UNIT- 1 ELECTROSTATICS STUDY MATERIAL

I.One marks (Book inside)

1. The unit of electric flux is

a) Nm^2C^{-1} b) Nm^{-2} C^{-1} c) Nm^2C d) Nm^{-2} C

2. An electric dipole is placed in a uniform electric field with its axis parallel to the field. It experiences

a) only a net force b) neither a net force nor a torque

c) both a net force and torque d) only a torque

3. The work done in moving 4μC charge from one point to another in an electric field is 0.012J. The potential difference between them is

a) 3000 V b)6000 V c)30 V d) 48 x 10^3 V

4. The electric field outside the two oppositely charged place sheets each of charge density σ is

a) $\frac{\sigma}{2\varepsilon_0}$ b) $-\frac{\sigma}{\varepsilon_0}$ c) $\frac{\sigma}{\varepsilon_0}$ d)zero

5. Which of the following quantities is a scalar?

a) Electric force b) Electric field c) Dipole moment d) Electric potential

6. Torque on a dipole in a uniform electric field is maximum when angle between P and E is

a)0^0 b) 90^0 c) 45^0 d) 180^0

7. Potential energy of two equal negative point charges of magnitude 2μC placed 1 m apart in air is

a) 2 J b) 0.36 J c)4 J d) 0.036 J

8. A hollow metallic spherical shell carrying an electric charge produces no electric field at points

a) on the surface of the sphere b) inside the sphere

c) at infinite distance from the centre of the sphere d) outside the sphere

9. The unit of electric field intensity is

a) NC^{-2} b) NC c) Vm^{-1} d) Vm

10. Four charges +q, +q, -q and –q respectively are place at the corners A, B,C and D of a square of side a. The electric potential at the centre O of the square is

a)1 /4 π ε_0 (q/a) b)1 /4 π ε_0 (2q/a) c) 1 /4 π ε_0 (4q/a) d) zero

11. The value of permittivity of free space is

a)8.854 x $10^{12}C^2N^{-1}$ m^{-2} b) 9 x 10^9 C^2N^{-1} m^{-2} c) 1/9x10^9 C^2N^{-1} m^{-2} d) 1/4 π x 9x 10^9 C^2N^{-1} m^{-2}

12. The principle use in lightining conductors is

a) corona discharge b)mutual induction c)self-induction d) electromagnetic induction

13. The unit of electric dipole moment is

a) volt / metre (V/m) b) coulomb / metre (C/m)

c) volt. metre (Vm) d) Coulomb. metre (Cm)

14. Electric potential energy of an electric dipole in an electric field is given as

a) pEsin θ b) –pEsin θ c) –pEcos θ d) pEcos θ

15. Electric field intensity is 400 V/m at a distance of 2m from a point charge. It will be 100 V/m at a distance of

a) 50 cm b) 4 cm c) 4m d) 1.5m

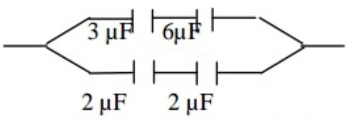
16. Which of the following is not a dielectric?

a) Ebonite b) Mica c) Oil d) Gold

17. The work done in moving 500μC charge between two points on equipotential surface is

a) zero b) finite positive c) finite negative d) infinite

18. In the given circuit, the effective capacitance between A and B will be



a) 3 μF b) 36/13 μF c) 13 μF

d) 7 μF

19. The direction of electric field at a point on the equatorial line due to an electric dipole is
a) along the equatorial line towards the dipole
b) along the equatorial line away from the dipole
c) parallel to the axis of the dipole and opposite to the direction of dipole moment
d) parallel to the axis of the dipole and in the direction of dipole moment.
20. The number of electric lines of force originating from a charge of 1 micro coulomb is
a) 1.129×10^{5} b) 1.6×10^{-19} c) 6.25×10^{18} d)8.85×10^{-12}
21. The equivalent capacitance of two capacitors in series is 1.5μF. The capacitance of one of them is 4 μF. The value of capacitance of the other is
a) 2.4 μF b)0.24 μF c) 0.417 μF d) 4.17 μF
22. The law that governs the force between electric charges is
a) Ampere's law b) Faraday;s law c) Coulomb's law d) Ohm's law
23. The unit of permittivity is
a) $C^2N^{-1}\ m^{-2}$ b) Nm^2C^{-2} c) Hm^{-1} d) $NC^{-2}\ m^{-2}$
24. An electric dipole place at an angle θ in a non- uniform electric field experiences
a) neither a force nor a torque b) torque only
c) bothe force and torque d) force only
25. A capacitor of capacitance 6 μF is connected to a 100 V battery. The energy stored in the capacitor is
a) 30 J b) 3J c) 0.03 J d) 0.06 J
26. When an electric dipole of dipole moment P is aligned parallel to the electric field E then the potential energy of the dipole is given as
a) PE b) zero c) –PE d) PE/.2
27. The capacitance of a paraller Plate capacitor increases from 5μF to 60 μF when a dielectric is filled between the plates. The dielectric constant of dielectric is
a) 65 b) 55 c) 12 d) 10
28. Quantisation of electric charges is given by
a) q = ne b) q = cv c) q = e/n d) q = c/v
29. An example of conductor is
a) glass b) human body c) dry wood d) ebonite
30. The magnitude of the force acting on a charge of 2 x 10-10 C placed in a uniform electric field of $10Vm^{-1}$ is
a) 2×10^{-9} N b) 4×10^{-9} N c) 2×10^{-10} N d) 4×10^{-10} N
31. Electric potential energy (U) of two point charges is
a) $q_1q_2 / 4\pi \varepsilon_0 r^2$ b) $q_1q_2 / 4\pi \varepsilon_0 r$ c) pE cosθ d) pE sinθ
32. The torque experienced by an electric dipole placed in a uniform electric field (E) at an angle θ with the field is
a) PE cosθ b) –PE cosθ c) PE sinθ d) 2PE sinθ
33. The capacitance of a parallel plate capacitor increases from 5 μF to 50 μF when a dielectric is filled between the plates. The permittivity of the dielectric is
a) $8.854 \times 10\text{-}^{12}\ C^2N^{-1}m^{-2}$ b) $8.854 \times 10^{-11}\ C^2N^{-1}m^{-2}$ c) 12 d) 10
34. The negative gradient of potential is
a) electric force b) torque c) electric current d) electric field intensity
35. When a point charge of 6μC is moved between two points in an electric field, the work done is 1.8×10^{-5} J. The potential difference between the two points is
a) 1.08 V b) 1.08 mV c) 3V d) 30 V
36. Three capacitors of capacitances 1μF, 2μF and 3μF are connected in series. The effective capacitance of the capacitors is
a) 6 μF b) 11 / 6 μF c) 6 / 11 μF d) 1 / 6 μF

37. An electric dipole of moment P is placed in a uniform electric field of intensity E at an angle θ with respect to the field. The direction of the torque is
a) along the direction of P b) opposite to the direction of P
c) along the direction of E d) perpendicular to the plane containing P and E
38. The electric field intensity at a distance r due to infinitely long straight charged wire is directly proportional to
a) r b) 1/r c) r^2 d) $1/r^2$
39. The ratio of electric potential at points 10 cm and 20 cm from the centre of an electric dipole along its axial line is
a) 1 : 2 b) 2 : 1 c) 1 : 4 d) 4 : 1
40. The intensity of electric field at a point is equal to
a) the force experienced by a charge q
b) the work done in bringing unit positive charge from infinity to that point
c) the positive gradient of the potential
d) the negative gradient of the potential
41. The capacitance of a capacitor is
a) directly proportional to the charge q given to it
b) inverely proportional to its potential V
c) directly proportional to the charge q and inversely proportional to the potential V
d) independent of both the charge q and potential V.
42. The intensity of the electric field that produces a force of 10-5 N on a charge of 5μC is
a) 5×10^{-11} NC^{-1} b) 50 NC^{-1} c) 2 NC^{-1} d) 0.5 NC^{-1}
43. The unit of the number of electric lines of force passing through a given area is
a) no unit b) NC^{-} ^{1}c) Nm^2C^{-1} d) Nm
44. If a point lies at a distance x from the mid – point of the dipole, the electric potential at this point is proportional to

a)$1/x^2$ b) $1/x^3$ c)$1/x^4$ d) $1/x^{3/2}$
45. A dielectric medium is placed in an electric field E_0. The field induced inside the medium
a) act in the direction of the electric field E_0 b) acts opposite to E_0
c)acts perpendicular to E_0 d) is zero
46. A non- polar dielectric is place in an electric field (E), its induced dipole moment
a) is zero b) acts in the direction of E
c)acts opposite to the direction of E d) acts perpendicular to E
47. n capacitors each of capacitance C are connected in series. The effective capacitance is
a) n/C b) C/n c) nC d) C
48. When the charge given to a capacitor is doubled, its capacitance
a) increases twice b) decreases twice
c)increases four times d)does not change
49. The value of relative permittivity of air is
a) 8.854 x 10- C^2 N m^{-2} b) 9×10^9 C^2 N m^{-2} c) 1 d) 8.854×10^{12}
50. The work done in moving 50μC charge between two points on equipotential surface is
a) zero b) finite positive c) finite negative d) infinite
51. The unit of relative permittivity is
a) C^2 N m^{-2} b) Nm^2C^{-2} c) No unit d) NC^{-2} m^{-2}
52. The electric field intensity at a short distance r from uniformly charged infinite plane sheet of charge is
a) proportional to r b) proportional to 1/r
c) proportional to $1/r^2$ d) independent of r
53. Two point charges +q and –q are placed at points A and B respectively separated by a small distance. The electric field intensity at the midpoint O of AB
a) is zero b) acts along AB

c)acts along BA d) acts perpendicular to AB

54. An electric dipole of dipole moment ‘p’ is kept parallel to an electric field of intensity ‘E’. The work done in rotating the dipole through an angle of 90^0 is :

a) zero b) – PE c) PE d) 2PE

55. The total flux over a closed surface enclosing a charge q (in $Nm^2 C^{-1}$)

a) $8\pi q$ b) $9 \times 10^9 q$ c) $36\pi \times 10^9 q$ d) 8.854×10^{-12} q

56. The repulsive force between two like charges of 1 coulomb each separated by a distance of 1 m in vacuum is equal to :

a) 9×10^9N b) 10^9N c) 9×10^{-9} N d) 9 N

57. What must be the distance between two equal and opposite point charges (say +q and –q) for the electrostatic force between them to have a magnitude of 16 N?

a) 4 √kq metre b)q/4 √k metre c) 4 kq metre d)4k / q metre

58. Point charges +q, +q, -q and –q are placed at the corners A,B,C and D respectively of a square is the point of intersection of the diagonals AC and BD. The resultant electric field intensity at the point O

(a) acts in a direction parallel to AB (b) acts in a direction parallel to BC

(c) acts in a direction parallel to CD (d) is zero.

59. The unit of molecular polarisability is

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

60. Two point charges $+q_1$ and $+q_2$ are placed in air at a distance of 2m apart, one of the charges is moved towards the other through a distance of 1m. The work done is.

a) $q_1q_2 / 4\pi \varepsilon_0$ b) $q_1q_2 / \pi \varepsilon_0$ c) $q_1q_2 / 8\pi \varepsilon_0$ d) $q_1q_2 / 16\pi \varepsilon_0$

61. Two capacitances 0.5µF and 0.75 µF are connects in parallel, Calculate the effective capacitance of the capacitor.

(a) 0.8µF (b) 0.7 µF (c) 0.25 µF (d) 1.25 µF

62. For which of the following medium, the value of relative permittivity is 1

(a) Mica (b) Air (c) Glass (d) Water

63. Van de Graff generator works on the principle of :

(a) electromagnetic induction and action of points (b) electrostatic induction and action of points

(c) electrostatic induction only (d) action of points only

UNIT : 1

(1)

ONE MARK ANSWER WITH SOLUTIONS

1. (a) $Nm^2 c^{-1}$
2. (b) neither a net force nor a torque.
3. (a). 3000V.
4. (d) 0
5. (d). Electric potential.
6. (b). 90°
7. (d) 0.036 J
8. (b) inside the sphere
9. (c) Vm^{-1}
10. (d) Zero
11. (d) $\frac{1}{4\pi \times 9\times10^9}$ $\quad c^2 N^{-1} m^{-2}$
12. (a) Corona discharge.
13. (d) Coulomb . metre.
14. (c) $-pE\cos\theta$.
15. (c) 4m.
16. (d) Gold.
17. (a) Zero.
18. (a) $3\mu F$
19. (c) Parallel to the axis of the dipole and opposite to the direction of dipole moment.
20. (a) 1.129×10^5
21. (a) $2.4\mu F$
22. (c) Coulomb's law
23. (a) $c^2 N^{-1} m^{-2}$
24. (c) both a force and torque
25. (c) 0.03 J

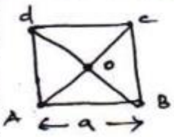
3. $V = W/q = \frac{0.012}{4\times10^{-6}} = \frac{12\times10^3}{4}$

$V = 3000\,V$.

7. $U = 9\times10^9 \times \frac{q_1 q_2}{r}$

$= \frac{9\times10^9 \times 2\times10^{-6}\times2\times10^{-6}}{1}$

$U = 0.036\,J$

10. 

$Ao = Bo = co = do = a/\sqrt{2}$

$V = \frac{9\times10^9 \times \sqrt{2}\ \text{Totalcharge}}{a}$

$V = \frac{9\times10^9\times\sqrt{2}}{a}[+q+q-q-q]$

$V = \frac{9\times10^9\times\sqrt{2}}{a}(0) = 0$

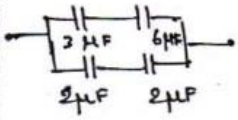
15. $E \propto 1/r^2$

$\frac{E_1}{E_2} = \frac{r_2^2}{r_1^2}$

$\frac{r_2}{r_1} = \sqrt{E_1/E_2}$

$r_2 = r_1\sqrt{E_1/E_2} = 2\times\sqrt{\frac{400}{100}}$

$r_2 = 2\times2 = 4\,m$.

18. 

$C_{s_1} = \frac{3\times6}{3+6} = 18/9 = 2\,\mu F$

$C_{s_2} = \frac{2\times2}{2+2} = 1\,\mu F$

$C_p = C_{s_1} + C_{s_2} = 2+1 = 3\,\mu F$

20. $N = \frac{q}{\varepsilon_0} = 1\times10^{-6}\times1.129\times10^{11}$

$N = 1.129\times10^5$

21. $\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2}$ $\quad \therefore 1/C_2 = \frac{1}{C_s} - \frac{1}{C_1}$

$\frac{1}{C_2} = \frac{1}{1.5} - \frac{1}{4} = \frac{4-1.5}{6} = \frac{2.5}{6}$

$\therefore C_2 = \frac{6}{2.5} = \frac{60}{25} = 2.4\,\mu F$

25. $E = \frac{1}{2}CV^2 = \frac{1}{2}\times6\times10^{-6}\times(100)^2$

$E = 0.03\,J$

26. (c) $-pE$
27. (c) 12
28. (a) $q = ne$
29. (b) human body.
30. (a) 2×10^{-9} N.
31. (b) $q_1q_2/4\pi\varepsilon_0 r$
32. (c) $pE\sin\theta$
33. (b) $8.854\times10^{-11}\ C^2N^{-1}m^{-2}$
34. (d) electric field intensity
35. (c) 3V.
36. (c) $6/11\ \mu F$
37. (d) $\perp r$ to the plane containing $\vec{p}$ and $\vec{E}$
38. (b) $1/r$
39. (d) 4 : 1
40. (d) the Negative gradient of the potential.
41. (d) independent of both the charge q and potential V
42. (c) $2\ NC^{-1}$
43. (c) Nm^2C^{-1}
44. (a) $1/x^2$
45. (b) acts opposite to E.
46. (b) acts in the direction of E
47. (b) c/n.
48. (d) does not change.
49. (c) 1.
50. (a) Zero
51. (c) No unit
52. (d) independent of "r"
53. (b) acts along "AB"
54. (c) pE
55. (c) $36\pi\times10^9\ q$

27. $\varepsilon_r = \frac{C_m}{C} = \frac{60}{5} = 12$

30. $F = Eq = 10 \times 2\times10^{-10} = 2\times10^{-9}$ N

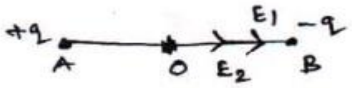
33. $\varepsilon = \varepsilon_0\varepsilon_r = \varepsilon_0 \frac{C_m}{C}$
$= 8.854\times10^{-12} \times \frac{50}{5}$
$\varepsilon = 8.854\times10^{-11}\ C^2N^{-1}m^{-2}$

35. $V = \frac{W}{q} = \frac{1.8\times10^{-5}}{6\times10^{-6}} = 3V$

36. $\frac{1}{C_s} = \frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3} = \frac{1}{1}+\frac{1}{2}+\frac{1}{3}$
$= \frac{6+3+2}{6} = 11/6$
$\therefore C_s = 6/11\ \mu F$

39. $V = p/4\pi\varepsilon_0 r^2 \quad \therefore V \propto \frac{1}{r^2}$
$\frac{V_1}{V_2} = \frac{r_2^2}{r_1^2} = \frac{20^2}{10^2} = 4$
$\therefore V_1 : V_2 = 4 : 1$

42. $E = F/q = \frac{10^{-5}}{5\times10^{-6}} = 2\ NC^{-1}$

53.


E acts AB

54. Work done $= pE(1-\cos\theta)$
$\theta = 90° \quad \therefore W = pE$

55. $\phi = \frac{q}{\varepsilon_0} = \frac{q}{\left[\frac{1}{4\pi\times9\times10^9}\right]}$
$= 36\pi\times10^9\ q$

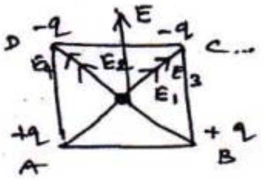
56. (a) 9×10^9 N.
57. (b) $\frac{q}{4}\sqrt{K}$. metre
58. (b) acts in a direction parallel to BC.
59. (a) $C^2 N^{-1} m$.
60. (c) $q_1 q_2 / 8\pi\varepsilon_0$.
61. (d) 1.25 μF.
62. (b) Air
63. (b) electrostatics induction and action of points.

57. $F = K \cdot \frac{q_1 q_2}{r^2}$

$r^2 = K \cdot \frac{q_1 q_2}{F} = \frac{K \cdot q^2}{16}$

$r = \sqrt{K \cdot q^2/16} = \frac{q}{4} \cdot \sqrt{K}$

58.



60. $|W| = U_F - U_I = \frac{q_1 q_2}{4\pi\varepsilon_0 r_2} - \frac{q_1 q_2}{4\pi\varepsilon_0 r_1}$

$= \frac{q_1 q_2}{4\pi\varepsilon_0}\left[\frac{1}{r_2} - \frac{1}{r_1}\right]$

$= \frac{q_1 q_2}{4\pi\varepsilon_0}\left[\frac{1}{1} - \frac{1}{2}\right] = \frac{q_1 q_2}{4\pi\varepsilon_0} \times \frac{1}{2}$

$W = \frac{q_1 q_2}{8\pi\varepsilon_0}$

61. $C_p = C_1 + C_2 = 0.5 + 0.75 = 1.25$ μF

Expressions , Unit , Important points , Terms

1. The force between two point charges q_1 and q_2 is given by the equation **F =** $\frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$5. If

2.. The force exerted by an electric field E on a charge q **F = Eq**.

3 The unit of electric dipole moment is **C m**

4. The electric field at any point on the axial line of an electric dipole is given by **E =** $\frac{1}{4\pi\varepsilon_0}\frac{2p}{r^3}$

5. The electric field at any point on the equatorial line of an electric dipole is **E =** $\frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$

6. The torque experienced by an electric dipole in an electric field is given by **τ** = pE sin **θ**

7. The direction of the electric dipole moment is from **-q , to +q**

8. The net force on an electric dipole in an electric field is **zero**

9. The relation between the electric field and the electric potential is given by **E = - dV / dr**

10.The total number of electric lines of forces passing through the given area is called **electric flux**

11. The unit of electric potential difference is **volt**

12. The unit of electric field intensity is **V m $^{-1}$**

13. The equation of electric potential at any point due to an electric dipole is …… **V =** $\frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^3}$

14. The work done in bringing each charge from infinite distance is called electric **potential energy**

15. The unit of electric flux is **N m ^{2} C^{-1}**

16. The electric field due to an infinite long straight charged wire is E = **λ / 2πε$_0$r**

17. The electric field due to an infinite long charged plane sheet is E = **σ / 2 ε$_0$**

18. Electric field at any point in between two parallel sheets of equal and opposite charges is **E = σ / εo**

19. The electric field at any point on the surface of a uniformly charged spherical shell is

E = $\frac{1}{4\pi\varepsilon_o}\frac{q}{R^2}$

20. Electrostatic shielding is based on the fact that the electric field inside a conductor is **zero**

21. The phenomenon of obtaining charges without any contact with another charge is called **electrostatic induction**

22.The unit of capacitance is **farad**

23 A capacitor is a device to store **charges**

24. The number of electric lines of force originating from 1 coulomb charge is **1.129 X 10^{11}**

25. Non polar molecule is **O_2. N_2, H_2**

26. Polar molecule is **N_2O, H_2O, HCl, NH_3**

27. The magnitude of the induced dipole moment p is directly proportional to **E**

28.Greater the radius of a conductor, **smaller** is the charge density.

29.The permittivity of a medium is **$\varepsilon_0\varepsilon_r$**

30.Direction of E – **outward for +q and inward for -q**

31.Gaussian Surface – Closed imaginary surface over an enclosed net charge

32.Capacitance of a capacitor **C = Q/V**

33.Electric dipole moment **p = 2qa**

34.Electric potential energy of dipole **U = -pEcosΘ**

35.Electric flux $\phi_E = \frac{Q}{\varepsilon_0}$

36.Electric field due to a uniformly charged sphere

i)Outside the sphere - **E** = $\frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}$ ii) On the sphere **E** = $\frac{1}{4\pi\varepsilon_o}\frac{q}{R^2}$ iii) Inside sphere – **Zero**

37.Work done by a charge W = qV

38.Charge density **σ = Q/A**

39.Linear charge density $\lambda = \frac{Q}{L}$

40.Polarization **p = ϰE**

41.Capacitance of a parallel plate capacitor $C = \frac{Q}{V} = \frac{Q}{\frac{Qd}{A\varepsilon_0}} = \frac{\varepsilon_{0A}}{d}$

42.Capacitance in series C_S = $1/C_1$ + $1/C_2$ In parallel C_P = C_1 + C_2

43.1 micro (μ) farad = 10^{-6} 1 pico farad = 10^{-12}

44.Unit of Charge = **Coulomb (C) .**

Electric field (E) = **NC^{-1} or Vm^{-1}** .

Electric potential (V) = **Volt or JC^{-1}** .

Dipole moment (p) = **Cm.**

Torque (τ) = **Nm** .

Charge density **σ** = **Cm^{-2}.**

Linear charge density **λ = Cm^{-1}.**

molecular polarisability =**$C^2 N^{-1}$ m.**

Dielectric strength = **Vm^1.**

Two marks (Book Back)

1.What is Quantisation of charges?

The charge *q* on any object is equal to an integral multiple of this fundamental unit of charge *e*.

$q = ne$ n is any integer (0, ±1, ±2, ±3, ±4………..).

This is called quantisation of electric charge.

2. Write down coulomb's law in vector form & mention what each term represents

According to Coulomb, the force on the point charge q_2 exerted by another point charge q_1 is $\vec{F}_{12} = k q_1 q_2 \hat{r}_{21} / r^2$

$\hat{r}_{21}$ is the unit vector directed from charge q_1 to charge q_2

k is the proportionality constant.

3. Difference between electrostatic force and gravitational force

Gravitational force	**Electrosatic force**
1. Force between two masses is always attractive	Force between two charges can be attractive or repulsive, depending on the nature of charges
2. The value of the gravitational constant **$G = 6.626\times10^{-11}\ Nm^2Kg^{-2}$**	The value of the constant k in Coulomb law is **$k = 9\times10^{9}\ Nm^2C^{-2}$**
3. force between two masses is independent of the medium.	force between the two charges depends on nature of the medium in which the two charges are kept at rest.
4. force between two point masses is the same whether two masses are at rest or in motion.	force between two point charges will change with respect to motion

4. **Define Superposition principle**

The total force acting on a given charge is equal to the vector sum of forces exerted on it by all the other charges.

5. Define Electric Field

The electric field at the point P at a distance r from the point charge q is the force experienced by a unit charge and is given by

$$\vec{E} = \frac{\vec{F}}{q_0} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\hat{r}$$

Qunatity ; vector quantity **Unit** ; NC^{-1}

6.What is meant by Electric field lines

Electric field vector are visualized by the concept of electric field lines . They form a set of continuous lines which represent the electric field in some region of space visually

7. The electric field never intersect.Justify

If some charge placed in intersection point then it has to move in two different direction at the same time , which is physically imposible .Hence Electric field lines do not intersect

8. Define electric dipole.

Two equal and opposite charges separated by a small distance constitute an electric dipole.

Ex : water , chloroform

9..Define dipole moment

It is product of any one of charges of dipole and distance(2d) between them

P=2qd **Quantity** ; vector quantity **Unit** ; Cm

10. Define electrostatic potential

The electric potential at a point P is equal to the work done by an external force to bring a unit positive charge with constant velocity from infinity to the point P in the region of the external electric field

Unit ; V or JC^{-1}

11. Define equipotential surface

An equipotential surface is a surface on which all the points are at the same potential

12. Write about Properties of equipotential surfaces

(i) The work done to move a charge q between any two points A and B is zero

(ii) The electric field is normal to an equipotential surface.

13.Give the relation between Electric field and electric potential

$dV = - E\,dx$

$E = -dV / dx$ Electric field is negative gradient of electric potential

14.Define electrostatic potential energy

It is defined as work done in bringing the various charges to their respective positions from infinitely large mutual separation

Unit : Joule

15. Define Electric Flux

The number of electric field lines crossing a given area kept normal to the electric field lines is called electric flux

Unit ; Nm^{2}C^{-1} **Φ_E = EA cosθ** **Quantity : scalar**

16. What is called energy density

The energy stored per unit volume of space is defined as energy density

$$u_E = \frac{U}{VOLUME}$$

17. Define electrostatic shielding

It is process of isolating of certain region of space from external space . It is based on the fact that electric field inside the cavity is zero

18. What is electric polarization

Polarisation is defined as the total dipole moment per unit volume of the dielectric

$$\vec{p} = \chi \vec{E}_{ext}$$

χ is a constant called the electric susceptibility which is a characteristic of each dielectric.

19. What is dielectric breakdown or strength

When the external electric field applied to a dielectric is very large, it tears the atoms apart so that the bound charges become free charges. Then the dielectric starts to conduct electricity

20. Define capacitance

The capacitance C of a capacitor is defined as the ratio of the magnitude of charge on either of the conductor plates to the potential difference existing between the conductors.

$C = \frac{Q}{V}$ **Unit** ; coulomb per volt or farad (F)

21. Write about action of points or corona discharge ?

Process of Leakage of charges from sharp pointed conductor

Its principle used in Vande – graff generator and lightning arrester

<u>Book inside</u>

1.What is capacitors

Capacitor is a device used to store electric charge and electrical energy. It consists of two conducting objects (usually plates or sheets) separated by some distance

2. What is dielectric

A dielectric is a non-conducting material and has no free electrons. The electrons in a dielectric are bound within the atoms.

Examples ; Ebonite, glass and mica

3.. What is Non-polar molecules

A non-polar molecule is one in which centers of positive and negative charges coincide.It has no permanent dipole moment.

Examples ; hydrogen (H_2), oxygen (O_2), and carbon dioxide (CO_2)

4. What is Polar molecules

In polar molecules, the centers of the positive and negative charges are separated even in the absence of an external electric field. They have a permanent dipole moment.

Examples ; H_2O, N_2O, HCl, NH_3.

5. Define electrostatic induction

Charging without actual contact is called electrostatic induction

6. Why it is always safer to sit inside a bus than in open ground or under a tree ?

The metal body of the bus provides electrostatic shielding, since the electric field inside is zero. During lightning, the charges flow through the body of the conductor to the ground with no effect on the person inside that bus.

7. Define Gauss's law

Gauss's law states that if a charge Q is enclosed by an arbitrary closed surface, then the total electric flux ΦE through the closed surface is

$$\Phi E = \frac{Q_{encl}}{\varepsilon_0}$$

8. What are two kind of electric field

Uniform electric field will have the same direction and constant magnitude at all points in space. **Non-uniform electric field** will have different directions or different magnitudes or both at different points in space

9. **.Define one coulomb**

One coulomb is a quantity of charge which when placed at a distance of one metre in air from equal and opposite charge experiences a repulsive force of 9×10^9

r = 1m   F = 9×10^9N $q_1 = q_2$ = 1C

10. State Coulomb's law.

Coulomb's law states that the electrostatic force is directly proportional to the product of the magnitude of the two point charges and is inversely proportional to the square of the distance between the two point charges.

$$F \propto \frac{q_1 q_2}{r^2}$$

11. **What is called triboelectric charging?**

Charging the objects through rubbing is called triboelectric charging

Book back long answers

1.Discuss the basic properties of electric charge

(i) Electric charge

a. **Electric charge** is intrinsic and fundamental property of particles..
b. The SI unit of charge is **coulomb**.

(ii) Conservation of charges

a. Charges are neither created or nor destroyed but can only be transferred from one object to other.
b. This is called conservation of total charges and is one of the fundamental conservation laws in physics

The total electric charge in the universe is constant and charge can neither be created nor be destroyed.

(iii) Quantisation of charges

The charge *q* on any object is equal to an integral multiple of this fundamental unit of charge *e*.

$q = ne$ n is any integer (0, ±1, ±2, ±3, ±4………..).

2.Explain in detail about Coulomb's law & its various aspects

It states that the electrostatic force is directly proportional to the product of the magnitude of the two point charges and is inversely proportional to the square of the distance between the two point charges.

$$F \propto \frac{q_1 q_2}{r^2}$$

The direction of forces is along the line joining two charges

$F = k\frac{q_1 q_2}{r^2}$ **where** $k = \frac{1}{4\pi\varepsilon_o}$ $k = 9\times10^9\ Nm^2C^{-2}$

ε_0 – **Permittivity of free space and its value is** $8.854\times10^{-12}\ C^2N^{-1}m^{-2}$

- One coulmb is defined as quantity of charges which when placed at a distance of 1m in air or vaccum from an equal and similar charge experiences a repulsive force of 9×10^9 In vaccum

$$F = \frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r^2}$$

In medium of permittivity

$$F_m = \frac{1}{4\pi\varepsilon}\frac{q_1 q_2}{r^2}$$

$\varepsilon > \varepsilon_0$,

Force between two point charges in a medium other than vacuum is always less than that in vacuum $\varepsilon_r = \frac{\varepsilon}{\varepsilon_0}$

Gravitational force	Electrostatic force
1. Force between two masses is always attractive	Force between two charges can be attractive or repulsive, depending on the nature of charges
2. The value of the gravitational constant **G = 6.626×10^{-11} Nm^{2}Kg^{-2}**	The value of the constant k in Coulomb law is **k = 9×10^9 Nm^{2}C^{-2}**
3. force between two masses is independent of the medium.	force between the two charges depends on nature of the medium in which the two charges are kept at rest.
4. force between two point masses is the same whether two masses are at rest or in motion.	force between two point charges will change with respect to change in motion of charges

3.**Define Electric field and its various aspect**

a. According to Faraday, every charge in the universe creates an electric field in the surrounding space, and if another charge is brought into its field, it will interact with the electric field at that point and will experience a force.Consider a source point charge q located at a point in space. Another point charge q_o (test charge) is placed at some point P which is at a distance r from the charge q.

b. Force experienced by the charge q_o due to q is $\mathbf{F} = \frac{kqq_0}{r^2}$

c. The charge q creates an electric field in the surrounding space. The electric field at the point P at a distance r from the point charge q is the force experienced by a unit charge and is given by

$$\mathbf{E} = F/q_0 = \frac{kq}{r^2}$$

Unit ; NC^{-1} **Quantity : vector**

Important aspects of Electric field

- charge *q* is positive -electric field points away from the source charge
- *q* is negative - electric field points towards the source charge *q*.

✓ Force experienced by test charge placed at point P is **Eq_0**

- From equation of electric field . it is depends only on the source charge q & independent on charge q_0

- The electric field is a vector quantity, at every point in space, this field has unique direction and magnitude
- Distance r decreases Electric field Increases

✓ The test charge is made sufficiently small such that it will not modify the electric field of the source charge

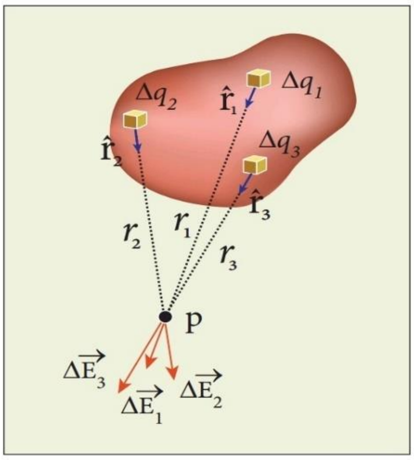
- The expression **E = F/ q₀** $= \frac{kq}{r^2}$ is valid only for point charges.
- Two kinds of the electric field: uniform (constant) electric field and non-uniform electric field.

Uniform electric field - same direction and constant magnitude at all points in space. **Non-uniform electric field** - different directions or different magnitudes or both at different points in space.

The electric field created by a point charge is basically a non uniform electric field.

4.How do we determine the electric field due to continuous distribution

The electric field due to such continuous charge distributions is found by involving the method of calculus.



Consider the following charged object of irregular shape as shown in Figure . The entire charged object is divided into a large number of charge elements $\Delta q_1, \Delta q_2, \Delta q_3 \ldots. \Delta q_n$ and each charge element Δq is taken as a point charge.

The electric field at a point P due to a charged object is approximately given by the sum of the fields at P due to all such charge elements.

$$\vec{E} \approx \frac{1}{4\pi\varepsilon_0}\left(\frac{\Delta q_1}{r_{1P}^2}\hat{r}_{1P} + \frac{\Delta q_2}{r_{2P}^2}\hat{r}_{2P} + \ldots\ldots\ldots + \frac{\Delta q_n}{r_{nP}^2}\hat{r}_{nP}\right)$$
$$\approx \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\frac{\Delta q_i}{r_{iP}^2}\hat{r}_{iP}$$

$\boldsymbol{\Delta q_i}$ – ith charge element

$\mathbf{r_{iP}}$ – distance of point P from ith charge element

$\widehat{\boldsymbol{r_{iP}}}$ unit vector from the ith charge element to the point P .

To incorporate the continuous distribution of charge, we take the limit $\boldsymbol{\Delta q} \rightarrow \mathbf{0}\ (= \boldsymbol{dq})$

$$\vec{E} = \frac{\mathbf{1}}{\mathbf{4\pi\varepsilon_0}}\int\frac{dq\hat{r}}{r}$$

r distance of point P from the infinitesimal charge dq

$\hat{\boldsymbol{r}}$ - unit vector from dq to point P .

a)If the charge Q is uniformly distributed along the wire of length L, then linear charge density $\lambda = \frac{Q}{L}$ **Unit : Cm^{-1}**

The charge present in the infinitesimal length *dl* is ***dq* = λdl**.

The electric field due to line of total charge Q is given by

$$\vec{E} = \frac{\lambda}{4\pi\varepsilon_o} \int \frac{dl}{r^2}\,\hat{r}$$

b) If the charge Q is uniformly distributed on a surface of area A, then surface charge density (charge per unit area) is **σ = Q/A Unit ; Cm^{-2}**

The electric field due to total charge Q is given by

$$\vec{E} = \frac{\sigma}{4\pi\varepsilon_o} \int \frac{da}{r^2}\,\hat{r}$$

c)If the charge Q is uniformly distributed in a volume V, then volume charge density is given by **ρ = Q/V Unit; Cm^{-3}**

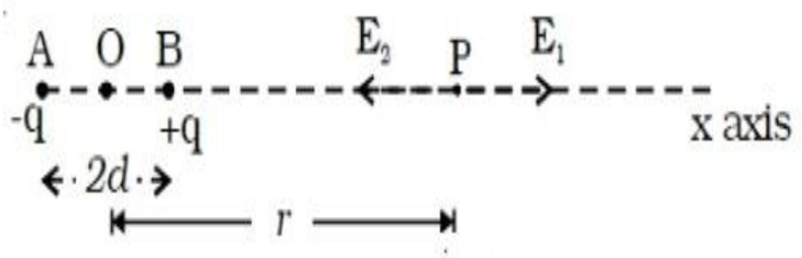
The electric field due to total charge Q is given by

$$\vec{E} = \frac{\rho}{4\pi\varepsilon_o} \int \frac{dV}{r^2}\,\hat{r}$$

5.**Calculate the electric field due to a dipole on axial and equatorial plane**

1. AB is an electric dipole of two point charges –q and +q separated by a small distance 2d. P is a point along the axial line of the dipole at a distance r from the midpoint O of the electric dipole.

2.



3. The electric field due to + q $E_1 = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r-d)^2}$ (along BP)

4. The electric field due to -q $E_2 = \frac{1}{4\pi\varepsilon_0}\frac{q}{(r+d)^2}$ (along PA)

5. $E = E_1 + (-E_2)$

6. $$E = \left[\frac{1}{4\pi\varepsilon_o}\frac{q}{(r-d)^2} - \frac{1}{4\pi\varepsilon_o}\frac{q}{(r+d)^2}\right] \text{along BP.}$$

$$E = \frac{q}{4\pi\varepsilon_o}\left[\frac{1}{(r-d)^2} - \frac{1}{(r+d)^2}\right] \text{along BP}$$

$$E = \frac{q}{4\pi\varepsilon_o}\left[\frac{4rd}{(r^2-d^2)^2}\right] \text{along BP.}$$

7. $d << r$ and **$p = 2dq$**

8. $$E = \frac{q}{4\pi\varepsilon_o}\frac{4rd}{r^4} = \frac{q}{4\pi\varepsilon_o}\frac{4d}{r^3}$$

9. $$E = \frac{1}{4\pi\varepsilon_o}\frac{2p}{r^3} \text{ along BP.}$$

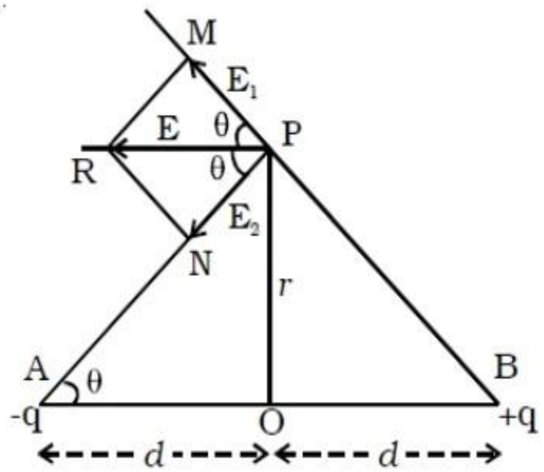
10. E acts in the direction of dipole moment.

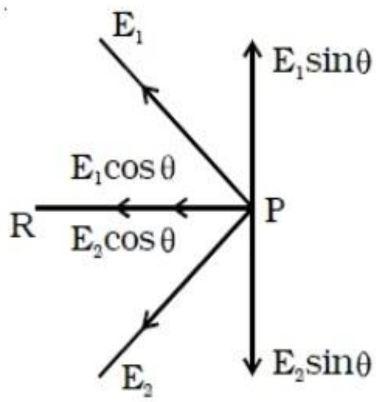
Equatorial plane

1. Consider an electric dipole AB. Let 2d be the dipole distance and p be the dipole moment. P is a point on the equatorial line at a distance r from the midpoint O of the dipole.
2. Electric field at a point P due to the charge +q $E_1 = \frac{1}{4\pi\varepsilon_o}\frac{q}{(r^2+d^2)}$ along BP
3. Electric field at a point P due to the charge -q $E_2 = \frac{1}{4\pi\varepsilon_o}\frac{q}{(r^2+d^2)}$ along PA
4. The magnitudes of E_1 and E_2 are equal. The **vertical** components $E_1 \sin\theta$ and $E_2 \sin\theta$ **cancel** each other. The ***horizontal*** components $E_1 \cos\theta$ and $E_2 \cos\theta$ will get ***added*** along PR.
5. Resultant electric field $\mathbf{E = E_1 \cos\theta + E_2 \cos\theta}$ (along PR)

   $E = 2E_1\cos\theta \;(\because E_1 = E_2)$
6. $E = 2 \times \frac{1}{4\pi\varepsilon_o}\frac{q}{(r^2+d^2)}\frac{d}{\sqrt{r^2+d^2}}$ $\left\{ \cos\theta = \frac{d}{\sqrt{r^2+d^2}} \right\}$

7. $E = \frac{1}{4\pi\varepsilon_o}\frac{p}{(r^2+d^2)^{3/2}}$
8. $d \ll r$ and **p= 2dq**
9. $$\boxed{E = \frac{1}{4\pi\varepsilon_o}\frac{p}{r^3}}$$
10. The direction of E is **opposite** to the direction of dipole moment.





6.Derive an expression for Torque experienced by a dipole due to a uniform electric field

- Consider an electric dipole of dipole moment $\vec{p}$ placed in a uniform electric field.
- The charge +q will experience a force q $\vec{E}$ in the direction of the field charge –q will experience a force -q$\vec{E}$ in a direction opposite to the field.
- Since the external field is uniform, the total force acting on the dipole is zero. These two forces acting at different points will constitute a couple and the dipole experience a torque.
- This torque tends to rotate the dipole.

The magnitude of torque is

τ = one of the forces × perpendicular distances between the forces

$= F \times 2d\sin\theta$

$= qE \times 2d\sin\theta$

$= pE\sin\theta$ (p=2qd)

In vector notation $\vec{\tau} = \vec{p} \times \vec{E}$

a)When $\theta = 0$ $\tau = 0$

The dipole moment of dipole **parallel** to electric field – No torque

b)When $\theta = 90$ $\tau = pE$

Dipole moment **perpendicular** to electric filed , torque is maximum

c) $\theta = 180^0$ $\tau = 0$

Dipole moment **antiparrallel** to electric filed , torque is zero

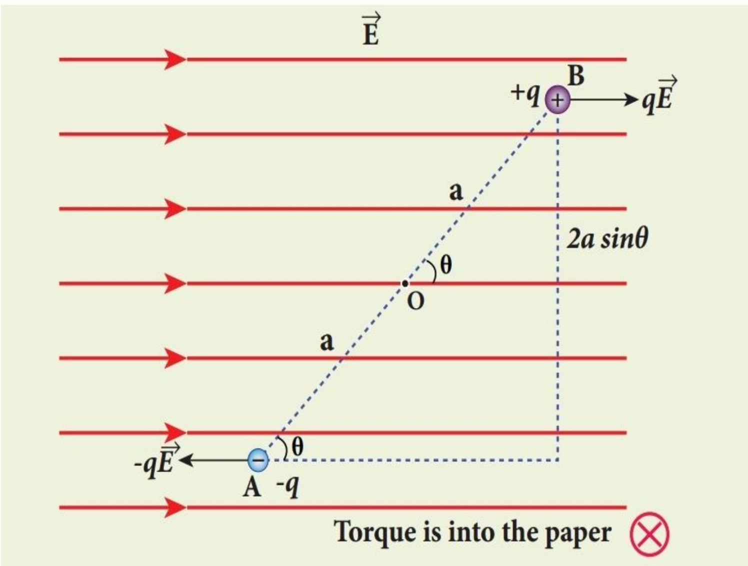


Figure 1.20 Torque on dipole

7.Derive an expression for electrostatic potential due to point charge

Consider a positive charge q kept fixed at the origin. Let P be a point at distance r from the charge q.

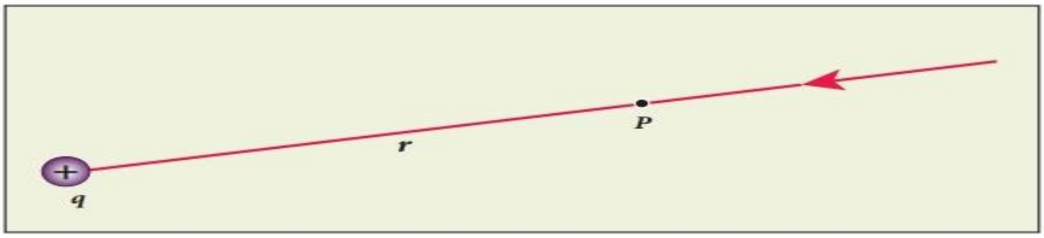


Figure 1.23 Electrostatic potential at a point P

The electric potential at the point P is

$$V = \int_{\infty}^{r} (-\vec{E}) \cdot d\vec{r} = -\int_{\infty}^{r} \vec{E} \cdot d\vec{r} \qquad (1.32)$$

Electric field due to positive point charge q is

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

$$V = \frac{-1}{4\pi\varepsilon_0} \int_{\infty}^{r} \frac{q}{r^2} \hat{r} . d\vec{r}$$

The infinitesimal displacement vector, $d\vec{r} = dr\hat{r}$ and using $\hat{r} . \hat{r} = 1$, we have

$$V = -\frac{1}{4\pi\varepsilon_\circ} \int_{\infty}^{r} \frac{q}{r^2} \hat{r} \cdot dr\hat{r} \quad = -\frac{1}{4\pi\varepsilon_\circ} \int_{\infty}^{r} \frac{q}{r^2} dr$$

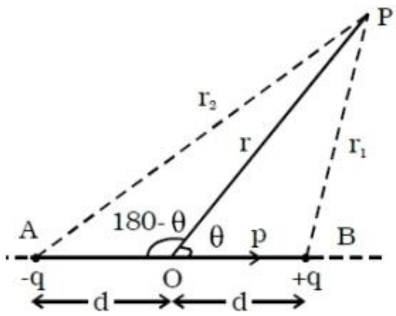
After the integration,

$$V = -\frac{1}{4\pi\varepsilon_\circ} q \left\{ -\frac{1}{r} \right\}_{\infty}^{r} = \frac{1}{4\pi\varepsilon_\circ} \frac{q}{r}$$

Hence the electric potential due to a point charge q at a distance r is

$$V = \frac{1}{4\pi\varepsilon_0} \frac{q}{r} \qquad (1.33)$$

8.Derive an expression for electrostatic potential due to an electric dipole



1. Consider an electric dipole AB. Let p be the point at a distance r from the midpoint of the dipole and θ be the angle between PO and the axis of the dipole OB.

2. Potential at P due to charge (+q) = $\frac{1}{4\pi\varepsilon_o}\frac{q}{r_1}$

Potential at P due to charge (–q) = $\frac{1}{4\pi\varepsilon_o}\left(-\frac{q}{r_2}\right)$

Total potential at P due to dipole is, V = $\frac{1}{4\pi\varepsilon_o}\frac{q}{r_1} - \frac{1}{4\pi\varepsilon_o}\frac{q}{r_2}$

$$V = \frac{q}{4\pi\varepsilon_o}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \quad ...(1)$$

3. Applying cosine law, $r_1^2 = r^2 + d^2 - 2rd\cos\theta$

Using the Binomial theorem and neglecting higher powers,

$$\frac{1}{r_1} = \frac{1}{r}\left(1 + \frac{d}{r}\cos\theta\right) \quad ...(2)$$

4. Similarly, $r_2^2 = r^2 + d^2 - 2rd\cos(180 - \theta) = r^2 + d^2 + 2rd\cos\theta.$

5. $$\frac{1}{r_2} = \frac{1}{r}\left(1 - \frac{d}{r}\cos\theta\right) \quad ...(3)$$

6. Substituting equation (2) and (3) in equation (1) and simplifying

$$V = \frac{q}{4\pi\varepsilon_o}\frac{1}{r}\left(1 + \frac{d}{r}\cos\theta - 1 + \frac{d}{r}\cos\theta\right)$$

$$\therefore \quad V = \frac{q\ 2d\cos\theta}{4\pi\varepsilon_o\ .\ r^2} = \frac{1}{4\pi\varepsilon_o}\frac{p\ .\ \cos\theta}{r^2} \quad ...(4)$$

7. <u>**Special cases:**</u>

(i) If $\theta = 0^0$; $V = \frac{p}{4\pi\varepsilon_o r^2}$

(ii) If $\theta = 180^0$; $V = -\frac{p}{4\pi\varepsilon_o r^2}$

(iii) If $\theta = 90^0$; **V=0**

9.Obtain an expression for potential energy due to collection of three point charges which are separated by finite distances

The electric potential at a point at a distance *r* from point charge q_1 is given by

$$V = \frac{1}{4\pi\varepsilon_o}\frac{q_1}{r}$$

This potential V is the work done to bring a unit positive charge from infinity to the point. Now if the charge q_2 is brought from infinity to that point at a distance r from q_1, the work done is the product of q_2 and the electric potential at that point.

W = q_2 V

This work done is stored as the electrostatic potential energy U

$$U = q_2V = \frac{1}{4\pi\varepsilon_o}\frac{q_1q_2}{r}$$

Three charges are arranged in the following configuration

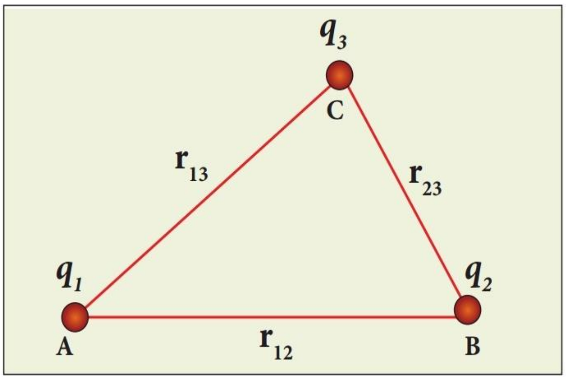


Figure 1.30 Electrostatic potential energy for Collection of point charges

i)Bringing a charge q1 from infinity to the point A requires no work, because there are no other charges already present in the vicinity of charge q_1

ii) To bring the second charge q_2 to the point B, work must be done against the electric field created by the charge q_1 So

the work done on the charge q_2 is $W = q_2 V_{1B}$.

Here V_{1B} is the electrostatic potential due to the charge q_1 at point B.

$$U = \frac{1}{4\pi\varepsilon_o}\frac{q_1q_2}{r_{12}}$$

iii) Similarly to bring the charge q3 to the point C, work has to be done against the total electric field due to both charges q_1 and q_2. So the work done to bring the charge q_3 is = q_3 ($V_{1C} + V_{2C}$). Here V_{1C} is the electrostatic potential due to charge q_1 at point C and V_{2C} is the electrostatic potential due to charge q_2 at point C.

$$U = \frac{1}{4\pi\varepsilon_o}\left(\frac{q_1q_3}{r_{13}} + \frac{q_2q_3}{r_{23}}\right)$$

iv) Total electrostatic potential energy for the system of charges q_1 , q_2 , q_3 is

$$U = \frac{1}{4\pi\varepsilon_o}\left(\frac{q_1q_3}{r_{13}} + \frac{q_2q_3}{r_{23}} + \frac{q_1q_2}{r_{12}}\right)$$

10.Derive an expression for electrostatic potential energy of the dipole in a uniform electric field

- Consider a dipole placed in the uniform electric field $\vec{E}$ .A dipole experiences a torque when kept in an uniform electric field $\vec{E}$.
- This torque rotates the dipole to align it with the direction of the electric field.
- To rotate the dipole (at constant angular velocity) from its initial angle θ' to another angle θ against the torque exerted by the electric field, an equal and opposite external torque must be applied on the dipole .

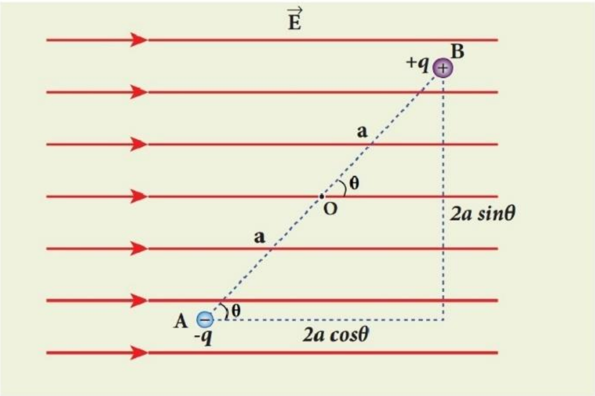


Figure 1.31 The dipole in a uniform electric field

The work done by the external torque to rotate the dipole from angle θ' to θ at constant angular velocity

$$W = \int_{\theta'}^{\theta} \tau_{ext}\, d\theta$$

$\tau = pE\sin\theta$

substituting τ in above equation

$$W = \int_{\theta'}^{\theta} pE\sin\theta\, d\theta$$

$$W = pE\,(\cos\theta' - \cos\theta)$$

If **θ' = 90**

The potential energy stored in the system of dipole kept in the uniform electric field is given by

$$U = -pE\cos\theta = -\vec{p}\cdot\vec{E}$$

Θ = 180 dipole aligned **antiparallel** to field U is maximum

θ= 0 dipole aligned **parallel** to field U is minimum

11.Obtain Gauss law from Coulomb's law

A positive point charge Q is surrounded by an imaginary sphere of radius r electric flux through the closed surface of sphere

$$\phi_E = \oint \vec{E}\cdot\overrightarrow{dA}\cos\theta$$

The electric field of the point charge is directed radially outward at all points on the surface of the sphere. Therefore, the direction of the area element $\overrightarrow{dA}$ is along the electric field $\vec{E}$ and $\theta = 0^0$

$$\phi_E = \oint E.dA$$

E is uniform on the surface of the sphere

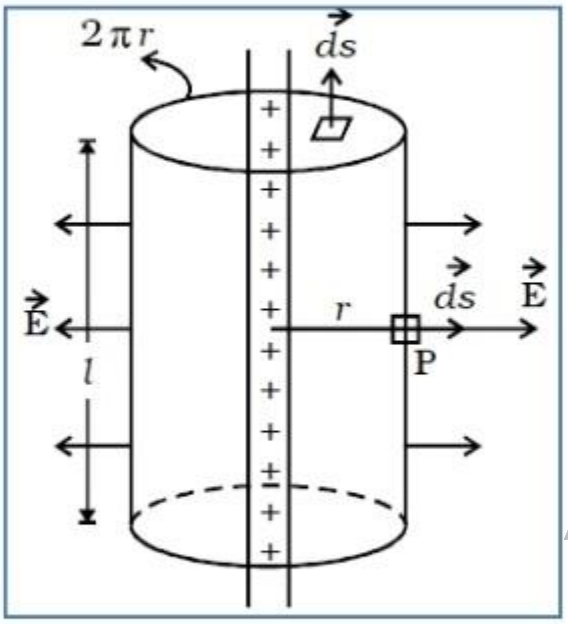
$\emptyset_E = E \oint . dA \qquad \oint . dA = 4\pi r^2$

Therefore $\emptyset_E = 4\pi r^2 E$

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

$\emptyset_E = \frac{1}{4\pi\varepsilon_o}\frac{Q}{r^2} \times 4\pi r^2 \qquad \emptyset_E = \frac{Q}{\varepsilon_0}$

12.Obtain expression for electric filed due to an infinitely long charged wire



- Consider an infinitely long straight wire having uniform linear charge density λ. Let P be a point located at a perpendicular distance r from the wire. .
- The electric field at the point P can be found using Gauss law. We choose two small charge elements A_1 and A_2 on the wire which are at equal distances from the point P.
- The resultant electric field due to these two charge elements points radially away from the charged wire and the magnitude of electric field is same at all points on the circle of radius r.

- Charged wire possesses a cylindrical symmetry of radius r and length L.

$\emptyset_E = \oint \vec{E} . \overrightarrow{dA}$

$= \oint \vec{E} . \overrightarrow{dA} + \oint \vec{E} . \overrightarrow{dA} + \oint \vec{E} . \overrightarrow{dA}$

Curved Surface **top surface** **bottom surface**

Since $\vec{E}$ *and* $\overrightarrow{dA}$ are right angles to each other , the electric flux through the place caps = 0

Flux through the curved surface = $\oint E . dA \ cos\theta$

$\theta = 0 \ cos0 = 1 \ \emptyset_E = \oint E . dA$

= E(2πrl) ……(1)

The net charge enclosed by Gaussian surface is

Q = λl

By Gauss law $\emptyset_E = \frac{Q}{\varepsilon_0}$ **…………(2)**

Equating (1) & (2)

E((2πrl) = $\frac{Q}{\varepsilon_0}$

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

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

Direction of electric field is radially outward if line charge is positive and inward , if the line charge is negative

In vector form $\vec{E} = \frac{\lambda}{2\pi\varepsilon_0 r}\vec{r}$

13. **Obtain expression for electric filed due to an charged infinitely plane sheet**

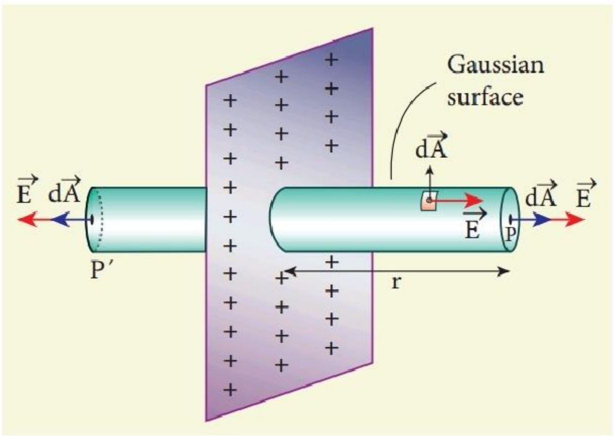


Figure 1.40 Electric field due to charged infinite planar sheet

Consider an infinite plane sheet of charges with uniform surface charge density σ. Let P be a point at a distance of r from the sheet

Since the plane is infinitely large, the electric field should be same at all points equidistant from the plane and radially directed at all points. A cylindrical shaped Gaussian surface of length 2r and area A of the flat surfaces is chosen such that the infinite plane sheet passes perpendicularly through the middle part of the Gaussian surface.

$\emptyset_E = \oint \vec{E}.\vec{dA}$

$= \oint \vec{E}.\vec{dA} + \oint \vec{E}.\vec{dA} + \oint \vec{E}.\vec{dA} = \frac{Q_{encl}}{\varepsilon_0}$

Curved P P'

The electric field is perpendicular to the area element at all points on the curved surface and is parallel to the surface areas at P and P' .Then

$\emptyset_E = \oint \vec{E}.\vec{dA} + \oint \vec{E}.\vec{dA} = \frac{Q_{encl}}{\varepsilon_0}$

P P'

Since the magnitude of the electric field at these two equal surfaces is uniform, E is taken out of the integration and $Q_{encl} = \sigma A$

$2E\int dA = \frac{\sigma A}{\varepsilon_0}$

The total area of surface either at P or P′ $\int dA = A$

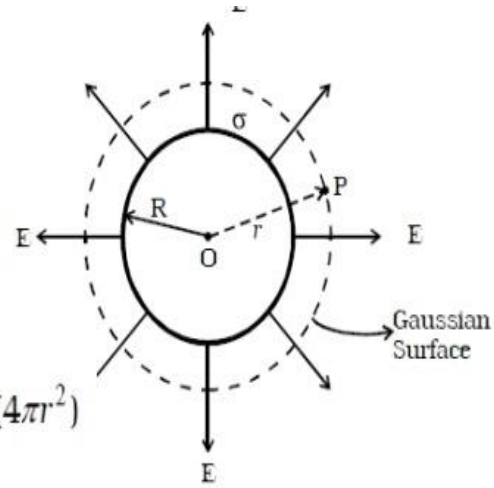
$2EA = \frac{\sigma A}{\varepsilon_0}$

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

In vector $\vec{E} = \frac{\sigma A}{2\varepsilon_0}\hat{n}$ $\hat{n}$ *is* outward unit vector normal to the plane.

The electric field due to an infinite plane sheet of charge depends on the surface charge density and **is independent of the distance r.**

14.Obtain expression for electric field due to uniformly charged spherical shell



Case (i) At a point outside the shell.

1. Consider a charged shell of radius R . Let P be a point outside the shell, at a distance r from the centre O.
2. Let us construct a Gaussian surface with r as radius. The electric field E is normal to the surface.
3. The flux crossing the Gaussian sphere normally in an outward direction is,

$$\phi = \int_S \vec{E} \cdot \vec{ds} = \int_S E\, ds = E\,(4\pi r^2)$$

(Since angle between E and ds is zero)

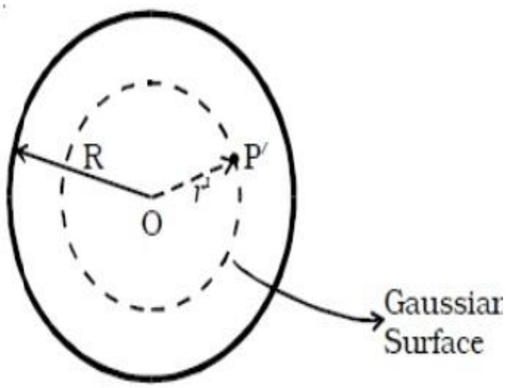
4. By Gauss's law, $E \cdot (4\pi r^2) = \frac{q}{\varepsilon_o}$
5. $$E = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}$$
6. The electric field at a point outside the shell will be the same as if the total charge on the shell is concentrated at its centre.

Case (ii) At a point on the surface.

7. The electric field E for the points on the surface of charged spherical shell is,

$$E = \frac{1}{4\pi\varepsilon_o}\frac{q}{R^2} \quad (\because\ r = R)$$

Case (iii) At a point inside the shell.



8. Consider a point P′ inside the shell at a distance r′ from the centre of the shell. Let us construct a Gaussian surface with radius r′.
9. The total flux crossing the Gaussian sphere normally in an outward direction is:

$$\phi = \int_S \vec{E} \cdot \vec{ds} = \int_S E ds = E \times (4\pi r'^2)$$

10. According to Gauss's law

$$E \times 4\pi r'^2 = \frac{q}{\varepsilon_o} = 0 \qquad \therefore\ E = 0$$

The field due to a uniformly charged thin shell is zero at all points inside the shell.

15.Discuss the various properties of conductors in electrostatic equilibrium

- The electric field is zero everywhere **inside the conductor. This is true regardless of whether the conductor is solid or hollow.**
- There is no net charge inside the **conductors. The charges must reside only on the surface of the conductors.**
- The electric field outside the conductor **is perpendicular to the surface of the conductor and has a magnitude of** $\frac{\sigma}{\varepsilon_0}$ **where σ is the surface charge density at that point.**
- The electrostatic potential has the **same value on the surface and inside of the conductor.**
- Since the electric field is zero inside the conductor, the potential is the same as the surface of the conductor. Thus at electrostatic equilibrium, the conductor is always at equipotential

16.Explain the process of electrostatic induction

Charging without actual contact is called electrostatic induction.
a)Consider an uncharged (neutral) conducting sphere at rest on an insulating stand. Suppose a negatively charged rod is brought near the conductor without touching it.

The negative charge of the rod repels the electrons in the conductor to the opposite side. As a result, positive charges are induced near the region of the charged rod while negative charges on the farther side.

Before introducing the charged rod, the free electrons were distributed uniformly on the surface of the conductor and the net charge is zero. Once the charged rod is brought near the conductor, the distribution is no longer uniform with more electrons located on the farther side of the rod and positive charges are located closer to the rod. But the total charge is zero.

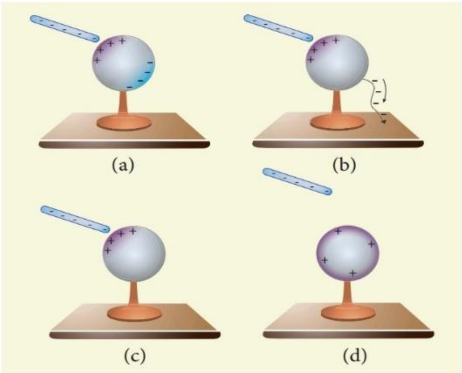


Figure 1.49 Various steps in electrostatic induction

b) Now the conducting sphere is connected to the ground through a conducting wire. This is called grounding.

c) When the grounding wire is removed from the conductor, the positive charges remain near the charged rod

d) Now the charged rod is taken away from the conductor. As soon as the charged rod is removed, the positive charge gets distributed uniformly on the surface of the conductor . By this process, the neutral conducting sphere becomes positively charged

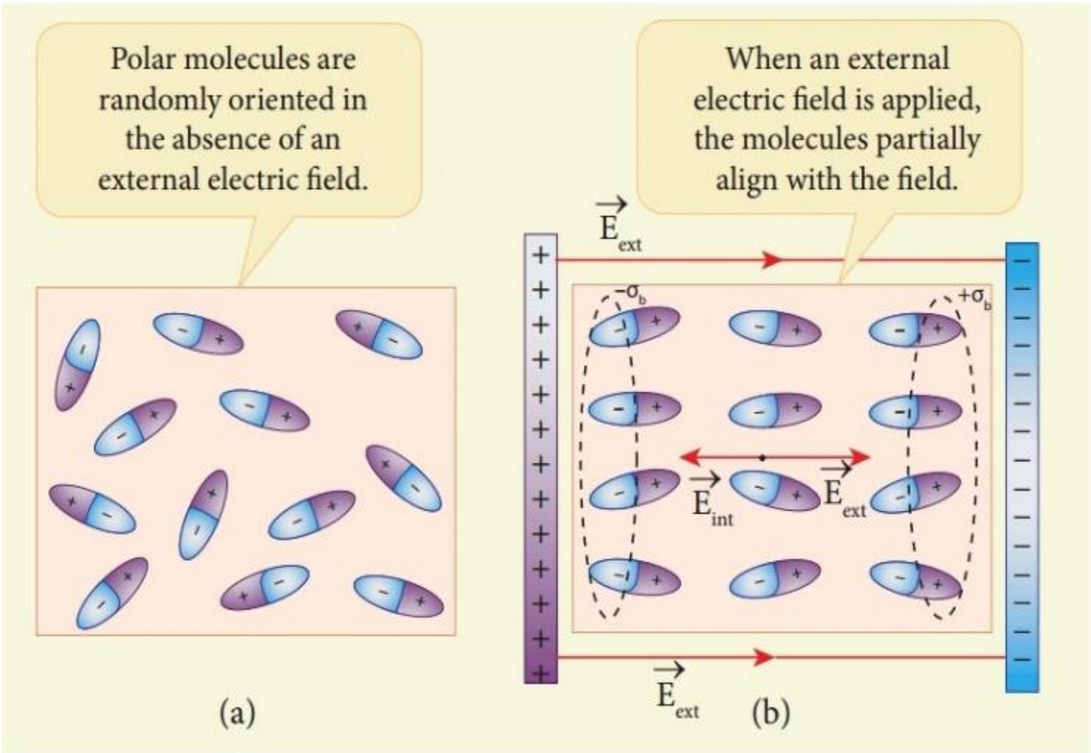
17.Explain dielectric in detail and how an electric field is induced inside a dielectric

i) In dielectric, which has no free electrons, when the external electric field is applied . the field only realigns the charges so that an internal electric field is produced.

ii) The magnitude of the internal electric field is smaller than that of external electric field. Therefore the net electric field inside the dielectric is not zero but is parallel to an external electric field with magnitude less than that of the external electric field.

let us consider a rectangular dielectric slab placed between two oppositely charged plates (capacitor)

The uniform electric field between the plates acts as an external electric field which polarizes the dielectric placed between plates. The positive charges are induced on one side surface and negative charges are induced on the other side of surface.
But inside the dielectric, the net charge is zero even in a small volume. So the dielectric in the external field is equivalent to two oppositely charged sheets with the surface charge densities $+\sigma_b$ and $-\sigma_b$. These charges are called bound charges. They are not free to move like free electrons in conductors.



18.Obtain the expression for capacitance for a parallel plate capacitor

Consider a capacitor with two parallel plates each of cross-sectional area A and separated by a distance d

The electric field between two infinite parallel plates is uniform and is given by

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

σ – Surface charge density on the plates (σ = Q/A)

The electric field between the plates is

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

Since the electric field is uniform, the electric potential between the plates having separation d is $V = Ed = \frac{Qd}{A\varepsilon_0}$

capacitance of the capacitor is given by

$$C = \frac{Q}{V} = \frac{Q}{\frac{Qd}{A\varepsilon_0}} = \frac{\varepsilon_0 A}{d}$$

$$C \propto A \quad C \propto \frac{1}{d}$$

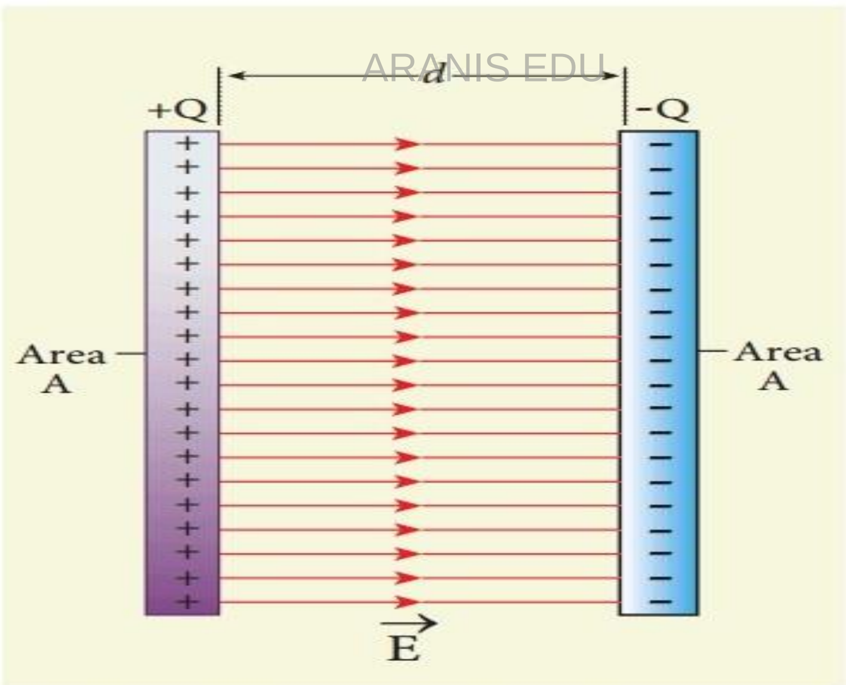
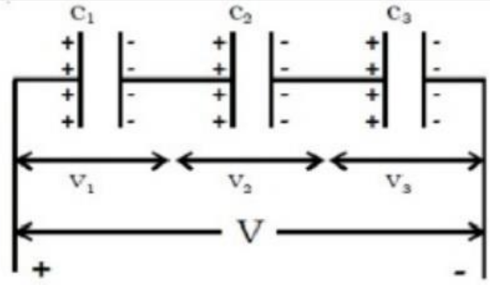
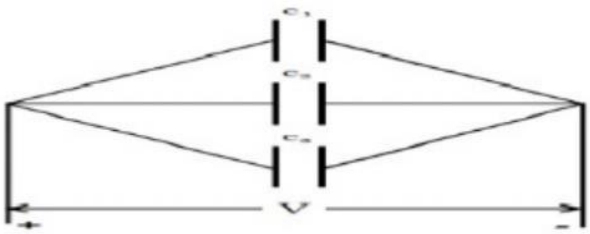


Figure 1.56 Capacitance of a parallel plate capacitor

21. Derive the expression for resultant capacitance when capacitors are connected in series and in parallel

Capacitors in series	Capacitors in parallel
1. C_1, C_2, C_3, capacitors are connected in series. Cs is the effective capacitances.	1. C_1, C_2, C_3, capacitors are connected in parallel. C_P is the effective capacitances.
	
3. Charge in each capacitor is same.	3. Potential in each capacitor is same.
4. $V = V_1 + V_2 + V_3$	4. $q = q_1 + q_2 + q_3$
5. $V_1 = \frac{q}{C_1}; V_2 = \frac{q}{C_2}; V_3 = \frac{q}{C_3}$ $V = \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3} = q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right]$	5. $q_1 = C_1V$, $q_2 = C_2V$, $q_3 = C_3V$. $q = C_1V + C_2V + C_3V$
6. $V = \frac{q}{C_S}$ $\frac{q}{C_S} = \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3}$	6. $q = C_p V$ $C_pV = V(C_1 + C_2 + C_3)$
7. $\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$	7. $C_P = C_1 + C_2 + C_3$
8. The reciprocal of the effective capacitance is equal to the sum of reciprocal of the capacitance of the individual capacitors.	8. The effective capacitance of the capacitors connected in parallel is the sum of the capacitances of the individual capacitors.

19.Obtain the expression for energy stored in parallel plate capacitor

Capacitor not only stores the charge but also it stores energy. When a battery is connected to the capacitor, electrons of total charge -Q are transferred from one plate to the other plate. To transfer the charge, work is done by the battery. This work done is stored as electrostatic potential energy in the capacitor.

To transfer an infinitesimal charge dQ for a potential difference V, the work done is given by

$$\mathbf{dW = V\,dQ}$$

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

The total work done to charge a capacitor is

$$\mathbf{W = \int_0^Q \frac{Q}{C}\,dQ = \frac{Q^2}{2C}}$$

This work done is stored as electrostatic potential energy (U_E) in the capacitor

$$\mathbf{U_E = \frac{Q^2}{2C} = CV^2}$$

$\mathbf{U_E \propto C}$ $\quad$ $\mathbf{U_E \propto V^2}$

20.Explain in detail effect of a dielectric placed in parallel plate capacitor

The dielectric can be inserted into the plates in two different ways. (i) when the capacitor is disconnected from the battery. (ii) when the capacitor is connected to the battery.

i) when the capacitor is disconnected **from the battery**

Consider a capacitor with two parallel plates each of cross-sectional area A and are separated by a distance d. The capacitor is charged by a battery of voltage V_0 and the charge stored is Q_0. The capacitance of the capacitor without the dielectric is

$\mathbf{C_0 = Q_0 / V_0}$

The battery is then disconnected from the capacitor and the dielectric is inserted between the plates

The introduction of dielectric between the plates will decrease the electric field.

Experimentally it is found that the modified

$$\mathbf{E = \frac{E_0}{\varepsilon_r}}$$

E_0 - electric field inside the capacitors when there is no dielectric

ε_r − relative permeability of the dielectric

$\mathbf{\varepsilon_r > 1}$**, the electric field** $\mathbf{E < E_o}$**.**

As a result, the electrostatic potential difference between the plates (V = Ed) is also reduced. But at the same time, the charge Q_o will remain constant once the battery is disconnected.

Hence the new potential difference is

$$V = Ed = \frac{E_0\, d}{\varepsilon_r} = V_0 / \varepsilon_r$$

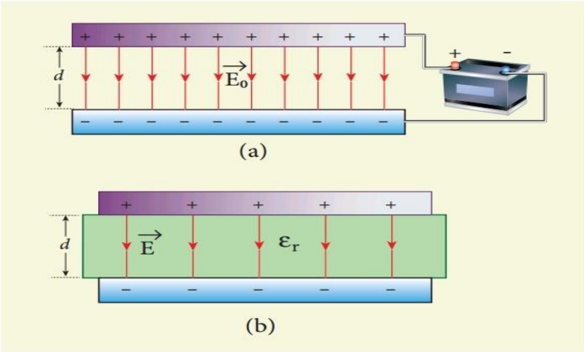


Figure 1.58 (a) Capacitor is charged with a battery (b) Dielectric is inserted after the battery is disconnected

We know that capacitance is inversely proportional to the potential difference. Therefore as V decreases, C increases. Thus new capacitance in the presence of a dielectric is

$$C = Q_0 / V = \varepsilon_r Q_0 / V = \varepsilon_r C_0$$

$\varepsilon_r > 1$, we have $C > C_0$. Thus insertion of the dielectric constant ε_r increases the capacitance.

$$C = \varepsilon_r \varepsilon_0 A / d = \varepsilon A / d$$

The energy stored in the capacitor before the insertion of a dielectric is given by

$$U_0 = \frac{{Q_0}^2}{2C_0}$$

After the dielectric is inserted, the charge remains constant but the capacitance is increased. As a result, the stored energy is decreased.

$$U = \frac{{Q_0}^2}{2C} = \frac{{Q_0}^2}{2\varepsilon_r C_0} = \frac{U_0}{2\varepsilon_r}$$

Since **$\varepsilon_r > 1$ we get $U < U_0$**. There is a decrease in energy because,when the dielectric is inserted, the capacitor spends some energy in pulling the dielectric inside.

ii) When the battery remains connected to the capacitor
refer text book

22.Explain in detail how charges are distributed in a conductor & the principle behind lightning conductor

Consider two conducting spheres A and B of radii r_1 and r_2 respectively connected to each other by a thin conducting wire .

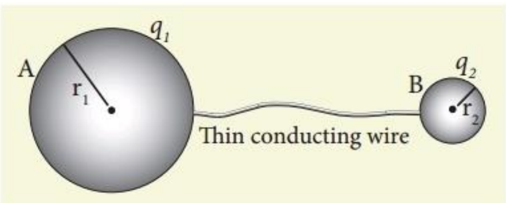


Figure 1.62 Two conductors are connected through conducting wire

The distance between the spheres is much greater than the radii of either spheres.

If a charge Q is introduced into any one of the spheres, this charge Q is redistributed into both the spheres such that the electrostatic potential is same in both the spheres. They are now uniformly charged and attain electrostatic equilibrium.

Let q_1 be the charge residing on the surface of sphere A and q_2 is the charge residing on the surface of sphere B such that $Q = q_1 + q_2$. The charges are distributed only on the surface and there is no net charge inside the conductor.
The electrostatic potential at the surface of the sphere A is given by

$$V_A = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_1}$$

The electrostatic potential at the surface of the sphere B is given by

$$V_b = \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_2}$$

The surface of the conductor is an equipotential. Since the spheres are connected by the conducting wire, the surfaces of both the spheres together form an equipotential surface. This implies that

$$V_A = V_B$$

$$\frac{q_1}{r_1} = \frac{q_2}{r_2}$$

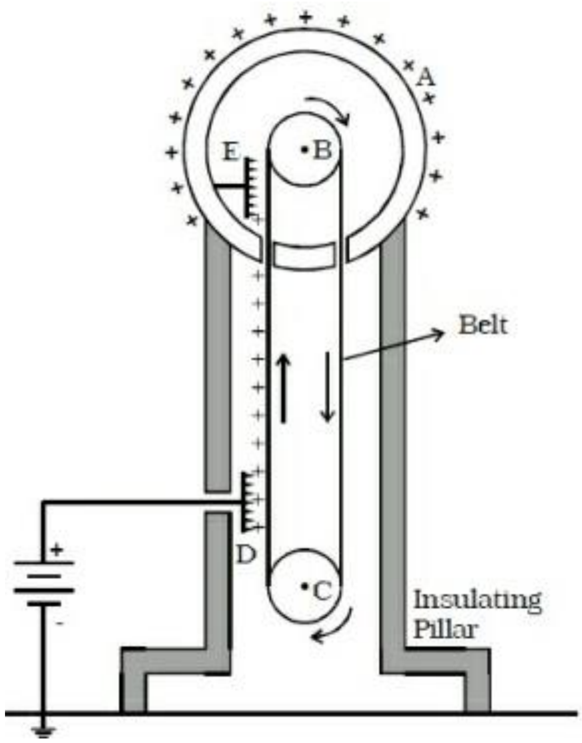
Let us take the charge density on the surface of sphere A is σ1 and charge density on the surface of sphere B is σ_2.
This implies that $\mathbf{q_1 = 4\pi r_1^2 \sigma_1}$ and
$\mathbf{q_2 = 4\pi r_2^2 \sigma_2}$
σr = constant
Thus the surface charge density σ is inversely proportional to the radius of the sphere. For a smaller radius, the charge density will be larger and vice versa

Lightning conductor is a device used to protect tall buildings from lightning strikes. It works on the principle of action at points or corona discharge. The leakage of charges from sharp pointed conductor is called corona discharge

23.Explain in detail the construction and working of a van de Graff generator
It is a machine which produces a large amount of electrostatic potential difference, up to several million volts (10^7 V).
Principle
Electrostatic induction and action at points
Construction
A large hollow spherical conductor is fixed on the insulating stand . A pulley B is mounted at the center of the hollow sphere and another pulley C is fixed at the bottom. A belt made up of insulating materials like silk or rubber runs over both pulleys. The pulley C is driven continuously by the electric motor. Two comb shaped metallic conductors E and D are fixed near the pulleys.
The comb D is maintained at a positive potential of 10^4 V by a power supply. The upper comb E is connected to the inner side of the hollow metal sphere.
Working

Due to the high electric field near comb D, air between the belt and comb D gets ionized. The positive charges are pushed towards the belt and negative charges are attracted towards the comb D. The positive charges stick to the belt and move up. When the positive charges reach the comb E, a large amount of negative and positive charges are induced on either side of comb E due to electrostatic induction. As a result, the positive charges are pushed away from the comb E and they reach the outer surface of the sphere. Since the sphere is a conductor, the positive charges are distributed uniformly on the outer surface of the hollow sphere. At the same time, the negative charges nullify the positive charges in the belt due to corona discharge before it passes over the pulley.

When the belt descends, it has almost no net charge. At the bottom, it again gains a large positive charge. The belt goes up and delivers the positive charges to the outer surface of the sphere. This process continues until the outer surface produces the potential difference of the order of 10^7 which is the limiting value. We cannot store charges beyond this limit since the extra charge starts leaking to the surroundings due to ionization of air. The leakage of charges can be reduced by enclosing the machine in a gas filled steel chamber at very high pressure.



Book inside questions

1.Write the applications of capacitors
2.Write about microwave oven
3.How is electric flux is related to electric field
4.Derive an electric flux in a non uniform electric field and an arbitarly shaped area
5.Write the special features of gauss law
6.Explain about lightning arrester or lightning conductor
7.Derive an expression for energy density in parallel plate capacitor