**Unit -1**

“Electrostatics”

Chapter-1

“Electric charges and fields”

**Q. Define electricity .**

Ans. Electricity is the energy due to which a substance acquire the property of attracting the light bodies.

**Q. Define frictional electricity ?**

Ans. The electricity which is produced due to the friction is called frictional electricity.

**Q. Define static electricity “or” Electrostatics?**

Ans. The electricity which does not allow to flow is called electrostatics “or” static electricity.

**Q. Define positive and negative charges?**

Ans. **Positive charges :-** when a glass rod is rubbed with the silk cloth then the charge produced on glass rod is called positive charge .

**Negative charge:-** when ebonite rod is rubbed with the fur (or cat skin) then the charge which is produced on the ebonite rod is called negative charge.

**Note:-**Two same charges always repel each other.

Two opposite charges always attract each other.

**Note:-**The following table represents the kinds of charges, obtained by the two bodies when

rubbed together .

**Positive charge**  **Negative charge**

1. Glass Silk

2. Fur Ebonite

3. Wool Rubber

4. Wool Plastic

**Q. Define law of conservation of charge with example ?**

Ans. By the law of conservation of charge, in an isolated system the charge can neither be

created nor can be destroyed. It is always conserved .

**Ex:-** (i)When glass rod is rubbed with a silk cloth then the positive charge which is produced on the glass rod is equal to the negative charge which is produced on the silk cloth .

(ii.) When a ebonite rod is rubbed with the fur, then the negative charge produced on the ebonite rod is equal to the positive charge produced on the fur.

**Note:-** positron (+1e0 ) is the antiparticle of electron.

Charge of positron = +1.6 10-19 coulomb

Mass of positron = 9.110-31 kg .

**Q. Define the following-(i) Fundamental charge (ii) law of quantization of charge?**

Ans. **(i) fundamental charge:-** " in nature the minimum value of charge is called fundamental charge or elementary charge." It is represented by the letter ‘e’ and its value is equal to the charge of electron. e =1.6 10-19 coulomb

**(ii) law of quantization of charge ‘or’ atomicity of charge:-** " in nature the charge is

always integer multiple of fundamental charge."

Q = Ne

Here, Q = charge

N= number of electron (N = 1, 2, 3, 4,……)

**Note:-**In the above formula Q = Ne, + sign denotes the deficiency of electrons and negative sign denotes excess of electrons.

**Note:-** Nobody can have charge 1.5e , . 9e, 1.2e etc.

**Q. Define which type of quantity is the charge and also define its unit and dimensional**

**formula ?**

Ans. charge is the scalar quantity.

**Unit of charge :-**

* e.s.u. (electro static unit) of charge .

In S.I. System Coulomb

In C.G.S. System stat Coulomb

|  |
| --- |
| 1 Coulomb = 3 109  Stat coulomb |

(2) e.m.u. (electro magnetic unit ) of charge ab coulomb

1 ab coulomb = 10 coulomb

Dimensional formula of charge we know that,

Q = I t

Q = (AT)

Thus, the Dimensional formula of charge is [A T].

**Q. The charge on a conductor is -1.6 coulomb How many electron are in excess on it from its normal state ?**

Ans.

**Q. On that conductor ?**

Ans. + 8 x c.

**Q. Find the charge on helium nucleus (z = 2 , A =4)**

Ans. 3.2 x c

**Note**- **Unit of force :-** In S.I. system Newton

In C.G.S. system Dyne

**Q. Define Coulombs inverse square law and derive the necessary relation for it ?**

Ans. **coulombs law:-** According to coulombs law. " the force of attraction or repulsion which is acting b/w the two static point charges is directly proportional to the product of the two charges and inversely proportional to the square of the distance b/w them."

**Relation for the coulomb s Law :-** By the definition of coulombs Law , We know that

 F Q1 .Q2 …….. (i)

F …….. (ii)

Combine eq. (i) and (ii)

F

F =

F = Newton () ( In S.I. System)

F = Dyne (In C.G.S. System)

F (for air or vacuum, k = 1)

Here, r = Distance b/w. the two charges.

0 = Permittivity in free space = 8.86 10-12 C2/Nm2

= absolute Permittivity.

k = (r) = Relative Permittivity or Dielectric constant of the medium

= 9 109

**Note**- For metal K =

For ir or Vacuum K = 1

For Insulators K > 1

For Water K 81

For Mica K = 6

**Q. Explain the similarities and dissimilarities b/w electrostatic force and gravitational force?**

Ans. **Similarities :-**

* Both the forces obey the inverse square law.
* Both the forces are central forces .
* Both the forces are conservative forces .
* Both the forces are active in the vacuum also .

**dissimilarities:-**

(i) The gravitational force is always attractive, while the electrostatic force can be attractive or repulsive.

(ii) The electrostatic force is always stronger than the gravitational force .

(iii) The electrostatic force depends on the di-electric constant of the medium but the gravitational force does not depend on the medium.

**Q. On the basis of coulomb’s law define unit charge ?**

Ans.By the coulomb’s law, we know that –

F =

In the above formula

Let, Q1 = Q2 = Q

k = 1

r = 1m

F = 9 109 N

Then,

9 109 =

Q2 = 1

Q = 1 coulomb

Thus, " when two same static point charges are placed in air or vacuum at distance of 1m. then if the repulsive force acting b/w the two charge is 9 109 N. Then each charge is called unit charge."

**Q. Explain the limitations of coulomb’s law ?**

Ans.(i) coulomb’s law is true only for the point charges .

* It is applicable only for the charges which are in rest position.
* This law is based on experimental results.
* Coulomb's law is the long range forces.(And its range is 10-15 m to some kilometers).
* The force acting b/w the two point charges is unaffected by the presence of other charges in their vicinity.

**Q. Define electric field ?**

Ans. The field where the effect of electricity is feel is called electric field.

**Q. Define electric lines of forces and its properties ?**

Ans. **Electric lines of forces :-** electric lines of forces are the open smooth curve in an electric

field on which if we draw a tangent at any point, then it will show the direction of electric field at that point .

**properties:-**

* Electric lines of forces starts from positive charge and end at negative charge.
* Two electric lines of forces never intersect each other because if they intersect, then at intersection point two tangents are drawn which will show the two direction of electric field at one point and this is not possible.
* In uniform electric field the electric lines of forces are parallel and equidistant to each other.

(iv ) If tangent is drawn at any point on the electric lines of forces, then it will show the direction of electric field at that point.

(v) The electric lines of forces are normal to the surf ace of conductor.

(vi) The electric lines of forces are the open smooth curve.

(vii) It does not present inside the conductor.

(viii) If the electric lines of forces are very close to each other then the intensity of electric field will be high and if the electric lines of forces are far from each other then intensity of electric field will be low.

**Q. Explain the difference b/w electric lines of forces and magnetic lines of forces ?**

Ans.

|  |  |
| --- | --- |
| **Electric lines of forces** | **Magnetic line of forces** |
| (i) It is open smooth curve . | (i) it is the close smooth curve |
| (ii) It is not present inside the conductor. | (ii) It is present inside the magnet. |
| (iii) Electric lines of forces starts from Positive charge and end at –ve charge. | (iii)The direction of magnetic lines of forces is from North pole to south pole outside the magnet and south pole to north pole inside the magnet. |

**Q. Define intensity of electric field and its unit and which type of quantity it is ?**

Ans. **Intensity of electric filed:-** "The intensity of electric field at any point in the electric field is equal to the force which is acting on a unit positive charge which is placed at that point Its unit is or and it is a vector quantity.

E =

Here, E = Intensity of electric field.

**Q. Find the dimensional formula of intensity of electric field ?**

Ans. E =

**Q. In an electric field, a test charge 1.2 x c experiences a force 14.4 at a point . calculate the electric field intensity at that point ?**

Ans. 1.2 x

**Q. A drop is suspended in equillibrium in the two horizontal charged plates . the mass of drop is 4.8 x g and charge on drop is 2.4 x c calculate the electric field the plates ?**

Ans. 1.96 x

**Q. Derive the relation for the intensity of electric field at any point due to a point charge.**

Ans. Consider a point charge Q which is placed at point O as shown in figure. We want to find the intensity of electric field at point P. which is at a distance r from the charge Q for this imagine a q= +1 coulomb charge which is placed at point P. Then the intensity of electric field at point P is :

 E =

E =

E=

**In S.I. system :–**

|  |
| --- |
| E = |

**In C.G.S. system :–**

E =

**Q. Explain the following –**

**(i) Linear charge density.**

**(i) Surface charge density.**

**(i) Volume charge density.**

Ans. **(i) Linear charge density:-** " The charge per unit length is called linear charge density."

It is represented by Symbol ‘’.

**=**

**(ii) surface charge density:-** " the charge per unit area is called surface charge density." It is represented by ‘’.

**(iii) Volume charge density :-** " the charge per unit volume is called volume

Charge density."

It is represented by ‘’

**Q. Define electric dipole and dipole moment. And also define the direction of dipole moment. And also define that whether it is a scalar quantity or vector quantity?**

Ans. **Electric Dipole :-** It is the system which is made by two equal and opposite charges which are placed at a small distance apart .The line which is joining the two charges is called dipole axis.

**Dipole moment :-** Dipole moment of a dipole is equal to the product of any one charge present in the dipole and distance b/w the two charges.

P = q2*l*

Its unit is c m.

Here , P = Dipole moment .

q = charge

2*l* = distance b/w two charges .

Dipole moment is a vector quantity and it's direction is from negative charge to positive charge (i.e. Opposite to the direction of electric lines of forces ).

its dimensional formula is [L T A ] .

**Q. In a hydrogen atom , proton (+ 1.6 x c )And electron (- 1.6 x ) are separated from each other by a distance of 0.5 Å calculate the dipole moment of atom ?**

Ans. 8x c m

**Q. Derive the relation for the intensity of electric field in end on position (or longitudinal or axial position) due to an electric dipole ?**

Ans. In fig. there is an electric dipole AB which consists of charges – q and + q respectively. The distance b/w two charge is 2. We want to find the intensity of electric field at point P in axial position . This point P is at distance ‘r’ from the centre O of the dipole then according to the fig.-

Intensity of electric field at point P due to –q charge .

E1 = (i)

Similarly , intensity of electric field at point P due to +q charge .

E2  =  (ii)

So , Net intensity of electric field at point P is E = E2 E1

E = -

E =

E =

E =

E =

E =

E =

If r >> *l*

E =

E =

**Q . Derive the relation for the intensity of electric field in broad side on position (or transverse or equatorial position) due to an short electric dipole?**

Ans. In fig. there is an electric dipole AB which consist of +q and –q charge . the centre of the dipole is O and the distance b/w. the two charger is 2. We want to find the intensity of electric field at point P which is on the bisector of the electric dipole . Let the Distance of point P from the centre O of the dipole is r . Then acc. to the figure. Intensity of electric field at point P due to – q charge .

E1 = (i)

Similarly , intensity of electric field at point P due to +q charge .

E2 =  (ii)

From eq. (i) and (ii)

E1 = E2 (iii)

 It is clear from the figure that E1  and E2  are equal (E1 = E2). and opposite in direction . So it will cancel each other .So , the total intensity of electric field at point P is -

E = E1 + E2

E = E2 + E2  {E1 = E2}

E = 2 E2

E = 2 [from eq (ii)]

E = { = }

E = { }

E =

If r >> *l* , then

E =

E =

The direction of net intensity of electric field at point P is parallel of the dipole axis and opposite to the direction of dipole moment .

**Note:-** the ratio of intensity of electric field due to an electric dipole In end on and broad on position at same distance is

 =

=

**Q. Two charges + 1.2 c and – 1.2 c are kept at a distance 10 cm apart . Calculate The dipole moment and find the intensity of electric field at distance 1.5 m from its centre in transverse position ?**

Ans. 1.2 x cm , 3.2 x N/C

**Q. Two charges + 2.4 and -2 .4 are situated at a separation of 2.5 x m and form an electric dipole calculate-**

**(i) dipole moment (ii) electric field at distance 0.30 m in end on position**

**(iii) electric field at distance 0.30 m in broad side on position ?**

Ans. (i) 6.0 xcm (ii) 4.0 x

(iii) 2.0 x

**Q. Derive the relation for the force and torque on an electric dipole which is placed in an uniform electric field. And on the basis of formula of torque . Explain the dipole moment ?**

Ans. In fig. there is an electric dipole which makes an angle with the direction of uniform electric field E. due to electric field ‘E’ the force on the +q charge is qE in the direction of electric field and the force on –q charge is qE in the opposite direction of electric field .

Because these forces are equal and opposite in direction . So

Net force on the dipole = 0

But the two equal and opposite forces makes a couple which try to rotate the dipole . So , the torque acting on the dipole is –

= force Perpendicular distance b/w the two forces

 = q E 2

= p E sin { p = q 2

**In vector form**:-

{ }

**In the above formula :-**

* If = 90 Then,

= PE sin 90

= PE

**Definition of the dipole moment on the basis of torque :-**

We know that –

If E = = 90

Then , = P

" The dipole moment of an electric dipole is equal to the maximum torque which is acting on the dipole which is placed at an angle of in the uniform electric field of intensity "

**Q. Two charges + 4e and – 4e are at a separation of 1.2 A This dipole is placed in a uniform electric field of 4x calculate –**

**(i) dipole moment (ii) Maximum torque on dipole**

Ans. (i) 7. 68x cm (ii) 3.072x



**Note:-** The area vector of any area is always in the perpendicular direction of that area.

**Q. Define Electric flux and which type of quantity it is ?**

**Ans**. **electric flux:-** " In an electric field , the total number of electric lines of forces which is

Passing normally through a surface is called electric flux." It is scalar quantity .

**In vector form :-**

Here ,

E = Intensity of electric field.

= Area.

= The electric flux which is passing through a small area

= Small amount of area.

= Total electric flux passing through the surface.

= The angle between intensity of electric field and area vector.

**Note:-** If in the above formula if the surface is to the electric field, then

And if the surface is parallel to are electric field then,

**Q. Define the types of electric flux ?**

Ans. Electric flux are of two types :

(**i) Positive electric flux:-** If the electric lines of forces goes out the closed surface then the electric flux is positive .

**(ii) Negative electric flux:-** If the electric lines of forces move inside the closed surface then the electric flux is negative.

**Q. square frame of each side 10 cm is placed in a uniform electric field 20 such that normal on the frame makes an angle 60 with the direction of electric field . calculate the electric flux linked with the frame ?**

Ans. 0.1Nm2/c

**Q. A surfaces = 10 is kept in an electric field = Calculate The electric flux linked with the surface.**

Ans. 20

**Q. Define gauss theorem and prove it ?**

**Ans**. **Gauss theorem :-** According to gauss theorem. The electric flux which is passing normally through a closed surface is equal to the times of the total charge present inside the closed surface .”

' or '

**Proof of gauss theorem:-** Let a charge Q is placed at a point O inside the closed surface .

Consider a small area dA at a point P on the surface. The distance of point P from the point O is r. Then according to the figure the electric flux passing through the small area is:

=

 =

=

{ for air ‘ or’ vacuum, }

**Q. A charge is placed inside a cube of side metre then calculate the electric flux which is passing through the one face of the cube.**

Ans.



**Note:-** Gauss theorem can be used to find the intensity of electric field at any point due to a charge. To find it, first we take a surface which is symmetrical for the given charge distribution. This surface is called Gaussian surface. as shown in figure.

**Q . Derive the relation for the intensity of electric field due to a point charge with the help of gauss theorem ?**

Ans. Let there is a point charge Q at a point O. We want to find the intensity of electric field at point P which is at a distance r from the charge Q. A Gaussian surface is drawn of radius r. Then According to the figure, the electric flux passing through Gaussian surface is :

 = E

= E

= E

**Q. With the help of gauss theorem, prove the coulomb's law ?**

Ans. In figure there is a point charge Q and another charge q is at a point P at distance r from the point O. We want to find the force which is acting b/w the two charges. For this draw a sphere of radius r known as Gaussian surface. On this surface at a point P consider a small area dA. Then according to the figure, the electric flux passing through this area through the surface is :

= E

= E

This is the coulomb's law.

**Q. Derive the relation for the intensity of electric field at a point P due to a uniformally charged conducting sphere (or a spherical shell ) with the help of gauss theorem –**

**(i) When the point P is outside the spherical shell .**

**(ii) When the point p is on the surface of spherical shell .**

**(iii) When the point P is inside the spherical shell ?**

Ans. Figure shows a conducting sphere of radius r with charge + Q. We want to find the intensity of electric field at a point P at a distance *x* from the centre of the sphere in the following three cases .

**(i) When the point P is outside the spherical shell :-** According to the figure consider a Gaussian surface of radius *x*. This surface is symmetrical to the spherical shell. Then electric flux passing through the Gaussian surface is :



= E

= E

**(ii) When the point p is on the surface of spherical shell:-** In this case , *x* = r

So ,

E =

**(iii) When the point P is inside the spherical shell :-** In this case , because there is no charge inside the spherical shell . So the net intensity of electric field inside the spherical shell is zero .

E = 0

**Note**:- The graph shows the variation of electric field intensity with distance *x* for the uniformally charged conducting sphere.

**Q. Derive the relation for the electric field intensity due to a linear charged conductor of infinite length.**

Ans. Figure shows a linear charged conductor of infinite length, which is having linear charge density (i.e. charge per unit length) on it. We want to determine the intensity of electric field at point P. For this we draw a Gaussian surface of radius and length . Then according to the figure the electric flux passing through the small area is

= E

**Q. Derive the relation for the electric field intensity due to a uniformly charged non conducting sheet of infinite length.**

Ans. Figure shows a uniformly charged non conducting sheet of infinite length. let this sheet is having surface charge density (i.e. charge per unit area) on it. Then according to the figure the total electric flux passing through this sheet is

**Q. Derive the relation for the electric field intensity due to two uniformly charged parallel infinite plane sheets at the following point –**

**(1) When the point is beyond the sheet.**

**(2) When the point is in bw. the sheets ( It is given that the charge density on the two sheets is of the opposite nature).**

Ans. Figure shows The two parallel non conducting sheets A and B which is having & charge density respectively. we want to find the intensity of electric field at point (which is beyond the sheet ) and (which is in between the sheet).

* Intensity of electric field at point =>

Intensity of electric field at point due to sheet A is –

Intensity of electric field at point due to sheet B is -

So, the net intensity of electric field at point is–

* Intensity of Electric Field at point :

Intensity of electric field at point due to sheet A is –

Intensity of electric field at point due to sheet B is –

So , the net intensity of electric field at point is -

* Intensity of electric field at point =>

intensity of electric field at point due to sheet A is

Intensity of electric field at point due to sheet B is.

So , the net intensity of electric field at point is –

**Q. Explain the following –**

* Conductor (ii) Insulators (iii) semiconductors

Ans. (i) conductors => conductors are those substance in which current can flow easily .in conductors there are very large number of free electrons. Examples of conductors are metals ,human body etc.

(ii)insulators=>insulators are those substance in which current does not flow because the number of free electrons in it is very less ex. Wood, plastics, rubber etc.

(iii)semi conductors=>semi conductors are those substance in which number of free electrons neither very large nor very less.in it at low temperature conduction is not possible. but at high temperature the electric conduction is possible in them. Ex=>carbon, silicon, germanium etc.

**Q. Explain the difference between conductors and insulators**

Ans.

|  |  |
| --- | --- |
| **Conductors** | **Insulators** |
| (i) Electric conduction is possible in it. | (i) Conduction of electricity is negligible in it. |
| (ii) It has very large number of free electrons. | (ii) It has negligible number of free electrons. |
| (iii) **Ex. :-** Metals, human body etc. | (iii) **Ex. :-** Wood, rubber, plastic etc. |

**Q. ordinary rubbers are insulator. but the tyres of an aeroplane are made little bit condcuting why.**

Ans.Because when aeroplane lands its tyres get charged , if tyres are made conducting

Then the charge will pass in to the earth. .

**Q. the vehicles carrying inflammable substance have metallic strings suspended from them touching the ground ,why .**

Ans. so that the charged produced on the body of the vehicles, due to the friction of tyre will pass to the earth through the metallic string touching the ground .

**Q. you are going by a car suddenly lightening appears . what will you do ?**

Ans. better to close the window and remain inside the car because the charge inside the car

is zero.

**Class E.M.**

**Chapter : Electrostatics**

**Q.1 Multiple choice questions :**

**(i) The number of electrons in one coloumb charge is :**

**(a) (b)**

**(c) (d)**

Ans. (b)

**(ii) The forces exerted on a point charge by three other respective point charges are and . The total force experienced by the point charge is :**

**(a) (b)**

**(c) (d) None of these**

Ans. (c)

**(iii) The unit of linear charge density is :**

**(a) coloumb (b) coulomb metre**

**(c) meter/coulomb (d) coulomb/metre**

Ans. (d) coulomb/metre

**(iv) The ratio of forces and between the two point charges and placed in air and in a medium of dielectric constant , respectively is equal to :**

**(a) (b) (c) (d)**

Ans. (a)

**(v) Te intensity of electric field E due to charge at distance r :**

**(a) (b) (c) (d)**

Ans. (b)

**(vi) The torque on an electric dipole placed in an electric field is :**

**(a) (b) (c) (d)**

Ans. (b)

**(vii) The potential energy of an electric dipole placed in a uniform electric field is :**

**(a) (b)**

**(c) (d)**

Ans. (c)

**(viii)Dielectric constant of air is :**

**(a) (b)**

**(c) Infinite (d) None of these**

Ans. (b)

**(ix) Electric field intensity inside a charged conducting hollow sphere :**

**(a) is zero at all points**

**(b) is equal to the electric field at the surface, at all points**

**(c) increases from surface to the centre**

**(d) decreases from surface to the centre**

Ans. (a) is zero at all points

**(x) A charge is kept inside a cubical box. The total electric flux coming out of one surface of the cube will be :**

**(a) (b) (c) (d) Zero**

Ans. (c)

**(xi) The electric field intensity at a distance ‘r’ from a charged plane sheet with surface density is :**

**(a) (b) (c) (d)**

Ans. (a)

**(xii) A force is acting between two point charges and placed at a distance If one charge is fixed and the other revolves around it in a circle of radius ‘’, then work done will be :**

**(a) (b) (c) (d) Zero**

Ans. (d) Zero

**Q.2 Fill in the blanks :**

**(i) The unit of surface charge density is ………………..**

Ans.

**(ii) Electric dipole moment is a …………..quantity.**

Ans. vector

**(iii) The force acting between two point charges is …………..proportional to the square of distance.**

Ans. inversely

**(iv) The S.I. unit of permittivity in free space is ………………..**

Ans.

**(v) The dimensional formula of electric dipole moment is ………………**

Ans.

**(vi) The charge on a proton is …………………..coulomb.**

Ans.

**(vii) represent the ………………of air.**

Ans. permittivity

**(viii) The charge on an electron is called ……………charge.**

Ans. Fundamental

**(ix) The S.I. unit of electric field intensity is ……………..**

Ans.

**(x) …………..electric lines of force are passing through coulomb charge.**

Ans.

**Q.3 TrueFalse :**

**(i) The unit of electric force in C.G.S. system is dyne.** (True)

**(ii) The amount of charge on a charged object is an integral multiple of charge** (True)

**(iii) The law of conservation of charge is not valid in relative motions.** (False)

**(iv) The coulombian force acting between two point charges is unaffected by the other charges present in that field.** (True)

**(v) Coulomb's inverse square law cannot be derived by Gauss' theorem.** (False)

**(vi) A torque acts on a dipole kept in an electric field of uniform intensity.**(True)

**Q.4 Match the pairs :**

**(i) The unit of intensity of electric field (a) coulomb metre**

**(ii) Potential energy of electric dipole (b) newton/coulomb**

**(iii) Unit of moment of force (c)**

**(iv) Quantization of charge (d) newton metre**

**(v) Electric dipole moment (e)**

Ans. (i) b (ii) c (iii) d (iv) e (v) a

**Important questions**

Q. (1) Explain the limitations of coulomb’s law.

(2) Define unit charge on the basis of coulomb’s law

(3) Electric dipole (4) Dipole Moment (5) Electric flux.

Q. Define electric lines of forces & its properties. (any Four )

Q. Derive the relation for the intensity of electric field due to an electric dipole in end on position when the dipole is very small.

Q. Derive the relation for the intensity of electric field due to an electric dipole in broad side on position. When the dipole is very small.

Q. Derive the relation for the force & torque which is acting on an electric dipole. Which is placed in an uniform electric field & when this force will be maximum and on the basis of formula of torque Define dipole moment.

Q. Define Gauss theorem & prove it.

Q. With the help of Gauss theorem Derive the relation for the Intensity of electric field due to a point charge .

Q. With the help of Gauss Theorem prove coulomb's law .