ARISE AWAKE ACHIEVE

SAIVEERA ACADEMY
PEELAMEDU COIMBATORE

+2 PHYSICS
STUDY MATERIAL
VOL - I

TABLE OF CONTENTS

STUDENT ALL THE BEST FOR YOUR FUTURE !

The true of purpose of education is to make minds , not careers

UNIT- 1 ELECTROSTATICS

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) 48×10^3 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)$1/4\pi\varepsilon_0$ (q/a) b)$1/4\pi\varepsilon_0$ (2q/a) c) $1/4\pi\varepsilon_0$ (4q/a) d) zero

11. The value of permittivity of free space is

a)$8.854 \times 10^{12} C^2N^{-1} m^{-2}$ b) $9 \times 10^9 C^2N^{-1} m^{-2}$

c) $1/9\times10^9 C^2N^{-1} m^{-2}$ d) $1/4\pi \times 9\times 10^9 C^2N^{-1} m^{-2}$

12. The principle use in lightning conductors is

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

13. The unit of electric dipole moment is

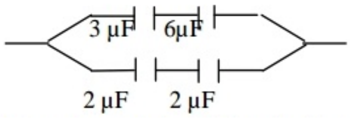
a) volt / metre (V/m) b) coulomb / metre (C/m)

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 4μF. 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) both 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

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) 8.854×10^{-12} $C^2 N m^{-2}$ b) $9 \times 10^9 C^2 N m^{-2}$ 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) 8πq 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) $\frac{1}{4\pi \times 9\times10^9}$ $c^2 N^{-1} m^{-2}$
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

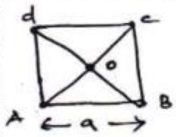
3. $V = W/q = \frac{0.012}{4\times10^{-6}} = \frac{12\times10^3}{4}$

$V = 3000\,V$.

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

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

$U = 0.036\,J$

10. 

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

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

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

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

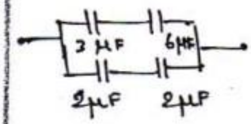
15. $E \propto 1/r^2$

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

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

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

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

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

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

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

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) $6/11$ μF
37. (d) ⊥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
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. $F = Eq = 10 \times 2\times10^{-10} = 2\times10^{-9}$ r

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. $\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} = \frac{1}{1} + \frac{1}{2} + \frac{1}{3}$

$= \frac{6+3+2}{6} = 11/6$

$\therefore C_s = 6/11$ μF

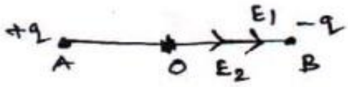
39. $V = P/4\pi\varepsilon_0 r^2$ $\therefore V \propto \frac{1}{r^2}$

$\frac{V_1}{V_2} = \frac{r_2^2}{r_1^2} = \frac{20^2}{10^2} = 4$

$\therefore V_1 : V_2 = 4 : 1$

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

53.



E acts AB

54. Work done $= PE(1-\cos\theta)$

$\theta = 90°$ $\therefore W = PE$

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

$= 36\pi\times10^9\ q$

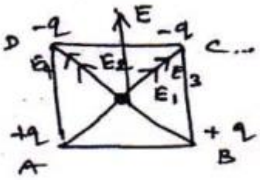
56. (a) 9×10^9 N.
57. (b) $q/4 \sqrt{K}$. Metre
58. (b) acts in a direction Parallel to BC.
59. (a) $C^2 N^{-1} m$.
60. (c) $q_1 q_2 / 8\pi\varepsilon_0$.
61. (d) 1.25 μF.
62. (b) Air
63. (b) electrostatics induction and action of Points.

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

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

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

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 = **$\sigma / 2\varepsilon_0$**
18. Electric field at any point in between two parallel sheets of equal and opposite charges is **$E = \sigma / \varepsilon_0$**
19. The electric field at any point on the surface of a uniformly charged spherical shell is $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}$
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 **1.129×10^{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 **$U = -pE\cos\theta$**
35.Electric flux $\phi_E = \frac{Q}{\varepsilon_0}$
36.Electric field due to a uniformly charged sphere i)Outside the sphere - $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$
ii) On the sphere $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}$ iii) Inside sphere – **Zero**
37.Work done by a charge W = qV
38.Charge density **$\sigma = Q/A$**
39.Linear charge density $\lambda = \frac{Q}{L}$
40.Polarization **$p = \varkappa E$**
41.Capacitance of a parallel plate capacitor $C = \frac{Q}{V} = \frac{Q}{\frac{Qd}{A\varepsilon_0}} = \frac{\varepsilon_0 A}{d}$
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.**

Book Back

Short answers questions

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 $\vec{F}_{12} = kq_1q_2\hat{r}_{21} / r^2$

$\hat{r}_{21}$ 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 impossible .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.

Book inside

Short answers questions

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

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

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 $F = \frac{kqq_0}{r^2}$

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

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.

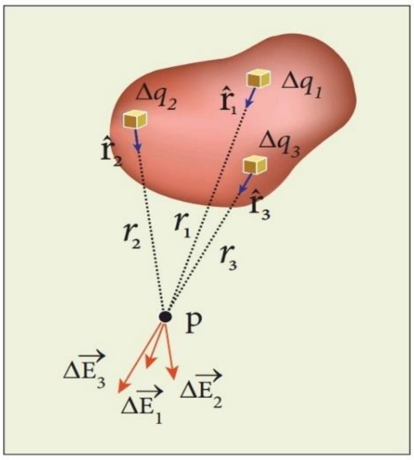
- ✓ Force experienced by test charge placed at point P is **Eq_0**
  - From equation of electric field . it is depends only on the source charge q & independent on charge q_0
  - The electric field is a vector quantity, at every point in space, this field has unique direction and magnitude
  - Distance 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/ q_0 =** $\frac{kq}{r^2}$ 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 Δq_1 , Δq_2 , Δq_3 .... Δq_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.



$$\vec{E} \approx \frac{1}{4\pi\varepsilon_0}\left(\frac{\Delta q_1}{r_{1P}^2}\hat{r}_{1P} + \frac{\Delta q_2}{r_{2P}^2}\hat{r}_{2P} + \dots\dots\dots + \frac{\Delta q_n}{r_{nP}^2}\hat{r}_{nP}\right)$$

$$\approx \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\frac{\Delta q_i}{r_{iP}^2}\hat{r}_{iP}$$

Δq_i – i[th] charge element

r_{iP} – distance of point P from i[th] charge element

$\widehat{r_{iP}}$ unit vector from the i[th] charge element to the point P .

To incorporate the continuous distribution of charge, we take the limit $\Delta q \to 0 (= dq)$

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

r distance of point P from the infinitesimal charge dq

$\hat{r}$ - 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 $dq = \lambda dl$.

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}**

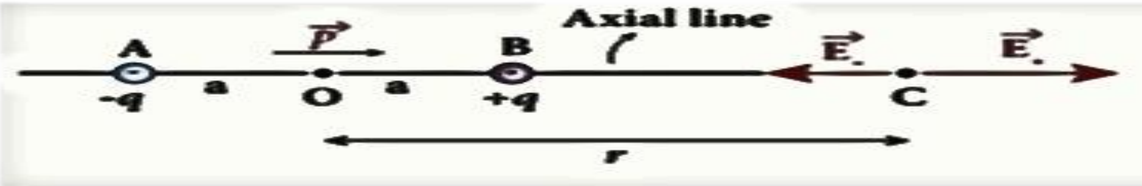
The electric field due to total charge Q is given by

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

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

<u>Electric field due to an electric dipole on the axial line</u>

- Consider an electric dipole placed on x axis.
- A point C is located at a distance of r from the midpoint O of the dipole along the axial line.



The electric filed at a point C due to +q

$$\overrightarrow{E_+} = \frac{1}{4\pi\varepsilon_o}\frac{q}{(r-a)^2} \text{ along } BC$$

$\hat{p}$ – Direction is -q to +q and along BC

$$\overrightarrow{E_+} = \frac{1}{4\pi\varepsilon_o}\frac{q}{(r-a)^2}\hat{p} \quad \text{..........(1)}$$

The electric filed at a point C due to -q

$$\overrightarrow{E_-} = -\frac{1}{4\pi\varepsilon_o}\frac{q}{(r+a)^2}\hat{p} \quad \text{..........(2)}$$

Total electric field at C calculated using super position principle

$\vec{E}_{\text{tot}} = \vec{E}_{+} + \vec{E}_{-}$

$$= \frac{1}{4\pi\varepsilon_o}\frac{q}{(r-a)^2}\hat{p} - \frac{1}{4\pi\varepsilon_o}\frac{q}{(r+a)^2}\hat{p}$$

$$= \frac{q}{4\pi\varepsilon_o}\left(\frac{4ra}{(r^2-a^2)^2}\right)\hat{p}$$

r>>a

$(r^2 - a^2)^2 = r^4$

$\vec{E}_{\text{tot}} = \frac{1}{4\pi\varepsilon_o}\left(\frac{4aq}{r^3}\right)\hat{p}$ **since $2aq\hat{p} = \vec{p}$**

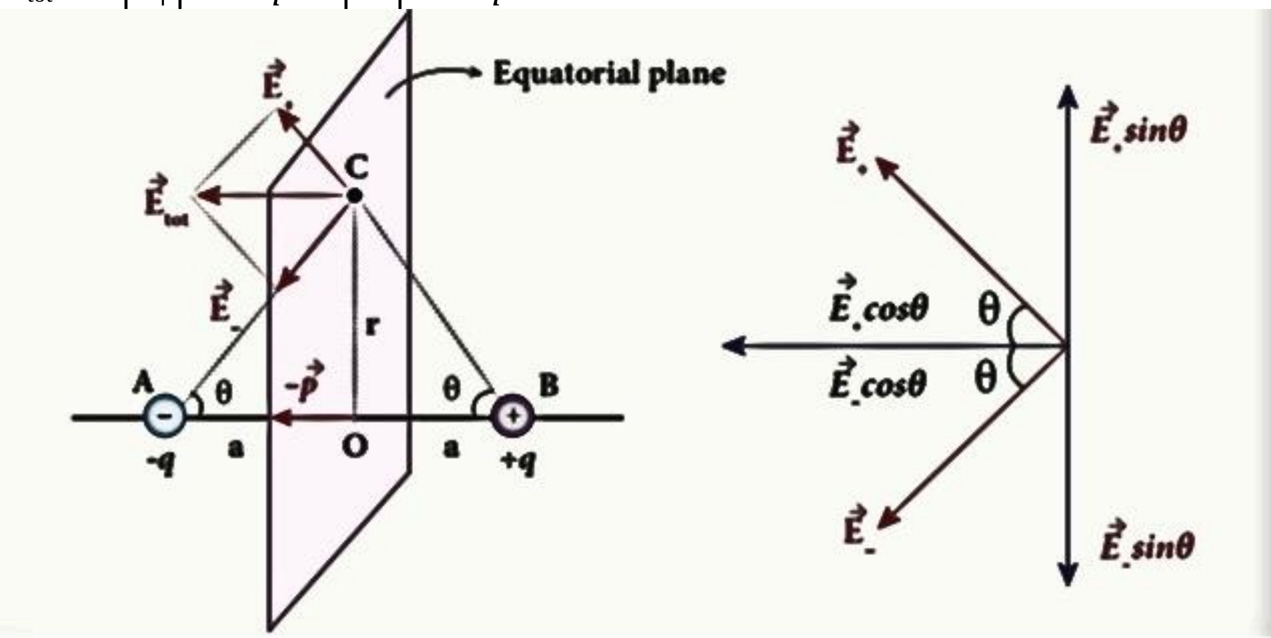
$$= \frac{1}{4\pi\varepsilon_o}\left(\frac{2\vec{p}}{r^3}\right)$$

The direction of electric field is along the direction of the dipole moment

<u>Electric field due to an electric dipole on the equatorial plane</u>

- Consider point C is located at a distance of r from the midpoint O of the dipole on the equatorial plane.
- C is equidistant from +q & -q , the magnitude of electric field of +q & -q are the same
- Direction of $\vec{E}_{+}$ along BC
- Direction of $\vec{E}_{-}$ along CA
- $\vec{E}_{+}$ & $\vec{E}_{-}$ resolved into two components : One component parallel to dipole and perpendicular to it
- Perpendicular components $E_{+}\sin\theta$ & $E_{-}\sin\theta$ are oppositely directed so cancel each other .

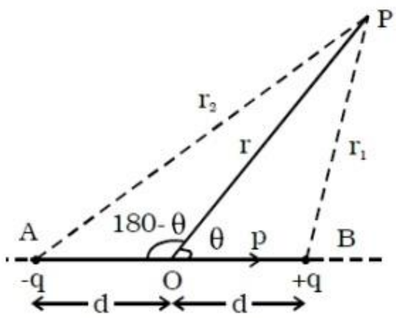
$\vec{E}_{\text{tot}} = -|\vec{E}_{+}|\cos\theta\hat{p} - |\vec{E}_{-}|\cos\theta\hat{p}$



$|\vec{E}_{+}| = |\vec{E}_{-}| = \frac{1}{4\pi\varepsilon_o}\frac{q}{(r+a)^2}$

$\vec{E}_{\text{tot}} = -\frac{1}{4\pi\varepsilon_o}\frac{2q\cos\theta\hat{p}}{(r+a)^2}$

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 = $\frac{1}{4\pi\varepsilon_o}\frac{q}{r_1}-\frac{1}{4\pi\varepsilon_o}\frac{q}{r_2}$

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

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

Using the Binomial theorem and neglecting higher powers,

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

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

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

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

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

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

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

Three charges are arranged in the following configuration

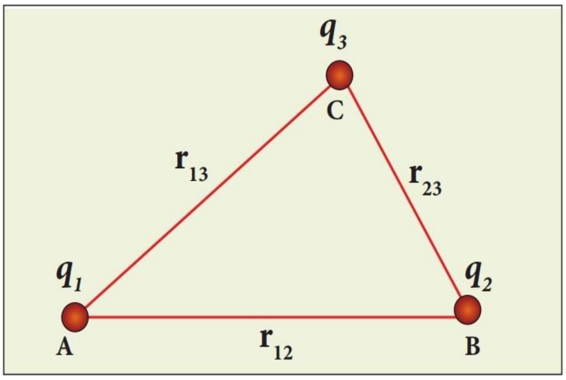


Figure 1.30 Electrostatic potential energy for Collection of point charges

i)Bringing a charge q_1 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 = $\frac{1}{4\pi\varepsilon_o}\frac{q_1 q_2}{r_{12}}$

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 = $\frac{1}{4\pi\varepsilon_o}\left(\frac{q_1 q_3}{r_{13}} + \frac{q_2 q_3}{r_{23}}\right)$

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

U = $\frac{1}{4\pi\varepsilon_o}\left(\frac{q_1 q_3}{r_{13}} + \frac{q_2 q_3}{r_{23}} + \frac{q_1 q_2}{r_{12}}\right)$

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 .

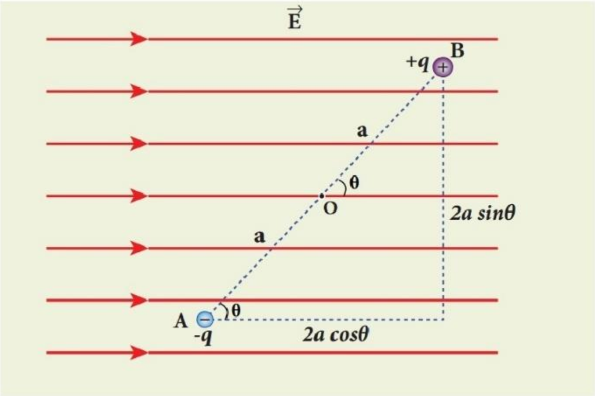


Figure 1.31 The dipole in a uniform electric field

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

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

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 $\vec{dA}$ 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

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

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**

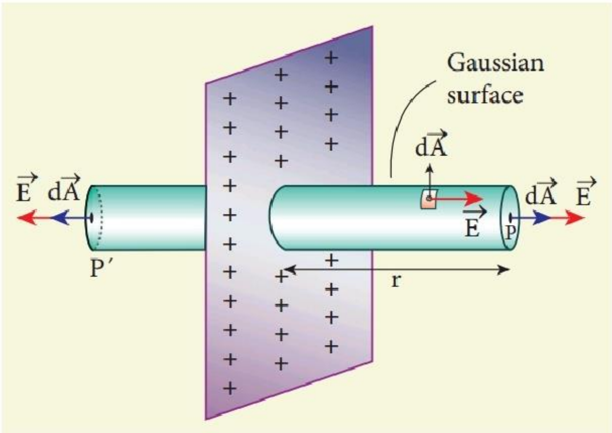


Figure 1.40 Electric field due to charged infinite planar sheet

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.

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

$$= \oint_{\text{Curved}} \vec{E}\,.\,\overrightarrow{dA} + \oint_{P} \vec{E}\,.\,\overrightarrow{dA} + \oint_{P'} \vec{E}\,.\,\overrightarrow{dA} = \frac{Q_{encl}}{\varepsilon_0}$$

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

$$\emptyset_E = \oint_{P} \vec{E}\,.\,\overrightarrow{dA} + \oint_{P'} \vec{E}\,.\,\overrightarrow{dA} = \frac{Q_{encl}}{\varepsilon_0}$$

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′ $\int dA = A$

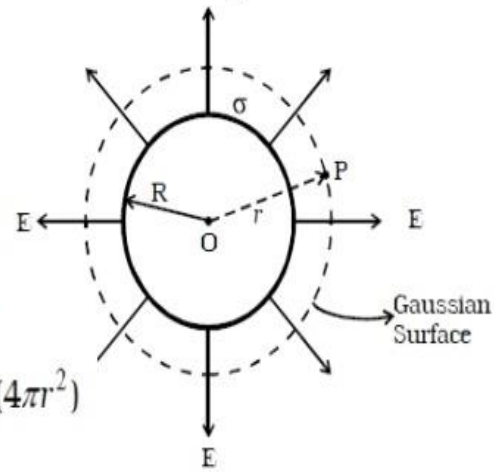
$$2EA = \frac{\sigma A}{\varepsilon_0}$$

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

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, $E \cdot (4\pi r^2) = \dfrac{q}{\varepsilon_o}$

5. $$\boxed{E = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}}$$

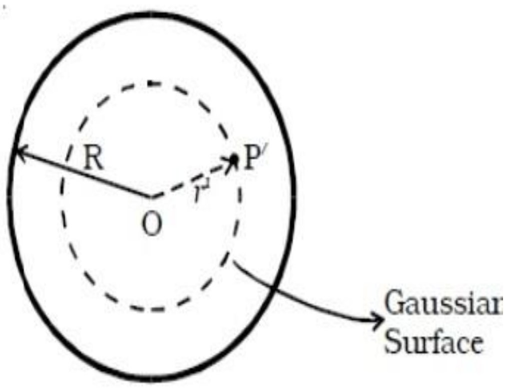
6. The electric field at a point outside the shell will be the same as if the total charge on the shell is concentrated at its centre.

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.

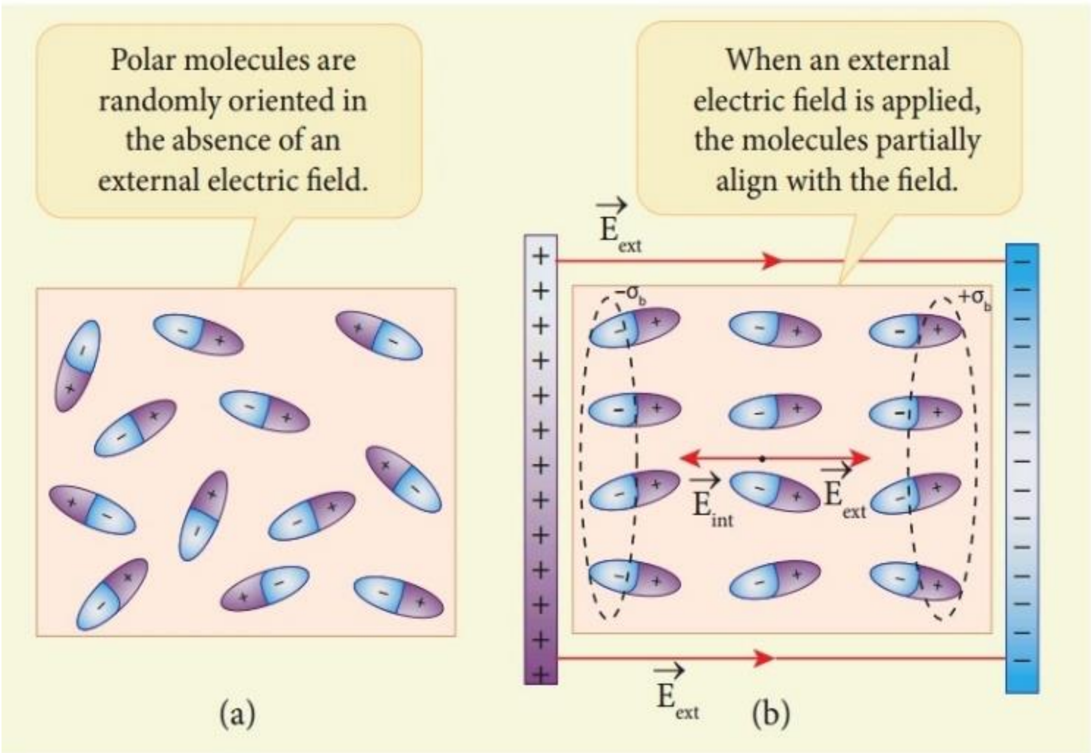
17.Explain dielectric in detail and how an electric field is induced inside a dielectric

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.

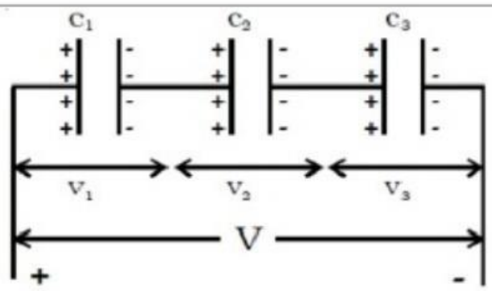
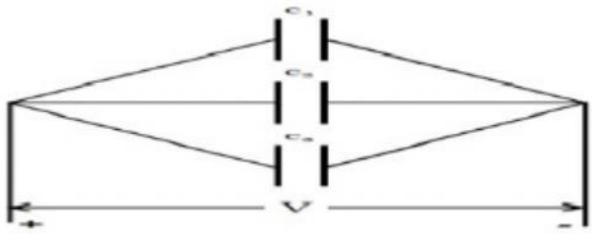
ii) The magnitude of the internal electric field is smaller than that of external electric field. Therefore the net electric field inside the dielectric is not zero but is parallel to an external electric field with magnitude less than that of the external electric field.

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.



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

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

$\mathbf{U_E \,\alpha\, C}$ $\mathbf{U_E \,\alpha\, V^2}$

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

$\varepsilon_r > 1$, the electric field $E < E_o$.

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

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

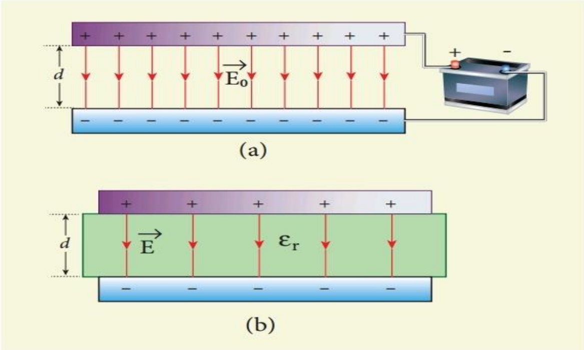


Figure 1.58 (a) Capacitor is charged with a battery (b) Dielectric is inserted after the battery is disconnected

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 $C > C_o$. 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 $U < U_o$**. 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

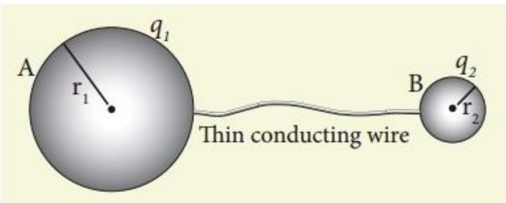


Figure 1.62 Two conductors are connected through conducting wire

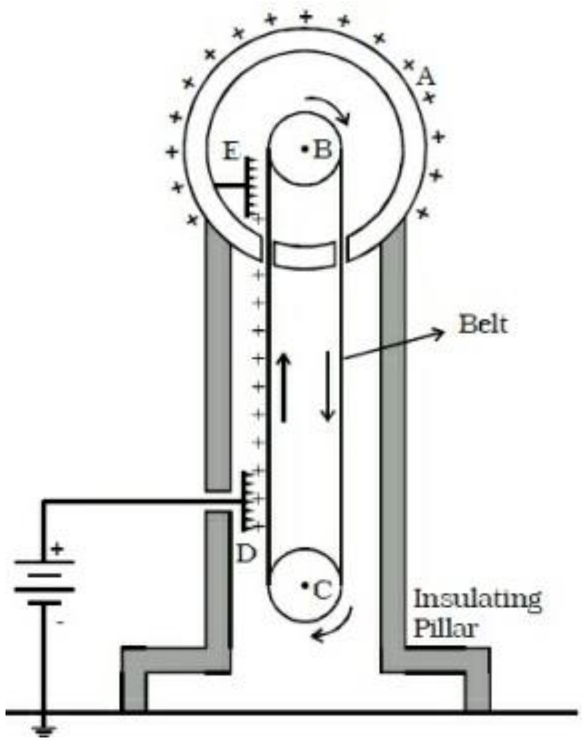
Consider two conducting spheres A and B of radii r_1 and r_2 respectively connected to each other by a thin conducting wire The distance between the spheres is much greater than the radii of either spheres.

If a charge Q is introduced into any one of the spheres, this charge Q is redistributed into both the spheres such that the

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.



UNIT – 2 CURRENT ELECTRICITY

I.One marks

1. Resistance of a metal wire of length 10cm is 2 Ω. If the wire is stretched uniformly to 50 cm ,resistance is
a) 25 Ω b) 10 Ω c) 5 Ω d) 50 Ω
2. The colour code on a carbon resistor is red – red – black. The resistance of the resistor is
a) 2.2 Ω b) 22 Ω c) 220 Ω d) 2.2 kΩ
3. The brown ring at one end of a carbon resistor indicates a tolerance of
a) 1% b) 2% c) 5% d) 10%
4. The unit of conductivity is
a) mho b) ohm c) ohm – m d)mho – m^{-1}
5. The material through which electric charge can flow easily is
a) quartz b) mica c) germanium d) copper
6. In the case of insulators, as the temperature decreases, the resistivity
a) decreases b) increases c) remains constant d) becomes zero
7. If the length of a copper wire has a certain resistance R, then on doubling the length its specific resistance
a) will be doubled b) will be 1/4th
c) will become four times d) will remain the same
8. When two 2 Ω resistances are in parallel their effective resistance is
a) 2 Ω b) 4 Ω c) 1 Ω d) 0.5 Ω
9. The transition temperature of mercury is
a) 4.2^0C b) 4.2 K c) 2.4^0C d) 2.4 K
10. The toaster operating at 240 V has a resistance of 120 Ω. The power is
a) 400 W b) 2 W c) 480 W d) 240 W
11. The relation between current and drift velocity is
a) $I = Av_d$ b) $I = nev_d$ c) $I = nv_d$ d) $I = neAv_d$
12.When the diameter of a conductor is doubled, its resistance
a) decreases twice b) decreases four times
c) decreases sixteen times d) increases four times
13. A cell of emf 2.2V sends a current of 0.2 A through a resistance of 10 Ω. The internal resistance of the cell is
a) 0.1 Ω b) 1 Ω c) 2 Ω d) 1.33 Ω
14. When n resistors of equal resistance (R) are connected in series the effective resistance is
a) n / R b) R / n c) 1/ nR d) nR
15. The electrical resistivity of a thin copper wire and a thick copper rod are respectively p_1 Ω m and p_2 Ω m. Then :
a) $p_1 > p_2$ b) $p_2 > p_1$ c) $p_1 = p_2$ d) $p_2/p_1 = \infty$
16. The unit of electrochemical equivalent is
a) Kg. coulomb b) kg/ ampere sec c) kg/ sec. d) C/kg
17. When 'n' resistors of equal resistance (R) are connected in series and in parallel respectively, then the ratio of their effective resistance is :

a) $1 : n^2$ b) $n^2 : 1$ c) $n : 1$ d) $1 : n$

18. A graph is drawn taking potential difference across the ends of a conductor along x - axis and current through the conductor along the y-axis the slope of the straight line gives.

(a) resistance (b) conductance (c) resistivity (d) conductivity

UNIT : 2

1. (d) 50 Ω.
2. (b) 22 Ω.
3. (a) 1 %.
4. (d) mho - m^{-1}
5. (d) copper.
6. (b) increases.
7. (d) will remain the same.
8. (c) 1 Ω.
9. (b) 4.2 K
10. (c) 480 W
11. (b) $I = nAV_d e$
12. (b) decreases four times
13. (b) 1 Ω
14. (d) nR
15. (c) $\rho_1 = \rho_2$
16. (b) kg / ampere. sec
17. (b) $n^2 : 1$
18. (b) conductance.

1. $R_2 = \left(\frac{l_2}{l_1}\right)^2 . R_1 = \left(\frac{50}{10}\right)^2 \times 2$

$= 25 \times 2 = 50\ \Omega$.

2. $22 \times 10^0 = 22\ \Omega$

8. $R_p = R/n = 2/2 = 1\ \Omega$

10. $P = V^2/R = \frac{240 \times 240}{120} =$

$= 480\ W$

12. $R \propto \frac{1}{A} \propto \frac{1}{d^2}$ $d_2 \to 2d_1$

$\frac{R_2}{R_1} = \frac{d_1^2}{d_2^2} = \frac{d_1^2}{(2d_1)^2}$

$R_2/R_1 = \frac{d_1^2}{4d_1^2} = 1/4$

$\therefore R_2 = \frac{R_1}{4}$

13. $r = \frac{E - V}{I} = \frac{E - IR}{I}$

$= \frac{2.2 - (0.2 \times 10)}{0.2}$

$= \frac{0.2}{0.2} = 1\Omega$

17. $R_s = nR$; $R_p = R/n$

$\frac{R_s}{R_p} = \frac{nR}{R/n} = n^2$

$\therefore n^2 : 1$

Based on concepts

1. Nichrome is used as heating element because it has
a) very low resistance b) low melting point
c) high specific resistance d) high conductivity
2. Peltier effect is the converse of
a) Joule effect b) Raman effect
c) Thomson effect **d) Seebeck effect**
3. In which of the following pairs of metals of a thermocouple the e.m.f. is maximum?
a) Fe – Cu b) Cu – Zn c) Pt - Ag **d) Sb – Bi**
4. Joule's law of heating is
a) $H = I^2 t/R$ b) $H = V^2Rt$ c) $H = IR^2t$ **d) $H = VIt$**
5.. Fuse wire is an alloy of
a) Lead and Tin b) Tin and Copper
c) Lead and Copper d) Lead and Iron
6. Fuse wire
a) is an alloy of lead and copper b) has low resistance
c) has high resistance d) has high melting point
7. In the case of insulators, as the temperature increases, the resistivity **decreases**
8. The drift velocity acquired per unit electric field is called **mobility**
9. Kirchoff's first law is a consequence of conservation of **charges**
10. Kirchoff's second law is a consequence of conservation of . **energy**
11. 1 kWh is equal to **36×10^5** J.
12. The quantity of charge passing per unit time through unit area is called as **current density**
13. Germanium and silicon are called as **semiconductors**
14. The electric iron works on the principle of **Joule's heating** effect of current.
15. The melting point of tungsten is **3380**$^\circ$C.
16. Fuse wire has high resistance and **low** melting point.
17. The alloy of nickel and chromium is called **nichrome**
18. Sn, Au, Ag, Zn, Cd, Sb show **Positive Thomson** effect.
19. Bi, Ni, Pt, Co, Fe, Hg show **Negative Thomson** effect.
20. Seebeck effect is a **Reversible** process.
21. Which of the following has negative temperature coefficient of resistance?
(a) copper (b) tungsten **(c) carbon** (d) silver
22. The temperature co-efficient of resistance for alloys is
(a) low **(b) very low** (c) high (d) very high
23. .Joule heating effect is desirable in
(a) AC dynamo (b) DC dynamo **(c) water heater** (d) Transformer
24.The resistivity of a wire depends on
(a) Length (b) material (c) area of cross section **(d) all the above**
25. Ohm's law is applicable for
(a) Complicated circuit **(b)simple circuit** (c) Primary circuit (d) secondary circuit

Notes

1.Instaneous Current $I = dq/dt$

2.Current $I = Q / t$ Unit : A

3.Drift velocity $v_d = a\,\tau$ Unit: m/s

4. **Mobility** $\mu = \frac{v_d}{E}$ **Unit :** m^2/Vs

5. **Current density** $J = \frac{I}{A}$ **Unit** : A/m^2 **Quantity :** Vector

6. **Ohm's law** $V \,\alpha\, I$ $V = IR$

V-potential difference **I** - current

R - resistance

7. **Resistance** $R = \frac{V}{I}$ **Unit :** ohm or Ω

8. **Electrical resistivity** $\rho = \frac{RA}{L}$ **Unit :** Ω m or ohm-meter

9.Resistors in series $R_s = R_1 + R_2 + R_3$

10.Resistors in parallel $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

11. Temperature coefficient of resistance $\alpha = \frac{\Delta\rho}{\Delta T\,\rho_0}$ **Unit :** per ^0C

12. Joule's law of heating. $H = I^2Rt$

13.Conductivity $\sigma = 1/\rho$ **Unit :** $\Omega^{-1}\,m^{-1}$

14.Internal resistance of the cell $r = \left(\frac{\xi - V}{V}\right) R$

15.Condition for bridge balance $\frac{P}{Q} = \frac{R}{S}$

16.In metre bridge ; Unknown resistance $P = Q\,\frac{l_1}{l_2}$

17.Electric power $P = VI = I^2R$

Two marks (Book back & Book inside)

1.Define electric current

The electric current in a conductor is defined as the rate of flow of charges through a given cross-sectional area A.

$\mathbf{I} = \frac{Q}{t}$ **Unit** : Ampere **Quantity** : scalar

2.Define 1 ampere current

1A of current is equivalent to 1 Coulomb of charge passing through a perpendicular cross section in 1second

$\mathbf{I} = \frac{1C}{1s}$

3.Define Drift velocity

The drift velocity is the average velocity acquired by the electrons inside the conductor when it is subjected to an electric field

$\mathbf{v_d = a\,\tau}$ **Unit:** m/s **quantity :** vector

4.Define mean free time

The average time between successive collisions is called the mean free time denoted by τ . $\boldsymbol{\tau} = \frac{v_d}{a}$ **Unit :** s

5.Define mobility

It is defined as the magnitude of the drift velocity per unit electric field.

$\mu = \frac{v_d}{E}$ **Unit :** m^2/Vs **Quantity :** scalar

6.Define Current density (BB-10)

The current density (J) is defined as the current per unit area of cross section of the conductor.

$\mathbf{J} = \frac{I}{A}$ **Unit** : A/m^2 **Quantity :** Vector

7.Write down microscopic model of ohm's law (BB-3)

$$\vec{J} = \sigma\vec{E}$$

J- Current density **σ** – conductivity

E – Electric field

8. **Why current is a scalar? (BB-1)**

Current I is defined as the scalar product of the current density and area vector in which the charges cross.

It does not obey vector law of addition and multiplication .& it cannot be resolved into components unlike other vector quantities

17.Define temperature coefficient of resistance (BB-7)

It is defined as the ratio of increase in resistivity per degree rise in temperature to its resistivity at T_0 .

$\alpha = \frac{\Delta\rho}{\Delta T\, \rho_0}$ **Unit :** per ^{0}C

18.Why temperature coefficient of resistance (α) is positive for conductor and negative for semiconductor

- If the temperature of a conductor increases, the average kinetic energy of electrons in the conductor increases. This results in more frequent collisions and hence the resistivity increases.
- As the temperature increases, more electrons will be liberated from their atoms . Hence the current increases and therefore the resistivity decreases.

19.Define thermistor

A semiconductor with a negative temperature coefficient of resistance is called a thermistor.

Ex: Germanium , silicon

20.Define transition or critical temperature

The resistance of certain materials become zero below certain temperature $T_{c.}$ This temperature is known as critical temperature or transition temperature.

21.What are superconductor

The resistance of certain materials become zero below certain temperature. The materials which exhibit this property are known as superconductors

22.When the car engine is started with headlights turned on, they sometimes become dim.

This is due to the internal resistance of the car battery.

23.Define Kirchhoff's first rule (Current rule or Junction rule) (BB-13)

It states that the algebraic sum of the currents at any junction of a circuit is zero. It is a statement of conservation of electric charge. Current entering the junction is taken as positive and current leaving the junction is taken as negative

24.Define Kirchhoff's Second rule (Voltage rule or Loop rule) (BB-14)

It states that in a closed circuit the algebraic sum of the products of the current and resistance of each part of the circuit is equal to the total emf included in the circuit. This rule follows from the law of conservation of energy for an isolated system.

25.Define Joule's heating effect.

When current flows through a resistor, some of the electrical energy delivered to the resistor is converted into heat energy and it is dissipated.

33. Define Thomson effect (BB-19)

Thomson showed that if two points in a conductor are at different temperatures, the density of electrons at these points will differ and as a result the potential difference is created between these points. Thomson effect is also reversible.

34.What is superconductivity (BB-8)

The ability of certain metals , their compounds and alloys to conduct electricity with zero resistance at very low temperature is called Superconductivity

35.What is electric power and energy (BB-9)

The electric power is defined as rate at which electrical energy is delivered

Unit : watt

Electric energy is work done by moving streams of electrons or charges

Unit : joule

36.Write down various from of expression for power in electric circuit (BB-12)

$P = VI = I^2R = V^2/ R$

37.Derive expression for power P=VI in electric circuit (BB-11)

$P = \frac{dW}{dt} = \frac{d}{dt}(V.dQ) = V\frac{dQ}{dt}$

Since $I = \frac{dQ}{dt}$

$\mathbf{P = VI}$

38.State principle of potentiometer (BB-15)

When a constant current flows through a wire of uniform area of cross section , The emf of the cell is directly proportional to the balancing length of wire between two points

$\mathbf{E \propto l}$

39.What do you meant by internal resistance of a cell (BB-16)

The resistance offered by electrolyte of a cell to the flow of current between its electrodes is called internal resistance of a cell

40.Distinguish between drift velocity and mobility (BB-2)

Drift velocity	**Mobility**
It is defined as velocity with which electrons get drifted towards positive terminal when electric field is applied	It is defined as the magnitude of the drift velocity per unit electric field
$v_d = a\,\tau$	$\mu = \frac{v_d}{E}$
Unit : m/s	**Unit :** $m^2V^{-1}s^{-1}$

Five marks (Book back)

1. Describe the microscopic model of current and obtain general form of Ohm's law

Consider a conductor with area of cross section A and an electric field applied from right to left. Suppose there are *n* electrons per unit volume in the conductor and assume that all the electrons move with the same drift velocity v_d

The electrons move through a distance *dx* within a small interval of *dt*

$v_d = \frac{dx}{dt}$ $dx = v_d dt$ **………..(1)**

A – area of cross section of the conductor

The electrons available in the volume of length dx = volume × n/V

= Adx × n **…………(2)**

Sub (2) in (1)

$= A v_d\, dt \times n$

Total charge in volume element dQ = charge × number of electrons in the volume element

$dQ = e A v_d\, dt \times n$

$I = \frac{dQ}{dt}$ **…………..(3)**

Sub (2) in (3)

$I = \frac{neAdtv_d}{dt}$

$I = neAv_d$

Since current density $\mathbf{J = I/A}$

$J = nev_d$ **……………(4)**

Sub v_d in (4)

$J = -\frac{n\tau e^2}{m}E$

$J = -\sigma E$

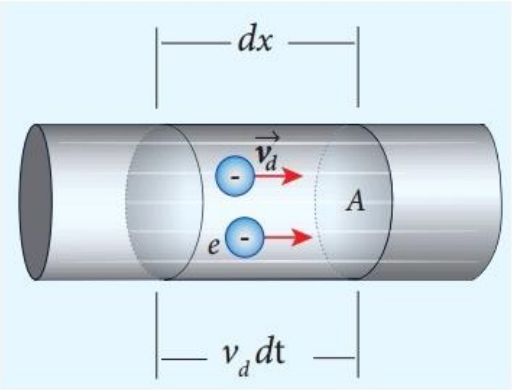


Figure 2.5 Microscopic model of current

But conventionally, we take the direction of (conventional) current density as the direction of electric field. So the above equation becomes

$\mathbf{J = \sigma E}$ **………(microscopic form's of ohm's law)**

$\boldsymbol{\sigma} = \frac{n\tau e^2}{m}$ is called conductivity

2. **Obtain the macroscopic form of Ohm's law from its microscopic form and discuss its limitation**

$\mathbf{J = \sigma E.}$ **……..(1)**

Consider a segment of wire of length *l* and cross sectional area A.

When a potential difference V is applied across the wire, a net electric field is created in the wire which constitutes the current.

We assume that the electric field is uniform in the entire length of the wire, the potential difference (voltage V) can be written as

$\mathbf{V = E}l$ $E = V/l$ ……… *(2)*

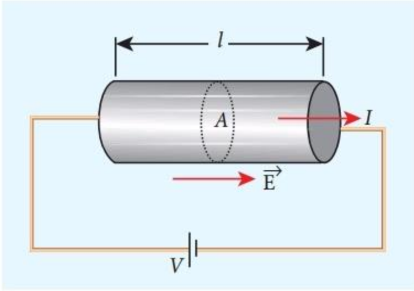


Figure 2.7 Current through the conductor

Sub (2) in (1)

$J = \sigma V/l$

$\mathbf{J = I/A}$

$\mathbf{I/A} = \sigma V/l$

By rearranging above equation

$V = I\,(l / \sigma A)$

$l / \sigma A$ - Resistance of a conductor (R)

$R \propto l \quad R \propto A$

Therefore, the macroscopic form of ohm's law can be stated as

$\mathbf{V = IR}$

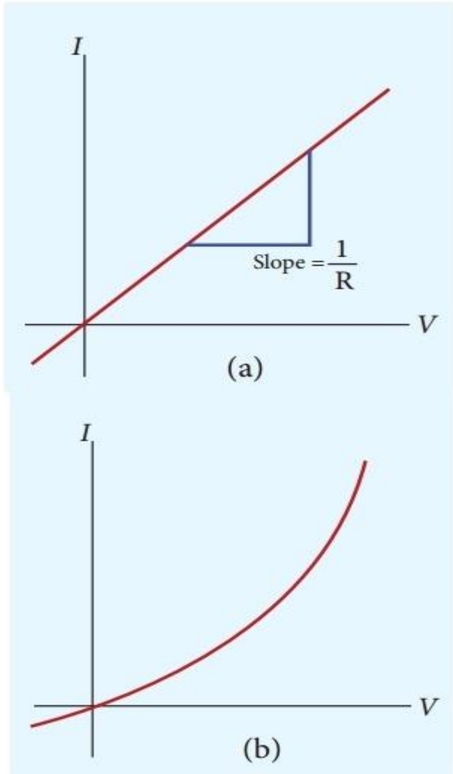


Figure 2.8 Current against voltage for (a) a conductor which obey Ohm's law and (b) for a non-ohmic device (Diode given in XII physics, unit 9 is an example of a non-ohmic device)

From the above equation, **the resistance is the ratio of potential difference across the given conductor to the current passing through the conductor.**

$\mathbf{R = V / I}$

Unit ; Ohm or Ω

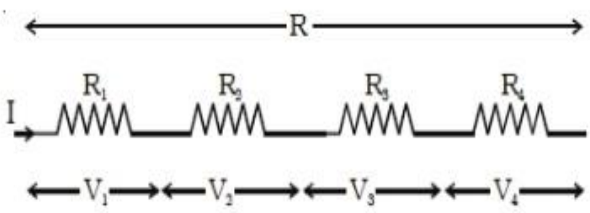
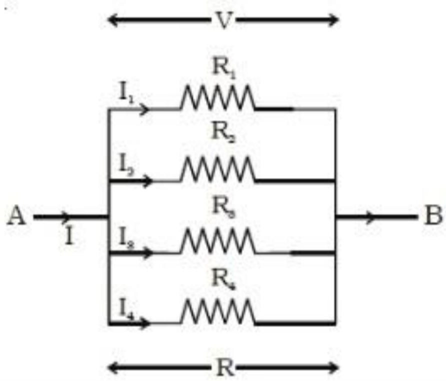
Limitations

A plot of I against V for a non-ohmic material is non-linear and they do not have a constant resistance

It is obeyed by many substance under certain conditions but it is not a fundamental law of nature

It is applicable only for simple circuits

3.Explain the equivalent resistance of a series and parallel resistor network

Resisters in series	Resisters in parallel
1. R_1, R_2, R_3, R_4 Resisters are connected in series. Rs is the effective resistance.	1. R_1, R_2, R_3, R_4 are Resisters connected in parallel. R_P is the effective resistance.
2. 	2. 
3. Current flowing through each resistor is the same.	3. Potential difference (V) across each resistor is same.
4. $V = V_1 + V_2 + V_3 + V_4$	4. $I = I_1 + I_2 + I_3 + I_4$.
5. $V_1 = IR_1$, $V_2 = IR_2$, $V_3 = IR_3$, $V_4 = IR_4$ and $V = IR_S$ $IR_S = IR_1 + IR_2 + IR_3 + IR_4$ **(Or) $R_S = R_1 + R_2 + R_3 + R_4$**	5. $I_1 = \frac{V}{R_1}$, $I_2 = \frac{V}{R_2}$, $I_3 = \frac{V}{R_3}$, $I_4 = \frac{V}{R_4}$ $\boxed{I = \frac{V}{R_P}}$ $\frac{V}{R_P} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} + \frac{V}{R_4}$ $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$
6. The equivalent resistance of a number of resistors in series connection is equal to the sum of the resistance of individual resistors.	6. The sum of the reciprocal of the resistance of the individual resistors is equal to the reciprocal of the effective resistance of the combination.

6. Obtain the condition for bridge balance in Wheatstone's bridge.

- An important application of Kirchhoff 's rules is the Wheatstone's bridge. It is used to compare resistances and also helps in determining the unknown resistance in electrical network.
- The bridge consists of four resistances P, Q, R and S connected .
- A galvanometer G is connected between the points B and D.
- The battery is connected between the points A and C. The current through the galvanometer is I_G and its resistance is G.

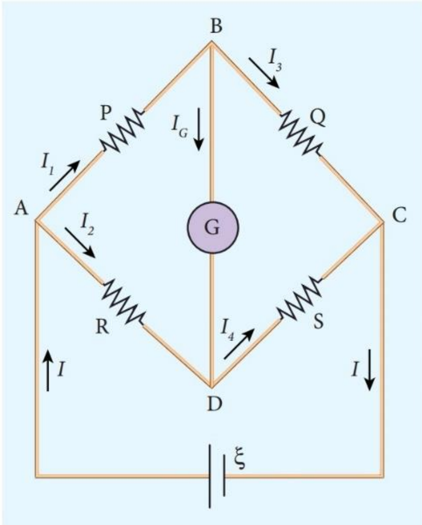


Figure 2.25 Wheatstone's bridge

Applying **Kirchhoff 's current rule to junction B**

$$I_1 - I_G - I_3 = 0 \quad \text{.................(1)}$$

Applying **Kirchhoff 's current rule to junction D,**

$$I_2 - I_G - I_4 = 0 \quad \text{.................(2)}$$

Applying **Kirchhoff 's voltage rule to loop ABDA,**

$$I_1P + I_GG - I_2R = 0 \quad \text{.................(3)}$$

Applying Kirchhoff 's voltage rule to loop ABCDA,

$$I_1P + I_3Q - I_2R - I_4S = 0 \quad \text{.................(4)}$$

When the points B and D are at the same potential, the bridge is said to be balanced , no current flows through galvanometer ($I_G = 0$).

Substituting $I_G = 0$ in (1) , (2) , (3) , (4)

$$I_1 = I_3 \quad \text{.................(5)} \qquad I_2 = I_4 \quad \text{.................(6)}$$

$$I_1P = I_2R \quad \text{.................(7)}$$

Substituting **(5) & (6) in (4)**

$$I_1P + I_1Q - I_2R - I_2S = 0$$

$$I_1(P + Q) = I_2(R + S) \quad \text{..................(8)}$$

Dividing (8) by (7)

$$\frac{P+Q}{P} = \frac{R+S}{R}$$

$$1 + \frac{Q}{P} = 1 + \frac{S}{R}$$

$$\frac{P}{Q} = \frac{R}{S}$$

7. Explain the determination of unknown resistance using meter bridge

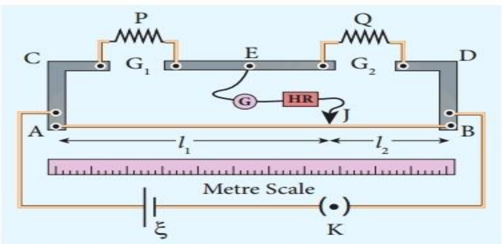


Figure 2.26 Meter bridge

1) The meter bridge is another form of Wheatstone's bridge.

2) It consists of a uniform manganin wire AB of one meter length.

3) This wire is stretched along a meter scale on a wooden board between two copper strips C and D.

4) Between these two copper strips another copper strip E is mounted to enclose two gaps G_1 and G_2 .
5) An unknown resistance P is connected in G_1 and a standard resistance Q is connected in G_2.
6) A jockey (conducting wire) is connected to the terminal E on the central copper strip through a galvanometer (G) and a high resistance (HR).
7) The exact position of jockey on the wire can be read on the scale. A Lechlanche cell and a key (K) are connected across the ends of the bridge.
8) The position of the jockey on the wire is adjusted so that the galvanometer shows zero deflection. Let the point be J. The lengths AJ and JB of the bridge wire now replace the resistance R and S of the Wheatstone's bridge. Then

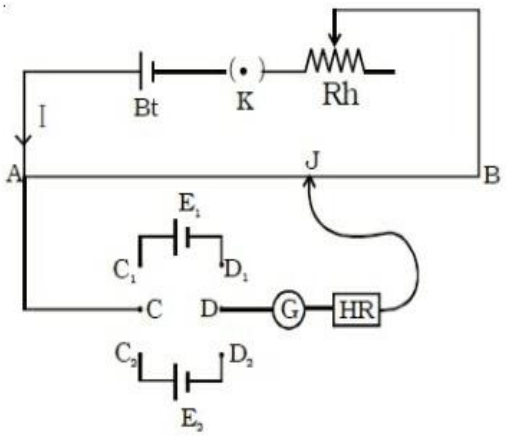
$$\frac{P}{Q} = \frac{R}{S} = \frac{R'\cdot AJ}{R'\cdot BJ}$$

$$\frac{P}{Q} = \frac{AJ}{JB} = \frac{l_1}{l_2}$$

$$\mathbf{P = Q}\,\frac{l_1}{l_2}$$

The bridge wire is soldered at the ends of the copper strips. Due to imperfect contact, some resistance might be introduced at the contact. These are called end resistances. This error can be eliminated, if another set of readings are taken with P and Q interchanged and the average value of P is found.

8. How the emf of two cells are compared using potentiometer?



- The end A of potentiometer is connected to the terminal C of a DPDT switch.
- Battery, key and rheostat are connected in series with B. terminal D is connected to the jockey (J) through a galvanometer and high resistance.
- Let I be the current flowing through the primary circuit and r be the resistance of the potentiometer wire per metre length.
- The jockey is moved on the wire and adjusted for zero deflection in galvanometer.
- $E_1 = Irl_1$ ---------------→(1)
- $E_2 = Irl_2$---------------→(2)

$$\boxed{\frac{E_1}{E_2} = \frac{l_1}{l_2}} \qquad \boxed{E_2 = E_1\frac{l_2}{l_1}}$$

The equivalent internal resistance of the battery is $\frac{1}{r_{eq}} = \frac{1}{r} + \frac{1}{r} + \frac{1}{r} \ldots\ldots \frac{1}{r}\,(\boldsymbol{n\ terms})$

$$r_{eq} = \frac{r}{n}$$

Total resistance of the circuit = R + $\frac{r}{n}$

Current in the circuit is given by I = $\frac{\xi}{R + \frac{r}{n}}$

$$I = \frac{n\xi}{nR + r}$$

Case (a) If r >> R, I = I = $\frac{n\xi}{R}$ ≈ $\mathbf{nI_1}$

I_1 - Current due to single cell

Case (b) If r<<R,

I = $\frac{\xi}{R}$

The above equation implies that current due to the whole battery is the same as that due to a single cell. Hence it is advantageous to connect cells in parallel when the external resistance is very small compared to the internal resistance of the cells.

2. **What is potentiometer and write down its principle**

- Potentiometer is used for the accurate measurement of potential differences, current and resistances.
- It consists of ten meter long uniform wire of manganin or constantan stretched in parallel rows each of 1 meter length, on a wooden board.
- The two free ends A and B are brought to the same side and fixed to copper strips with binding screws. A meter scale is fixed parallel to the wire. A jockey is provided for making contact.

Principle

A steady current is maintained across the wire CD by a battery*Bt*.

The battery, key and the potentiometer wire are connected in series forms the primary circuit. The positive terminal of a primary cell of emf ξ is connected to the point C and negative terminal is connected to the jockey through a galvanometer G and a high resistance HR. This forms the secondary circuit.Let contact be made at any point J on the wire by jockey. If the potential difference across CJ is equal to the emf of the cell ξ then no current will flow through the galvanometer and it will show zero deflection. CJ is the balancing length *l*. The potential difference across CJ is equal to *Irl* where *I* is the current flowing through the wire and *r* is the resistance per unit length of the wire. ξ = ***Irl***

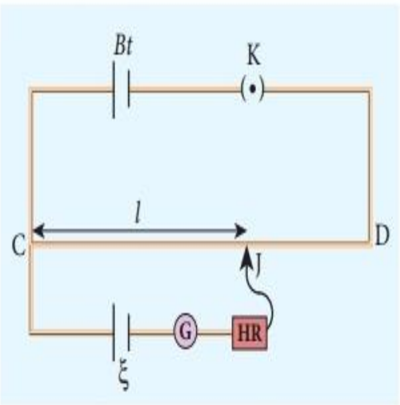


Figure 2.27 Potentiometer

Since I and r are constants

The emf of the cell is directly proportional to the balancing length.

3. Explain determination of internal resistance of a cell by potentiometer

To measure the internal resistance of a cell, the circuit connections are made

The end C of the potentiometer wire is connected to the positive terminal of the battery Bt and the negative terminal of the battery is connected to the end D through a key K_1. This forms the primary circuit.

The positive terminal of the cell ξ whose internal resistance is to be determined is also connected to the end C of the wire. The negative terminal of the cell ξ is connected to a jockey through a galvanometer and a high resistance. A resistance box R and key K_2 are connected across the cell ξ. With K_2 open, the balancing point J is obtained and the balancing length CJ = l_2 is measured. Since the cell is in open circuit, its emf is

$$\xi \propto l_1$$

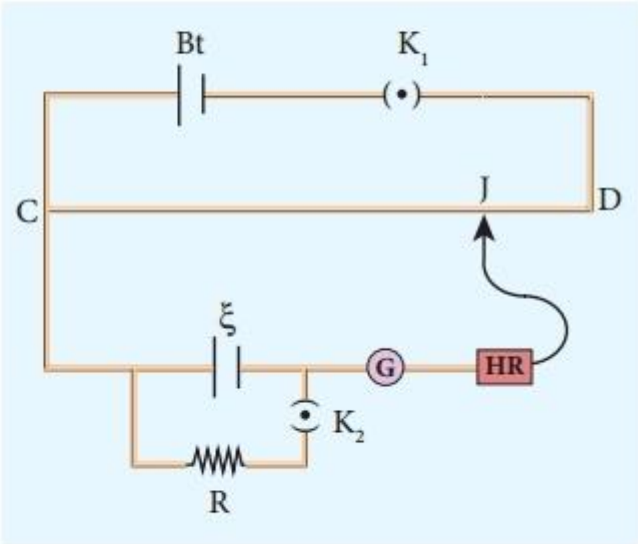


Figure 2.29 measurement of internal resistance

A suitable resistance (say, 10 Ω) is included in the resistance box and key K_2 is closed. Let r be the internal resistance of the cell. The current passing through the cell and the resistance R is given by

$$I = \frac{\xi}{R+r} \quad \text{.........(1)}$$

The potential difference across R is

$$V = \frac{\xi R}{R+r}$$

When this potential difference is balanced on the potentiometer wire, let $l2$ be the balancing length. $\frac{\xi R}{R+r} \propto l_2$ **.............(2)**

From (1) & (2)

$$\frac{R+r}{R} = \frac{l_1}{l_2}$$

$$r = R\left(\frac{l_1 - l_2}{l_2}\right)$$

Unit – 3 MAGNETISM AND MAGNETIC EFFECTS OF ELECTRIC CURRENT

One marks

1. The unit of reduction factor of tangent galvanometer is
a) no unit b) tesla **c) ampere** d) ampere / degree
2. A galvanometer is converted into a voltmeter by connecting a
a) low resistance in series b) high resistance in parallel
c) high resistance in series d) low resistance in parallel
3. Of the following devices which has small resistance?
a) Voltmeter b) Ammeter of range 0 – 10 A
c) Moving coil Galvanometer **d) Ammeter of range 0 – 1 A**
4. In a tangent galvanometer a current 1 A, produces a deflection of 30^0. The current required to produce a deflection of 60^0 is
a) 3A b) 2A c) √3 A d) 1 / √3 A
5. Peltier effect is the converse of
a) Joule effect b) Raman effect c) Thomson effect **d) Seebeck effect**
6. The torque experienced by a rectangular current loop placed perpendicular to a uniform magnetic field is
a) maximum **b) zero** c) finite minimum d) infinity
7. In a tangent galvanometer, for a constant Current, the deflection is 30^0. The place of the coil is rotated through 90^0. Now, for the same current, the deflection will be
a) 30^0 b) 60^0 c) 90^0 **d) 0^0**
8. An ideal voltmeter has
a) zero resistance b) finite resistance between zero and G
c) resistance greater than G but less than infinity **d) infinite resistance**
9. Peltier coefficient at a junction of a thermocouple depends on
a) the current in the thermocouple b) the time for which current flows
c) the temperature of the junction
d) the charge that passes through the thermocouple
10. The torque on a rectangular coil placed in a uniform magnetic field is large, when :
(a) the number of turns is large (b) the number of turns is less
(c) the plane of the coil is perpendicular to the field (d) the area of the coil is small
11. Phosphor – bronze wire is used for suspension in a moving coil galvanometer because it has
a) high conductivity b) high resistivity
c) large couple per unit twist **d) small couple per unit twist**
12. When the number of turns (n) in a galvanometer is doubled, current sensitivity
a) remains constant b) decreases twice
c) increases twice d) increases four times
13. An electron is moving with a velocity of 3×10^6 ms $^{-1}$ perpendicular to a uniform magnetic field of induction 0.5 T. The force experienced by the electron is
a) 2.4×10^{-13} N b) 13.6×10^{-21} N c) 13.6×10^{-11} N d) zero

14. The period of revolution of a charged particle inside a cyclotron does not depend on

a) the magnetic induction b) the charge of the particle

c) the velocity of the particle d) the mass of the particle

15. The direction of force on a current carrying conductor placed in a magnetic field is given by :

a) Fleming's Left Hand Rule b) Fleming's Right Hand Rule

c) End Rule d) Right Hand Palm Rule

16. AB is a rod of lead, The end A is heated. A current I is allowed to flow along AB. Now due to Thomson effect in rod AB

a) heat is absorbed b) heat is liberated

c) heat is neither absorbed nor liberated d) heat is first absorbed and then liberated

17. A proton and α – particle are projects with this same velocity normal to a uniform magnetic field. The ratio of the magnetic Lorentz force experienced by the proton and the α particle is

(a) 1:1 **(b) 1 : 2** (c) 2:1 (d) 1:0

Fill ups

1.Tangent galvanometer works on the principle of **Tangent law**

2.The torque on a current carrying coil is **maximum** when the coil is **parallel** to the magnetic field.

3.The product of current and the loop area is called **magnetic dipole moment**

4.The value of gyro magnetic ratio is **8.8×10^{10}**

5.The magnetic field in a moving coil galvanometer is the **radial magnetic field**

6.The unit of magnetic induction is **tesla**

7.Bohr magneton value **9.27×10^{-24} Am^2**

8. A vertical plane passing through the geographic axis is called **geographic meridian**

9. A great circle perpendicular to Earth's geographic axis is called **geographic equator.**

10. The straight line which connects magnetic poles of Earth is known as **magnetic axis.**

11.A vertical plane passing through magnetic axis is called **magnetic meridian** and a great circle perpendicular to Earth's magnetic axis is called **magnetic equator**

12.At At **higher latitudes**, the **declination is greater** whereas **near the equator**, the **declination is smaller**.

13. For Chennai, **magnetic declination angle is $-1^o 8'$ & inclination angle is $14^o 16'$.**

14. **Horizontal component** of magnetic field is **maximum at equator** and **zero at poles**.

15.Vertical component is zero at equator and maximum at equator.

16.A freely suspended magnet always point along **north – south direction**

17**.** Pole strength depends on the **nature of materials of the magnet, area of cross- section and the state of magnetization.**

18. If a magnet is cut into **two equal halves along the length** then **pole strength is reduced to half.**

19. If a magnet is cut into **two equal halves perpendicular to the length, then pole strength remains same.**

20. Dimensional formula for magnetic flux is **$[MLT^{-2}A^{-1}]$**

(7) Magnetic induction due to a long solenoid carrying current $B = \mu n I = \mu_0 \mu_r n I = \mu_0 \mu_r \left(\frac{N}{L}\right) L$

(8) Magnetic Lorentz force.
Force on a moving charge in a magnetic field $\vec{F} = q\left[\vec{v} \times \vec{B}\right]$

(9) In the presence of an electric field $\vec{F} = q\left(\left(\vec{v} \times \vec{B}\right) + \vec{E}\right)$

(10) Radius of the circular path $r = \frac{mv}{Bq}$

Angular velocity $\omega = \frac{Bq}{m}$; Period of rotation $T = \frac{2\pi}{\omega} = \frac{2\pi m}{Bq}$

(11) Force on a current carrying conductor placed in a magnetic field $\vec{F} = \vec{Il} \times \vec{B}$ (or) $F = BIl\sin\theta$.

(12) Force between two parallel long current carrying conductors $\vec{F} = \frac{\mu_0}{2\pi} \frac{I_1 I_2 dl}{r} \hat{j}$ (or) $\frac{\vec{F}}{l} = \frac{\mu_0 I_1 I_2}{2\pi r} \hat{j}$

(13) Torque experienced by current loop in a uniform magnetic field $\vec{\tau}_{net} = IBA\sin\theta\, \vec{k}$

(14) Moving coil galvanometer, $I = G\theta$; $G = \frac{K}{NBA}$ (Galvanometer constant)

(15) Current sensitivity of galvanometer $\frac{\theta}{I} = \frac{NBA}{K} = I_S$

(16) Voltage sensitivity of galvanometer $\frac{\theta}{V} = \frac{NBA}{KG} = V_S$

(17) Conversion of galvanometer into an ammeter.

Value of shunt resistance $S = \frac{I_g R_g}{I - I_g}$; Effective resistance $R_a = \frac{R_g S}{R_g + S}$

(18) Conversion of galvanometer into a voltmeter $R = \frac{V}{I_g} - R_g$

Effective resistance $R_V = R_g + R_h$

(19) Current loop as a magnetic dipole $\vec{B} = \frac{\mu_0}{2\pi} \frac{\vec{P}_m}{z^3} \hat{k}$; ($\vec{P}_m = IA$)

(20) Magnetic dipole moment of a revolving electron $\mu_L = \frac{neh}{4\pi m}$

(21) Minimum value of magnetic moment $(\mu_l)_{min} = \frac{eh}{4\pi m}$

(22) Bohr magneton $= \frac{eh}{4\pi m}$

Book Back

Short Answers Questions

1.What is meant by magnetic induction or total magnetic filed

The magnetic induction (**total magnetic field**) inside the specimen $\vec{B}$ is equal to the sum of the magnetic field B produced in vacuum due to the magnetising field and the magnetic field $\overrightarrow{B_m}$ due to the induced magnetisation of the substance.

$\vec{B} = \overrightarrow{B_m} + \overrightarrow{B_0}$

2.Define magnetic flux

The number of magnetic field lines crossing per unit area is called magnetic flux Φ_B

$\Phi_B = \vec{B}.\vec{A}$ = BA COSΘ

Unit : weber (Wb)

Quantity : Scalar

3.Define dipole moment

The magnetic dipole moment is defined as the product of its pole strength and magnetic length.

Magnitude of dipole moment

$P_m = 2\, q_m l$

Unit : Am^2

Quantity : Vector

4.State COULOMB'S INVERSE SQUARE LAW OF MAGNETISM

The force of attraction or repulsion between two magnetic poles is directly proportional to the product of their pole strengths and inversely proportional to the square of the distance between them.

$\vec{F} \propto \frac{q_{mA} q_{mB}}{r^2} \hat{r}$

5.What is magnetic susceptibility ?

- It is defined as the ratio of the intensity of magnetisation ($\vec{M}$) induced in the material due to the magnetising field ($\vec{H}$)
- $\chi_m = \frac{|\vec{M}|}{|\vec{H}|}$
- It is a **dimensionless quantity**

6.State Biot – Savart's law

Biot and Savart observed that the magnitude of magnetic field $\overrightarrow{dB}$ at a point P at a distance r from the small elemental length taken on a conductor carrying current varies

(i) directly as the strength of the current I

(ii) directly as the magnitude of the length element $\overrightarrow{dl}$

(iii) directly as the sine of the angle (say,θ) between $\overrightarrow{dl}$ and $\hat{r}$

Book inside

Short answers

1. What is Geomagnetism

The branch of physics which deals with the Earth's magnetic field is called Geomagnetism or Terrestrial magnetism.

2. What are elements of the Earth's magnetic field.

(a) magnetic declination (D)
(b) magnetic dip or inclination (I)
(c) the horizontal component of the Earth's magnetic field (B_H)

3. Define Magnetic declination

The angle between magnetic meridian at a point and geographical meridian is called the *declination or magnetic declination (D)*.

At higher latitudes, the declination is greater whereas near the equator, the declination is smaller.

4. Define dip or magnetic inclination

The angle subtended by the Earth's total magnetic field with the horizontal direction in the magnetic meridian is called dip or magnetic inclination (I) at that point

5. Define horizontal component of Earth's magnetic field

The component of Earth's magnetic field along the horizontal direction in the magnetic meridian is called horizontal
component of Earth's magnetic field, denoted by B_H.

6.Define Magnetic field

The magnetic field at a point is defined as a force experienced by the bar magnet of unit pole strength

$$\vec{B} = \frac{F}{q_m}$$

Unit : $\mathbf{N\ A^{-1}\ m^{-1}}$

7.What are Types of magnets and its difference

Types : Natural magnets and Artificial magnets.

Natural Magnet	Artificial magnet
Strengths of natural magnets are very weak and the shapes of the magnet are irregular.	It have desired shape and strength
Ex: iron, cobalt, nickel	**Ex:** Bar magnet

15. Define Intensity of magnetisation for bar magnet

For a bar magnet the intensity of magnetisation can be defined as the pole strength per unit area

$$M = \frac{q_m}{A}$$

Unit ; Am^{-1}

16.Define Meissner effect.

The expulsion of magnetic flux from a superconductor during its transition to the superconducting state is known as Meissner effect.

17.Define Curie's law

Susceptibilty is inversely proportional to temperature

$$\chi_m \ \alpha \ \frac{1}{T}$$

18.Why there is a strong net magnetisation of the Ferro magnetic material in the direction of the applied field

1)The domains having magnetic moments parallel to the field grow in size

2) the other domains (not parallel to field) are rotated so that they are aligned with the field.

19.Define Curie-Weiss law.

At a particular temperature, ferromagnetic material becomes paramagnetic. This temperature is known as Curie temperature T_C. The susceptibility of the material above the Curie temperature is given by

$$\chi_m = \frac{C}{T - T_C}$$

20.Define coercivity.

The magnitude of the reverse magnetising field for which the residual magnetism of the material vanishes is called its coercivity.

21.Define retentivity

It is defined as the ability of the materials to retain the magnetism in them even magnetising field vanishes.

22.State Right hand thumb rule

If we hold the current carrying conductor in our right hand such that the thumb points in the direction of current flow, then the fingers encircling the wire points in the direction of the magnetic field lines produced.

23. **State Maxwell's right hand cork screw rule**

If we rotate a right hand screw using a screw driver then the direction of current is same as direction in which screw advances and the direction of rotation of screw gives direction of magnetic field

24. Difference between Coulomb's law and Biot – Savart law

Electric field	Magnetic field
Produced by **scalar source (q)**	Produced by **vector source** (I $\vec{dl}$)
It is directed along the position vector joining the source & the point at which field is calculated	It is directed perpendicular to the position vector $\vec{r}$ **and the current element** I. $\vec{dl}$
Does not depend on **angle**	Depend an angle between position vector and current element

25. Define the magnetic dipole moment of any current loop

The magnetic dipole moment of any current loop is equal to the product of the current and area of the loop.

$\vec{P}_m = I\vec{A}$

Unit : A m^2

26.State Right hand thumb rule (mnemonic)

It states that If we curl the fingers of right hand in the direction of current in the loop, then the stretched thumb gives the direction of the magnetic moment associated with the loop.

26.Define magnetic Lorentz force

If the charge moves in the magnetic field, it experiences a force.

This force is known as magnetic force If the charge is moving in both the electric and magnetic fields, the total force experienced by the charge is given by

$\vec{F} = q\ (\vec{E} + (\vec{v} \times \vec{B}\ )\ )$It is known as Lorentz force.

27.Define one tesla

The strength of the magnetic field is one tesla if unit charge moving in it with unit velocity experiences unit force $F_m = Bq\,v\sin\theta$

$F_m = 1N \quad q = 1C \qquad v = 1\ m/s$

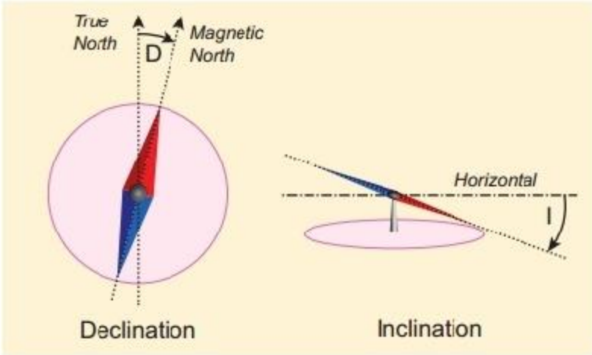
$1\ T = 1\ N A^{-1} m^{-1}$

Book Back

Long Answer Question

1.Discuss Earth's magnetic field in detail

Gover suggested that the Earth's magnetic field is due to hot rays coming out from the Sun. These rays will heat up the air near equatorial region. Once air becomes hotter, it rises above and will move towards northern and southern hemispheres and get electrified. This may be responsible to magnetize the ferromagnetic materials near the Earth's surface



The north pole of magnetic compass needle is attracted towards the magnetic south pole of the Earth which is near the geographic north pole . Similarly, the south pole of magnetic compass needle is attracted towards the geographic north pole of the Earth which is near magnetic north-pole. **The branch of physics which deals with the Earth's magnetic field is called Geomagnetism or Terrestrial magnetism.**

The three elements of of the Earth's magnetic field are

(a) magnetic declination (D)
(b) magnetic dip or inclination (I)
(c) the horizontal component of the Earth's magnetic field (B_H)

The angle between magnetic meridian at a point and geographical meridian is called the declination or magnetic declination (D).

The angle subtended by the Earth's total magnetic field with the horizontal direction in the magnetic meridian is called dip or magnetic inclination (I) at that point

The component of Earth's magnetic field along the horizontal direction in the magnetic meridian is called horizontal component of Earth's magnetic field, denoted by B_H.

2.Deduce the relation for the magnetic induction at a point due to an infinitely long straight conductor carrying current

Consider a long straight wire NM with current I flowing from N to M.P be the point at a distance *a* from point O.Consider an element of length d*l* of the wire at a distance *l* from point O

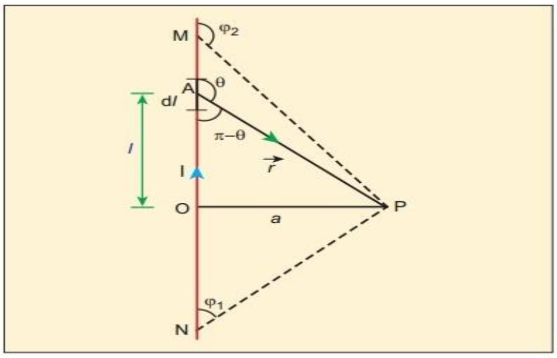


Figure 3.39 Magnetic field due to a long straight current carrying conductor

$\vec{r}$ be the vector joining the element d*l* with the point P.

θ – angle between $\vec{r}$ & $\overrightarrow{dl}$ Then, the magnetic field at P due to the element is

- Consider a current carrying circular loop of radius R.
- I be the current flowing through the wire in the direction as shown in Figure .
- The magnetic field at a point P on the axis of the circular coil at a distance *z* from its center of the coil O.

- It is computed by taking two diametrically opposite line elements of the coil each of length $\vec{dl}$ at C & D

According to Biot-Savart's law, the magnetic field at P due to the current element I $\vec{dl}$ is

$\vec{dB} = \frac{\mu_0}{4\pi} \frac{I\vec{dl}\times\hat{r}}{r^2}$ **............(1)**

- The magnitude of magnetic field due to current element $I\,\vec{dl}$ at C and D are equal because of equal distance from the coil.

- The magnetic field due to each current element $I\,\vec{dl}$ is resolved into two components; dB sin θ along y - direction and dB cos θ along z - direction.

Horizontal components of each current element cancels out while the vertical components (dB cos θ) alone contribute to total magnetic field at the point P.

PC = PD = r = $\sqrt{R^2 + Z^2}$

Then the net magnetic field at point P is

$\vec{B} = \int \vec{dB} = \int dB \cos\theta \hat{k}$

$= \frac{\mu_0}{4\pi} I \int \frac{dB}{r^2} \cos\theta \hat{k}$ …….. (2)

By triangle POD

cos $\theta = \frac{R}{\sqrt{R^2+Z^2}}$

sub cos θ value in (2) ,

integrating line element from 0 to 2πR, we get

$$\vec{B} = \frac{\mu_0}{2\pi} I \frac{R^2}{(R^2+z^2)^{\frac{3}{2}}} \hat{k}$$

4.Compute the torque experienced by a magnetic needle in a uniform magnetic field

- Consider a magnet of length 2*l* of pole strength q_m kept in a uniform magnetic field
- Each pole experiences a force of magnitude q_mB but acts in opposite direction.
- Therefore, the net force exerted on the magnet is zero, so that there is no translatory motion. These two forces constitute a couple (about midpoint of bar magnet) which will rotate and try to align in the direction of the magnetic field

The force experienced by north pole

$\vec{F_N} = q_m B$ **……….(1)**

The force experienced by South pole

$\vec{F_S}$ = -q_m B ……….(2)

Adding (1) & (2)

Net force on the dipole as

$\vec{F} = \vec{F_N} + \vec{F_S} = 0$

The moment of force or torque experienced by north and south pole about point O is

$\vec{\tau} = \vec{ON} \times \vec{F_N} + \vec{OS} \times \vec{F_S}$

$= \vec{ON} \times q_m B + \vec{OS} \times (-q_m B)$

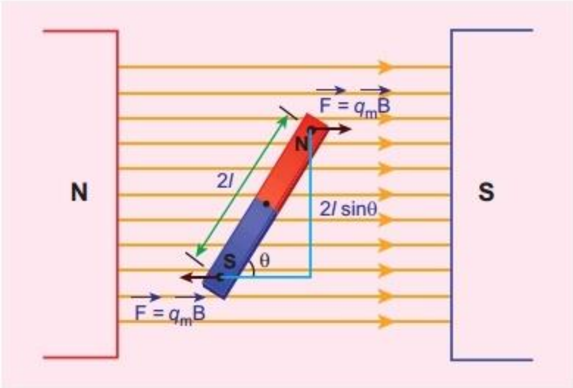


Figure 3.19 Magnetic dipole kept in a uniform magnetic field

By using right hand cork screw rule, we conclude that the total torque is pointing into the paper.

Since the magnitudes

$|\vec{ON}| = |\vec{OS}| = l$

$|Bq_m| = |-Bq_m|$

magnitude of total torque about point O

$\tau = l \times q_m B \sin\theta + l \times q_m B \sin\theta$

$= 2l \times q_m B \sin\theta$

Since $P_m = q_m \times 2l$

$= P_m B \sin\theta$

In vector notation

$\vec{\tau} = \vec{P_m} \times \vec{B}$

5.Calculate the magnetic induction at a point on the axial line of bar magnet

Consider a bar magnet NS.

Let N be the North Pole and S be the south pole of the bar magnet, each of pole strength q_m and separated by a distance of 2l.

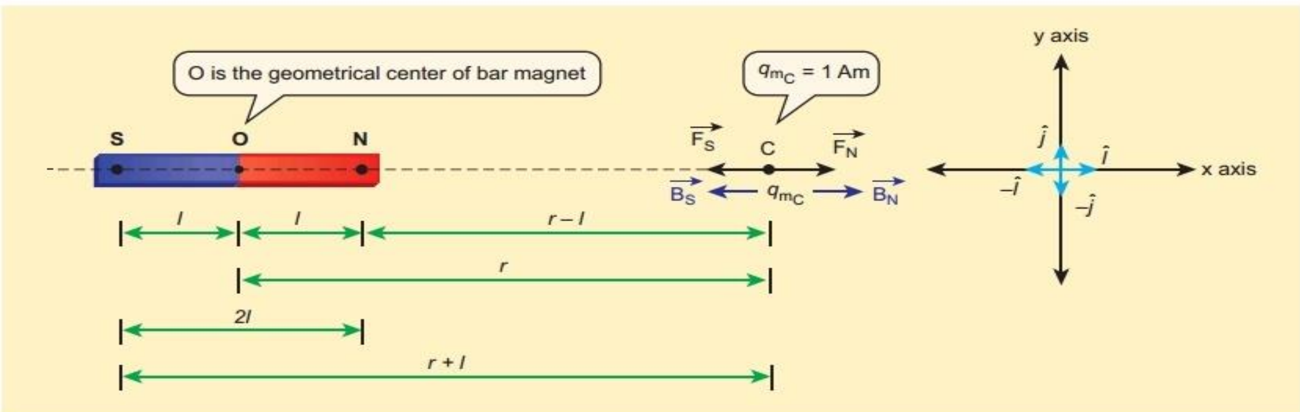


Figure 3.16 Magnetic field at a point along the axial line due to magnetic dipole

The force of repulsion between North Pole of the bar magnet and unit north pole at point C (in free space) is

$\vec{F_N} = -F_N \cos\theta\, \hat{i} - F_N \sin\theta\, \hat{j}$

$F_N = \frac{\mu_0}{4\pi}\frac{q_m}{(r')^2}$

$\vec{F_S} = -F_S \cos\theta\, \hat{i} - F_S \sin\theta\, \hat{j}$

$F_S = \frac{\mu_0}{4\pi}\frac{q_m}{(r')^2}$

$\vec{F} = \vec{F_N} + \vec{F_S}$

$\vec{B} = -(F_N + F_S)\cos\theta\, \hat{i}$

$F_N = F_S$

$\vec{B} = -2\frac{\mu_0}{4\pi}\frac{q_m}{(r')^2}\cos\theta\, \hat{i}$

$r'^2 = r^2 + l^2$

In right angle triangle

$\cos\theta = \frac{l}{(r^2+l^2)^{\frac{1}{2}}}$

Sub $\cos\theta = \frac{1}{(r^2+l^2)^{\frac{1}{2}}}$ **in above quation**

$\vec{B} = -2\frac{\mu_0}{4\pi}\frac{q_m}{r^2+l^2} \times \frac{1}{(r^2+l^2)^{\frac{1}{2}}}\, \hat{i}$

$= -\frac{\mu_0}{4\pi}\frac{2l \times q_m}{(r^2+l^2)^{\frac{3}{2}}}\, \hat{i}$

$= -\frac{\mu_0}{4\pi}\frac{P_m}{(r^2+l^2)^{\frac{3}{2}}}\, \hat{i}$ (since $P_m = q_m \times 2l$)

r >> l l^2 can neglected

$(r^2 + l^2)^{\frac{3}{2}} = (r^2)^{\frac{3}{2}} = r^3$

$\vec{B} = -\frac{\mu_0}{4\pi}\frac{P_m}{r^3}\, \hat{i}$

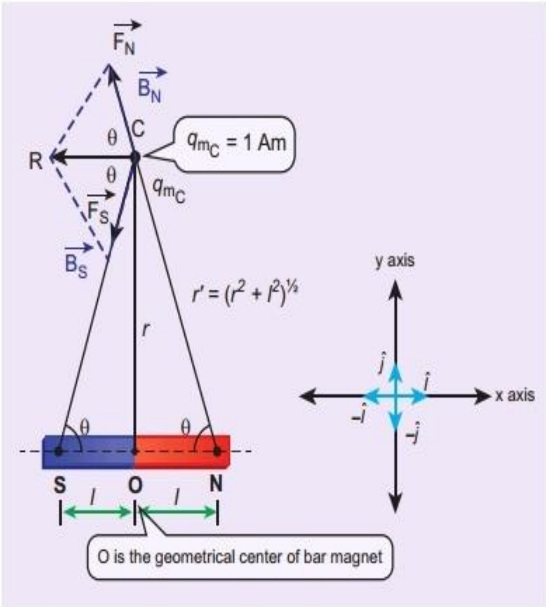


Figure 3.17 Magnetic field at a point along the equatorial line due to a magnetic dipole

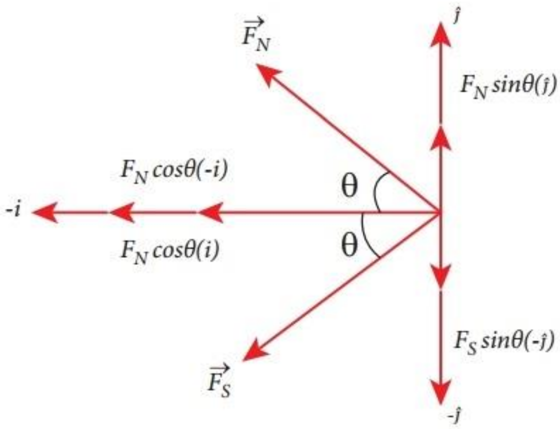


Figure 3.18 Components of force

- At this time, the polarities of the Dees are reversed so that the ion is now accelerated towards Dee-2 with a greater velocity.
- For this circular motion, the centripetal force of the charged particle q is provided by Lorentz force.

Lorentz force = Bqv

Centripetal force $= \frac{mv^2}{r}$

$\frac{mv^2}{r} = Bqv$

r $= \frac{mv}{qB}$ **........ (1)**

r α v

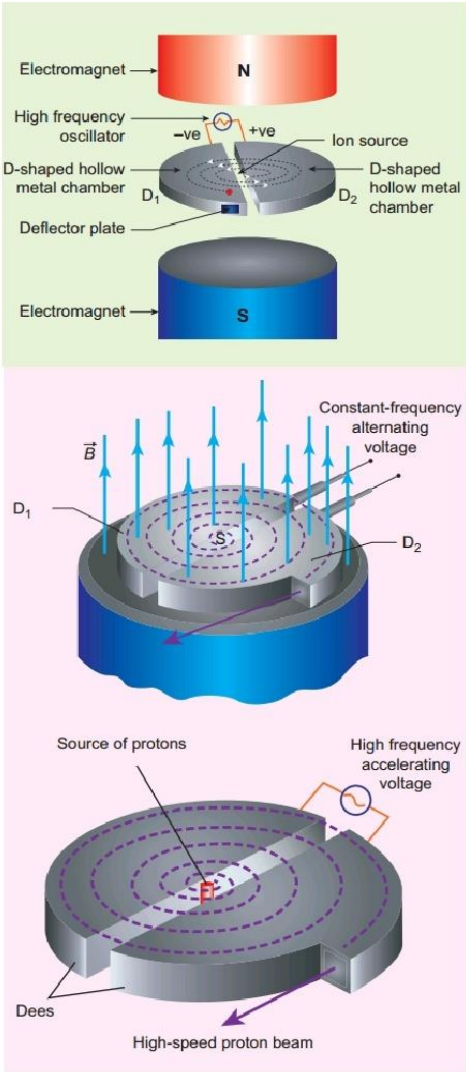


Figure 3.55 construction and working of cyclotron

From the equation (1), the increase in velocity increases the radius of circular path. This process continues and hence the particle undergoes spiral path of increasing radius. Once it reaches near the edge, it is taken out with the help of deflector plate and allowed to hit the target T.

Very important condition in cyclotron operation is the resonance condition. It happens when the frequency *f* at which the positive ion circulates in the magnetic field must be equal to the constant frequency of the electrical oscillator $f_{osc} = \frac{qB}{2\pi m}$

Time period of oscillation T $= \frac{1}{f_{osc}} = \frac{2\pi m}{qB}$

Kinetic energy of a particle K.E = ½ mv²

From (1) $v = \frac{rqB}{m}$

K.E $= \frac{q^2B^2r^2}{2m}$

Working

- Coil PQRS whose length be l and breadth b. PQ = RS = l and QR = SP = b.
- Let I be the electric current flowing through the rectangular coil PQRS The horse-shoe magnet has hemi - spherical magnetic poles which produces a radial magnetic field.
- Due to this radial field, the sides QR and SP are always parallel to to the B-field (magnetic field) and experience no force.
- The sides PQ and RS are always parallel to the B-field and experience force and due to this, torque is produced.

For single turn, the deflection couple as

$$\tau = bF = bBIl = (lb)\, BI = ABI$$
$$A = lb$$

For coil with N turns, we get

$$\tau = NABI \quad \ldots\ldots\ldots.. (1)$$

- Due to this deflecting torque, the coil gets twisted and restoring torque (also known as restoring couple) is developed. Hence the magnitude of restoring couple is proportional to the amount of twist θ

$$\tau = K\,\theta \quad \ldots\ldots\ldots\ldots.(2)$$

- K is the restoring couple per unit twist or torsional constant of the spring
- At equilibrium, the deflection couple is equal to the restoring couple

$$NABI = K\,\theta$$
$$I = K\frac{\theta}{NAB}$$
$$I = G\,\theta$$

$G = \frac{K}{NAB}$ galvanometer constant or current reduction factor of the galvanometer.

11.Discuss the conversion of galvanometer into an ammeter and also a voltmeter

Galvanometer to an Ammeter

- A galvanometer is converted into an ammeter by connecting a low resistance in parallel with the galvanometer. This low resistance is called shunt resistance S.
- The scale is now calibrated in ampere and the range of ammeter depends on the values of the shunt resistance.
- Let I be the current passing through the circuit .
- When current I reaches the junction A, it divides into two components.
- Let I_g be the current passing through the galvanometer of resistance R_g through a path AGE and the remaining current $(I - I_g)$ passes along the path ACDE through shunt resistance S.
- value of shunt resistance is so adjusted that current I_g produces full scale deflection in the galvanometer. The potential difference across galvanometer is same as the potential difference across shunt resistance.

$$V_{galvanometer} = V_{shunt}$$
$$I_g\, R_g = (I - I_g)\, S$$

$$S = \frac{I_g}{(I - I_G)} R_g$$

$$I_g = \frac{S}{S + R_g} I$$

$I_g \ \alpha \ I$

Since, the deflection in the galvanometer is proportional to the current passing through it.

$\Theta = \frac{1}{G} I_g$ $\quad \theta \ \alpha \ I_g \quad \theta \ \alpha \ I$

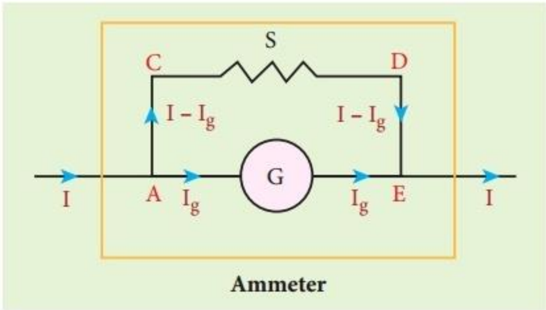


Figure 3.69 Shunt resistance connected in parallel

So, the deflection in the galvanometer measures the current I passing through the circuit (ammeter).

Galvanometer to a voltmeter

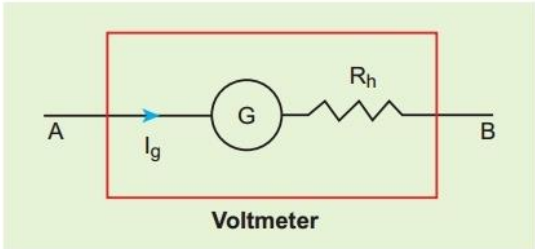


Figure 3.70 Shunt resistance connected in series

- Voltmeter must have high resistance and when it is connected in parallel, it will not draw appreciable current so that it will indicate the true potential difference
- A galvanometer is converted into a voltmeter by connecting high resistance R_h in series with galvanometer.
- The scale is now calibrated in volt and the range of voltmeter depends on the values of the resistance connected in series i.e. the value of resistance is so adjusted that only current Ig produces full scale deflection in the galvanometer.
- Let R_g be the resistance of galvanometer and I_g be the current with which the galvanometer produces full scale deflection.
- Since the galvanometer is connected in series with high resistance, the current in the electrical circuit is same as the current passing through the galvanometer.

$I = I_g$

$$I_g = \frac{potential\ difference}{total\ resistance}$$

Since the galvanometer and high resistance are connected in series, the total resistance or effective resistance gives the resistance of voltmeter. The voltmeter resistance is

$\mathbf{R_V = R_S + R_h}$

$$I_g = \frac{V}{R_s + R_h}$$

$$R_h = \frac{V}{I_g} - R_s$$

$\mathbf{I_g \ \alpha \ V}$

Book inside

Long answers

1. Write about Properties of magnet

1.A freely suspended bar magnet will always point along the north-south direction.

2. A magnet attracts another magnet or magnetic substances towards itself. The attractive force is maximum near the end of the bar magnet

3.When a magnet is broken into pieces, each piece behaves like a magnet with poles at its ends.

4. Two poles of a magnet have pole strength equal to one another.

5. The length of the bar magnet is called geometrical length and the length between two magnetic poles in a bar magnet is called magnetic length. Magnetic length is always slightly smaller than geometrical length. The ratio of magnetic length and geometrical length is 5 / 6

2.Write about properties of Magnetic field lines

1. Magnetic field lines are continuous closed curves.

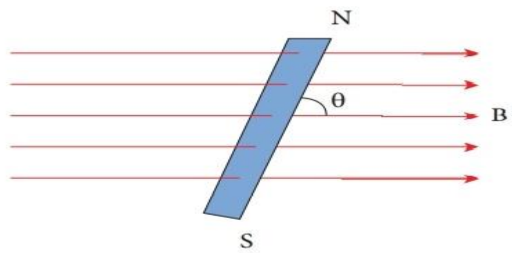
2.The direction of magnetic field lines is from North pole to South pole outside the magnet and South pole to North pole inside the magnet.

3. The direction of magnetic field at any point on the curve is known by drawing tangent to the magnetic line of force at that point.

4. Magnetic field lines never intersect each other.

5. The degree of closeness of the field lines determines the relative strength of the magnetic field. The magnetic field is strong where magnetic field lines crowd and weak where magnetic field lines thin out.

3.Derive Potential energy of a bar magnet in a uniform magnetic field



When a bar magnet (magnetic dipole) of dipole moment $\vec{P}_m$ is held at an angle θ with the direction of a uniform magnetic field $\vec{B}$, the magnitude of the torque acting on the dipole is

$$|\vec{\tau}| = |\vec{P}_m||\vec{B}|\sin\theta$$

If the dipole is rotated through a very small angular displacement dθ against the torque at constant angular velocity, then the work done by external torque for this small angular displacement is given by

$$dW = |\vec{\tau}_{ext}| d\theta$$

The bar magnet has to be moved at constant angular velocity, which implies that

$$|\vec{\tau}_{ext}| = |\vec{\tau}|$$

$$dW = P_m B\sin\theta \, d\theta$$

Total work done in rotating the dipole from θ′ to θ is

$$W = \int_{\theta'}^{\theta} \tau d\theta = -P_m B(\cos\theta - \cos\theta')$$

This work done is stored as potential energy in bar magnet at an angle θ when it is rotated from θ′ to θ and it can be written as

$$U = -P_m B(\cos\theta - \cos\theta')$$

$B_H = \mu_0 \frac{NI}{2R} \frac{1}{\tan\theta}$ in tesla

$I = K\,\theta$

$K = \frac{2RB_H}{N\mu_0}$ ……… **Reduction factor**

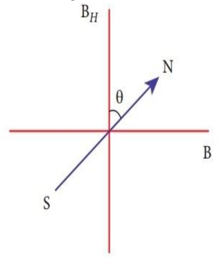


Figure 3.24 (a) circuit connection
(b) resultant position of pivoted needle

The tangent Galvanometer is most sensitive at a deflection of 45°. Generally the deflection is taken between 30° and 60°.

5.Difference between soft and hard ferro magnet

Soft ferro magnetic materials	**Hard ferro magnetic materials**
Area of loop is small	Area of loop is large
Retentivity is low	Retentivity is large
Coercivity is low	Coercivity is large
Hysteresis loss is less	Hysteresis loss is More
Uses ; Solenoid core, transformer core and electromagnets	**Uses ;** Permanent magnets
Susceptibility and magnetic permeability **is high**	Susceptibility and magnetic permeability **is low**
When external field is removed Magnetisation disappears	When external field is removed Magnetisation persists
Examples ; Soft iron, Mumetal, Stalloy	**Example :** Steel,Alnico, Lodestone etc

6. .What are Applications of hysteresis loop

i) Permanent magnets:

The materials with high retentivity, high coercivity and high permeability are suitable for making permanent magnets.

Examples: Steel and Alnico

ii) Electromagnets:

The materials with high initial permeability, low retentivity, low coercivity and thin hysteresis loop with smaller area are preferred to make electromagnets.

iii.Core of the transformer:

The materials with high initial permeability, large magnetic induction and thin hysteresis loop with smaller area are needed to design transformer cores.

Examples: Soft iron

7. State Biot – Savart's law

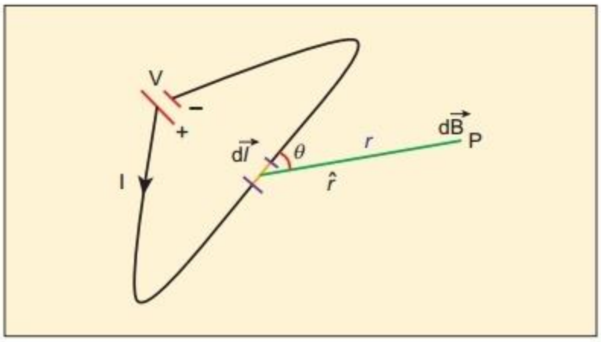


Figure 3.37 Magnetic field at a point P due to current carrying conductor

Biot and Savart observed that the magnitude of magnetic field $\vec{dB}$ at a point P at a distance r from the small elemental length taken on a conductor carrying current varies

(i) directly as the strength of the current I

(ii) directly as the magnitude of the length element $\vec{dl}$

(iii) directly as the sine of the angle (say,θ) between $\vec{dl}$ and $\hat{r}$

(iv) inversely as the square of the distance between the point P and length element $\vec{dl}$.

dB α $\frac{Idl}{r^2}$ sinΘ

dB = $k\frac{Idl}{r^2}$ sinΘ

k = $\frac{\mu_0}{4\pi}$ in S.I unit

In vector notation

$$\vec{dB} = \frac{\mu_0}{4\pi}\ \frac{I\vec{dl}\times\hat{r}}{r^2}$$

8.Derive Magnetic dipole moment of revolving electron

Suppose an electron undergoes circular motion around the nucleus ,The circulating electron in a loop is like current in a circular loop (since flow of charge is current). The magnetic dipole moment due to current carrying circular loop is

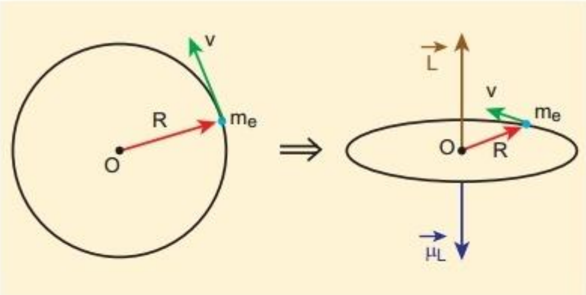


Figure 3.41 (a) Electron revolving in a circular orbit (b) Direction of magnetic dipole moment vector and orbital angular momentum vector are opposite

$\vec{\mu}_L$ = I $\vec{A}$ …….. (1)

In magnitude μ_L **= IA ………(2)**

If T is the time period of an electron, the current due to circular motion of the electron is

I = $\frac{-e}{T}$ ………… (3)

Velocity of electron v = $\frac{distance}{time\ taken}$ = $\frac{2\pi R}{T}$ … (4)

Sub T value in (3)

I = $\frac{-ev}{2\pi R}$ …….. (5)

Sub (5) in (2) where A = πR^2

$\mu_L = \frac{-ev}{2\pi R} \times \pi R^2 = \frac{-evR}{2}$ …….. (6)

Multiplying and divide (6) by m

$\mu_L = \frac{-emvR}{2m}$ …..(7)

Where Magnitude of angular moment pf electron about O is L = mvR …….(8)

By (8) , eq (7) became

$\frac{\mu_L}{L} = \frac{-e}{2m}$ ………. (9)

The negative sign indicates that the magnetic moment and angular momentum are in opposite direction.

In magnitude $\frac{\mu_L}{L}$ **= 0.0878 × 10^{12}**

= 8.78 × 10^{10} C Kg^{-1}

= constant

According to Neil's Bohr quantization rule, the angular momentum of an electron moving in a stationary orbit is quantized, which means

L = n $\frac{h}{2\pi}$

$\frac{\mu_L}{L} = \frac{e}{2m}$ ………. (10)

Sub L value in (10)

μ_L = n $\frac{h}{2\pi}$ $\frac{e}{2m}$

$B_S = \mu_0 \frac{NI}{2\pi r_2}$

$\frac{N}{2\pi r_2} = n$

$B_S = \mu_0 \, nI$

10. Explain about Force on a moving charge in a magnetic field

When an electric charge q is moving with velocity $\vec{v}$ in the magnetic field $\vec{B}$, it experiences a force, called magnetic force .

After careful experiments, Lorentz deduced the force experienced by a moving charge in the magnetic field

$\vec{F}_m = q(\vec{v} \times \vec{B})$

In magnitude F_m = qvbsin θ

Force is directly proportional to

(i)Magnetic field $\vec{B}$

(ii)velocity $\vec{v}$

(iii) directly proportional to sine of the angle between the velocity and magnetic field

(iv)charge q

Direction of force is always perpendicular to $\vec{v}$ & $\vec{B}$

Direction of force on negative charge is opposite to direction of force on positive charge

If velocity of the charge is along magnetic field then force is zero

11.Explain about Motion of a charged particle in a uniform magnetic field

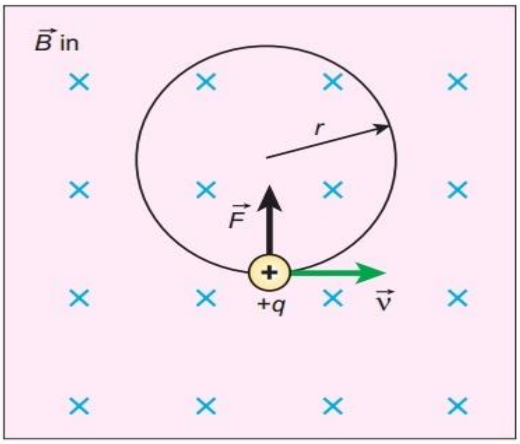


Figure 3.50 Circular motion of a charged particle in a perpendicular uniform magnetic field

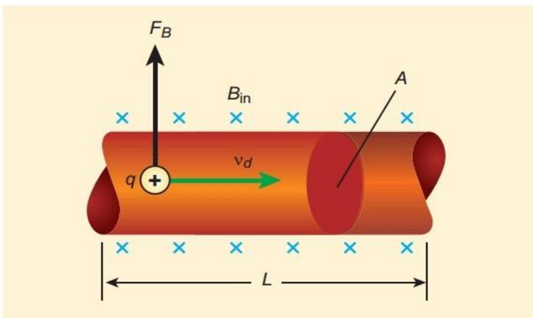


Figure 3.56 Current carrying conductor in a magnetic field

Consider a charged particle of charge q having mass m enters into a region of uniform magnetic field $\vec{B}$ with velocity$\vec{v}$ such that velocity is perpendicular to the magnetic field. As soon as the particle enters into the field, Lorentz force acts on it in a direction perpendicular to both magnetic field and velocity .

The force in a straight current carrying conducting wire of length *l* placed in a uniform magnetic field is

$\vec{F} = I\vec{l} \times \vec{B}$

In magnitude F = BIl sinΘ

(a) If the conductor is placed along the direction of the magnetic field, the angle between them is θ = 0°. Hence, the force experienced by the conductor is zero.

(b) If the conductor is placed perpendicular to the magnetic field, the angle between them is θ =90° Hence, the force experienced by the conductor is maximum, which is *F = BIl.*

13.Derive Force between two long parallel current carrying conductors

Two long straight parallel current carrying conductors separated by a distance r are kept in air

I_1 and I_2 be the electric currents passing through the conductors A and B in same direction (i.e. along z - direction)

The net magnetic field at a distance r due to current I_1 in conductor A is

$$\vec{B}_1 = \frac{\mu_0 I_1}{2\pi r}(-\hat{i}) = -\frac{\mu_0 I_1}{2\pi r}\hat{i} \quad ....(1)$$

From thumb rule, the direction of magnetic field is perpendicular to the plane of the paper and inwards i.e along negative $\hat{i}$ direction .

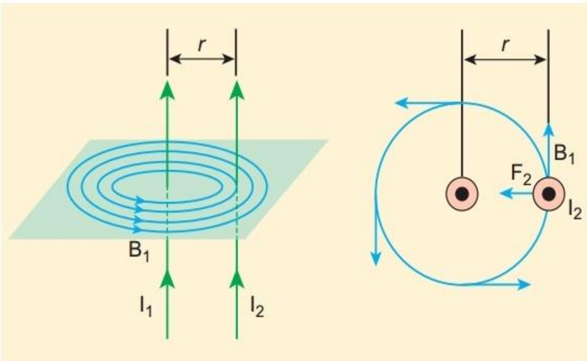


Figure 3.58 Two long straight parallel wires

Lorentz force on the element d*l* of conductor B at which the magnetic field $\vec{B}_1$ is present is

$$\vec{dF} = (I_2\vec{dl} \times \vec{B}_1) = -I_2 dl\frac{\mu_0 I_1}{2\pi r}(\hat{k} \times \hat{i})$$

$$= -\frac{\mu_0 I_1 I_2 dl}{2\pi r}\hat{j}$$

The force per unit length of the conductor B due to the wire conductor A is

$$\frac{\vec{F}}{l} = -\frac{\mu_0 I_1 I_2}{2\pi r}\hat{j} \quad ....(1)$$

In the same manner, we compute the magnitude of net magnetic induction due to current I_2 (in conductor A) at a distance r in the elemental length *dl* of conductor A is

$$\vec{B}_2 = \frac{\mu_0 I_2}{2\pi r}\text{-}\hat{i}$$

From the thumb rule, direction of magnetic field is perpendicular to the plane of the paper and outwards i.e., along positive $\hat{i}$ direction

Lorentz force on the element d*l* of conductor A at which the magnetic field $\vec{B}_2$ is present is

$$\vec{dF} = (I_1\vec{dl} \times \vec{B}_1) = I_1 dl\frac{\mu_0 I_2}{2\pi r}(\hat{k} \times \hat{i})$$

$$= -\frac{\mu_0 I_1 I_2 dl}{2\pi r}\ \hat{j}$$

The force per unit length of the conductor B due to the wire conductor A is

$$\frac{\vec{F}}{l} = -\frac{\mu_0 I_1 I_2}{2\pi r}\ \hat{j} \quad \text{…………(2)}$$

Thus the force experienced by two parallel current carrying conductors is attractive if the direction of electric current passing through them is same & force experienced by two parallel current carrying conductors is repulsive if they carry current in the opposite directions

13.Explain about Hysteresis loop

A ferromagnetic material (example, Iron) is magnetised slowly by a magnetising field . The magnetic induction of the material increases from point A with the magnitude of the magnetising field and then attains a saturated level. This response of the material is depicted by the path AC.Saturation magnetization is defined as the maximum point up to which the material can be magnetised by applying the magnetising field.

If the magnetising field is now reduced, the magnetic induction also decreases but does not retrace the original path CA. It takes different path CD. When the magnetising field is zero, the magnetic induction is not zero and it has positive value. This implies that some magnetism is left in the specimen even when H = 0. The **residual magnetism AD present in the specimen is called remanence or retentivity. It is defined as the ability of the materials to retain the magnetism in them even magnetising field vanishes.**

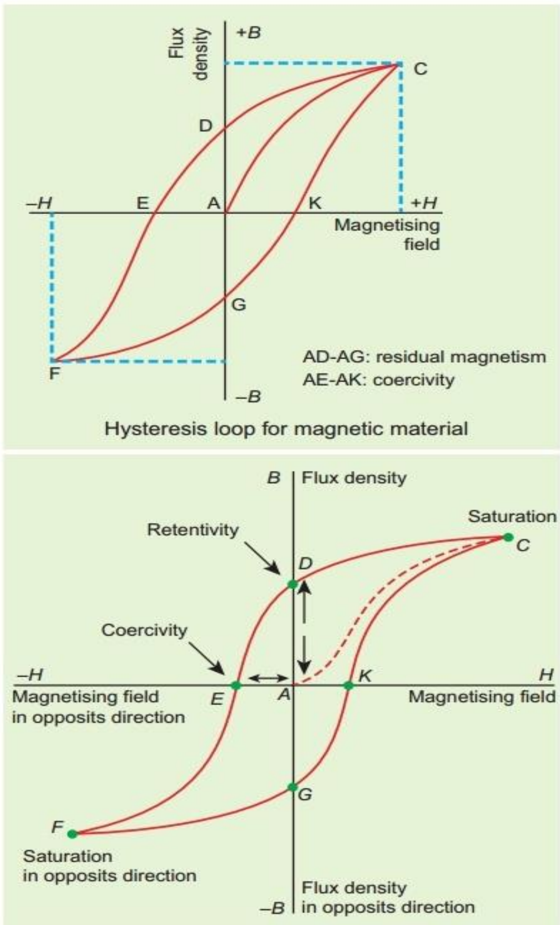


Figure 3.30 Hysteresis – plot for B vs H

In order to demagnetise the material, the magnetising field is gradually increased in the reverse direction. Now the magnetic induction decreases along DE and becomes zero at E. The magnetising field AE in the reverse direction is required to bring residual magnetism to zero. **The magnitude the residual magnetism of the material vanishes is called its coercivity.** Further increase of in the reverse direction, the magnetic induction increases along EF until it reaches saturation at F in the reverse direction. If magnetising field is decreased and then

UNIT – 4 ELCTROMAGNETIC INDUCTION AND ALTERNATING CURRENT

One marks

1. Electromagnetic induction is not used in
a) Transformer b) room heater c) A.C. generator d) choke coil
2.The angle between the area vector A and plane of the area A is
a) π b) 2π c)$\pi/2$ d) Zero
3. If the flux associated with a coil varies at the rate of 1 Wb/minute then the induced e.m.f. is
a)1V b) 1/60 V c) 60 V d) 0.60 V
4. The average power consumed over one cycle in an a.c. circuit is
a) E_{rms} I_{rms} b) E_{rms} $I_{rms}\cos\emptyset$ c) E_{rms} I_{rms} $\sin\emptyset$ d) E_0 I_0
5. In LCR series a.c. circuit, the phase difference between current and voltage is 30^o. The reactance of the circuit is 17.32 Ω. The value of resistance is
a) 30 Ω b) 10 Ω c) 17.32 Ω d) 1.732 Ω
6.An emf of 12 V is induced when the current in the coil changes from 2 A to 6 A in 0.5 s. The coefficient of self – induction of the coil is
a) 1.5 H b) 6 H c) 0.3 H d) 30 H
7. In an a.c. circuit with an inductor
a) Voltage lags current by $\pi/2$ b) voltage and current are in phase
c) voltage leads current by π d) current lags voltage by $\pi/2$
8. The unit of henry can also be written as
a) V As^{-1} b) Wb^{-1} A c) Ω s d) all of these
9. The generator rule is
a) Fleming's left hand rule b) Fleming's right hand rule
b) Maxwell's right hand corkscrew rule d) Right hand palm rule
10. The power loss is less in transmission line when
a) voltage is less but current is more b) both voltage and current are more
c) voltage is more but current is less d) both voltage and current are less
11. In an a.c. circuit, the current $I = I_0 \sin(\omega t - \pi/2)$ lags behind the e.m.f. $e = E_0 \sin(\omega t + \pi/2)$ by
a) 0 b) $\pi/4$ c) $\pi/2$ d) π
12. In a step – up transformer the input voltage is 220 V and the output voltage is 11 kV. The ratio of number of turns of primary to secondary is
a) 50 : 1 b) 1 : 50 c) 25 :1 d) 1 : 25
13. In LCR circuit when $X_L = X_C$ the current
a) is zero b) is in phase with the voltage
c) leads the voltage d) lags behind the voltage
14. Transformer works on
a) Both AC and DC b) AC more effectively than DC
c) AC only d) DC only

31. Which of the following devices does not allow direct current (D.C.) to pass through?
a) Capacitor b) Inductor c) Resistor d) All of these
32. A coil of area of cross – section $0.5m^2$ with 10 turns is in a plane which is perpendicular to a uniform magnetic field of 0.2 Wb/m^2. The magnetic flux through the coil is
a) 100 Wb b) 10 Wb c) 1 Wb d) zero
33. An e.m.f of 12V is induced when the current in the coil changes at the rate of 40 As^{-1}. The Coefficient of self – induction of the coil is
a) 0.3 H b) 0.003 H c) 30 H d) 4.8 H
34. That part of the A.C, generator that passes. The current from the coil to the external circuit is
a) field magnet b) split rings c) slip – rings d) brushes
35. The r.m.s. value of the alternating current flowing through a resistor is 5A.its peak value is
a) 3.536 A b) 70.7 A c) 7.07A d) 7A
36. In an A.c. circuit average power consumed is 200 W and the apparent power is 300 W. the power factor is
a) 1.5 b) 0.66 c) 0.33 d) 1
37. The effective value of alternating current is
a) $\frac{I_O}{2}$ b) $\frac{I_O}{\sqrt{2}}$ c) $I_0\sqrt{2}$ d) 2 I_0
38. A rectangular coil is uniformly rotated in a uniform magnetic field such that the axis of rotation is perpendicular to the direction of the magnetic field. When the plans of the coil is perpendicular to the magnetic field
a) (i) Magnetic flux is zero. (ii) induced e.m.f is zero
b) (i) magnetic flux ix maximum (ii) induced e.m.f is maximum
c) (i) magnetic flux is maximum (ii) induced e.m.f is zero
d) (i) magnetic flux is zero, (ii) induced e.m.f is maximum
39. In an a.c. circuit, the voltage leads the current by a phase of $\frac{\pi}{2}$, then the circuit has
a) Only an inductor (L) b) only a capacitor (C)
c) only a resistor (R) d) L, C and R in series
40. The resonant frequency of RLC circuit is γ_0 The inductance is doubled. The capacitance is also doubled. Now the resonant frequency of the circuit is
a) $2\gamma_0$. b) $\frac{\gamma_0}{2}$ c) $\frac{\gamma_0}{4}$ d) $\frac{\gamma_0}{\sqrt{2}}$
41. When the frequency of an a.c. circuit increases, the capacitive reactance offered by capacitor connected in the circuit
a) increases b) decreases c) remains the same d) becomes zero
42. The coefficient of self – induction of a solenoid is independent of
a) the number of turns in coil b) the area of cross – section of the coil
c) the length of the coil d) the current passing through the coil.
a) The instantaneous emf and current equations of an a.c circuit are respectively

43. e = 200 sin (ωt + π/3) and i = 10 sin ωt The average power consumed over one complete cycle is:

a) 2000 W b) 1000 W c) 500 W d) 707 W

44. If an emf of 25V is induced when the current in the coil changes at the rate of 100 As^{-1}, then the coefficient of self induction of the coil is :

a) 0.3 H b) 0.25 H c) 2.5 H d) 0.25 mH

45. In an A.C Circuit, the instantaneous values of emf and current are respectively
e = 200 sin ((ωt - π/3) i = 10 sin (ωt + π/6)

(a) voltage lags behind current by a phase angle of π/3
(b) current leads voltage by a phase angle of π/6
(c) Current leads voltage by a phase angle of π/2
(d) voltage leads current by a phase angle of π/2

46. In a LCR series a.c circuit, the phase difference between current and voltage is 60°. if the net reactance of the circuit is 17.32 Ω, the value of the resistance is :

(a) 30 Ω (b) 17.32 Ω (c) 10 Ω (d) 17.32 Ω

UNIT : 4

1. (b) room heater
2. (c) $\pi/2$
3. (b) $1/60$ V.
4. (b) $E_{rms} I_{rms} \cos\phi$
5. (a) 30 Ω.
6. (a) 1.5 H.
7. (d) Current lags voltage by $\pi/2$
8. (c) Ωs

3. $e = \frac{d\phi}{dt} = 1 \text{ Wb/minute}$
$= \frac{1}{60} \frac{Wb}{sec} = 1/60 \text{ V}$

5. $\tan\phi = \frac{X_L - X_C}{R}$
$R = \frac{X_L - X_C}{\tan\phi} = \frac{17.32}{\tan 30°} = \frac{10\times\sqrt{3}}{1/\sqrt{3}} =$
$= 10\times 3 = 30 \ \Omega$

6. $L = e/(dI/dt) = \frac{12}{\left(\frac{6-2}{0.5}\right)} = \frac{6}{4} = 1.5 \text{ H}$

9. (b) Fleming's right hand rule
10. (c) Voltage is more but current is less.
11. (d) π
12. (b) 1 : 50.
13. (b) is in phase with the voltage.
14. (c) Ac only
15. (a) Conservation of energy
16. (a) Zero
17. (a) Infinity.
18. (b) 94.2 Ω
19. (b) 220V.
20. (a) Iron.
21. (a) 50 A.
22. (b) laminated Core made of stelloy
23. (c) Input power.
24. (b) Infinity
25. (c) $Q = \frac{1}{R}\sqrt{L/C}$
26. (c) 120°
27. (b) 5 A rms current.
28. (d) Current is in phase with the voltage.
29. (a) The average value of Current is Zero.
30. (d) None of these.
31. (a) capacitor.
32. (c) 1 wb.
33. (a) 0.3 H
34. (d) [illegible] brushes.
35. (c) 7.07 A.
36. (b) 0.66.
37. (b) $I_0/\sqrt{2}$
38. (c) (i) Magnetic flux is Maximum, induced emf is Zero
39. (a) only an inductor (L)
40. (b) $\nu_0/2$

11. $\phi = \pi/2 - (-\pi/2)$
$= \pi/2 + \pi/2 = \pi$

12. $\frac{N_P}{N_S} = \frac{E_P}{E_S} = \frac{220}{11\times10^3} = 1/50.$

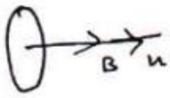
17. $\nu_0 = 0$; $X_C = \frac{1}{C.\omega} = \frac{1}{C.2\pi\nu}$
$\therefore X_C = \frac{1}{C.2\pi.0} = \frac{1}{0} = \infty$

18. $X_L = L.\omega = L.2\pi\nu =$
$= 300\times10^{-3}\times 2\times3.14\times50$
$= 94.2\ \Omega$

19. $E_{rms} = \frac{E_0}{\sqrt{2}} = 0.707 = 311\times0.707$
$= 220V$

21. $I = P/V = \frac{11000}{220} = 50\ A$

32. $\theta = 0^\circ$



$\phi = NAB\cos\theta$
$= 10\times0.5\times0.2\times\cos 0$
$= 10\times0.5\times0.2\times1 = 1\ Wb$

33. $L = \frac{e}{(dI/dt)} = \frac{12}{40} = 0.3\ H$

35. $I_{rms} = I_0/\sqrt{2}$
$\therefore I_0 = \sqrt{2}\ I_{rms} = 1.414\times I_{rms}$
$= 1.414\times5 = 7.07A$

36. $\cos\phi = \frac{P_{av}}{P_{app}} = \frac{200}{300} = 0.66$

40. $\nu = 1/2\pi\sqrt{LC}$
$L' \to 2L$
$C' \to 2C$
$\nu' = \frac{1}{2\pi\sqrt{L'C'}}$
$\nu' = \frac{1}{2\pi\sqrt{2L.2C}}$
$= \frac{1}{2.2\pi\sqrt{LC}} = \frac{\nu_0}{2}$

41. (b) decreases
42. (d) the current passing through the coil.
43. (c) 500 W
44. (b) 0.25 H
45. (c) Current leads voltage by a phase angle of $\pi/2$
46. (c) 10Ω

43. $P_{av} = I_{rms} \cdot E_{rms} \cdot \cos\phi$

$$= \frac{I_0 E_0}{2} \cdot \cos\phi$$

$$= \frac{10 \times 200 \times \cos \pi/3}{2}$$

$$= \frac{10 \times 200 \times}{2} \frac{1}{2}$$

$$P_{av} = 500\ W$$

44. $L = e/(dI/dt) = \frac{25}{100} = 0.25\ H$

45. Phase difference

$$= -\pi/3 - (+\pi/6) = -\pi/3 - \pi/6$$

$$= \frac{-2\pi - \pi}{6} = -\frac{3\pi}{6} = -\pi/6$$

$\therefore$ Current leads

46. $R = \frac{X_L - X_C}{\tan\phi} = \frac{17.32}{\tan 30^\circ}$

$$R = 10 \times \sqrt{3} \times \frac{1}{\sqrt{3}} = 10\ \Omega$$

(1) Magnetic flux $\Phi_B = \vec{B}.\vec{A} = BA\cos\theta$

(2) Rate of change of magnetic flux $\dfrac{d\Phi_B}{dt}$

(3) Magnitude of induced emf $e = \varepsilon = -\dfrac{Nd\Phi_B}{dt} = -\dfrac{d}{dt}(N\Phi_B)$ $N\Phi_B \rightarrow$ flux linkage

(4) Coefficient of self induction and law of electro magnetic induction are related as $\varepsilon = -\dfrac{d}{dt}(L$

(5) Self inductance of a long solenoid : $L = \mu n^2 Al$ $(\therefore n = \dfrac{N}{l})$

$$L = \frac{\mu_0 N^2 A}{l};\ L = \mu_0\mu_r n^2 Al$$

(6) Quantity of energy stored in an inductor $U_B = \dfrac{1}{2}Li^2$

(7) Coefficient of mutual induction $M_{12} = -\dfrac{\varepsilon_1}{\frac{di_2}{dt}}$ (or) $M_{21} = -\dfrac{\varepsilon_2}{\frac{di_1}{dt}}$

(8) Mutual induction of two long solenoids $M = \mu n_1 n_2 Al = \mu_0\mu_r n_1 n_2 Al$

(9) Induced emf, $\varepsilon = -\dfrac{d}{dt}(NBA\cos\theta)$; $(\theta = \omega t)$

(10) Induced emf, $\varepsilon = -Blv$ (by changing the area enclosed by the coil) (ε = motional emf)

(11) Induced emf, $\varepsilon = -NA\cos\theta\left(\dfrac{dB}{dt}\right)$ (by changing the magnetic induction)

(12) Induced emf, $\varepsilon = NBA\,\omega\sin\omega t \Rightarrow \sin\omega t$, Also Induced current, $i = I_m \sin\omega t$

(13) Transformer, $\dfrac{N_s}{N_p} = \dfrac{I_p}{I_s} = \dfrac{V_s}{V_p} = k$

(14) Step up transformer : $k > 1$

(15) Step down transformer : $k < 1$

(16) Efficiency of transformer $\eta = \dfrac{\text{output power}}{\text{input power}} \times 100\%$

(17) AC voltage

$\varepsilon = I_m \sin\omega t$; $E_m = NBA\,\omega$ (max emf) (Also AC Voltage $v = V_m \sin\omega t$)

(18) AC current

$i = E_m \sin\omega t$

(19) Effective current $I_{eff} = I_{rms} = \dfrac{I_m}{\sqrt{2}}$; $I_m = \sqrt{2}\, I_{eff}$

(20) Effective voltage $E_{eff} = E_{rms} = \dfrac{E_m}{\sqrt{2}}$; $E_m = \sqrt{2}\, E_{eff}$

Book back

Short Answers

1.What is meant by electromagnetic induction?

- Whenever the **magnetic flux** linked with a closed coil **changes**, an **emf is induced** and hence an electric current flows in the circuit.
- This current is called an induced current and the emf giving rise to such current is called an induced emf.
- This phenomenon is known as electromagnetic induction.

2.State Faraday's law of electro magnetic induction.

First law

Whenever **magnetic flux** linked with a closed circuit **changes**, an **emf is induced** in the circuit.

Second law

The **magnitude of induced emf** in a closed circuit is equal to the **rate of change of magnetic flux** linked with the circuit.

3.State Lenz's law

It states that the **direction of the induced current** is such that it always **opposes the cause responsible for its production**.

4.State Fleming's right hand rule

If the **index finger** points the **direction of the magnetic field** and the **thumb** indicates the **direction of motion of the conductor**, then the **middle finger** will indicate the **direction of the induced current**.

5.How is Eddy current is produced ? How do they flow in a conductor

- For **a conductor** in the form of a sheet or plate, an **emf is induced** when magnetic **flux** linked with it **changes**.
- The induced **currents flow** in concentric **circular paths**
- As these **electric currents** resemble **eddies** of water, these are known as **Eddy currents 0r Foucault current**

6.Mention the ways of producing induced emf .

$\boldsymbol{\varepsilon = \frac{d}{dt}(\mathrm{BA}\cos\theta)}$

(i) By changing the magnetic field *B*

(ii) By changing the area *A* of the coil and

(iii) By changing the relative orientation θ of the coil with magnetic field

14.How will you define RMS value of alternating current

- **It is defined as that value of the steady current which when flowing through a given circuit for a given time produces the same amount of heat as produced by the alternating current when flowing through the same circuit for the same time.**

- RMS value of alternating current is defined as square root of mean of squares of all the current over one cycle

15.What are phasors ?

A sinusoidal alternating voltage (or current) can be represented by a **vector** which **rotates** about the **origin in anti-clockwise** direction at a **constant angular velocity ω**. Such a rotating vector is called a phasor.

16.Define electrical resonance

When the **frequency of the applied alternating source is equal to the natural frequency of the *RLC* circuit**, the current in the circuit reaches its maximum value.

Then the circuit is said to be in electrical resonance. The **frequency** at which **resonance takes place** is called **resonant frequency.**

17.What do you meant by resonant frequency ?

- When the **frequency of the applied alternating source (ω_r) is equal to the natural frequency of the *RLC* circuit ($\frac{1}{\sqrt{LC}}$)**, the current in the circuit reaches its maximum value.
- Then the circuit is said to be in electrical resonance. The **frequency** at which **resonance takes place** is called **resonant frequency.**

18.How will you define Q – factor

It is defined as the ratio of voltage across *L* or *C* to the applied voltage.

$$\textbf{Q – factor} = \frac{Voltage\ across\ L\ or\ C}{Applied\ voltage}$$

19.What is meant by wattles current?

The current component **(I_{RMS} sin∅)** which has a **phase angle of π/2** with the voltage is called **reactive component.**

$P_{av} = V_{RMS} I_{RMS} \cos\emptyset \qquad \emptyset = \frac{\pi}{2}$

$P_{av} = 0$

So that it is also known as ‘Wattless’ current.

20.Give any one definition of power factor

I)Power factor = cos ϕ = cosine of the angle of lead or lag

II) Power factor = $\frac{R}{S} = \frac{RESIATANCE}{IMPEDANCE}$

6.Define Electromotive force

It is the work done in moving unit electric charge around the circuit.

Unit ; $J\,C^{-1}$ or volt.

7.How will you induce emf by changing the magnetic field

The change in flux is brought about by

(i) relative motion between the circuit and the magnet

(ii) variation in current flowing through the nearby coil

8.What do you meant by A.C generator?

It is a device which **converts mechanical energy into electrical energy.**

9.How will you generate alternating emf

It is generated by **rotating a coil in a magnetic field or by rotating a magnetic field within a stationary coil.**

First method is used for **small AC generators**

Second method is employed for **large AC generators.**

10. What is polyphase generator

It contains more than one coil in the armature core and each coil produces an alternating emf. In these generators, more than one emf is produced.

Additional information ;

Two phase generator - If there are two alternating emfs produced in a generator, it is called two- phase generator.

Three phase generator - In some AC generators, there are three separate coils, which would give three separate emfs. Hence they are called three-phase AC generators.

11.What are advantages of three phase generator

1) For a given dimension of the generator, **three-phase machine** produces **higher power output** than a single-phase machine.

2) For the same capacity, **three-phase alternator is smaller in size** when compared to single phase alternator.

3**) Three-phase transmission system is cheaper**. A relatively thinner wire is sufficient for transmission of three-phase power.

12.Give the principle of Transformer

The principle of transformer is the **mutual induction between two coils.** That is, when an electric current passing through a coil changes with time, an emf is induced in the neighbouring coil.

13.What do you meant by efficiency of transformer

The efficiency η of a transformer is defined as the ratio of the useful output power to the input power

$$\eta = \frac{output\ power}{input\ power} \times 100$$

They are **highly efficient devices** having their efficiency in the range of **96 – 99%.**

14.What is alternating voltage

An alternating voltage is the **voltage** which **changes polarity at regular intervals** of time and the direction of the resulting alternating current also changes accordingly**.**

15.Define sinusoidal alternating voltage

If the wave form of alternating voltage is a sine wave , then it is called as sinusoidal voltage $V = V_m \sin\omega t$

16. What are Applications of series RLC resonant circuit

Filter circuits, oscillators, voltage multipliers , tuning circuits of radio and TV systems.

17.Explain about how tuning is done

- The tuning is commonly achieved by varying capacitance of a parallel plate variable capacitor, thereby changing the resonant frequency of the circuit.
- When resonant frequency is nearly equal to the frequency of the signal of the particular station, the amplitude of the current in the circuit is maximum.
- Thus the signal of that station alone is received.

18.Why resonance not occur in a *RL* and *RC* circuits.

- The phenomenon of electrical resonance is **possible** when the circuit **contains both *L* and *C*.**
- Only then the voltage across *L* and *C* cancel one another when V_L and V_C are 180° out of phase and the circuit becomes purely resistive.

19.What is meant by wattful current?

The component of current (**$I_{RMS} \cos\emptyset$)** which is in phase with the voltage is called active component.

$P_{av} = V_{RMS} I_{RMS} \cos\emptyset$ $\quad \emptyset = 0$ $P_{av} = V_{RMS} I_{RMS}$

The power consumed by this current. So that it is also known as 'Wattful' current.

20.How LC oscillations become damped oscillations

- The **Joule heating and radiation of electromagnetic waves** from the circuit decrease the energy of the system.
- Therefore, the oscillations become damped

Book back

Long answers question

1.Establish the fact that the relative motion between the coil and the magnet induces an emf in the coil of closed circuit .

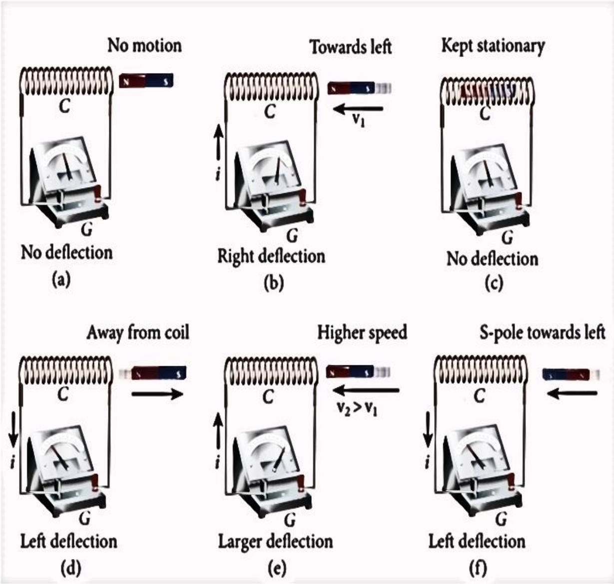


Figure 4.2 Faraday's first experiment

- When a bar magnet is placed close to a coil, some of the magnetic field lines of the bar magnet pass through the coil i.e., the magnetic flux is linked with the coil.
- When the bar magnet and the coil approach each other, the magnetic flux linked with the coil increases.
- So this increase in magnetic flux induces an emf and hence a transient electric current flows in the circuit in one direction
- At the same time, when they recede away from one another, the magnetic flux linked with the coil decreases.
- The decrease in magnetic flux again induces an emf in opposite direction and hence an electric current flows in opposite direction.
- So there is deflection in the galvanometer which indicates current is induced when when there is a relative motion between the coil and the magnet.

Whenever the magnetic flux linked with a closed coil changes, an emf (electromotive force) is induced and hence an electric current flows in the circuit. This current is called an induced current and the emf giving rise to such current is called an induced emf. This phenomenon is known as electromagnetic induction.

2.Give an illustration of determining direction of induced current by using Lenz's law

- Consider a uniform magnetic field, with its field lines perpendicular to the plane of the paper and pointing inwards.
- These field lines are represented by crosses (x)
- A rectangular metallic frame *ABCD* is placed in this magnetic field, with its plane perpendicular to the field. The arm *AB* is movable so that it can slide towards right or left.
- If the arm AB slides to our right side, the number of field lines (magnetic flux) passing through the frame *ABCD* increases and a current is induced.
- By Lenz's law, the induced current opposes this flux increase and it tries to reduce it by producing **another magnetic field pointing outwards i.e., opposite to the existing magnetic field.**
- From the direction of the magnetic field thus produced, the direction of the induced current is found to be anti-clockwise by using right-hand thumb rule.

- Lorentz force creates accumulation of free electrons which produces a potential difference across the rod which in turn establishes an electric field $\vec{E}$ directed along BA.
- Due to the electric field the coulomb force starts acting on the free electrons along *AB* and is given by

$$\vec{F}_E = -e\vec{E}$$

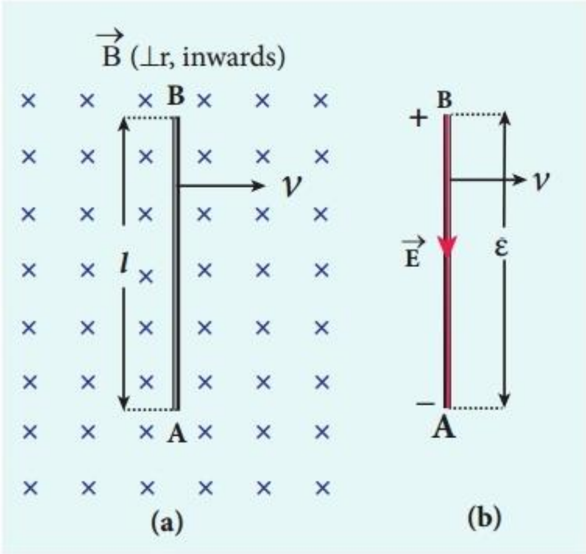


Figure 4.9 Motional emf from Lorentz force

- F_E increases as electric field increases as long as accumulation of electron at the end A continues
- At equilibrium, the magnetic Lorentz force and the coulomb force balance each other and no further accumulation of free electrons at the end *A* takes place.

$$|\vec{F}_B| = |\vec{F}_E|$$

$$|-e(\vec{v} \times \vec{B})| = |-e\vec{E}|$$

$$\mathbf{vB = E}$$

The potential difference between two ends of the rod is

$$V = El$$

$$V = vBl$$

Thus the Lorentz force on the free electrons is responsible to maintain this potential difference and hence produces an emf.

$$\varepsilon = Blv$$

As this emf is produced due to the movement of the rod, it is often called as motional emf.

5.Using Faraday's law of electromagnetic induction , derive an equation for motional emf

- Let us consider a rectangular conducting loop of width l in a uniform magnetic field $\vec{B}$ which is perpendicular to the plane of the loop and is directed inwards.
- A part of the loop is in the magnetic field while the remaining part is outside the field
- When the loop is pulled with a constant velocity $\vec{v}$ to the right, the area of the portion of the loop within the magnetic field will decrease.
- Thus, the flux linked with the loop will also decrease.
- According to Faraday's law, an electric current is induced in the loop which flows in a direction so as to oppose the pull of the loop.

x - length of the loop which is still within the magnetic field,

$A = lx$

$\phi_B = \int \vec{B}.\vec{dA}$ = BA cosθ [θ = 0° cos0 = 1]

$= Blx$

$\varepsilon = \frac{d\phi_B}{dt}$

$= Bl\frac{dx}{dt}$

both B and l are constants.

$\varepsilon = Blv$

[$v = \frac{dx}{dt}$] *velocity of loop*

This emf is known **as motional emf since it is produced due to the movement of the loop** in the magnetic field.

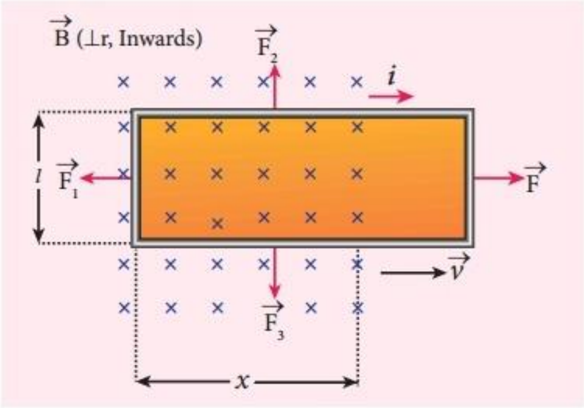


Figure 4.10 Motional emf from Faraday's law

6.Give the uses of Foucault current or Eddy current

i. Induction stove

ii. Eddy current brake

iii. Eddy current testing

iv. Electromagnetic damping

<u>i. Induction stove</u>

- **It is used to** cook the food quickly and safely with less energy consumption.
- Below the cooking zone, there is a tightly wound **coil of insulated wire.**
- The cooking pan made of suitable material, is placed over the cooking zone.
- When the stove is switched on, an **alternating current** flowing in the coil **produces high frequency alternating magnetic field** which induces very **strong eddy currents** in the cooking pan.
- The eddy currents in the pan produce so much of **heat** due to **Joule heating** which is used to cook the food.

<u>ii. Eddy current brake</u>

- This eddy current braking system is generally used in **high speed trains** and **roller coasters**. **Strong electromagnets** are fixed just above the rails.
- To stop the train, **electromagnets are switched on.**
- The magnetic field of these magnets induces eddy currents in the rails which **oppose or resist the movement of the train.**
- This is **Eddy current linear brake.**

<u>iii. Eddy current testing</u>

- It is one of the **simple non–destructive** testing methods to find defects like surface cracks, air bubbles present in a specimen.

- A coil of insulated wire is given an **alternating electric current** so that it produces **an alternating magnetic field.**
- When this coil is brought near the test surface, **eddy current** is induced in the test surface.
- **The presence of defects** causes the **change in phase and amplitude** of the eddy current that can be detected by some other means.
- In this way, the defects present in the specimen are identified

<u>iv. Electromagnetic damping or dead beat galvanometer</u>

- The armature of the galvanometer coil is wound on a soft iron **cylinder.**
- **Once the armature** is **deflected,** the relative motion between the soft iron cylinder and the **radial**

  magnetic field induces eddy current in the cylinder .
- **The damping force** due to the flow of eddy current **brings the armature to rest immediately** and then galvanometer shows a steady deflection.

7.Define self – inductance of a coil in terms of magnetic flux and induced emf

<u>Self induction</u>

The property of a coil which enables to produce an **opposing induced emf** in it when the **current i**n the coil **changes** is called self induction.

<u>self – inductance of a coil in terms of magnetic flux</u>

When current I flows through a coil of N turns , the magnetic flux ϕ_B linked with the coil is proportional to current

$N\phi_B \;\alpha\; i$

$N\phi_B = Li$

L – Coefficient of self induction

$L = \frac{N\phi_B}{i}$

$i = IA$

$L = N\phi_B$

Self-inductance or simply inductance of a coil is defined as the **flux linkage of the coil** when **1A current** flows through it.

<u>self – inductance of a coil in terms of induced emf</u>

When the current *i* changes with time, an emf is induced in it.

From Faraday's law of electromagnetic induction

$\varepsilon = -\frac{d(N\phi_B)}{dt}$

$N\phi_B = Li$

$\varepsilon = -\frac{d(Li)}{dt}$

$\boldsymbol{\varepsilon = -L\frac{di}{dt}}$ $\boldsymbol{L = \frac{-\varepsilon}{di/dt}}$

$\boldsymbol{\frac{di}{dt} = 1\ A/s}$ **then** $\mathbf{L = -\varepsilon}$

Inductance of a coil is also defined as the **opposing emf** induced in the coil when the **rate of change of current** through the coil is **1** $\boldsymbol{A\ s^{-1}}$

8.How will you define the unit of inductance

Inductance is a scalar

$\boldsymbol{L = \frac{-\varepsilon}{di/dt}\left(\frac{Wb}{As^{-1}}\right)}$

Therefore unit of inductance is Wb $\mathbf{A^{-1}}$ **s**

It is also measured in henry (H).

$\boldsymbol{\frac{di}{dt} = 1\ A/s}$ **then** $\mathbf{L = -\varepsilon}$

It is also measured in henry (H).

1 H = 1 Wb $\mathbf{A^{-1}}$ **s or 1 V s** $\mathbf{A^{-1}}$

The inductance of the coil is one henry if a current changing at the rate of 1 $A\ s^{-1}$ induces an opposing emf of 1 V in it.

$\boldsymbol{L = \frac{N\phi_B}{i}\left(\frac{Wb}{A}\right)}$

Therefore unit of inductance is Wb $\mathbf{A^{-1}}$

$\boldsymbol{i = IA}$

$\boldsymbol{L = N\phi_B}$

The inductance of the coil is said to be **one henry** if a current **of 1** $\boldsymbol{A}$ **produces unit flux** linkage in the coil.

9.What do you understand by self – inductance of a coil ? .Give its physical significance .

<u>Self induction</u>

The property of a coil which enables to produce an **opposing induced emf** in it when the **current i**n the coil **changes** is called self induction.

<u>Physical significance</u>

- The inductance plays the same role in a circuit as mass and moment of inertia play in mechanical motion.
- When a circuit is switched on, the increasing current induces an emf which **opposes the growth of current** in a circuit.
- Likewise, when circuit is broken, the decreasing current induces an emf in the reverse direction. This emf now **opposes the decay of current .**

Let us assume that electrical resistance of the inductor is negligible and inductor effect alone is considered.

The induced emf at any instant *t* is

$\varepsilon = -L\frac{di}{dt}$…………..(1)

Let *dW* be work done in moving a charge *dq* in a time *dt* against the opposition, then

dW = Vdq …………..(2)

$V = -\varepsilon$ $dq = idt$

Sub V & dq values in (2) equation

dW = = $-\varepsilon\, idt$

Sub $\varepsilon = -L\frac{di}{dt}$ **in above equation**

$= -\left(-L\frac{di}{dt}\right) idt$

dW = ***Lidi***

On integration

W = ½ Li²

This work done is stored as magnetic potential energy

$U_B = \frac{1}{2} Li^2$

The energy density is the energy stored per unit volume of the space and is given by

$u_B = \frac{U_B}{Al}$

$u_B = \frac{B^2}{2\mu_0}$

12.Show that the mutual inductance between a pair of coil is same ($M_{12} = M_{21}$)

Mutual induction

- When an **electric current** passing through a coil **changes** with time, an **emf** is induced in the **neighbouring coil.** This phenomenon is known as mutual induction and the emf is called mutually induced emf.

Consider two coils which are placed close to each other. If an electric current i_1 is sent through coil 1, the magnetic field produced by it is also linked with coil 2.

ϕ_{21} **-** magnetic flux linked with each turn of the coil 2 of N_2 turns due to coil 1.

$$N\phi_{21} \;\alpha\; i_1$$
$$N\phi_{21} = M_{21} i_1$$

$M_{12} -$ mutual inductance of the coil 2 with respect to coil 1. It is also called as coefficient of mutual induction.

$$\varepsilon_2 = -\frac{d\,(N_2\,\phi_{21})}{dt}$$

Sub $N\phi_{21} = M_{12} i_1$ **in above equation**

$$\varepsilon_2 = -M_{21}\frac{di_1}{dt}$$

- When the coil is rotated through **90°** from initial position, **sin ωt = 1**.
- Then the maximum value of induced emf is

$$\varepsilon = N\phi_m \omega sin\omega t$$

sin ωt = 1 → $\varepsilon_m = N\phi_m\omega$

sub $\varepsilon_m = N\phi_m\omega$ in above equation

Therefore, the value of induced emf at that instant is then given by

$\varepsilon = \varepsilon_m sin\omega t$

- It is seen that the induced emf varies as sine function of the time angle ωt.
- The graph between induced emf and time angle for one rotation of coil will be a sine curve and the emf varying in this manner is called sinusoidal emf or alternating emf.
- If this alternating voltage is given to a closed circuit, a sinusoidally varying current flows in it.

This current is called alternating current & is given by $i = i_m sin\omega t$

15.Elaborate the standard construction details of AC generator

It consists of two major parts – **stator and rotor**

Stator – Stationary

Rotor – Rotates inside the stator

- Armature winding is mounted on stator
- Field magnet mounted on rotor

Construction details of

i)Stator

- The stationary part which has armature windings mounted in it is called stator.
- It has three components, namely stator **frame, stator core and armature winding**.

Stator frame

- This is the **outer frame** used for **holding stator core and armature windings** in proper position.
- Stator frame provides best ventilation with the help of holes provided in the frame itself

Stator core

- Stator core or armature core is **made** up of **iron or steel alloy**.
- It is a **hollow cylinder** and is **laminated** to minimize eddy current loss.
- The slots are cut on inner surface of the core to **accommodate armature windings**.

Armature winding

- Armature winding is the coil, wound on slots provided in the armature core.
- One or more than one coil may be employed, depending on the type of alternator.

Two types of windings

i) single-layer winding

ii) double-layer winding.

- In single-layer winding, a slot is **occupied by a coil as a single layer**.

Working

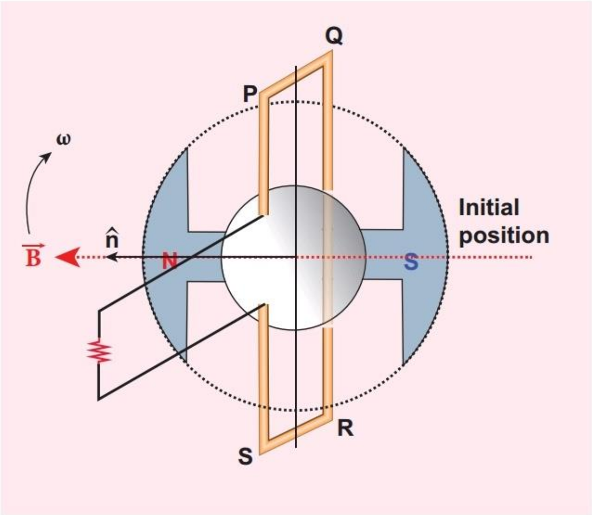


Figure 4.33 The loop PQRS and field magnet in its initial position

- The loop PQRS is stationary and is perpendicular to the plane of the paper.
- When field windings are excited, magnetic field is produced around it.
- Let the field magnet be rotated in clockwise direction by the prime mover.
- The axis of rotation is perpendicular to the plane of the paper.
- Assume that initial position of the field magnet is horizontal.
- At that instant, the direction of magnetic field is perpendicular to the plane of the loop PQRS.
- The induced emf is zero
- When field magnet rotates through 90°, magnetic field becomes parallel to PQRS.
- The induced emf's across PQ and RS would become maximum.
- Since they are connected in series, emfs are added up and the direction of total induced emf is given by Fleming's right hand rule.
- The direction of the induced emf is at right angles to the plane of the paper.
- For PQ, it is downwards and for RS upwards. Therefore, the current flows along PQRS. The point A in the graph represents this maximum emf.
- For the rotation of **180°** from the initial **position, the field is again perpendicular to PQRS** and the induced **emf becomes zero**. This is represented by point B.
- The field magnet becomes again parallel to PQRS **for 270°** rotation of field magnet. The **induced emf is maximum but the direction is reversed**. Thus the current flows along SRQP. This is represented by point C.
- On completion of **360°**, the induced **emf becomes zero** and is represented by the point D. From the graph, it is clear that emf induced in PQRS is alternating in nature.
- Therefore, when field magnet completes one rotation, induced emf in PQRS finishes one cycle.
- The **frequency** of the induced emf depends on the **speed** at which the field magnet rotates.

(Draw the sine wave given in Q.no 14)

18.Explain the construction and working of transformer

Principle ; Mutual induction between two coils.

Construction

- There are **two coils of high mutual inductance** wound over the same transformer core.
- The core is **generally laminated** and is made up of a good magnetic material like silicon steel.
- The coil across which **alternating voltage is applied is called primary coil *P*** and the coil from which **output power is drawn out is called secondary coil *S*.**
- The assembled core and coils are kept in a container which is filled with suitable medium for better insulation and cooling purpose.

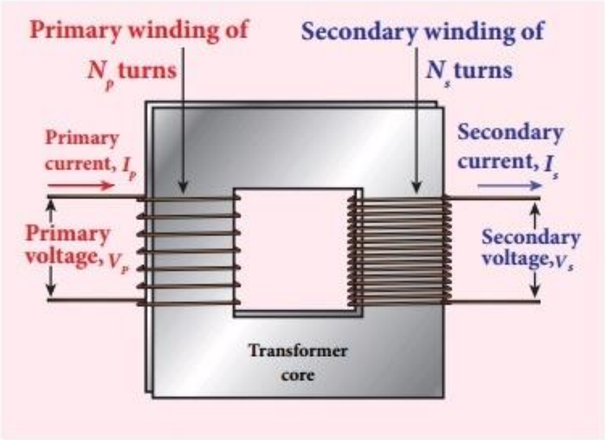


Figure 4.37(a) Construction of transformer

- Coils are **electrically insulated** but magnetically linked via transformer core

Working

- If the primary coil is connected to a source of alternating voltage, an alternating magnetic flux is set up in the laminated core.
- Rate at which magnetic flux changes through each turn is same for both primary and secondary coils.
- As a result of flux change, emf is induced in both primary and secondary coils.
- The emf induced in the primary coil ε_p is almost equal and opposite to the applied voltage v_p and is given by

$$V_P = \varepsilon_P = -N_P \frac{d}{dt}(N\phi_B) \quad \text{..........(1)}$$

- The frequency of alternating magnetic flux in the core is same as the frequency of the applied voltage.
- Therefore, induced emf in secondary will also have same frequency as that of applied voltage. The emf induced in the secondary coil ε_S is given by

$$\varepsilon_S = -N_S \frac{d}{dt}(N\phi_B)$$

N_P , N_S - number of turns in the primary and secondary coil

If the secondary circuit is open, then $\varepsilon_s = v_s$ where v_s is the voltage across secondary coil.

$$V_S = \varepsilon_S = -N_S \frac{d}{dt}(N\phi_B) \quad \text{.........(2)}$$

Dividing (2) by (1)

$$\frac{V_S}{V_P} = \frac{N_S}{N_P} = \text{K}$$

K – **voltage Transformer ratio**

21.Find out phase relationship between voltage and current in a pure inductor circuit

Consider a circuit containing a pure inductor of **inductance *L*** connected across an alternating voltage source).

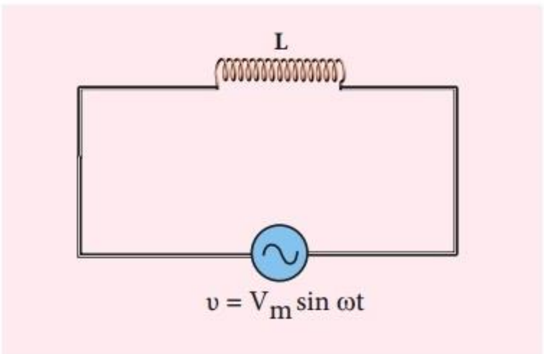


Figure 4.47 AC circuit with inductance

The alternating voltage is given by the equation

V = V_m sinωt ………. (1)

The alternating current flowing through the inductor induces a self-induced emf or back emf in the circuit.

Back emf $\varepsilon = -L\frac{di}{dt}$ …….(2)

By applying Kirchoff's loop rule to the purely inductive circuit, we get

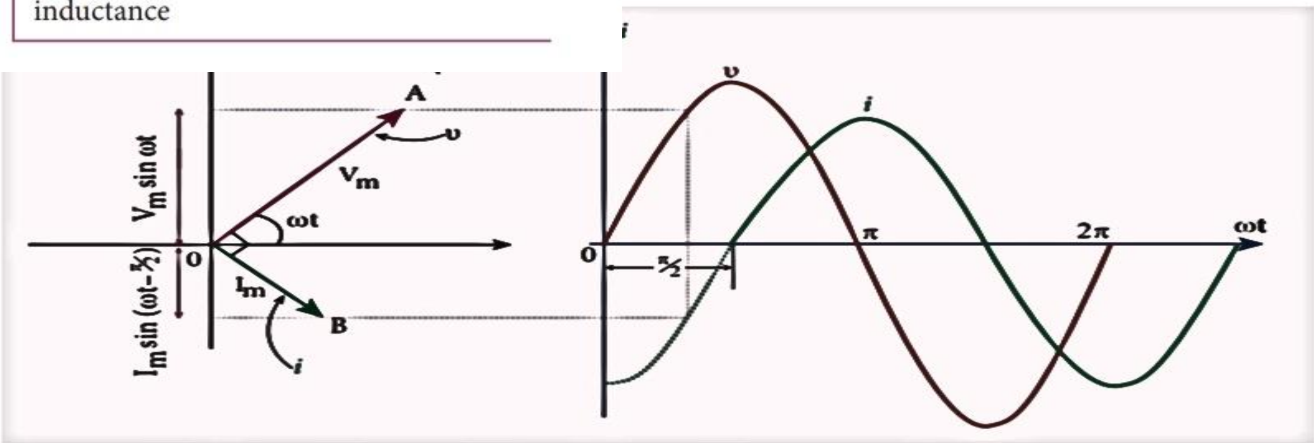


Figure 4.48 Phasor diagram and wave diagram for AC circuit with L

V + ε = 0

$V_m \sin \omega t - L\frac{di}{dt} = 0$

$V_m \sin\omega t = -L\frac{di}{dt}$

di = $\frac{V_m}{L}$ sinωt dt

Integrating both sides

I = $\frac{V_m}{L}\int \sin\omega t dt$

= $\frac{V_m}{L\omega}(-\cos \omega t)$ + constant

The integration constant in the above equation is independent of time so integration constant is zero

I = $\frac{V_m}{L\omega}(\sin \omega t - \pi/2)$

I = $I_m (\sin \omega t - \pi/2)$ ………(3)

where $\frac{V_m}{L\omega}$ = **I_m** the peak value of the alternating current in the circuit.

From (1) and (3) it is evident that current lags behind the applied voltage by π/2 in an inductive circuit.

Inductive reactance $X_L = \omega L$

22.Derive an expression for phase angle between the applied voltage and current in a series RLC circuit

Consider a circuit containing a resistor of resistance *R*, a inductor of inductance *L* and a capacitor of capacitance *C* connected across an alternating voltage source

The applied alternating voltage is

$V = V_m \sin\omega t$ ………. (1)

Let *i* be the resulting circuit current in the circuit at that instant.

As a result, the voltage is developed across *R*, *L* and *C*.

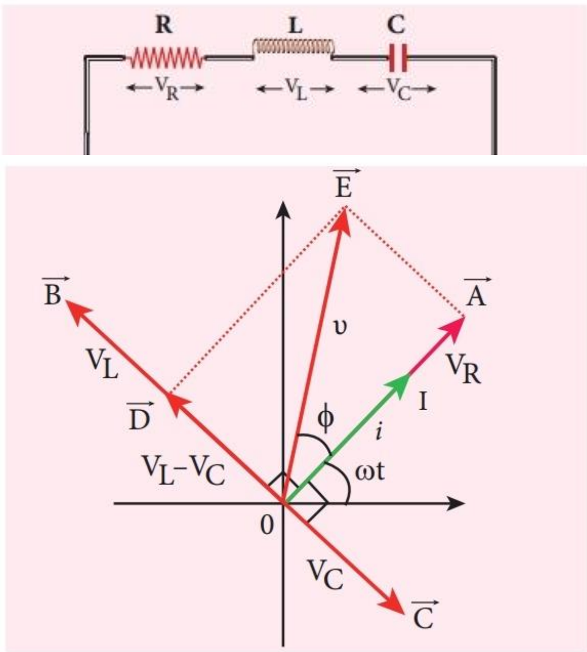


Figure 4.52 Phasor diagram for a series *RLC* – circuit when $V_L > V_C$

Voltage across R (V_R) is in pahse with i

Voltage across L (V_L) Leads i by π/2

Voltage across C (V_C) Lags i by π/2

V_L & V_C are 180° out of phase with each other and the resultant of V_L and V_C is ($V_L - V_C$)

Assuming circuit to be predominantly inductive.

The applied voltage equals the vector sums of V_L , V_C , V_R

$OI = I_m$

$V_R = OA = I_m R \quad V_L = OB = I_m X_L$

$V_R = OC = I_m X_C$

By parallelogram law, the diagonal $\overrightarrow{OE}$ gives the resultant voltage υ of V_R and $(V_L - V_C)$ and its length OE is equal to V_m. Therefore,

$$V_m^2 = V_R^2 + (V_L - V_C)^2$$

$$= \sqrt{(I_m R)^2 + (I_m X_L - I_m X_C)^2}$$

$$= I_m \sqrt{(R)^2 + (X_L - X_C)^2}$$

$$I_m = V_m / Z$$

$$Z = \sqrt{(R)^2 + (X_L - X_C)^2}$$

Z - impedance of the circuit which refers to the effective opposition to the circuit current by the series *RLC* circuit

From phasor diagram, the phase angle between υ and *i* is found out from the following relation

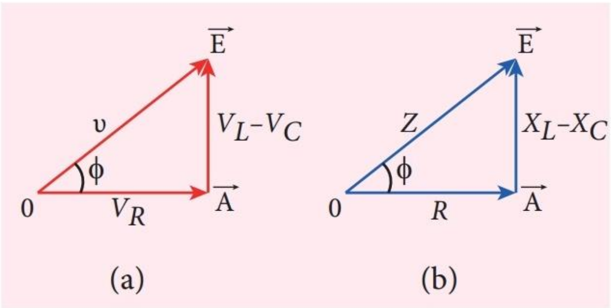


Figure 4.53 Voltage and impedance triangle when $X_L > X_C$

$$\tan\emptyset = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R}$$

Special cases

X_L, X_C	$X_L - X_C$	$\emptyset$	circuit
$X_L > X_C$	+ve	$\emptyset = +ve$ **V leads I by** $\emptyset$	**Inductive**
$X_L < X_C$	-ve	$\emptyset = -ve$ **V lags I by** $\emptyset$	**Capacitive**
$X_L = X_C$	0	$\emptyset = 0$ **V is in phase with I**	**Resistive**

23.Define inductive and capacitive reactance Give their units

Inductive reactance

Resistance offered by **inductor** is called inductive reactance

Unit : ohm

$X_L = \omega L \quad \omega = 2\pi\upsilon$

For **d.c** $\upsilon = 0$ $X_L = 0$

Thus pure inductor offers zero resistance to d.c

But in **A.C** circuit **reactance α frequency**

Capacitive reactance

Resistance offered by **capacitor** is called capacitive reactance

Unit : ohm

$X_C = \frac{1}{\omega C} \quad \omega = 2\pi\upsilon \quad X_C = \frac{1}{2\pi\upsilon C}$

$P_{av} = V_{RMS}\, I_{RMS} \cos\emptyset$

(iv) For series **RLC** circuit at **resonance**,

$\emptyset = 0$ $\cos\emptyset = 1$ $P_{av} = V_{RMS}\, I_{RMS}$

25.Show that the total energy is conserved during LC oscillations.

- During LC oscillations in LC circuits , the energy of the system oscillates between the electric field of the capacitor and the magnetic field of the inductor .
- These two forms of energy varies with times , the total energy remains constant.
- LC oscillations takes place in accordance with law of conservation of energy

Total energy $U = U_E + U_B$

$U_E = \frac{q^2}{2C}$ $U_B = \frac{Li^2}{2}$

$U = \frac{q^2}{2C} + \frac{Li^2}{2}$

Considering 3 different stages of LC oscillations and calculating the total energy of the system

Case (i) Charge in capacitor $q = Q_m$

Current through inductor $i = 0$

Total energy $U = \frac{Q_m^2}{2C} + 0 = \frac{Q_m^2}{2C}$ ....(1)

Case (ii) Charge in capacitor $q = 0$

Current through inductor $i = I_m$

Total energy $U = 0 + ½ \frac{LI_m^2}{2}$

$= \frac{LI_m^2}{2}$

$I_m = Q_m\, \omega$ where $\omega = \frac{1}{\sqrt{LC}}$

$I_m = Q_m \times \frac{1}{\sqrt{LC}}$

$U = \frac{Q_m^2}{2C}$ …………(2)

Case (iIi) Charge in capacitor $q = q$

Current through inductor $i = i$

Total energy $U = \frac{q^2}{2C} + \frac{Li^2}{2}$

$q = Q_m \cos\omega t$ $i = -\frac{dq}{dt} = Q_m\, \omega \sin\omega t$

Negative sign in current indicates charge in capacitor decreases with time

$$U = \frac{q^2}{2C} + \frac{Li^2}{2}$$
$$= \frac{Q_m^2 sin^2\omega t}{2C} + \frac{LQ_m^2 sin^2\omega t}{2LC} \qquad (\omega = \frac{1}{\sqrt{LC}})$$
$$= \frac{Q_m^2(COS^2\omega t + sin^2\omega t)}{2C}$$
$$= \frac{Q_m^2}{2C} \quad ....(3)$$

From (1) , (2) , (3) it is clear that total energy of the system remains constant i.e conserved

Book inside Long answers

1. Calculate the Mutual inductance between two long co-axial solenoids

- Consider two long co-axial solenoids of same length *l*.
- The length of these solenoids is large when compared to their radii so that the magnetic field produced inside the solenoids is uniform and the fringing effect at the ends may be ignored.
- **A_1 and A_2** - Area of cross section of the solenoids
- $A_1 > A_2$
- **n_1 & n_2** - The turn density of these solenoids
- i_1 - current flowing through solenoid 1
- Then the magnetic field produced inside it is

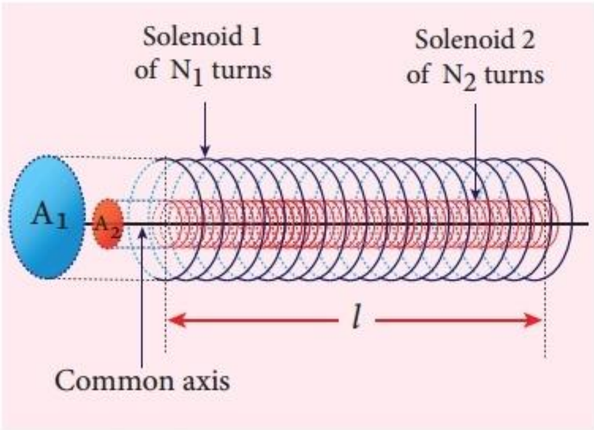


Figure 4.23 Mutual inductance of two long co-axial solenoids

$B_1 = \mu_o n_1 i_1$

As the field lines of B_1 are passing through the area bounded by solenoid 2 the magnetic flux is linked with each turn of solenoid 2 due to solenoid 1

$$\emptyset_{21} = B_1 A_2$$

Sub B_1 in above equation

$$\emptyset_{21} = (\mu_o n_1 i_1) A_2$$

The flux linkage of solenoid 2 with total turns N_2 is

$N_2 \emptyset_{21} = (\mu_o n_1 i_1)(n_2 l) A_2$ **where N_2 = nl**

$\quad = (\mu_o n_1 n_2 l A_2) i_1 ....(1)$

$N_2 \emptyset_{21} = M_2 i_1 ....(2)$

Comparing (1) and (2)

$$M_2 i_1 = (\mu_o n_1 n_2 l A_2) i_1$$
$$M_2 = \mu_o n_1 n_2 l A_2$$

mutual inductance of the solenoid 2 with respect to solenoid 1 is

$M_2 = \mu_o n_1 n_2 l A_2 ....(3)$

similarly

- As it is seen in single phase AC generator, when field magnet is rotated from that position in **clockwise direction**, alternating emf ε_1 in coil 1 begins a cycle from origin O.
- The corresponding cycle for alternating emf ε_2 **in coil 2** starts at point A after field magnet has rotated through 120°.
- Therefore, the phase difference between and is 120°. Similarly, emf ε_3 in coil 3 would begin its cycle at point B after 240° rotation of field magnet from initial position.
- Thus these **emf's** produced in the three phase AC generator have **120° phase difference between one another**.

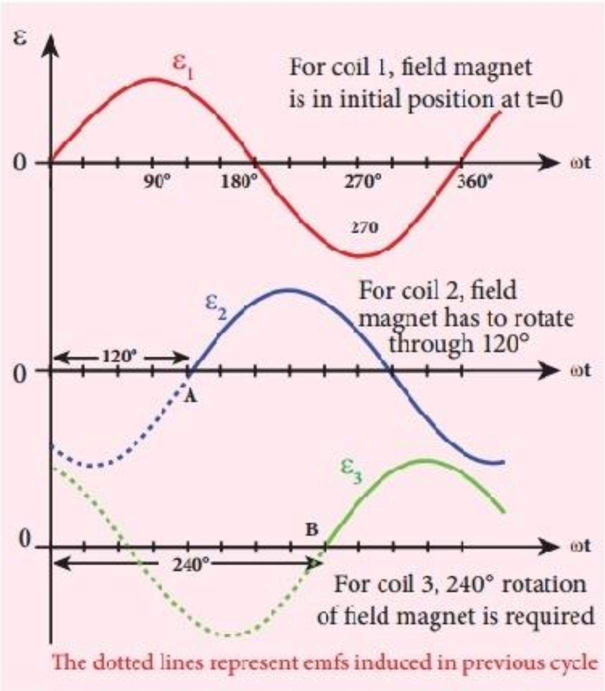


Figure 4.36 Variation of emfs ε_1, ε_2 and ε_3 with time angle.

3.Find out the phase relationship between voltage and current in pure resistive circuit

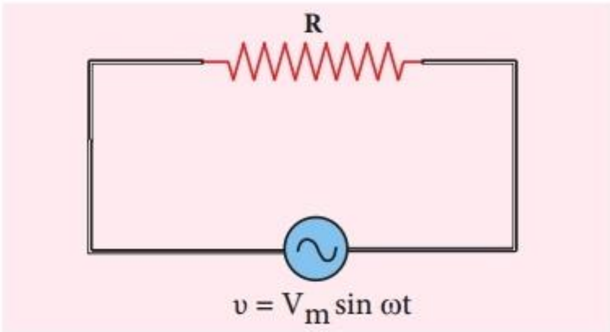


Figure 4.45 AC circuit with resistance

- Consider a circuit containing a pure resistor of resistance *R* connected across an alternating voltage source
- The instantaneous value of the alternating voltage is given by

$V = V_m \sin\omega t$ …………(1)

- An alternating current *i* flowing in the circuit due to this voltage, develops a potential drop across *R* and is given by

$V_R = iR$ …………….(2)

Kirchoff 's loop rule states that the algebraic sum of potential differences in a closed circuit is zero.

Unit – 5 ELECTROMAGNETIC WAVES

One marks

1. The existence of electromagnetic waves was confirmed experimentally by
a) Hertz b) Maxwell c) Huygens d) Planck
2. Which one of the following is not an electromagnetic wave
a) X – rays b) γ– rays c) U – V rays **d)β – rays**
3. Atomic spectrum should be
a) Pure line spectrum b) emission band spectrum
c) Absorption line spectrum d) absorption band spectrum
4. Electric filament lamp gives rise to
a) Line spectrum **b) continuous spectrum**
c) band spectrum d) line absorption spectrum
5. Which of the following gives rise to continuous emission spectrum?
a) Electric filament lamp b) Sodium vapour lamp
c) Gases in the discharge tube d) Calcium salt in bunsen flame
6. In an electromagnetic wave
a) Power is equally transferred along the electric and magnetic fields
b) Power is transmitted in a direction perpendicular to both the fields
c) Power is transmitted along electric field
d) Power is transmitted along magnetic field
7. Electromagnetic waves are
a) Transverse b) longitudinal
c) may be longitudinal or transverse d) neither longitudinal nor transverse
8. In an EM wave, the angle between the electric and the magnetic field vectors are at **90º**
9. The example of line absorption spectrum is **solar** spectrum
10. The **line** spectrum is used to identify the gas.
11. Incandescent solids, carbon arc lamp etc. give **continuous** spectrum.
12 Electromagnetic waves are discovered by **J.C.Maxwell1**
13.. An accelerated charge is a source of **electromagnetic radiation**
14. spectra of atomic hydrogen, helium is **line emission spectrum**

Rays	Wavelength	Frequency	Uses
Radio waves	1×10^{-1} m to 1×10^{4} m	3×10^{9} Hz to 3×10^{4} Hz.	radio and television
Microwaves	1×10^{-3} m to 3×10^{-1} m	3×10^{11} Hz to 1×10^{9} Hz.	Aircraft , microwave oven
Infrared radiation	8×10^{-7} m to 5×10^{-3} m	4×10^{14} Hz to 6×10^{10} Hz.	Infrared photo , tv remote , night vision
Visible light	4×10^{-7} m to 7×10^{-7} m	7×10^{14} Hz to 4×10^{14} Hz.	Study structure
Ultraviolet radiation	6×10^{-10} m to 4×10^{-7} m	5×10^{17} Hz to 7×10^{14} Hz.	Sterilizing agent
X-rays	10^{-13} m to 10^{-8} m	3×10^{21} Hz to 1×10^{16} Hz.	detecting fractures
Gamma rays	1×10^{-14} m to 1×10^{-10} m	3×10^{22} Hz to 3×10^{18}	atomic nuclei

1. Velocity of EM wave in Vacuum $C=\frac{1}{\sqrt{\mu_0\varepsilon_0}}$

   μ - permeability of free space ; ε_0 - permittivity of free space

2. Frequency of oscillation of charges between plates $v=\frac{1}{2\pi\sqrt{LC}}$

   C = capacitance, L - inductance (small wire)

3. The speed of electromagnetic wave $v=\frac{E_0}{B_0}$

   E_0 = Amplitude of oscillating electric filed ; B_0 = Amplitude of oscillating magnetic field.

4. Intensity (I) = $\frac{\text{Power (P)}}{\text{Surface Area (A)}} = \frac{\text{Total electromagnetic energy}}{\text{Surface Area (A)} \times \text{time (t)}}$

5. The average energy density of electromagnetic wave is $u = \varepsilon_0 E^2 = \frac{1}{\mu_0} \times B^2$

   ε_0 = Permittivity of free space ; μ_0 = Permeability of free space

6. Momentum Imparted by electromagnetic wave on the surface is $p = \frac{U}{c} = \frac{\text{Energy}}{\text{Velocity of light}}$

---

7. Ampere's Maxwell Law : $\oint \vec{B}\cdot\vec{dl}=\mu_0 I_{enclosed}+\mu_0\varepsilon_0\frac{d}{dt}\int\vec{E}\cdot d\vec{A}$

8. Faraday's Law : $\oint \vec{E}\cdot\vec{dl}=\frac{d}{dt}\Phi_B$; Φ_B - Magnetic flus.

9. Gauss's Law : $\oint \vec{E}\cdot d\vec{A}=\frac{Q_{enclosed}}{\varepsilon_0}$

10. Ampere's circuital Law : $\oint \vec{B}\cdot\vec{dl}=\mu_0 I_0$; I_c conduction current

11. Refractive Index of the medium $\mu=\sqrt{\varepsilon_r\mu_r}$

Book back

Short answers

1.What is displacement current?

It can be defined as the current which comes into play in the region in which the **electric field** and the **electric flux are changing** with **time**

2.What are electromagnetic waves?

Electromagnetic waves are non-**mechanical waves** which **move** with **speed equals to the speed of light** (in vacuum).

3.Write down the integral form of modified Ampere's circuital law

$$\oint \vec{B}.d\vec{S} = \mu_0(I_c + I_d)$$

I_c - Conduction current
I_d – Displacement current

4.Explain the concept of intensity of electromagnetic waves

The energy crossing per unit area per unit time and perpendicular to the direction of propagation of electromagnetic wave is called the intensity.

Intensity = $\frac{Total\ electro\ magnetic\ energy\ (U)}{Surface\ area\ (A) \times time\ (t)}$

Intensity = $\frac{Power\ (P)}{Surface\ area\ (A)}$

5.What is Fraunhofer lines?

When the **spectrum obtained from the Sun** is examined, it consists of large number of **dark lines** (line absorption spectrum). These dark lines in the solar spectrum are known as **Fraunhofer lines**.

The absorption spectra for various materials are compared with the

Book inside short answers

1.What is electromagnetic spectrum?

Electromagnetic spectrum is an orderly distribution of electromagnetic waves in terms of wavelength or frequency

2.What is dispersion of light

- A beam of white **light** made to pass through the **prism** , it is split into its **seven constituent colours** which can be viewed on the screen as **continuous spectrum.**
- This phenomenon is known as dispersion of light

3.What do you meant by spectrum

- A beam of white **light** made to pass through the **prism** , it is split into its **seven constituent colours** which can be viewed on the screen as **continuous spectrum.**
- This phenomenon is known as dispersion of light.
- Pattern of colours obtained on the screen after dispersion is called as spectrum

4. What is radiation pressure?

The force exerted by an electromagnetic wave on unit area of a surface is called radiation pressure.

5.What are the application of electromagnetic waves

Medical - **LASER surgery**,
Defence **- RADAR signals** and also in **fundamental scientific research**.

6.Derive the energy density of the electromagnetic wave

The energy density (energy per unit volume) associated with an electromagnetic wave propagating in vacuum or free space is

$$u = \frac{1}{2}\varepsilon_o E^2 + \frac{1}{2\mu_o}B^2$$

where, $\frac{1}{2}\varepsilon_o E^2 = u_E$ is the energy density in an electric field and $\frac{1}{2\mu_0}B^2 = u_B$ is the energy density in a magnetic field.

Since, $E = Bc \Rightarrow u_B = u_E$.

The energy density of the electromagnetic wave is

$$u = \varepsilon_0 E^2 = \frac{1}{\mu_0}B^2$$

7.What is pointing vector?

The rate of flow of energy crossing a unit area is known as pointing vector for electromagnetic waves

Unit : W m^{-2}.

$$\vec{S} = \frac{1}{\mu_0}(\vec{E} \times \vec{B}) = c^2 \varepsilon_0 (\vec{E} \times \vec{B})$$

8.What are uses of Fraunhofer lines?

Fraunhofer lines in the solar spectrum, which helps in identifying elements present in the **Sun's atmosphere**

Book back

Long answers

1.Write down Maxwell equation in integral form.

1. First equation - Gauss's law.

It relates the net electric flux to net electric charge enclosed in a surface

$$\oint \vec{E}.\vec{dA} = \frac{Q_{enclosed}}{\varepsilon_0} \text{ (Gauss law)}$$

$Q_{enclosed}$ - Charge enclosed

$\vec{E}$ – Electric field

It means that isolated positive charge or negative charge can exist

2. Second equation has no name. But this law is similar to Gauss's law in electrostatics. So this law can also be called as Gauss's law in magnetism.

$$\oint \vec{B}.\vec{dA} = 0$$

$\vec{B}$- **Magnetic field**

It means that no isolated magnetic monopole exists

3. Third equation is Faraday's law of electromagnetic induction

$$\oint \vec{E}.\vec{dl} = \frac{d}{dt}\phi_B$$

$\vec{E}$ – Electric field

This equation implies that the line integral of the electric field around any closed path is equal to the rate of change of magnetic flux through the closed path bounded by the surface.

4. Fourth equation is **modified Ampere's circuital law**. This is also known as Ampere – Maxwell's law. This law relates the **magnetic field** around **any closed path** to the **conduction current and displacement current** through that path.

$$\oint \vec{B}.\vec{dl} = \mu_o I_{enclosed} + \mu_o \varepsilon_o \frac{d}{dt}\int_s \vec{E}.\vec{dA}$$

These four equations are known as Maxwell's equations in electrodynamics.

This equation ensures the existence of electromagnetic waves.

2.Write short notes in a) microwave b) X-ray c)radio waves d)Visible light spectrum

a) Microwaves

- It is produced by **electromagnetic oscillators** in electric circuits.
- **Wavelength** range is **1×10^{-3} m to 3×10^{-1} m**
- **Frequency** range is **3×10^{11} Hz to 1×10^{9} Hz.**
- It obeys **reflection** and **polarization**.

Uses

Radar system for aircraft navigation, speed of the vehicle, microwave oven for cooking and very long distance wireless communication through satellites.

b)X – rays

- It is produced when there is a sudden deceleration of high speed electrons at high-atomic number target, and also by electronic transitions among the innermost orbits of atoms.
- The **wavelength** range **10^{-13} m to 10^{-8} m**
- **Frequency** range are **3×10^{21} Hz to 1×10^{16} Hz.**
- X-rays have **more penetrating power** than ultraviolet radiation.

Uses

- X-rays are used extensively in studying structures of inner atomic electron shells and crystal structures.
- It is used in detecting fractures, diseased organs, formation of bones and stones, observing the progress of healing bones.
- Further, in a finished metal product, it is used to detect faults, cracks, flaws and holes.

c)Radio waves

- It is **produced by oscillators** in electric circuits.
- **Wavelength** range is **1×10^{-1} m to 1×10^{4} m Frequency** range is **3×10^{9} Hz to 3×10^{4} Hz.**
- It obeys **reflection** and **diffraction**.

Uses

- Radio and television communication systems In cellular phones to transmit voice communication in the ultra high frequency band.

d) **Visible light**

- It is produced by **incandescent bodies** and also it is **radiated by excited atoms in gases.**
- **Wavelength** range is **4×10^{-7} m to 7×10^{-7} m**
- **Frequenc**y range are **7×10^{14} Hz to 4×10^{14} Hz**.
- It obeys the laws of reflection, refraction, interference, diffraction, polarization, photo-electric effect and photographic action.

Uses

It can be used to study the structure of molecules, arrangement of electrons in external shells of atoms and sensation of our eyes.

3.Discuss briefly the experiment conducted by Hertz to produce and detect electromagnetic waves

Construction

- It consists of two metal electrodes which are made of small spherical metals .
- These are connected to larger spheres and the ends of them are connected to induction coil with very large number of turns.

Between the plates, the conduction current
$I_c = 0$ and hence $I_d = I$.

5.Write down properties of electromagnetic waves

1) They are produced by any **accelerated charge**.

2) They do not **require any medium for propagation**. So it is a **non-mechanical wave**.

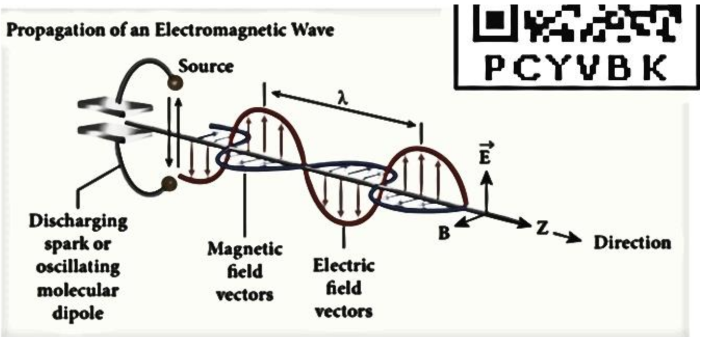


Figure 5.9 Oscillating charges - sources of electromagnetic waves

3) They are **transverse** in nature. Oscillating electric field vector, oscillating magnetic field vector and propagation vector (gives direction of propagation) are **mutually perpendicular to each other.**

4) Electromagnetic waves travel with speed which is equal to the speed of light in vacuum or free space,

$$c = \frac{1}{\sqrt{\mu_o \varepsilon_0}} = \mathbf{3 \times 10^{-}\ m\ s^{-1}}$$

5) They are **not deflected** by electric field or magnetic field.

6) They can show **interference, diffraction and can also be polarized**.

7) They also carry energy and momentum.The force exerted by an electromagnetic wave on unit area of a surface is called **radiation pressure**.

8) Electromagnetic waves carries not only energy and momentum but **also angular momentum.**

6.Discuss the source of electromagnetic waves

- When the charge moves with uniform velocity, it produces steady current which gives rise to magnetic field (not time dependent, only space dependent) around the conductor in which charge flows.
- If the charged particle accelerates, in addition to electric field it also produces magnetic field.
- Both electric and magnetic fields are time varying fields.

- Since the electromagnetic waves are transverse waves, the direction of propagation of electromagnetic waves is perpendicular to the plane containing electric and magnetic field vectors.
- Any oscillatory motion is also an accelerating motion, so, when the charge oscillates (oscillating molecular dipole) about their mean position it produces electromagnetic waves.
- Suppose the electromagnetic field in free space propagates along *z* direction, and if the electric field vector points along y axis then the magnetic field vector will be mutually perpendicular to both electric field and the propagation vector direction, which means

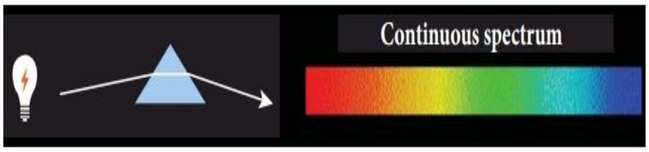


Figure 5.13 continuous emission spectra

$E_y = E_0 \sin(kz - \omega t)$

$B_y = B_0 \sin(kz - \omega t)$

E_0, B_0 - Amplitude of oscillating electric and magnetic field,

k - wave number

ω - angular frequency of the wave

$\hat{k}$ - propagation vector (denotes the direction of propagation of electromagnetic wave)

In free space or in vacuum,

speed of light **c** = E_0 / B_0

Energy of electromagnetic waves comes from the energy of the oscillating charge.

7.What is emission spectra? Give their types

Emission spectra

- When the **spectrum of self luminous source** is taken, we get emission spectrum.
- Each source has its **own characteristic emission spectrum**.
- It has **three** types

(i) Continuous emission spectra (or continuous spectra)

- If the light from incandescent lamp (filament bulb) is allowed to pass through prism (simplest spectroscope), it splits into seven colours.
- Thus, it consists of wavelengths containing all the visible colours ranging from violet to red.

Examples:

- Spectrum obtained from carbon arc, incandescent solids
- liquids gives continuous spectra.

- **For diagram refer book**

Example

- Similarly, if the light from the carbon arc is made to pass through sodium vapour, a continuous spectrum of carbon arc with two dark lines in the yellow region of sodium vapour is obtained.

(iii) Band absorption spectrum

- When the **white light** is passed through the **iodine vapour**, **dark bands on continuous bright background** is obtained.
- This type of band is also obtained when white light is passed through diluted solution of blood or chlorophyll or through certain solutions of organic and inorganic compounds.

Book inside long answers

1.What are the properties and uses of Infrared radiation and Ultraviolet radiation

Infrared radiation

Properties

- It is produced from **hot bodies** (also known as heat waves) and also when the molecules **undergo rotational and vibrational transitions**.
- **Wavelength** range is **8×10^{-7} m to 5×10^{-3} m**
- **Frequency range** are **4×10^{14} Hz to 6×10^{10} Hz.**

Uses

- It provides electrical energy to satellites by means of solar cells.
- It is used to produce dehydrated fruits, in green houses to keep the plants warm, heat therapy for muscular pain or sprain, TV remote as a signal carrier
- To look through haze fog or mist and used in night vision or infrared photography.

Ultraviolet radiation

Properties

- It is produced by **Sun, arc and ionized gases. Wavelength** range is **6×10^{-10} m to 4×10^{-7} m**
- **Frequency** range are **5×10^{17} Hz to 7×10^{14} Hz.** It has less penetrating power.
- It can be absorbed by atmospheric ozone and harmful to human body.

Uses

- It is used to destroy bacteria, sterilizing the surgical instruments, burglar alarm, detect the invisible writing, finger prints and also in the study of molecular structure.