77.** Explain in detail that when a metalic object is placed in an electric field then what happens ?

Ans. We know that there are infinite free electrons in a metal and every metal are electrically neutral in a normal situation. If an object made of metal is placed in an electric field as shown in the first figure then electric force acts on its free electrons by the external electric field $\vec{E}_o$ along its opposite direction. Due to this, some free electrons concentrate on the bach surface of the metalic object as shown in the second figure and just opposite to it positive charge of same amount create on its front surface. In such a way developed charges are called induced charge, whose magnitudes are equal and natures are opposite. A different electric field developes inside the metalic object due to these induced charges from the induced positive charge to the induced negative charge or just opposite to the external electric field, which is called induced electric field $\vec{E}_i$. The value of induced electric field is equal to the value of external electric field inside the metalic object in equilibrium and due to this both concel the effects of each-other and the value of electric field inside the metal is zero. So, there is no electric field inside a metalic object, when it is placed in an electric field.




**78.** Statement- I : The value of electric field inside a metal is zero, when a metal is placed in an electric field.

Statement- II : Electric field lines can not cross through a metal.

Ans. C.

**79.** Electric field lines can cross through a metal.

Ans. True.

**80.** When a metal is placed in an electric field, then ___________ are induced at the front surface of the metal and ________ are induced at the back surface of the metal.

Ans. Positive charge ; negative charge.

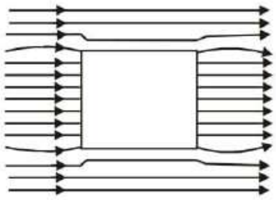
**81.** The value of electric field is always zero inside a metal in the portion of material.

Ans. True.

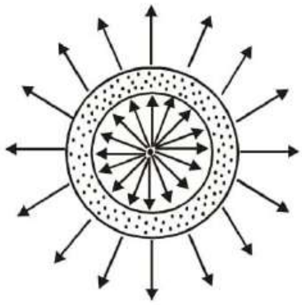
**82.** When a metal is placed in an electric field, then the induced electric field and the external electric field are equal in magnitude and opposite in direction always.

Ans. True.

**83.** When a hollow or solid metalic cube is placed in a uniform electric field in such a way that its any two surfaces are perpendicular to electric field, then show electric field lines.

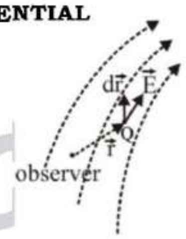
Ans. 

**84.** There is a metalic sphere, which has a spherical cavity in the centre of the sphere. Show the electric field lines, when a positive point charge is placed in the centre of the cavity.

Ans. 

## RELATION BETWEEN ELECTRIC FIELD AND ELECTRIC POTENTIAL

85. Derive the relation between electric field and electric potential.




Ans. Suppose that there is a region of electric field. The value of electric field is $\vec{E}$ at the position vector $\vec{r}$. Let the electric potential at that point is V. If a point charge q is placed at that point, then the value of electric force acting on the charge will be :-

$$\vec{F}_e = q\vec{E} \qquad \text{..... (i)}$$

Now, if the charge is displaced by $d\vec{r}$, then the work done by the electric field will be:-

$$dW = \vec{F}_e.d\vec{r} \qquad \Rightarrow dW = q\vec{E}.d\vec{r} \qquad \{\text{from (i)}\} \qquad \text{.... (i)}$$

But, the work done by electric force is like as work done by internal force. So, the change in electric potential energy will be :-

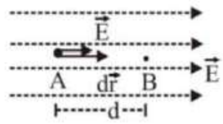
$$dU = -dW \qquad \Rightarrow dU = -q\vec{E}.d\vec{r} \qquad \{\text{from (ii)}\} \qquad \text{.... (ii)}$$

So, change in electric potential will be :-

$$dV = \frac{dU}{q} \qquad \Rightarrow dV = \frac{-q\vec{E}.d\vec{r}}{q} \qquad \{\text{from (iii)}\}$$

$$\therefore dV = -\vec{E}.d\vec{r}.$$

86. Find the change in electric potential if we move some distance in a uniform electric field along the electric field.




Ans. Suppose that there is a uniform electric field $\vec{E}$. The distance betgween two points A and B is d. Both the points are parallel to the electric field. Let electric potentials at A and at B are $V_A$ and $V_B$ respectively. So, it can be written as :-

$$dV = -\vec{E}.d\vec{r} \qquad \Rightarrow \int_{V_A}^{V_B} dV = \int_o^d -\vec{E}.d\vec{r}$$

$$\Rightarrow \quad [V]_{V_A}^{V_B} = -\int_o^d E.dr.\cos 0^o \qquad \{\because \theta = 0^o = \text{constant}\}$$

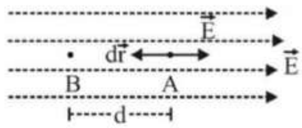
$$\Rightarrow \quad V_B - V_A = -E\int_o^d dr \qquad \{\cos 0^o = 1 \text{ and E is constant}\}$$

$$\Rightarrow \quad V_B - V_A = -E[r]_o^d \qquad \Rightarrow V_B - V_A = -Ed$$

$$\therefore V_A - V_B = Ed$$

So, if we move in a uniform electric field $\vec{E}$ by a distance d, towards the electric field, then electric potential decreases by Ed.

87. Find the change in electric potential if we move some distance in a uniform electric field opposite to the electric field.




Ans. Suppose that there is a uniform electric field $\vec{E}$. The distance between two points A and B is d. Both the points are parallel to the electric field. Let electric potentials at A and B are $V_A$ and $V_B$ respectively. So, it can be written as :-

$$dV = -\vec{E}.d\vec{r} \qquad \Rightarrow \int_{V_A}^{V_B} dV = \int_o^d -\vec{E}.d\vec{r}$$

$$\Rightarrow \quad [V]_{V_A}^{V_B} = -\int_o^d E.dr.\cos 180^o \qquad \{\because \theta = 180^o = \text{constant}\}$$

$$\Rightarrow \quad V_B - V_A = -\int_o^d E.dr.(-1) \qquad \Rightarrow V_B - V_A = E\int_o^d dr$$

{∵ cos 180° = −1 and E is constant}

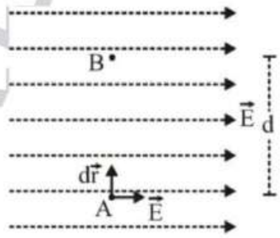
$\Rightarrow \quad V_B - V_A = E[r]_0^d \qquad \Rightarrow V_B - V_A = E[d-0]$

$\therefore V_B - V_A = Ed$

So, if we move in a uniform electric field $\vec{E}$ by a distance d opposite to the electric field, then electric potential increases by E.d.

88. Find the change in electric potential if we move some distance in a uniform electric field along the perpendicular direction.

Ans. Suppose that there is a uniform electric field $\vec{E}$. The distance between two points A and B is d. Both the points are perpendicular to the electric field. Let electric potentials at A and B are $V_A$ and $V_B$ respectively. So, it can be written as :-




$dV = -\vec{E}.d\vec{r} \qquad \Rightarrow \int_{V_A}^{V_B} dV = \int_0^d -\vec{E}.d\vec{r}$

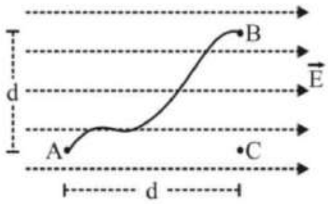
$\Rightarrow \quad [V]_{V_A}^{V_B} = -\int_0^d E.dr.\cos 90^o \qquad \{\because \theta = 90^o = \text{constant}\}$

$\Rightarrow \quad V_B - V_A = -\int_0^d E.dr.0 \qquad \Rightarrow V_B - V_A = 0 \qquad \therefore V_A = V_B$

So, if we move in a uniform electric field along perpendicular to the electric field, then electric potential does not change.

89. Find change in electric potential if we move in a uniform electric field through zig-zag path.

Ans. Suppose that there is a uniform electric field $\vec{E}$. There are two points A and B. Let the electric potentials at A and B are $V_A$ and $V_B$ respectively. Let, another point C, which is parallel to A and perpendicular to B. So, it can be written as :-



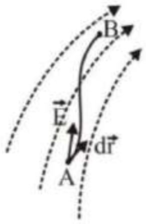

$V_B - V_A = (V_B - V_C) + (V_C - V_A) \qquad \{\because V \text{ is a scalar}\}$

$\Rightarrow V_B - V_A = 0 + (-Ed) \qquad \Rightarrow V_B - V_A = -Ed \qquad \therefore V_A - V_B = Ed$

So, it we move in an electric field, then change in electric potential depends on the component of its displacement, which is parallel to the electric field. The shape of the path of the movement is not a matter here.

90. How will you obtain the change in electric potential, if we move in a non-uniform electric field from one point to the other point ?

Ans. Suppose that there is a non uniform electric field and we move from a point A to the point B as shown in the figure. Let electric potentials at A and B are $V_A$ and $V_B$ respectively. So, it can be written as :-

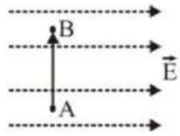



$dV = -\vec{E}.d\vec{r} \qquad \Rightarrow \int dV = \int_{r_A}^{r_B} -\vec{E}.d\vec{r}$

$\Rightarrow \quad [V]_{V_{QA}}^{V_B} = -\int_{r_A}^{r_B} \vec{E}.d\vec{r} \qquad \therefore V_B - V_A = -\int_{r_A}^{r_B} \vec{E}.d\vec{r}$

## INTRODUCTORY

1. There is a uniform electric field of 30 N/C. Find the potential difference between A and B. The distance between A and B is 7 m.




Ans. zero.

2. There is a uniform electric field of 60 N/C along east. If one moves by a distance of 4m along the electric field, then will electric potential increase or decrease. Find its vlaue.

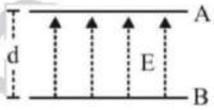
Ans. decrease ; 240 V.

3. There is a uniform electric field of 5 N/C along +2-axis. Find change in electric potential, if it is moved by 2m along –Z-axis.

Ans. 10 V

**ZERO LEVEL**

4. The given figure shows two metallic plates A and B placed parallel to each-other at a separation d. A uniform electric field E exists between the plates in the direction from plate B to plate A. Find the potential difference between the plates. **(H.C. Verma)**




Ans. Ed.

5. A uniform electric field of 10 N/C exists in the vertically downward direction. Find the increase in the electric potential as one goes up through a height of 50 cm.

Ans. 5 V **(H.C. Verma)**

6. There is a uniform electric field of 4 N/C along +X-axis. Find the value of change in electric potential, if it is moved from $A \equiv (-2,-1)\text{m}$ to (6, 4)m.

Ans. –32 V.

**LEVEL - I**

7. An electric field of 20 N/C exists along the X-axis in space. Calculate the potential difference $V_B - V_A$ where the points A and B are given by :- **(H.C. Verma)**

*a.* $A \equiv (0,0)$; $B \equiv (4\text{m}, 2\text{m})$

*b.* $A \equiv (4\text{m}, 2\text{m})$; B=(6m, 5m)

*c.* $A \equiv (0,0)$; B=(6m, 5m).

do you find any relation between the answers of parts a, b and c ?

Ans. *a.* –80 V *b.* – 40V *c.* –120 V

8. There is a uniform electrid field of $\vec{E} = \left(2\hat{i} + 3\hat{j} - 4\hat{k}\right)\frac{N}{C}$. Find the change in electric potential, if it is moved from $\vec{r}_i = \left(-2\hat{i} + 4\hat{j} - \hat{k}\right)$ to $\vec{r}_f = \left(3\hat{j} + 2\hat{k}\right)$.

Ans.

9. An electric field $\vec{E} = \left(\hat{i}20 + \hat{j}30\right)\text{N/C}$ exists in the space. If the potential at the origin is taken to be zero, find the potential at (2m, 2m). **(H.C. Verma)**

Ans.–100 V.

10. An electric field $\vec{E} = \hat{i}Ax$ exists in the space, where A=10 v/m$^2$. Take the potential at (10m,20m) to be zero. Find the potential at the origin. **(H.C. Verma)**

Ans. 500 V.

11. There is an electric field along +X-axis and its magnitudes varies according to the equation $E = \left(4x^2 + 2x\right)\text{N/C}$. Find the potential difference between the poinits x=2m and x=5m.

Ans.

91. If the relation between electric potential and different position are given, then how will you obtain the value of electric field in that region ?

Ans. We know that $dV = -\vec{E}.d\vec{r}$

$\Rightarrow \quad dV = -\vec{E}.\left(d\vec{x} + d\vec{y} + d\vec{z}\right)$ {where, $d\vec{r} = d\vec{x} + d\vec{y} + d\vec{z}$ }

$\Rightarrow \quad dV = -\left(E_x\hat{i} + E_y\hat{j} + E_z\hat{k}\right).\left(d\vec{x} + d\vec{y} + d\vec{z}\right)$ {where $\vec{E} = E_x\hat{i} + E_y\hat{j} + E_z\hat{k}$ }

$\Rightarrow \quad dV = -\left(E_x\hat{i} + E_y\hat{j} + E_z\hat{k}\right).\left(dx.\hat{i} + dy.\hat{j} + dz.\hat{k}\right)$

$\Rightarrow \quad dV = -\left(E_x.dx + E_y.dy + E_z.dz\right)$ .... ($\alpha$)

So, if it is assumed that y and z are constants, then dy=0 and dz=0. So, from ($\alpha$):-

$dV = -E_x.dx \qquad \Rightarrow E_x = -\frac{dV}{dx}$ .... (i)

Again, if it is assumed that z and x are constants, then dz=0 and dx=0. So, from ($\alpha$):-

$dV = -E_y.dy \qquad \Rightarrow E_y = -\frac{dV}{dy}$ ....... (ii)

and, if it is assumed that x and y are constants, then dx=0 and dy=0. So, from ($\alpha$):-

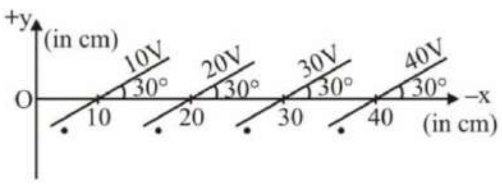
$dV = -E_z.dz \qquad \Rightarrow E_z = -\frac{dV}{dz}$ .... (iii)

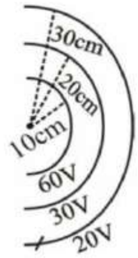
So, the resultant electric field will be obtained by the vector sum of the above three equations (i), (ii) and (iii) :- $\vec{E} = E_x\hat{i} + E_y\hat{j} + E_z\hat{k}$

**LEVEL - I**

1. The electric potential existing in space is V(x, y, z) = A(xy+yz+zx). *a.* Write the dimensional formula of A. *b.* Find the expression for the electric field. *c.* If A is 10 SI units, find the magnitude of the electric field at (1m, 1m, 1m). **(H.C. Verma)**

Ans. *a.* $MT^{-3}I^{-1}$ *b.* $-A\left\{\hat{i}(y+z) + \hat{j}(z+x) + \hat{k}(x+y)\right\}$ *c.* 35 N/C

2. 




Some equipotential surfaces are shown in figure. What can you say about the magnitude and the direction of the electric field. **(H.C. Verma)**

Ans. *a.* 200 V/m making an angle 120° with the X-axis. *b.* radially outward, decreasing with distance as $E = \frac{6Vm}{r^2}$.

92.

1. What do you mean by an electric dipole ?

Ans. When two charges of equal magnitude and opposite nature are placed very near to each other, then this arrangement is called on electric dipole.

2. The total charge of an electric dipole is ........ always.

Ans. zero.

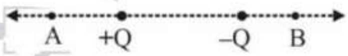
3. What do you mean by charge of an electric dipole ?

Ans. The meaning of 'charge of an electric dipole', is the value of positive charge of the electric dipole.

So, in the given figure, +Q is the charge of the electric dipole.

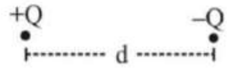

4. What is the axis of an electric dipole ?

Ans. A straight line passing through both the charges of an electrid dipole is called in axis of the electric dipole. In the given figure, AB is the axis of the electric dipole.




5. What do you mean by length of an electric dipole ?

Ans. The distance between both the charges of an electric dipole is called the length of the electric dipole. It is denoted by d.




6. What is the length vector of an electric dipole ?

Ans. The length of an electric dipole is treated as a vector, which direction is from the negative charge to the positive charge. It is called the length vector of the electric dipole. In the given figure $\vec{d}$ is the length vector.


7. What do you mean by electric dipole moment ?

Ans. The product of positive charge and length vector of an electric dipole is called its electric dipole moment. It is denoted by $\vec{p}$.


So, $\vec{p} = Q\vec{d}$

8. The direction of electric dipole moment is from the ....... charge to the ...... charge of an electric dipole.

Ans. negative; positive.

9. Electric dipole moment is a ....... quantity, its SI unit will be ........ and its dimensional formula will be ...... .

Ans. Vector; Coulomb-metre (C-m); LIT.

10. What do you mean by 'a point on end on position'.

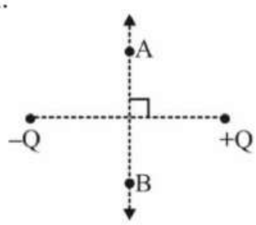
Ans. If a point is on the axis of an electric dipole, then this point is called 'a point on end on position'.

In the given figure, A and B are the points on end on position.

11. What do you mean by 'a poiint on broadside on position'.

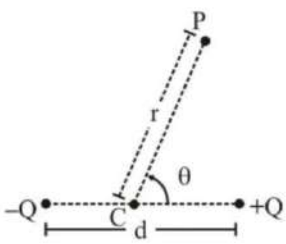
Ans. If a poiint is on the perpnedicular bisector of an electric dipole, then this point is called 'a point on broadside on position'.

In the given figure, A and B are the points on broadside on position.

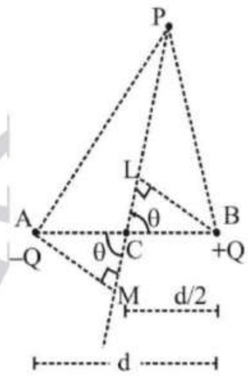



12. Obtain the value of electric potential at an arbitrary point due to an electric dipole.

Ans. Suppose that there is an electric dipole having charges –Q and +Q. The distance between both the charges is d. We have to obtain electric potential at a point P, which distance is r from the middle point of the electric dipole. Let the angle between r and d is $\theta$. Here, d<<r.



Now, we extend the line PC and draw two perpendiculars BL and AM on it from the points B and A respectively. Let, electric potentials at P created by –Q and +Q are $V_-$ and $V_+$ respectively.




Now, in $\Delta CBL$ :-

$$\cos\theta = \frac{CL}{BC}$$

$$\Rightarrow \quad \cos\theta = \frac{CL}{\frac{d}{2}} \qquad \therefore CL = \frac{d}{2}\cos\theta \quad ..... \text{(i)}$$

and, in $\Delta ACM$ :-

$$\cos\theta = \frac{CM}{AC} \qquad \Rightarrow \cos\theta = \frac{CM}{\frac{d}{2}}$$

$$\therefore CM = \frac{d}{2}\cos\theta \quad .... \text{(ii)}$$

So, electric created by –Q at P will be :-

$$V_- = \frac{1}{4\pi\varepsilon_o}.\frac{-Q}{PA} \qquad \Rightarrow V_- = \frac{1}{4\pi\varepsilon_o}.\frac{-Q}{PM} \qquad \{\because d<<r \ \therefore \angle APM \text{ is very small } \therefore PA \approx PM\}$$

$$\Rightarrow \quad V_- = \frac{1}{4\pi\varepsilon_o}.\frac{-Q}{PC+CM}$$

$$\Rightarrow \quad V_- = \frac{1}{4\pi\varepsilon_o}.\frac{-Q}{r+\frac{d}{2}\cos\theta} \qquad \{\text{from (ii)}\} \qquad ...... \text{(iii)}$$

And, now electric potential created by +Q at P will be :-

$$V_+ = \frac{1}{4\pi\varepsilon_o}.\frac{+Q}{PB} \quad \Rightarrow V_+ = \frac{1}{4\pi\varepsilon_o}.\frac{+Q}{PL} \quad \{\because d<<r. \ \therefore \angle BPL \text{ is very small } \therefore PB \approx PL\}$$

$$\Rightarrow \quad V_+ = \frac{1}{4\pi\varepsilon_o}.\frac{+Q}{PC-CL}$$

$$\Rightarrow \quad V_+ = \frac{1}{4\pi\varepsilon_o}.\frac{+Q}{r-\frac{d}{2}\cos\theta} \qquad \{\text{from (i)}\} \qquad ..... \text{(iv)}$$

So, the total electric poential at the point P will be :- $V = V_- + V_+$

$$\Rightarrow \quad V = \frac{1}{4\pi\varepsilon_o}.\frac{-Q}{r+\frac{d}{2}\cos\theta} + \frac{1}{4\pi\varepsilon_o}.\frac{+Q}{r-\frac{d}{2}\cos\theta} \qquad \{\text{from (iii) and (iv)}\}$$

$$\Rightarrow \quad V = \frac{1}{4\pi\varepsilon_o}.Q\left[\frac{-1}{r+\frac{d}{2}\cos\theta} + \frac{1}{r-\frac{d}{2}\cos\theta}\right] \qquad \Rightarrow V = \frac{1}{4\pi\varepsilon_o}.Q\left[\frac{-\left(r-\frac{d}{2}\cos\theta\right)+\left(r+\frac{d}{2}\cos\theta\right)}{\left(r+\frac{d}{2}\cos\theta\right).\left(r-\frac{d}{2}\cos\theta\right)}\right]$$

$$\Rightarrow \quad V = \frac{1}{4\pi\varepsilon_o}.Q\left[\frac{-r+\frac{d}{2}\cos\theta+r+\frac{d}{2}\cos\theta}{r^2-\frac{d^2}{4}\cos^2\theta}\right]$$

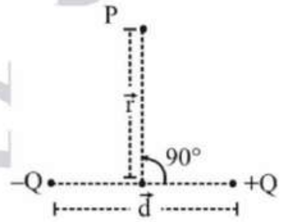
$$\Rightarrow \quad V = \frac{1}{4\pi\varepsilon_o}.Q\left[\frac{d\cos\theta}{r^2}\right] \qquad \left\{\because d<<r. \therefore \frac{d^2}{4}\cos^2\theta << r^2\right\}$$

$$\Rightarrow \quad V = \frac{1}{4\pi\varepsilon_o}.\frac{Qd\cos\theta}{r^2} \qquad \therefore V = \frac{1}{4\pi\varepsilon_o}.\frac{p\cos\theta}{r^2} \quad \{\because p = Qd\}$$

13. Find the value of electric potential due to an electric dipole in various special cases.

Ans. These special cases are following :-

**Case - I :-** If the point P is on the broadside on position :-



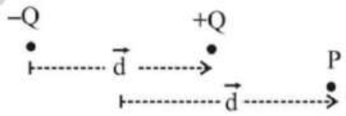

In this case the angle between $\vec{d}$ and $\vec{r}$ will be 90°. So, the electric potential at point P will be :-

$$\because V = \frac{1}{4\pi\varepsilon_o}.\frac{p\cos\theta}{r^2}$$

$$\Rightarrow \quad V = \frac{1}{4\pi\varepsilon_o}.\frac{p.\cos 90^o}{r^2} \qquad \Rightarrow \quad V = \frac{1}{4\pi\varepsilon_o}.\frac{p.0}{r^2}$$

$\therefore$ V= 0

**Case - II :-** If the point P is on end on position towards the positive charge :-



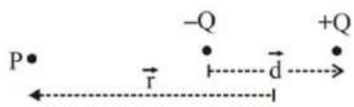

In this case the angle between $\vec{d}$ and $\vec{r}$ will be 0°. So, the electric potential at point P will be :-

$$\because V = \frac{1}{4\pi\varepsilon_o}.\frac{p\cos\theta}{r^2} \qquad \Rightarrow V = \frac{1}{4\pi\varepsilon_o}.\frac{p.\cos 0^o}{r^2}$$

$$\Rightarrow \quad V = \frac{1}{4\pi\varepsilon_o}.\frac{p.1}{r^2} \qquad \therefore V = \frac{1}{4\pi\varepsilon_o}.\frac{p}{r^2}.$$

**Case - III :-** If the point P is on end on position towards the negative charge :-

In this case, the angle between $\vec{d}$ and $\vec{r}$ will be 180°. So, the electric potential at point P will be :-



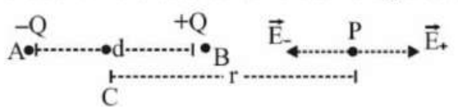

$$\because \quad V = \frac{1}{4\pi\varepsilon_o}.\frac{p\cos\theta}{r^2}$$

$$\Rightarrow \quad V = \frac{1}{4\pi\varepsilon_o}.\frac{p\cos 180^o}{r^2}$$

$$\Rightarrow \quad V = \frac{1}{4\pi\varepsilon_o}.\frac{p.(-1)}{r^2} \qquad \therefore V = -\frac{1}{4\pi\varepsilon_o}.\frac{p}{r^2}.$$

14. Obtain the value of electric field due to an electric dipole at a point on its end on position.

Ans. There may be two cases, when we want to obtain electric field due to an electric dipole at a point on its end on position :-




**Case - I :-** When the point is towards the positive charge :-

Suppose that there is an electric dipole having charges –Q and +Q at a separation d. And, we have to obtain electric field at the point P as shown in the figure. So, charge –Q will create electric field at P towards the electric dipole and charge +Q will create electric field at P away to the electric dipole. If, $\vec{E}_-$ be the electric field at P created by –Q and $\vec{E}_+$ be the electric field at P created by +Q, then

$$E_- = \frac{1}{4\pi\varepsilon_o}.\frac{|-Q|}{AP^2} \qquad \Rightarrow E_- = \frac{1}{4\pi\varepsilon_o}.\frac{Q}{(CP+AC)^2}$$

$$\Rightarrow \quad E_- = \frac{1}{4\pi\varepsilon_o}.\frac{Q}{\left(r+\frac{d}{2}\right)^2} \qquad ....... (\alpha)$$

and $E_+ = \frac{1}{4\pi\varepsilon_o}.\frac{|+Q|}{BP^2} \qquad \Rightarrow E_+ = \frac{1}{4\pi\varepsilon_o}.\frac{Q}{(CP-BC)^2}$

$$\Rightarrow \quad E_+ = \frac{1}{4\pi\varepsilon_o}.\frac{Q}{\left(r-\frac{d}{2}\right)^2} \qquad ........ (\beta)$$

From both the above equation, it is clear that $\left(r+\frac{d}{2}\right) > \left(r-\frac{d}{2}\right)$. So, $E_- < E_+$. So, the resultant electric field will be along the $E_+$ or towards the electric dipole moment and its magnitude will be :- $E = E_+ - E_-$.

$$\Rightarrow \quad \frac{1}{4\pi\varepsilon_o}.\frac{Q}{\left(r-\frac{d}{2}\right)^2} - \frac{1}{4\pi\varepsilon_o}.\frac{Q}{\left(r+\frac{d}{2}\right)^2} \qquad \Rightarrow E = \frac{1}{4\pi\varepsilon_o}.Q\left[\frac{1}{\left(r-\frac{d}{2}\right)^2} - \frac{1}{\left(r+\frac{d}{2}\right)^2}\right]$$

$$\Rightarrow \quad E = \frac{1}{4\pi\varepsilon_o}.Q\left[\frac{\left(r+\frac{d}{2}\right)^2 - \left(r-\frac{d}{2}\right)^2}{\left(r-\frac{d}{2}\right)^2.\left(r+\frac{d}{2}\right)^2}\right]$$

$$\Rightarrow \quad E = \frac{1}{4\pi\varepsilon_o}.Q\left[\frac{\left(r^2+\frac{d^2}{4}+2.r.\frac{d}{2}\right) - \left(r^2+\frac{d^2}{4}-2.r.\frac{d}{2}\right)}{\left\{\left(r-\frac{d}{2}\right)\left(r+\frac{d}{2}\right)\right\}^2}\right]$$

$$\Rightarrow \quad E = \frac{1}{4\pi\varepsilon_o}.Q\left[\frac{r^2+\frac{d^2}{4}+rd-r^2-\frac{d^2}{4}+rd}{\left(r^2-\frac{d^2}{4}\right)^2}\right]$$

$$\Rightarrow \quad E = \frac{1}{4\pi\varepsilon_o}.Q\left[\frac{2rd}{(r^2)^2}\right] \qquad \{\because r >> d. \therefore r^2 >> \frac{d^2}{4}\}$$

$$\Rightarrow \quad E = \frac{1}{4\pi\varepsilon_o}.Q.\frac{2rd}{r^4} \qquad \Rightarrow E = \frac{1}{4\pi\varepsilon_o}.\frac{2.Qd}{r^3}$$

$$\Rightarrow \quad E = \frac{1}{4\pi\varepsilon_o}.\frac{2p}{r^3}$$

and, the direction of the electric field is along the direction of the electric dipole moment. So, the above equation may also be written as :-

$$\vec{E} = \frac{1}{4\pi\varepsilon_o}.\frac{2\vec{p}}{r^3}.$$

**Case - II :-** When the point is towards the negative charge :-

In this case also the magnitude of electric field will be :-

$$E = \frac{1}{4\pi\varepsilon_o}.\frac{2p}{r^3}.$$

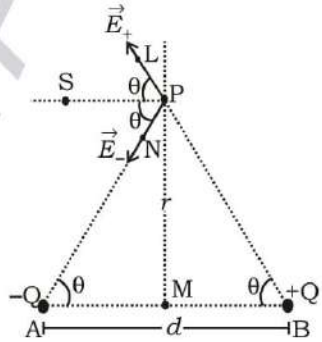

and, the direction of the electric field is also along the direction of the electric dipole moment. So, the above equation may also be written as :-

$$\vec{E} = \frac{1}{4\pi\varepsilon_o}.\frac{2\vec{p}}{r^3}$$

15. Obtain the value of electric field due to an electric dipole at a point on its broadside on position.

Ans. A point on the perpendicular bisector of an electric dipole is called a broadside on position.

Suppose that there is an electric dipole as shown in the figure. PM is its perpendicular bisector, so the point P is on a broadside on position. So, the charge –Q will create an electric field $\vec{E}_-$ along $\overrightarrow{PA}$ as shown in the figure and the charge +Q will create an electric field $\vec{E}_+$ along $\overrightarrow{BP}$. The distance of P from the middle point of the electric dipole is $r$.




$$\therefore E_- = \frac{1}{4\pi\varepsilon_o}.\frac{|-Q|}{PA^2} \qquad \Rightarrow E_- = \frac{1}{4\pi\varepsilon_o}.\frac{Q}{PM^2 + MA^2}$$

$$\Rightarrow E_- = \frac{1}{4\pi\varepsilon_o}.\frac{Q}{r^2 + \frac{d^2}{4}} \qquad \&,\ E_+ = \frac{1}{4\pi\varepsilon_o}.\frac{|+Q|}{PB^2}$$

$$\Rightarrow E_+ = \frac{1}{4\pi\varepsilon_o}.\frac{Q}{PM^2 + MB^2} \qquad \Rightarrow E_+ = \frac{1}{4\pi\varepsilon_o}.\frac{Q}{r^2 + \frac{d^2}{4}}$$

Now, we draw a line PS which is parallel to the line AB. Because the line PM is perpendicular bisector of AB. So, $\Delta PAM \cong \Delta PBM$.

So, $\angle PAM = \angle PBM = \theta$ (let)

$\therefore \angle LPS = \angle PBM = \theta$ &, $\angle NPS = \angle PAM = \theta$.

So, PS is the bisector of the angle LPN. The angle between $\vec{E}_+$ and $\vec{E}_-$ is $2\theta$ and their magnitudes are equal. So, their resultant will be along $\overrightarrow{PS}$ and the magnitude will be :-

$$F = 2E_+ \cos\frac{2\theta}{2} \qquad \Rightarrow E = 2.\frac{1}{4\pi\varepsilon_o}.\frac{Q}{r^2 + \frac{d^2}{4}}.\cos\theta$$

$$\Rightarrow E = \frac{1}{4\pi\varepsilon_o}.\frac{2Q}{r^2+\frac{d^2}{4}}.\frac{\frac{d}{2}}{\sqrt{r^2+\frac{d^2}{4}}}$$

$$\Rightarrow E = \frac{1}{4\pi\varepsilon_o}.\frac{Qd}{\left(r^2+\frac{d^2}{4}\right)^{3/2}}$$

$$\Rightarrow E = \frac{1}{4\pi\varepsilon_o}.\frac{p}{\left(r^2\right)^{3/2}} \quad \{\because\ r >> d\}$$

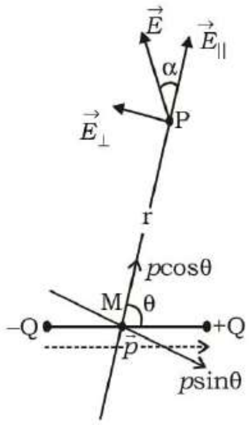
$$\Rightarrow E = \frac{1}{4\pi\varepsilon_o}.\frac{p}{r^3}.$$

But, this electric field is just opposite to the electric dipole moment. So, the electric field may be written as :-

$$\boxed{\vec{E} = -\frac{1}{4\pi\varepsilon_o}.\frac{\vec{p}}{r^3}.}$$

So, the electric field on a broadside on position is opposite and half of the electric field on an end on position at the same distance from the middle point of the electric dipole.

16. Obtain the value of electric field due to an electric dipole at a poinit on an arbitrary position.




Ans. Suppose that there is an electric dipole having electric dipole moment $\vec{p}$ as shown in the figure. We have to find the electric field at the point P at a distance $r$ from the middle point of the electric dipole along the direction making an angle q with the electric dipole moment. Electric dipole moment is a vector, so we resolve the electric dipole moment in two mutual perpendicular direction :- One along the line PM and the other perpendicular to the line PM. So, the first component is pcosq and the other component is psinq. So, the point P is an end on position of the first component and is a broadside on position of the second component. Let, the electric field at P due to the first component is $\vec{E}_{||}$ and due to the second component is $\vec{E}_\perp$. So,

$$E_{||} = \frac{1}{4\pi\varepsilon_o}.\frac{2p\cos\theta}{r^3} \quad \text{..............} (\alpha)$$

and, $$E_\perp = \frac{1}{4\pi\varepsilon_o}.\frac{p\sin\theta}{r^3} \quad \text{..............}(\beta)$$

because, the angle between $E_{||}$ and $E_\perp$ is 90°. So, the magnitude of the resultant electric field will be :-

$$E = \sqrt{E_{||}^2 + E_\perp^2}$$

$$\Rightarrow E = \sqrt{\left(\frac{1}{4\pi\varepsilon_o}.\frac{2p\cos\theta}{r^3}\right)^2 + \left(\frac{1}{4\pi\varepsilon_o}.\frac{p\sin\theta}{r^3}\right)^2}$$

$$\Rightarrow E = \sqrt{\left(\frac{1}{4\pi\varepsilon_o}.\frac{p}{r^3}\right)^2(2\cos\theta)^2 + \left(\frac{1}{4\pi\varepsilon_o}.\frac{p}{r^3}\right)^2.(\sin\theta)^2}$$

$$\Rightarrow E = \sqrt{\left(\frac{1}{4\pi\varepsilon_o}.\frac{p}{r^3}\right)^2\left[(2\cos\theta)^2 + (\sin\theta)^2\right]}$$

$$\Rightarrow E = \frac{1}{4\pi\varepsilon_o}.\frac{p}{r^3}\sqrt{(2\cos\theta)^2 + (\sin\theta)^2}$$

$$\Rightarrow E = \frac{1}{4\pi\varepsilon_o}.\frac{p}{r^3}\sqrt{4\cos^2\theta + \sin^2\theta}$$

$$\Rightarrow E = \frac{1}{4\pi\varepsilon_o}.\frac{p}{r^3}\sqrt{3\cos^2\theta + \left(\cos^2\theta + \sin^2\theta\right)}$$

$$\therefore E = \frac{1}{4\pi\varepsilon_o}.\frac{p\sqrt{3\cos^2\theta + 1}}{r^3}$$

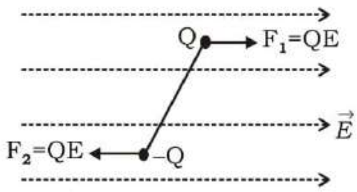
&, the angle of the electric field with respect to $E_{||}$ will be :-

$$\alpha = \tan^{-1}\left(\frac{E_{\perp}}{E_{||}}\right) \qquad \Rightarrow \alpha = \tan^{-1}\left[\frac{\frac{1}{4\pi\varepsilon_o}.\frac{p\sin\theta}{r^3}}{\frac{1}{4\pi\varepsilon_o}.\frac{2p\cos\theta}{r^3}}\right]$$

$$\Rightarrow \alpha = \tan^{-1}\left[\frac{\sin\theta}{2\cos\theta}\right] \qquad \therefore \alpha = \tan^{-1}\left(\frac{\tan\theta}{2}\right)$$

17. Find the value of resultant electric force acting on an electric dipole, when it is placed in a uniform electric field.

Ans. Suppose that, there is a uniform electric field $\vec{E}$ as shown in the figure. An electric dipole of charges –Q and +Q has been placed in it. If $\vec{F_1}$ and $\vec{F_2}$ are forces acting on the positive and negative charges of the electric dipole respectively, then



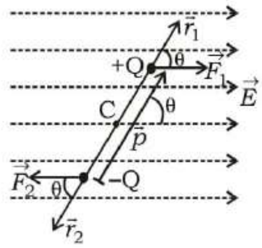

$\vec{F_1} = QE$ along the electric field

&, $\vec{F_2} = QE$ opposite to the electric field.

Now, we imagine the electric dipole as a point object and apply both the forces. The resultant force acting on the electric dipole is zero. So, from the newton's first law of motion the electric dipole will be non accelerated and the electric dipole has a constant velocity.


18. Find the value of resultant torque on an electric dipole, when it is placed in a uniform electric field.

Ans. Suppose that there is a uniform electric field $\vec{E}$ as shown in the figure. An electric dipole of charge Q and length $d$ has been placed in the field, so that the angle between the electric dipole moment and the electric field is q. The charge +Q will experience the force $\vec{F_1} = QE$ along the electric field and the charge –Q will also experience the force $\vec{F_2} = QE$ opposite to the electric field. The middle point C is the centre of mass of the electric dipole. So, this point is also the centre of rotation of the electric dipole. So, the torque on the positive charge will be :-




$$\vec{\tau} = \vec{r_1} \times \vec{F_1}$$

$\Rightarrow \vec{\tau}_+ = r_1F_1\sin\theta$ along perpendicular inward of the plane

$\Rightarrow \vec{\tau}_+ = \frac{d}{2}.qE\sin\theta$ along perpendicular inward of the plane.

And, the torque on the negative charge will be :-

$$\vec{\tau}_- = \vec{r}_2 \times \vec{F}_2$$

$\Rightarrow \vec{\tau}_- = r_2 F_2 \sin\theta$ along perpendicular inward of the plane.

$\Rightarrow \vec{\tau}_- = \frac{d}{2} qE \sin\theta$ along perpendicular inward of the plane.

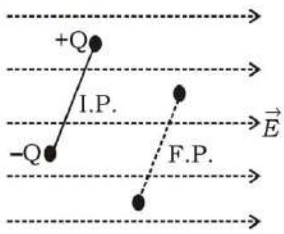
So, the net torque acting on the electric dipole will be :- $\vec{\tau} = \vec{\tau}_+ + \vec{\tau}_-$

$\Rightarrow \vec{\tau} = dqE \sin\theta$ along perpendicular inward of the plane.

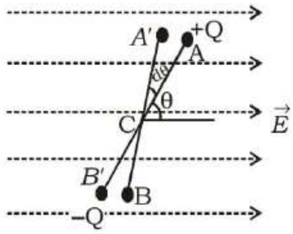
$\Rightarrow \vec{\tau} = p.E.\sin\theta$ along perpendicular inward of the plane.

$$\therefore \boxed{\vec{\tau} = \vec{p} \times \vec{E}}$$

19. Obtain the value of electric potential energy, when an electric dipole is placed in a uniform electric field.




Ans. Suppose that there is a uniform electric field and an electric dipole has been placed in the electric field at initial position (I.P.). The net force acting by the electric field to the electric dipole is equal to zero. So, the electric potential energy of the system will not change when the electric dipole is displaced parallel to the initial position. So, the work done on the system is equal to zero to do so.




Now, suppose that the angle between the electric dipole moment and the electric field is $\theta$ at a particular instant as shown in the figure. So, the torque acting on the electric dipole is $\vec{\tau} = pE \sin\theta$ along perpendicular inward direction. So, the electric potential energy of the system will change, if it is rotated. Suppose that it is rotated by a small angle $d\theta$ to increase the angle between the electric dipole moment and the electric field.

So, the direction between the torque and the small angular displacement is just opposite and the angle between them is 180°. So, the small work done by the torque will be :-

$dW = \vec{\tau}.d\vec{\theta}$ $\qquad \Rightarrow dW = \tau.d\theta.\cos 180^o$

$\Rightarrow dW = pE \sin\theta.d\theta.(-1)$ $\qquad \Rightarrow dW = -pE \sin\theta d\theta.$

So, the net work done by the torque to rotate it from $\theta_1$ to $\theta_2$ will be :-

$W = \int dW$ $\qquad \Rightarrow W = \int_{\theta_1}^{\theta_2} -pE \sin\theta d$ $\qquad \Rightarrow W = -pE \int_{\theta_1}^{\theta_2} \sin\theta d\theta$ $\qquad \Rightarrow W = -pE[-\cos\theta]_{\theta_1}^{\theta_2}$

$\Rightarrow W = pE[\cos\theta]_{\theta_1}^{\theta_2}$ $\qquad \Rightarrow W = pE(\cos\theta_2 - \cos\theta_1)$

This torque is internal torque. So, this work has been done by an internal torque. So, the change in electric potential energy of the system will be :-

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

but, the electric potential energy of the system is assumed to be zero, when $\theta = 90^o$. So,

$U_\theta - U_{90^o} = pE[\cos 90^o - \cos\theta]$ $\qquad \Rightarrow U_\theta = pE(0 - \cos\theta)$ $\qquad \Rightarrow U_\theta = -pE \cos\theta$

So, the electric potential energy at the angle $\theta$ will be :-

$U = -pE \cos\theta$ $\qquad \therefore U = -\vec{p}.\vec{E}$