ELECTROSTATICS

One Marks Questions with Answers:

1.What is an electric charge?

Ans: It is a fundamental property of matter which is responsible for all electrical effects

2. Write the SI unit of charge?

Ans: The SI unit of charge is coulomb (C).

3.Write the dimensional formula of electric charge.

Ans: $[M^0 L^0 T^1 A^1]$

4. Electric charge is conserved. Explain.

Ans: The principle of conservation of charge states that the total charge of an isolated system remains constant. It means that charges can neither be created nor be destroyed.

5.Electric charge is quantized. Explain.

Ans: The Principle of quantization states that in nature there is a certain smallest amount of electric charge and all the electric charges are integral multiples of the smallest unit. The total charge on a body is –e, -2e, -3e,………..-ne if it is negatively charged and +e, +2e, +3e, …………+ne if it is positively charged.

6.Is the charge of a body get affected due to its motion?

Ans: No The charge on a body is not affected due to its motion. $q_{static} = q_{dynamic}$

7. What is meant by electrification by friction?

Ans: The process of charging an uncharged body by rubbing it with another suitable body is called electrification by friction .

8.What is electrification?

Ans: Electrification is the process of charging a body by adding electrons to it or by removing electrons from it.

9.Name the different methods of charging a body.

Ans: (i) charging by friction (ii) charging by conduction and (iii) charging by induction.

10.Which is bigger – the charge on the electron or one coulomb (1 C)?

Ans: One coulomb is bigger than the charge on the electron. The charge on the electron is $e = 1.6 \times 10^{-19}$ C.

11.If 1000 electrons are removed from an isolated neutral metal sphere, calculate the charge acquired by sphere.

Ans: Charge acquired by the sphere is given by

Q = ne = 1000 x 1.6 x 10^{-19} C = 16 x 10^{-17} C.

12.Calculate the number of electrons that must be transferred to a neutral body to have a charge of -3.2 C.

Ans: Number of electrons to be transferred to a neutral body ,

n = $\frac{q}{e} = \frac{3.2\ C}{1.6\ x\ 10^{-19} C}$ = 2 x 10^{19}

13.Where do charge reside on conductor?

Ans: Charges reside on the outer surface of a conductor.

14.How many electrons make one coulomb of charge?

Ans: 6.25 x 10^{18} or 625 x 10^{16} electrons make one coulomb of charge.

15. At what regions on a conductor the charge accumulate more in quantity?

Ans: Charge accumulate more in quantity at the pointed ends of a conductor.

16.Define surface density of charge.

Ans: Surface density of charge at a point on the surface of a conductor is the ratio of total charge over a small area surrounding the point to the area. Charge per unit area is also called surface density of charge. It is denoted by σ and measured as C m^{-2}.

17.How is surface density of charge depend on the curvature of surface?

Ans: Surface density of charge is directly proportional to curvature of the surface.

18. How is surface density of charge depend on the radius of curvature of surface?

Ans: Surface density of charge is inversely proportional to the radius of curvature of the surface. i.e., $\sigma \propto \frac{1}{R}$

19. State Coulomb's law.

Ans: In a given medium, the electrostatic force of attraction or repulsion between two point charges is directly proportional to the product of the magnitude of charges and inversely proportional to the square of the distance between them. The force acts along the line joining the two charges.

20.Define unit charge or coulomb.

Ans: Unit charge is a charge which when placed in air at a distance of 1 m from an equal and similar charge exerts a repulsive force of 9 x 10^9 N.

21.If the distance between two charges is doubled how does the force between them change?

Ans: Force between them-becomes one fourth of the original value.

22.What is the value of permittivity of free space (ε_0)?

Ans: The value permittivity of free space is (ε_0) =8.854×10^{-12} Fm^{-1}

23.Does electrostatics force obey Newton's third law.

Ans: Yes. If charge Q_1 exerts a force on Q_2 then the charge Q_2 also exerts an equal and opposite force on Q_1.

24.Define relative permittivity (dielectric constant) in terms of electrostatic force.

Ans: Dielectric constant or relative permittivity of a medium is the ratio of the force between two point charges separated by a certain distance in air to the force between the same two charges separated by the same distance in the given medium.

i.e., $\epsilon_r = F_{air} / F_{medium}$

25.Is coulomb's law valid for all types of charge distributions?

Ans: Coulomb's law is valid for only stationary and point charge.

26. Coulomb's law valid for solids and moving charges?

Ans: No. Coulomb's law is not valid for solids and moving charges.

27.Is Coulomb's law an universal law?

Ans: Coulomb's law is not an universal law because it depends on the properties of intervening medium.

28.Is electrostatic force a conservative force?

Ans: Yes. Electrostatic force is a conservative force.

29.What is the absolute permittivity of a medium whose relative permittivity is 20?

Ans: Absolute permittivity is given by

$\varepsilon = \varepsilon_0 \ \varepsilon_r = 8.854 \times 10^{-12} \times 20 = 17.708 \times 10^{-11}$ Fm^{-1}.

30.Write down Coulombs law in vector form.

Ans: In vector form, Coulomb's law is

$$\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}^2} \times \hat{r}_{21} \quad \text{or} \quad \vec{F}_{21} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}^2} \times \hat{r}_{12}$$

31.What happens to force between two charged bodies when a glass plate is introduced in between them?

Ans: The force between two charged bodies decreases when a glass plate is introduced in between them..

32.How many electrons make one nano coulomb of electric charge?

Ans: Number of electrons n = $\frac{q}{e}$ = $\frac{10^{-9}C}{1.6x10^{-19}C}$ = 625 x 10^7 = 6.25 x 10^9

33.What is the force between two point charges which are 1 C each separated by 1 m in air?

Ans : F= $\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$ = $\frac{(9x10^9)x1x1}{(1^2)}$ = 9 x 10^9 N

TWO MARKS QUESTIONS WITH ANSWERS.

34.Write any two properties of charge.

Ans: (i) Like charges repel each other and unlike charges attract each other.

(ii) Charge is additive in nature. That is the net charge of a system is the algebraic sum of the charges comprising the system.

35.State and explain Coulomb’s inverse square law in electrostatics. What is the direction of electrical force between two point charges?

Ans: The electrostatic force of attraction or repulsion between two point charges is directly proportional to the magnitude of charges and inversely proportional to the square of the distance between them. The force acts along the line joining the two charges.

Consider two point charges q_1 and q_2 at rest in vacuum. Let r be the separation between them . According to Coulomb’s law, the force F between two point charges is given by

$$F \propto q_1q_2 \text{ and } F \propto \frac{1}{r^2} \;\therefore\; F \propto \frac{q_1q_2}{r^2} \text{ or } F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$$

ELECTROSTATIC FIELD

One Mark Questions with Answers:

1.Define electric intensity at a point in an electric filed.

Ans: Electric intensity at a point in an electric field can be defined as the force acting on an unit positive charge placed at that point.

2.Mention the SI unit of electric intensity.

Ans: SI unit of electric intensity is newton per coulomb (NC^{-1}) or volt per metre ($V\ m^{-1}$)

3.Is electric filed intensity a vector or a scalar?

Ans: Electric field intensity is a vector quantity.

4. Write an expression for electric field due to a point charge.

Ans: Electric field due to a point charge, E = $\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$

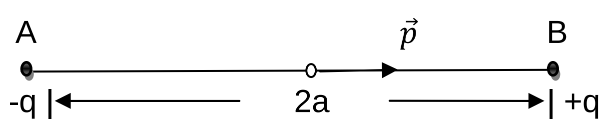
5.What is the force acting on a charge q placed in the electric field of intensity $\bar{E}$?

Ans: Force acting on a charge in electric field of intensity E is $\bar{F}$ = q $\bar{E}$.

6.Write the dimensions of E.

Ans: Dimensions of E = $\frac{F}{q}$ = $\frac{F}{It}$ = $\frac{[MLT^{-2}]}{AT}$ = $[M^1L^1T^{-3}A^{-1}]$

7.What is an electric dipole?



Ans: A pair of equal and opposite charges separated by a small distance is called an electric dipole.

8.Define electric dipole moment.

Ans: Dipole moment is defined as the product of one of the charges q and the distance (or separation) between the charge 2a along the dipole axis i.e.,

$$\vec{p} = q \times 2\vec{a} \quad \text{or} \quad \vec{p} = 2a\,q\,\hat{p} \quad \text{or} \quad \vec{p} = (q)\ (2a)\ \hat{p}$$

9. What is the direction of the dipole moment?

Ans: The dipole moment is a vector directed from the negative to the positive charge along the dipole axis.

10.Write the SI unit of dipole moment.

Ans: The SI unit of dipole moment is coulomb meter (C-m)

11.Is dipole moment a vector or a scalar?

Ans: Dipole moment is a vector.

12.Write the dimensions of dipole moment.

Ans: Dimensions of dipole moment.

P = q x 2a = (It) x 2a = (AT)L= $[M^0L^1T^1A^1]$

13.Write an expression for electric intensity at a point on the axial line of the dipole.

Ans: Electric intensity . $\vec{E}_{\text{axial}} = \frac{1}{4\pi\varepsilon_0}\frac{2pr}{(r^2-a^2)^2}\ \hat{p}$. If a^2 is neglected, a << r

Then $\boldsymbol{\vec{E}_{\text{axial}} = \frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}\ \hat{p}}$

14.Write an expression for electric intensity at a point on the equatorial line the dipole.

Ans: Electric Intensity, $\vec{E}_{\text{equatorial}} = \frac{1}{4\pi\varepsilon_0}\frac{p\qquad\hat{p}}{(r^2+a^2)^{3/2}}$. If a^2 is neglected, a << r

Then $\boldsymbol{\vec{E}_{\text{equatorial}} = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}\ \hat{p}}$

15.Write an expression for electric intensity at a point due to an electric dipole.

Ans: Intensity at a point $\boldsymbol{\vec{E} = \frac{1}{4\pi\varepsilon_0}\ \frac{p}{r^3}\ \sqrt{3cos^2\theta + 1}\ \ \hat{p}}$

16.If E_{axial} and $E_{equatorial}$ are the electric intensities at a point in the end on position and at equidistance point in the broad side-on position respectively of a dipole, then give their ratio.

Ans: $\boldsymbol{\frac{\text{Eaxial}}{\text{Eequatorial}} = \frac{2}{1}}$ or $E_{axial} : E_{equatorial}$ = 2:1

17.What happens to an electric dipole when it is placed in an uniform electric field?

Ans: When an electric dipole is placed in a uniform electric field it is acted upon by a torque. The net force on the dipole is zero. If free to move, the dipole must align with its dipole moment vector along the direction of the field.

18.What is the net force on an electric dipole which is placed in a uniform electric field?

Ans: The net force on the dipole is zero.

19.Define dipole moment of an electric dipole in terms of the torque acting on it in a uniform electric filed.

Ans: The dipole moment of an electric dipole is equal to the torque acting on the dipole when it is placed at right angles to a uniform electric field of unit strength.

20.For what angle of inclination, the torque on a dipole in an electric field be

(a) maximum and (b) minimum?

Ans:(a) The torque on a dipole is maximum when $\theta = 90^0$ i.e., when axis of the dipole is perpendicular to the direction of electric field. (b) the torque on a dipole is minimum when $\theta = 0^0$ i.e., axis of the dipole is parallel to the direction of electric field.

21.Is torque acting on an electric dipole a scalar or a vector?

Ans: The torque acting on an electric dipole is a vector.

22.What are dielectrics?

Ans: Dielectrics are insulators. They have no free electrons and hence they do not conduct electricity .However they transmit electric filed.

23.What are polar molecules?

Ans: The molecules of a dielectric which act like tiny electric dipoles and posses permanent dipole moment are called polar molecules.

Ex HCl , N_2O, H_2O, NH_3 etc.

24.What are non-polar molecules?

Ans: The molecules of a dielectric which do not possess a permanent dipole moment but get induced with dipole moment in an electric field are non-polar molecules.

Ex: N_2 ,H_2 , CO_2 etc.

25.What is meant by electric polarization?

Ans: The elongation of dielectric atoms due to separation of charges in the atoms under the action of external electric field is called electric polarization.

26.What is the effect of dielectric when it is placed in an electric field?

Ans: The total electric field inside the dielectric material gets decreased.

27. Define dielectric strength of a dielectric.

Ans: The maximum value of the electric field that can be applied to the dielectric, without causing electric breakdown is called the dielectric strength of the dielectric.

28.Write the SI unit of dielectric strength.

Ans: Dielectric strength is expressed in kilo volt per millimeter (kV mm^{-1}).

29.Define an electric line of force.

Ans: Electric line of force in an electric field is defined as an imaginary path along which an isolated unit positive charge moves or tends to move. It may be straight or curved.

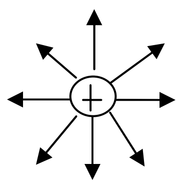
30.Can two electric lines of force intersect each other?

Ans: No. Two electric lines of force never intersect each other.

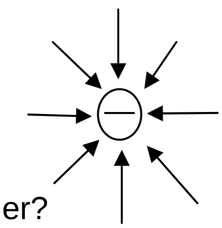
31.Draw the lines of force around an isolated (i) positive point charge (ii) negative point charge.

Ans:

a) Positive Point charge q > o



b)Negative point charge q < 0



32.Why two electric lines of force never intersect each other?

Ans: The tangent drawn to the electric lines force give the direction of electric filed. In case two lines of force intersect, there will be two directions of the electric field at the point of intersection, which is not possible.

33. What is neutral point in a combined electric field?

Ans: A neutral or null point in a combined electric field is that point at which the resultant electric field is zero.

34.Define electric flux.

Ans: The number of electric field lines penetrating normally through a surface is called electric flux.

35.Is electric flux a vector or a scalar?

Ans: Electric flux is a scalar quantity.

36. What is the unit of electric flux?

Ans: SI unit of electric flux is N m^2 C^{-1} or V m.

37. State Gauss's theorem in electrostatics.

Ans: The total electric flux through any closed hypothetical surface is equal to $(1/\varepsilon_0)$

times the net charge enclosed by the surface.

38.What is magnitude of electric intensity inside a charged hollow sphere?

Ans: The electric intensity at a point inside a charged hollow sphere is zero.

39.A charge q is placed at the center of a cube of side a. what is the electric field at the centre of the cube?

Ans: Electric filed at the center of the cube is zero.

40. Define electric potential at a point.

Ans: Electric potential at a point in an electric field is the work done in bringing a unit positive charge from infinity to that point against the direction of the field.

41.Name the SI unit of electric potential.

Ans: The SI unit of electric potential is volt (V).

42.Is electric potential a scalar or a vector?

Ans: Electric potential is a scalar quantity.

43.What is an equipotential surface? Write examples.

Ans: An equipotential surface in an electric field is a surface on which the electric potential is same at all points on the surface Ex: (i) surface of a charged spherical conductor (ii) Surface of a charged conductor of any shape. (iii) Surface of a sphere which enclose a point charge at its centre.

44.Explain why the work done in moving a charge on an equipotential surface is zero?

Ans: Work done to move a charge along an equipotential surface is zero.Since any two points on it are at the same potential the Potential difference between them is zero.

45.Is electric field parallel or perpendicular to the equipotential surface?

Ans: The electric field E is always perpendicular to the equipotential surface.

46.Do two equipotential surface intersect each other?

Ans: No.Two equipotential surfaces will never intersect each other. If they intersect,then at the point of intersection there will be two values for the same potential, which is not possible.

47.What is the unit of potential gradient?

Ans: SI unit of potential gradient is V/m

48. Is electric potential at a point zero when electric field is not zero at that point?

Ans: Yes it can be zero e.g. at any point on the equatorial line of the dipole.

49.What is the value of electric potential at infinity?

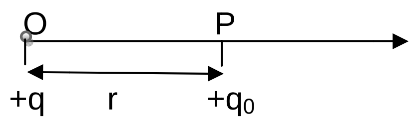
Ans: The value of electric potential is zero at infinity.

50.Define electric potential energy of a charge at a point in an electric field?

Ans: The electric potential energy of a charge at a point in an electric field is the work done in bringing the charge from infinity to that point.

51.Derive an expression for electric intensity at a point due to an isolated point charge.

Ans: Consider a point charge +q at a point O. Let P be a point at a distance r from the charge at 0. To determine the electric intensity at *P.* a test charge + q_0 is placed at p.



According to Coulomb's law force on test charge q_0 due to charge q is

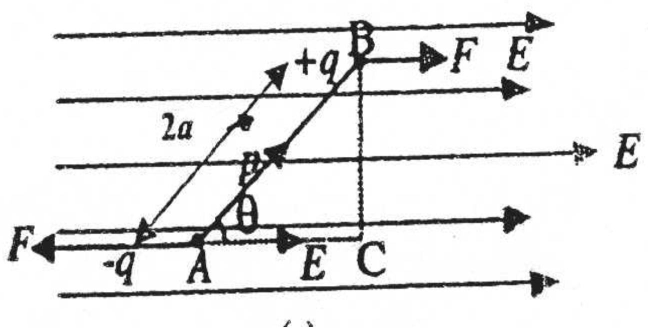
F = —— —— in the direction OP.

Since electric field E = —   force per unit positive charge

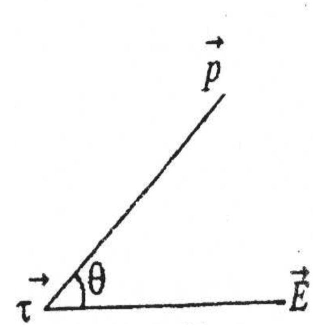
Electric intensity at *P* is $\boxed{E = —— —}$ along OP i.e., from source charge to test charge.

52.Derive an expression for torque acting on a dipole situated in electric field.

Ans



(a)



(b)

Consider an electric dipole made of charges –q and +q separated by a small distance 2 a placed in a uniform electric field E. Let the dipole be in equilibrium in the field making an angle   with the filed direction. Force on charge +q at B F = qE along the direction of

Force on charge – q at A F = qE along the direction of -$\vec{E}$. The dipole is under the action of two equal and opposite parallel forces. The net force on the dipole is zero. These unlike parallel force form a couple which rotates the dipole in the clock wise direction tending to along it in the direction to field.

Torque on the dipole. τ = One of the forces x perpendicular distance between the two forces

$\tau =$ F x BC = F x AB sin θ = F 2a sin θ

τ = qE 2a sin θ or τ = (2a)q. E sin θ = pE sin θ

In vector form, $\vec{\tau} = \vec{P} \times \vec{E}$

53. Write any two characteristics of lines of force.

Ans: Any two of the following.

(a) Electric lines always start from positive charge and end at negative charge.

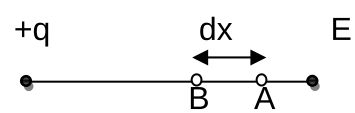
(b) Electric lines of force can never intersect each other.

(c) Electric lines of force always in a state of tension.

(d) Electric lines of force are always perpendicular to a charged conductor.

54. Derive the relation between electric intensity and electric potential due to a point charge.

Ans: Consider two points A and B separated by a small distance dx in an electric field. Since dx is small, the electric field E is assumed to be uniform along AB. The force acting on a unit positive charge at A is equal to E.



(Relation between electric potential and electric field)

Work done in moving a unit positive charge from A to B against the electric field is

dW = - E dx. The negative sign shows that the work is done against the direction of the field. Since the work done is equal to p.d dV between A and B then

dV = - E dx or $\boxed{E = -\frac{dV}{dx}}$

Thus, the electric field at a point is the negative potential gradient at that point.

55.An electric dipole of moment 2 x 10^{-8} C m is placed in an electric field of 5 x 10^{-5} NC^{-1}, with its axis making an angle of 30^0 with the field. What is the torque acting on the dipole?

Solution : Given p = 2 x 10^{-8} C m, E = 5 x 10^{-5} NC^{-1} and $\theta = 30^0$. Torque acting on the dipole is τ = p E sin θ = 2 x 10^{-8} x 5 x 10^{-5} x sin 30^0 = 5 x 10^{-13} N m

56.Write an expression for potential energy of system of three charges.

Ans: Potential energy, $U = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1 q_2}{r_{12}} + \frac{q_2 q_3}{r_{23}} + \frac{q_3 q_1}{r_{31}}\right]$

Four Marks Questions with Answers:

57. Write any four properties of lines of force.

Ans: The imaginary path traced by a unit positive charge in an electric field is known as the line of force.

(1) The lines of force originate from a positive charge and terminate at a negative charge.
(2) Electric lines of force are crowded and more curved where the charges are more.
(3) Electric lines of force can never intersect each other.
(4) Electric lines of force are always perpendicular to a charged conductor.

58. State Gauss' theorem. Derive an expression for electric intensity at a point outside a charged spherical conductor.

Ans: Consider a spherical conductor of radius R carrying a charge of +q. The charge is distributed uniformly on the outer surface of a spherical conductor.

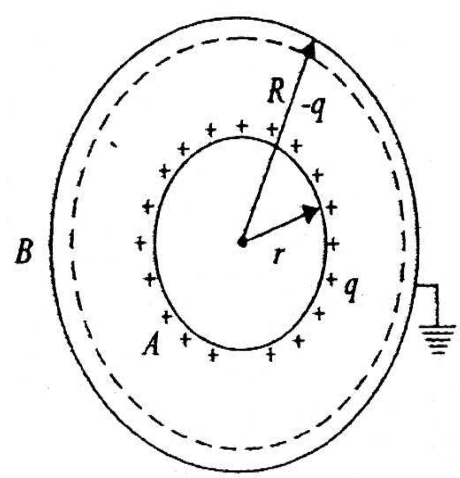


Fig. 11.4 Spherical capacitor

Case 1: **At a point outside the spherical conductor.**

Ans: Let P be a point outside the spherical conductor at a distance d from the center of the sphere. To find electric intensity at P imagine a Gaussian sphere of radius d passing through P with O as centre. Since the charges are distributed uniformly on the surface of the conductor, the electric intensity E is same at all points on the Gaussian surface. The flux on this surface is normal everywhere.

Total electric flux through the Gaussian surface is $\phi = \sum(E\ cos\theta)$ ds

But $\theta = 0^0$ since E is along the normal to the surface at all points.

$\therefore \phi = E \sum dS = E\ 4\ \pi\ d^2$

Here $dS = 4\pi\ d^2$, area of the Gaussian spherical surface.

According to Gauss's theorem, $\phi = \frac{1}{\varepsilon_0} \times q$

From Eq.s. (1) and (2) $\quad E.\ 4\ \pi\ d^2 = \frac{q}{\varepsilon_0}$

or $\quad E = \frac{1}{4\pi\varepsilon_0}\frac{q}{d^2}$

In vector notation. $\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{d^2}\ \hat{d}$ where $\hat{d}$ is an outward drawn normal.

Case 2: **For a point near the surface of the conductor.** If the point P is near or on the surface of the spherical conductor then d = R. Then.

Electric intensity $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2} = \frac{\sigma}{\varepsilon_0}$ where $\sigma = \frac{q}{4\pi R^2}$ the surface density of charge.

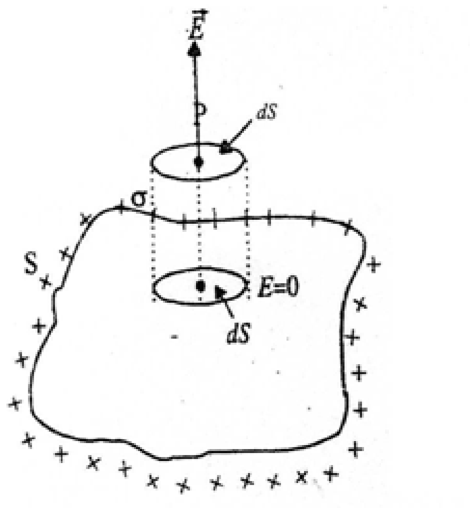
Case 3: **For a point inside the conductor.**

If the point P is inside the sphere, the closed spherical Gaussian surface passing through P does not enclose any charge i.e., q=0. Because the charges reside only on the outer surface of the conductor so E = 0 ($\because \phi = 0$)

Note: No electric filed inside a charging conducting spherical conductor.

59.Derive an expression for electric intensity at a point neat the surface of a charged conductor.

Ans: Consider a surface S of a charged conductor of an arbitrary shape. The density of charge may vary from point to point. Let P be a point near the surface and σ be the surface charge density at a point on the conductor close top. The direction of electric field near the conductor is normal to the surface.



Electric field near a charged conductor

Construct a cylindrical pill box (Gaussian surface) of area of cross-section dS. One end face of area dS containing the point P lies outside the surface and the other end face of area dS lies inside the surface of a charged conductor. Thus, the electric flux across the end face inside the surface of the conductor is zero since the electric intensity is zero. Electric flux through the curved side surface of cylinder is also zero. The electric flux through the end face of area dS outside the surface is E dS.

Total electric flux through the Gaussian surface is

$$\phi = E\ dS$$

Charge enclosed by the closed surface is q = σ ds

According to Gauss's theorem,

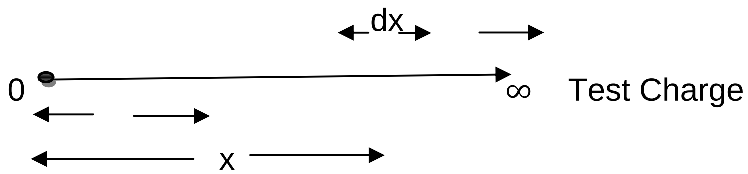
$$\phi = \frac{1}{\varepsilon_0} q = \frac{1}{\varepsilon_0} (\sigma\ dS)$$

From the above equation E dS = $\frac{1}{\varepsilon_0} (\sigma\ dS)$

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

or

60.Derive an expression for electric potential at a point due to an isolated charge.



Consider a point charge +q located in free space at O. Let P be a point at a distance r from the charge. We have to find the electric potential at P. Let A and B be two points in the electric field separated by a small distance dx. Let A be a point a distance x from O.

The electric intensity at A is given by E = $\frac{1}{4\pi\varepsilon_0}\frac{q}{x^2}$ along OA.

Work done in moving a test charge from A to B through a small distance dx against the electric field is given by,

dW = - F *x* dx (∵ Work = Force x Displacement)

Negative sign indicates that work is done against the electric field.

dV q_0 = - (E q_0) dx

dV = - E dx = - $\frac{1}{4\pi\varepsilon_0}\frac{q}{x^2}$ dx……….(1)

Total work done in moving a test charge from ∞ to a point P can be obtained by integrating equation (1) between the limit x = ∞ and x = r

Electric potential at P is given by

$$\int dV = -\int_{x=\infty}^{x=r}\frac{1}{4\pi\varepsilon_0}\frac{q}{x^2}\,dx$$

$$V = \frac{q}{4\pi\varepsilon_0}\int_{x=\infty}^{x=r}\left\{\frac{-1}{x^2}\right\}dx = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{x}\right]_{x=\infty}^{x=r}$$

$$V = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r}-\frac{1}{\infty}\right] = \frac{q}{4\pi\varepsilon_0}\left[\frac{1}{r}\right]$$

Electric potential at P, V = $\frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

Electric potential is a scalar quantity.

When q is positive, potential V is positive and when q is negative, V is negative.

CAPACITORS

One Mark Questions with Answers:

1. Define Capacitance of a conductor.

Ans: Capacitance of a conductor is its ability to store the charges and it is given by the ratio of charge added to the conductor to the raise in its potential.

2. Mention the factors on which capacitance of a conductor depends.

Ans: Capacitance of a conductor depends on (i) its size and shape, (ii) dielectric constant of the medium and (iii) nature of nearby conductors.

3. What is a capacitor?

Ans: Capacitor is device used to store electrical charges or electrical energy. In its simplest form it has two parallel conductors separated by certain distance.The spac between the plates can be filled by a dielectric material.

4. Name the SI unit of capacitance.

Ans: The SI unit of capacitance is farad (F).

5. Define farad.

Ans: Capacitance of a conductor is said to be one farad if one coulomb of charge added the conductor raise its potential by one volt.

6.What is 1 coulomb/volt?

Ans: 1 coulomb/volt = 1 farad $\because$ q/V = C.

7.Is capacitance a scalar or a vector?

Ans: Capacitance is a scalar.

8.Write the expression for capacitance of a spherical conductor.

Ans: Capacitance of a spherical conductor of radius r is given by C = $\mathbf{4\pi\varepsilon_0 r}$.

9.A solid sphere and a hollow sphere have equal radii. Which one has higher capacitance?

Ans: Both have the same capacitance.

10.What is the effect on the capacitance of a capacitor if the space between the plates is filled with a dielectric medium of dielectric constant K?

Ans: The capacitance of the capacitor increase by a factor *K.*

11.How can the capacitance of a parallel plate capacitor be increased?

Ans: The capacitance of a parallel plate capacitor can be increased by (i) increasing the area A of the plates. (ii) decreasing the distance d between the plates and (iii) using a medium of higher dielectric constant $\boldsymbol{\varepsilon_r}$.

12. A parallel plate capacitor is connected to battery. A metal sheet of negligible thickness is placed between the plates. What is its effect on the capacitance?

Ans: The capacitance remains the same.

13.Write an expression for the capacitance of a spherical capacitor.

Ans: Capacitance $C_{\textbf{spherical}} = 4\, \boldsymbol{\pi}\, \boldsymbol{\varepsilon_0} \left(\frac{\boldsymbol{R\,r}}{\boldsymbol{R-r}}\right)$

R is radius of outer sphere and r is radius of inner sphere.

14.How can the capacitance of a spherical capacitor be increased?

Ans: The capacitance of a spherical capacitor can be increased by (i) using spheres of large radii (ii) decreasing the space between the conductors and (iii) using a medium of higher dielectric constant.

15.Define dielectric constant in terms of capacitance of a capacitor.

Ans: Dielectric constant, $\boldsymbol{\varepsilon_r} = C_{medium} / C_{air}$, The ratio of the capacitance of the capacitor with the given medium between the plates to that with air is known as dielectric constant.

16. Write an expression for capacitance of a cylindrical capacitor.

Ans: Capacitance of cylindrical capacitor is given by $C = \frac{\boldsymbol{2\pi\varepsilon_0 l}}{\boldsymbol{2.303\, log_{10}(R/r)}}$ where *l* is the length of the cylinder , R is the radius of outer cylinder and r is the radius of inner cylinder.

17. Write an expression for energy stored in a charged capacitor.

Ans: Energy, $\mathbf{U} = \frac{1}{2}\mathbf{CV^2} = \frac{1}{2}\frac{q^2}{C} = \frac{1}{2}\mathbf{q\,V}$

18.What happens to the energy stored in a capacitor when the charge on it is doubled?

Ans: Energy stored, U $= \frac{1}{2}\frac{(2q)^2}{C} = \mathbf{4}\left\{\frac{1}{2}\frac{q^2}{C}\right\}$ i.e the energy becomes four times the original value.

19. What is meant by equivalent capacitor?

Ans: An equivalent capacitor is a single capacitor that has the same capacitance as the actual combination of capacitors.

20. What fraction of energy drawn from the charging battery is stored in a capacitor?

Ans: Energy drawn , $U = q$ V

Energy stored is $\boldsymbol{U = \frac{1}{2} C V^2 = \frac{1}{2} q V}$ Therefore 50% of the energy drawn is stored.

21. Write the dimensional formula of capacitance.

Ans: $C = \frac{q}{V} = \frac{q}{W/q} = \frac{q^2}{W} = \frac{(It)^2}{W} = \frac{A^2s^2}{Nm} = \frac{A^2s^4}{kgm^2} = [M^{-1}L^{-2}T^4A^2]$

22. What is the dielectric constant of a perfect conductor?

Ans: Dielectric constant of a perfect conductor is infinity (∞).

23.Mention any two uses of capacitors?

Ans:(i) Capacitors are used in oscillatory circuits to generate desired frequency of oscillations. (ii) They are used to measure small currents.

24.Write the formula for the effective capacitance of a number of capacitors in series.

Ans: If C_p is the effective capacitance of a number of capacitors of capacitance C_1, C_2, C_3 ……C_n connected in parallel, then $\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots\ldots + \frac{1}{C_n}$

25. Write the formula for the effective capacitance of a number of capacitors in parallel.

Ans: If C_p is the effective capacitance of a number of capacitance of capacitance C_1, C_2 , C_3 , …………..C_n connected in parallel, then $C_p = C_1 + C_2 + C_3 + \ldots\ldots + C_n$.

26. 20 Capacitors, each of capacitance 5 μF are connected in series. What is the effective capacitance of the combination?

Ans: Effective capacitance, $C_s = \frac{C}{n} = \frac{5\mu F}{20} = 0.25\ \mu F$

27. 10 capacitors, each of capacitance 10 μF are connected in parallel. What is the effective capacitance of the combination?

Ans: Effective capacitance. $C_p = n\,C = 10 \times 10\ \mu F = 100\ \mu F$

28. What is the ratio of equivalent capacitance of n similar capacitors first connected first connected in parallel and then in series?

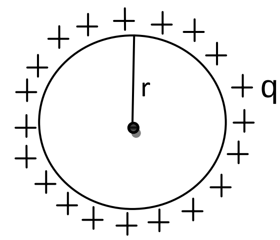
We know that $C_{p} =$ nC and $\mathbf{C_s = \frac{C}{n}}$ $\therefore \frac{C_p}{C_s} = \frac{n\,C}{C} = \mathbf{n^2}$

29. Derive an expression for the capacitance of a spherical conductor.

Ans: Consider an isolated spherical conductor of radius r and having a charge q placed in air or vacuum. The charge is distributed uniformly over the surface of the sphere. The potential at any point on the surface of the conductor is given by.

$$\mathbf{V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}}$$

$$\boxed{\textbf{Capacitance, } C = \frac{q}{v} = \frac{q}{q/4\pi\varepsilon_0 r} = 4\pi\varepsilon_0 r}$$



30.Mention the factors on which the capacitance of a parallel plate capacitor depends.

Ans: The capacitance of a parallel plate capacitor depends upon (i) The area A of the plate (ii) Distance d between the plates. (iii) The electric constant ε_r of the medium between the plates.

31. Mention the factors on which the capacitance of a spherical capacitors depends.

Ans: The capacitance of a spherical capacitance depends upon: (i) The radius r of inner conductor (ii) The radius R of outer conductor. (iii) Distance (R-r) between the separation between the conductors.

32.Mention the factors on which the capacitance of a cylindrical capacitor depends.

Ans: The capacitance of a cylindrical capacitor depends upon. (i) Length l of the cylinder.(ii) The radius r of inner conductor. (iii) The radius R of outer conductor (iv) The dielectric constant $\boldsymbol{\varepsilon_r}$ of the medium between the conductors.

33.Calculate the radius of a spherical conductor of capacitance 1 nF.

Ans: Radius, r = $\frac{C}{4\pi\varepsilon_0}$ = 9 x 10^9 x 10^{-9} = 9 m

34. Two metal spheres of radii R_1 and R_2 are charged to the same potential. What is the ratio of the change on the two spheres?

Ans: We know that

$C_1 = \frac{q_1}{V} = 4\pi\varepsilon_0 R_1$, and $C_2 = \frac{q_2}{V} = 4\pi\varepsilon_0 R_2$

$$\therefore \frac{q_1}{q_2} = \frac{4\pi\varepsilon_0 R_1}{4\pi\varepsilon_0 R_2} = \frac{R_1}{R_2}$$

35. A 20 pF capacitor is connected to 100 V battery. What is the energy stored in the capacitor?

Solution: Give C = 20 pF, V = 100 V and U =?

Energy stored in the capacitor is given by

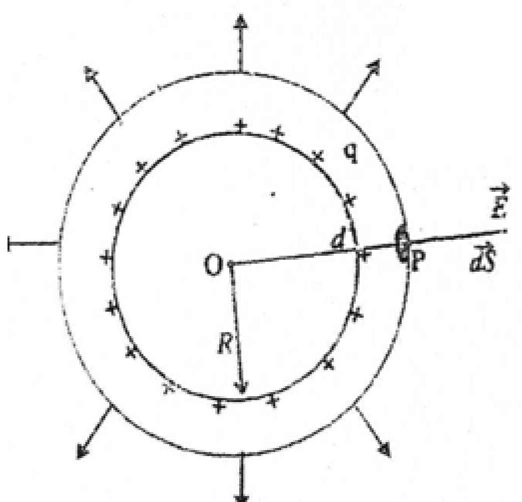
$$U = \frac{1}{2} CV^2 = \frac{1}{2} \times 20 \times 10^{-12} \times (100)^2 = 10^{-7}\ J$$

36.Write the expression for capacitance of a spherical capacitance with a diagram.

Ans: A spherical capacitor consist of two concentric hollow metallic spheres A and B which do not touch each other. The outer sphere is earthed while the charge is given to the inner sphere. Let r and R be the radii of spheres A and B respectively.

Capacitance of spherical capacitor is given by

$$C = 4\pi\varepsilon_0 \left(\frac{Rr}{R-r}\right)$$



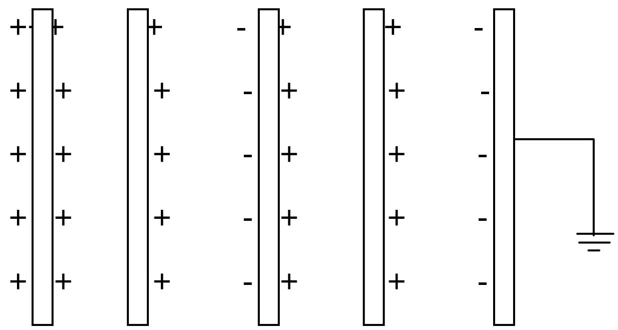
Electric field due to a charged spherical conductor

Four Marks Questions with Answers:

37. Explain with diagram the principle of a capacitor and define the capacitance of a capacitor.

Ans: A single conductor can store charge. But there is a limit. The amount of charge that same conductor can store may be increased if another identical conductor is brought near it. Consider a conductor M which carries charge +Q [Fig. 11.7(a)]. Let another identical conductor N be brought near M. Due to electrostatic induction, negative charges will be induced on the father face of N. The induced negative charge on N decreases the potential of M, where the induced positive charge on N increases the potential of M. Since the negative charge on N is nearer to M than the positive charge on N, the net potential of M is decreased. Therefore, to restore the potential of M to its initial value. Some amount of charge has to be given to it. The capacitance is thus increased by a small amount.

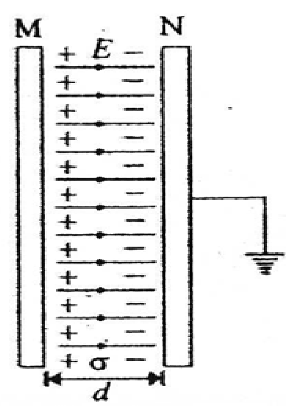
Let the second conductor N be earthed [Fig. 11.7(c)]. The positive charge on N gets neutralised due to the flow of electrons from the earth to the plate N. The induced negative charge on N greately reduced the potential of M. Hence, the capacitance is increased by a large amount. Thus, when a second earthed conductor is brought near M, it is able to store more charge. Capacitance of a capacitor is defined as the ratio of the magnitude of charge on either conductor to the p.d between the conductor forming the capacitor.



(principle of a capacitor)

38.Derive an expression for the capacitance with a diagram of a parallel plate capacitor.

Ans: A parallel plate capacitor consists of two insulated metal plates of the same dimensions placed parallel to each other, separated by a small distance d, compared with the plate dimensions. If the two plates are given equal and opposite uniform charge



Parallel plate capacitor

densities $\pm\sigma$, then the electric field between the plates is uniform and is given by

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

The electric field is directed from positive to the negative plates is uniform and is given by

$$Q = \sigma A$$

Potential difference between the plates = V = Ed = $\frac{\sigma d}{\varepsilon_0}$

Capacitance of the capacitor, C = $\frac{Q}{V} = \frac{\sigma A}{\frac{\sigma d}{\varepsilon_0}} = \frac{\varepsilon_0 A}{d}$

If the space between the plates is field with dielectric constant ε_r , then capacitance.

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

The capacitance (C) of a capacitor depends upon.

(a) The area of the plates (A)
(b) Distance between the plates (d)
(c) The dielectric constant of the medium between the plates (ε_r).

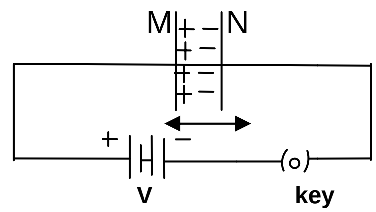
39. Derive an expression for the energy stored in a capacitor of capacitance C, carrying a charge Q at a potential difference V.

Ans: Capacitor is an electrical device used to store electric energy. Let the plates of a capacitor be connected to a battery of emf V volt and a plug key as shown in the figure. When the key is closed. Free electrons flow from the cell to the capacitor. This process is called charging the capacitor. When the capacitor is charged work is done by the battery. The work done is stored in the form of electrical potential energy in the capacitor. The potential difference across the capacitor is then.

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

Where C is the capacitance of the capacitor.

The work done in transferring an additional charge dQ at this potential is dU = V dQ = – dQ



The total work done in transferring a charge Q is

– – — —

U = —

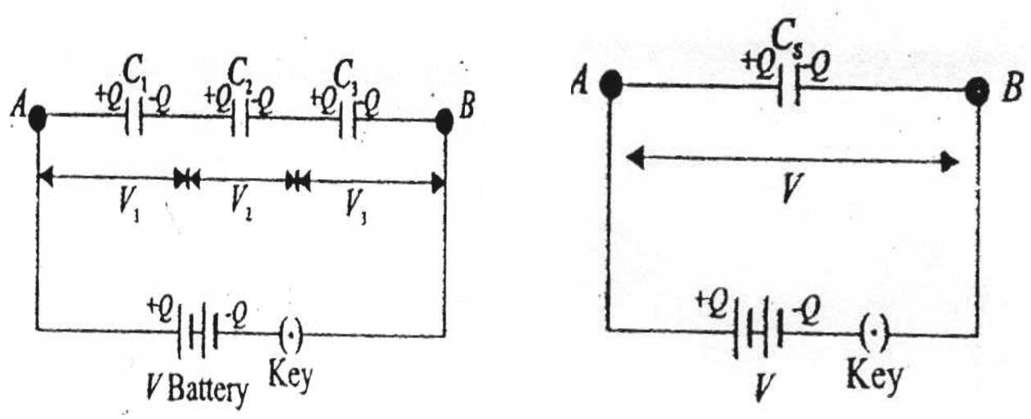
The amount of work done is stored as electrostatic potential energy. Thus, the energy stored in the capacitor is

Since Q = CV, U = —— **=** – CV^2

Also C = – , V = —— **=** – QV

Energy of the capacitor, U = – CV^2 = – — = – QV

40.Derive an expression for effective capacitance of three capacitors connected in series.



Ans: Consider three capacitors of capacitances C_1, C_2, and C_3 connected end to end between the points A and B as shown in the Fig. 11.12 (a). Let a battery of emf *V* volt be connected across the combination. Since the capacitors are connected in series, the charges on the plates are the same. Let the charges on the plates be +Q and –Q. Let

V_1, V_2 and V_3 be the potential differences across the plates of the capacitors C_1, C_2 and C_3 respectively.

$V_1 = \frac{Q}{C_1}$, $V_2 = \frac{Q}{C_2}$ and $V_3 = \frac{Q}{C_3}$

Since the p.d. across the combination is V.

$V = V_1+V_2+V_3 = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$

$V = Q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right]$

Let the series combination of capacitors between A and B be replaced by a single capacitor known as equivalent capacitor as shown in Fig 11.12(b). If C_s is the equivalent capacitance of the combination it should charge Q when changed to a potential V, then

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

Equating Equation (1) and (2) $\frac{Q}{C_s} = Q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right]$

$$\boxed{\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}}$$

For a number of capacitors C_1 , C_2, C_3, C_4………the effective capacitance in series is given by

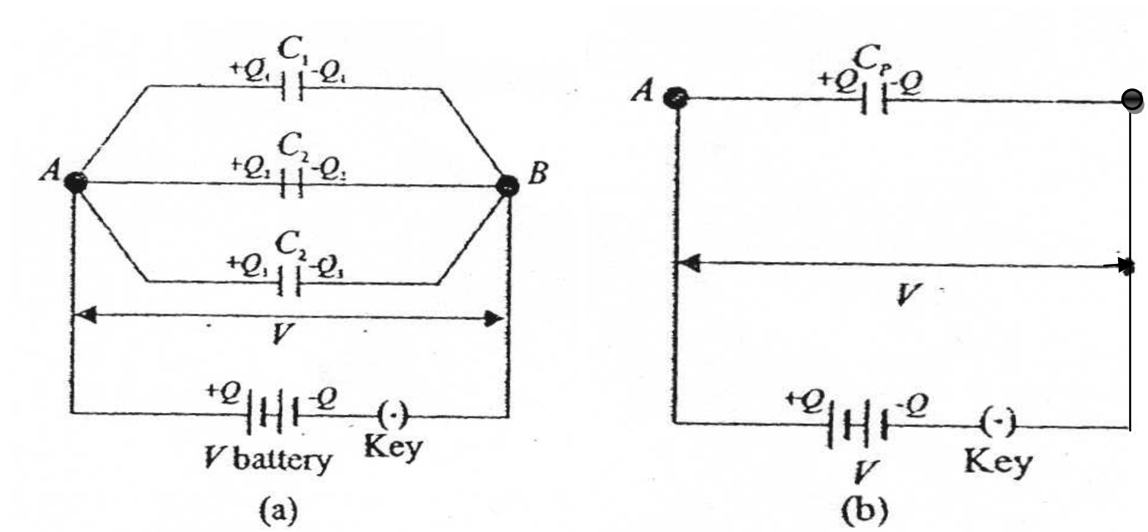
$\frac{1}{C_s} + \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \ldots\ldots + \frac{1}{C_n}$

Thus, the reciprocal of the equivalent capacitance C_s of a number of capacitors connected in series is equal to the sum of the reciprocals of the individual capacitances.

If all the capacitors are equal, then $\frac{1}{C_s} = \frac{n}{C}$ or $\boxed{C_s = \frac{C}{n}}$

Note: The equivalent capacitance of a series combination is always less than the least capacitance in the combination.

41.Derive an expression for the equivalent capacitance of three capacitors connected in parallel.



Ans: Consider three capacitors of capacitances C_1, C_2 and C_3 connected in parallel between A and B as shown in Fig. 11.13

(a) Let a battery of *emf* V volt be connected across the combination. Each capacitor has the same potential difference V.

The battery supplies a charge + Q which is distributed on the left plates of C_1, C_2 and C_3 connected to A. Let Q_1, Q_2 and Q_3 be the charges on the capacitors C_1, C_2 and C_1 respectively. Then

$$Q_1 = C_1V,\ Q_2 = C_2V \text{ and } Q_3 = C_3V$$

Total charge, $Q = Q_1 + Q_2 + Q_3 = C_1V + C_2V + C_3V$

$$Q = V(C_1+C_2+C_3)$$

Let the combination of capacitors between A and B be replaced a single capacitor known as equivalent capacitor as shown in Fig. 11.13(b). Let C_p be the capacitance of the equivalent capacitor, then

$$Q = VC_p$$

Equating Equation (1) and (2) $VC_p = V(C_1+C_2+C_3)$

For a number of capacitors C_1, C_2, C_3, C_4……….the effective capacitance in parallel is given by

$$C_p = C_1+C_2+C_3+\ldots\ldots\ldots.+C_n$$

Thus for parallel arrangement of capacitors, the sum of the individual capacitances is equal to the effective capacitance of the arrangement.

If all the capacitors are equal, then $\boxed{\mathbf{C_p = nC}}$

Note: In parallel combination, the equivalent capacitance is greater than the greatest capacitance.

42. Write the uses of Capacitors.

Ans: (1) Capacitors are used to store electric charges to produce high voltages.

(2) They are used to produce electric fields within a small space.

(3) They are used in oscillatory circuits to produce desired frequency of oscillation.

(4) They are used to eliminate sparking in electrical devices like induction coil etc.

(5) They are used to measure small currents.

(6) They are used in radio circuits for tuning.

(7) They are used to study the behavior of electrical materials when placed in an electric field.

(8) They are used to generate different types of waveforms such as saw tooth, triangular, square etc.

(9) It is used to determine dielectric constant of a material self inductance of a coil, mutual inductance of a pair of coils etc.

10.They are used to generate and detect electromagnetic waves.

11.They are used in ignition system of automobile engines.

12.Capacitor acts as a wattless resistance to the flow of alternating current but acts as an insulator to the flow of direct current.

13.They are used in electric flash lights.