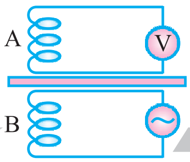


Unit III and IV

Section - 2

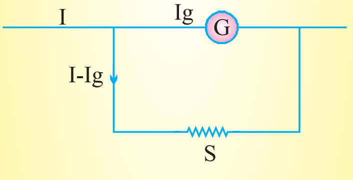
KEY POINTS

Physical Quantity	Formulae	SI Unit
Biot-Savart's Law	$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\times\vec{r}}{r^3}$	Tesla (T);
	$\lvert d\vec{B}\rvert = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$	10^4 Gauss = 1T
Magnetic field due to a straight current carrying conductor	$B = \frac{\mu_0 I}{2\pi R}$	T
Magnetic field at the centre of	$B = \frac{\mu_0 I}{2a}$	T
a circular loop	$B = \frac{\mu_0 nI}{2a}$ (For n loops)	
Magnetic Field at a Point on the Axis of a current carrying loop	$B = \frac{\mu_0 I}{4\pi}\frac{2\pi a^2}{(a^2+x^2)^{\frac{3}{2}}}$	T
	When, $x = 0$, $B = \frac{\mu_0 I}{2a}$	
	For $a << x$, $B = \frac{\mu_0 Ia^2}{2x^3}$	
	For n loops, $B = \frac{\mu_0 nIa}{2x^3}$	
Ampere's Circuital Law	$\oint \vec{B}.d\vec{l} = \mu_0 I$	$T - m$

Magnetic field due to a long straight solenoid	$B = \mu_0 n I$ At the end of solenoid, $B = \frac{1}{2}\mu_0 n I$ If solenoid is filled with material having magnetic permeability μr $B = \mu_0 \mu_r nI$	T
Magnetic field due to a toroidal solenoid	$B = \mu_0 nI$	T
Motion of a charged particle inside electric field	$y = \frac{qE}{2m}\left(\frac{x}{v_x}\right)^2$	m
Megnetic force on a moving charge	$\vec{F} = q\left(\overline{v} \times \vec{B}\right)$ Or $F = qv B \sin \theta$	N
Lorentz Force (Electric and Magnetic)	$\vec{F} = q\vec{E} + q\left(\overline{v} \times \vec{B}\right)$	N
The Cyclotron		
Radius of circular path	$r = \frac{mv}{Bq}$	
The period of circular motion	$T = \frac{2\pi m}{Bq}$	
The cyclotron frequency	$v = \frac{1}{T} = \frac{Bq}{2\pi m}$	
Maximum energy of the positive ions	$\frac{1}{2}mv_{max}^2 = \frac{B^2q^2r^2}{2m} = qV = qV$	
The radius corresponding to maximum velocity	$r = \frac{1}{B}\left(\frac{2mV}{q}\right)^{\frac{1}{2}}$	

The maximum velocity	$V_{max} = \frac{Bqr}{m}$	
The radius of helical path when $\bar{v}$ and $\vec{B}$ are inclined to each other by an angle θ	$r = \frac{mv \sin\theta}{qB}$	
Force on a current carrying conductor placed in a magnetic field	$\vec{F} = I\left(\vec{l} \times \vec{B}\right)$	N
Force per unit length betwen two parallel current carrying conductors	$f = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r}$	Nm^{-1}
Magnetic dipole moment	$\vec{M} = I\vec{A}$	Am^2 or JT^{-1}
Torque on a rectangular current carrying loop ABCD	$\vec{\tau} = \vec{M} \times \vec{B}$ $\Rightarrow \tau = MB \sin\alpha$ If coil has n turns, $\tau = n\,B\,I\,A \sin\alpha$ $\alpha \rightarrow$ angle between normal drawn on the plane of loop and magnetic field	
Period of oscillation of bar magnet if external magnetic field	$T = 2\pi\sqrt{\frac{I}{MB}}$	S
The potential energy associated with magnetic field	$U = -\vec{M}\cdot\vec{B} = -MB\cos\theta$	
Current through a galvanometer $\phi \rightarrow$ angle by which the coil rotates	$I = \frac{k}{nBA}\phi = G\phi;$ $G \rightarrow$galvanometer constant	A

Sensitivity of a galvanometer or Current sensitivity	$I_s = \frac{\theta}{I} - \frac{nBA}{k} = \frac{1}{G}$	rad A^{-1}
Voltage sensitivity	$V_s = \frac{\theta}{V} = \frac{nBA}{kR} = \frac{1}{GR}$	rad V^{-1}
The current loop as a magnetic dipole on axis at very large distance from the centre	$B = \frac{\mu_0}{4\pi}\frac{2M}{x^3}$ T	
Gyromagnetic ratio	$\frac{\mu_e}{L} = \frac{e}{2m_e} = 8.8\times10^{10}\ \frac{C}{kg}$ → Angular momentum	C Kg^{-1}
Bohr magneton	$(\mu_e)_{min} = \frac{e}{4\pi m_e}h$ $= 9.27\times10^{-24}$	Am^2
Magnetic dipole moment	$\vec{M} = m\left(2\vec{l}\right)$	JT^{-1} or Am^2
Magnetic field on axial line of a bar magnet	$B_{axial} = \frac{\mu_0}{4\pi}\left[\frac{2Mr}{(r^2 - l^2)^2}\right]$ When, $l << r$, $B_{eq} = \frac{\mu_0}{4\pi}\frac{M}{r^3}$	T
Gauss's Law in magnetism	$\oint_S \vec{B}.d\vec{S} = 0$	Tm^2 or weber
Magnetic inclination (or Dip)	$\tan\delta = \frac{B_V}{B_H}$, $\delta \rightarrow$ angle of dip	
Magnetic intensity (or Magnetic field strength)	$H = \frac{B_0}{\mu_0} = nI$ n is the no. of	Am^{-1} terms/length
Intensity of magnetization	$I_m = \frac{M}{V}$	Am^{-1}

Magnetic flux	$\phi = \vec{B}.\Delta\vec{S}$	Weber or Tm^2
Magnetic induction (or Magnetic flux density or Magnetic field)	$B = B_0 + \mu_0 I_m$ $= \mu_0 (H + I_m)$	T
Magnetic susceptibility	$\chi_m = \dfrac{I_m}{H}$ —	
Magnetic permeability	$\mu = \dfrac{B}{H}$ TmA^{-1} (or NA^{-2})	
Relative permeability (μ)	$\dfrac{\mu}{\mu_0} = \mu_r = (1 + \chi_m)$	
Curie's Law	$\chi_m = \dfrac{C}{T}$, C → curie constant	
Conversion of a Galvanometer into Ammeter 	$IgG = (I - Ig)S$ $Ig(G+S) = SI$ $Ig = \left(\dfrac{S}{G+S}\right)I$ S → shunt resistance	
Conversion of a Galvanometer into voltmeter  $R = \dfrac{V}{Ig} - G$	G → Galvanometer resistance	

UNIT–III & UNIT–IV

MAGNETIC EFFECTS OF CURRENT AND MAGNETISM & E.M.I. AND ALTERNATING CURRENT

QUESTIONS

VERY SHORT ANSWER QUESTIONS (1 Mark)

1. Must every magnetic field configuration have a north pole and a south pole? What about the field due to a toroid?

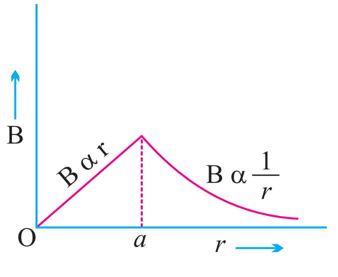
Ans. No, pole exists only when the source has some net magnetic moment. There is no pole in toroid. Magnetic field due to a toroid $B = \mu_0 \, nI$

2. How are the figure of merit and current sensitivity of galvanometer related with each other ?

Ans. Reciprocal.

3. Show graphically the variation of magnetic field due to a straight conductor of uniform cross-section or radius '*a*' and carrying steady currently as a function of distance *r* ($a > r$) from the axis of the conductor.

Ans.



4. The force per unit length between two parallel long current carrying conductor is F. If the current in each conductor is tripled, what would be the value of the force per unit length between them?

Ans. $F = \dfrac{\mu_w I_1 I_2}{2\pi r}$

$$F = \frac{\mu_0 (3I_1)(3I_2)}{2\pi r} = 9 \text{ times}$$

5. How does the angle of dip vary from equator to poles?

Ans. 0º to 90º

6. What is the effect on the current measuring range of a galvanometer when it is shunted?

Ans. Increased.

7. An electric current flows in a horizontal wire from East to West. What will be the direction of magnetic field due to current at a point (i) North of wire; (ii) above the wire.

Ans.

(i) Going into the plane of the paper.

(ii) Going out of the plane of paper.

8. Suggest a method to shield a certain region of space from magnetic fields.

Ans. By using a ferromagnetic case. Put an iron ring in the magnetic field inside the ring field will be zero.

9. Why the core of a moving coil galvanometer is made of soft iron?

Ans. To increase magnetic flux linked and sensitivity.

10. Where on the earth's surface is the vertical component of earth's magnetic field zero?

Ans. At equator.

11. If the current is increased by 1% in a moving coil galvanometer. What will be percentage increase in deflection?

Ans. 1%.

12. Write S.I. unit of (i) Pole strength and (ii) Magnetic dipole moment.

Ans. (i) Am

(ii) Am^2

13. If the magnetic field is parallel to the positive y-axis and the charged particle is moving along the positive x-axis, which way would the Lorentz force be for (a) an electron (negative charge), (b) a proton (positive charge) ?

Ans. When velocity ($\vec{v}$) of positively charged particle is along x-axis and the magnetic field ($\vec{B}$) is along y-axis, so $\vec{v} \times \vec{B}$ is along the z-axis (Fleming's left hand rule).

Therefore,

(a) for electron Lorentz force will be along -z axis;

(b) for a positive charge (proton) the force is along +z axis.

14. If a toroid uses Bismuth at its core, will the field in the core be lesser or greater than when it is empty?

Ans. Bismuth is diamagnetic, hence, the overall magnetic field will be slightly less.

15. An electron beam projected along + x-axis, experiences a force due to a magnetic field along the + y-axis. What is the direction of the magnetic field?

Ans. + Z-axis

16. What do you understand by figure of merit ?

Ans. Figure of merit is defined as the current required per division of deflection derivation

$$K = \frac{I}{\theta}, \text{ SI unit A/div}$$

in observation for half deflection method

$$i_g = K\theta,\ i_g = \frac{E}{R+G}$$

$$k = \frac{1}{\theta}\left[\frac{E}{R+G}\right]$$

It enables us to find current required for full scale deflection.

17. What is the direction of magnetic dipole moment ?

Ans. S to N.

18. What is the angle of dip at a place where vertical and horizontal component of earth's field are equal ?

Ans. 45°

19. Does a charge Particle gain K.E. when passed through magnetic field region? Justify.

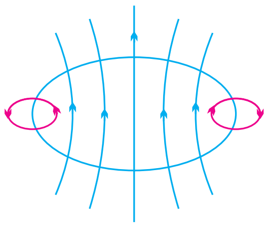
Ans. No, as the magnetic force acting on the charge particle is always perpendicular to the velocity, hence

$$\frac{d\omega}{dt} = \vec{f} \cdot \vec{v} = f\, v \cos 90° = 0$$

$\therefore$ there is no gain in KE of particle.

20. Sketch the magnetic field lines for a current carrying circular loop.

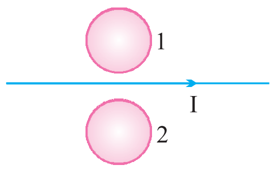
Ans.



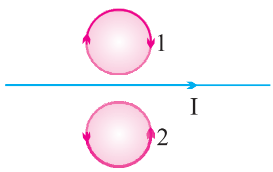
21. Why core of a transformer is laminated ?

Ans. To reduce loss due to eddy currents.

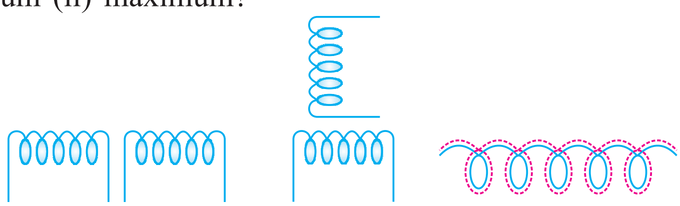
22. What is the direction of induced currents in metal rings 1 and 2 seen from the top when current I in the wire is increasing steadily ?



Ans.



23. In which of the following cases will the mutual inductance be (i) minimum (ii) maximum?



(a) (b) (c)

Ans. (i) b (ii) c

24. In a series L–C–R circuit, voltages across inductor, capacitor, and resistor are V_L, V_C and V_R respectively. What is the phase difference between (i) V_L and V_R (ii) V_L and V_C?

Ans. (i) $\frac{\pi}{2}$ (ii) π

25. Why can't transformer be used to step up or step down dc voltage?

Ans. In steady current no induction phenomenon will take place.

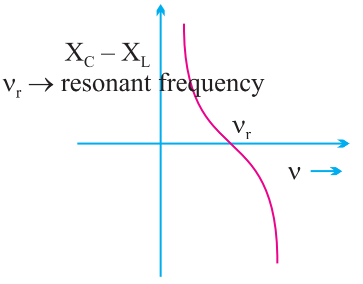
26. In an a.c. circuit, instantaneous voltage and current are V = 200 sin 300 *t* volt and *i* = 8 cos 300*t* ampere respectively. What is the average power dissipated in the circuit?

Ans. As the phase difference between current and voltage is $\frac{\pi}{2}$.

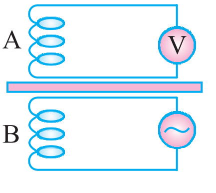
$$\therefore\ P_{av} = I_{v}E_{v} \cos\frac{\pi}{2} = 0$$

27. Sketch a graph that shows change in reactance with frequency of a series LCR circuit. (x) (ν)

Ans.



28. A coil A is connected to an A.C. ammeter and another coil B to A source of alternaing e.m.f. How will the reading of ammeter change if a copper plate is introduced between the coils as shown.



Ans. Reading of ammeter will decrease due to eddy currents.

29. In a circuit instantaneously voltage and current are V = 150 sin 314t volt and i = 12 cos 314t ampere respectively. Is the nature of circuit is capacitive or inductive ?

Ans. $i = 12 \sin\left(314t + \frac{\pi}{2}\right)$

i.e. Current is ahead the voltage by a phase difference of $\frac{\pi}{2}$. Hence circuit is a capacitive circuit.

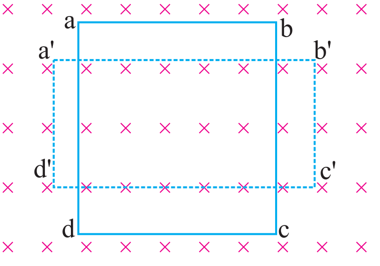
30. In a series L–C–R circuit $V_L = V_C \neq V_R$. What is the value of power factor?

Ans. At Resonance cos ϕ = 1.

31. In an inductor L, current passed I_0 and energy stored in it is U. If the current is now reduced to $I_0/2$, what will be the new energy stored in the inductor?

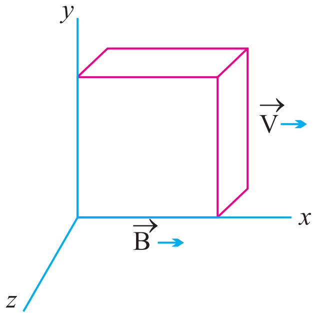
Ans. $U_L \propto I^2 \Rightarrow U' = \frac{U}{4}$

32. A square loop *a, b, c, d* of a conducting wire has been changed into a rectangular loop *a′, b′, c′, d′* as shown in figure. What is the direction of induced current in the loop?



Ans. Clockwise.

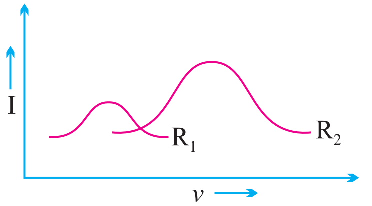
33. Twelve wires of equal lengths are connected in the form of a skeleton of a cube, which is moving with a velocity $\vec{V}$ in the direction of magnetic field $\vec{B}$. Find the emf in each arm of the cube.



Ans. emf in each branch will be zero since V & B are parallel for all arms.

$$\therefore \ \vec{F} = q\left(\vec{V} \times \vec{B}\right) = 0$$

34. Current versus frequency (I – v) graphs for two different series L–C–R circuits have been shown in adjoining diagram. R_1 and R_2 are resistances of the two circuits. Which one is greater–R_1 or R_2?



Ans. $R_1 > R_2$ as I is smaller in larger resistance.

35. Why do we prefer carbon brushes than copper in an a.c. generator?

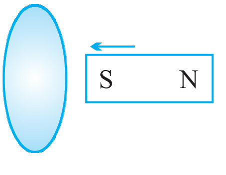
Ans. Corrosion free and small expansion on heating maintains proper contact.

36. What are the values of capacitive and inductive reactance in a dc circuit?

Ans. $X_{C\,=}\ \infty$ for dc $\upsilon = 0$ $X_C = \dfrac{1}{\omega_c} = \dfrac{1}{2\pi\upsilon c} = \infty$

$$X_L = 0 \quad \& \quad X_L = \omega\, L = 2\pi\upsilon L = 0$$

37. Give the direction of the induced current in a coil mounted on an insulating stand when a bar magnet is quickly moved along the axis of the coil from one side to the other as shown in figure.

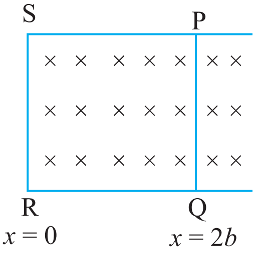


Ans. If observer is situated at the side from which bar magnet enters the loop. The direction of current is clockwise when magnet moves towards the loop and direction of current is anticlockwise when magnet moves away from the loop.

38. In figure, the arm PQ is moved from $x = 0$ to $x = 2b$ with constant speed V. Consider the magnet field as shown in figure. Write

(i) direction of induced current in rod

(ii) polarity induced across rod.

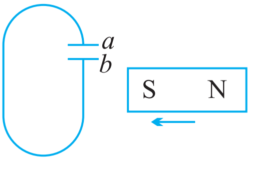


39. A wire moves with some speed perpendicular to a magnetic field. Why is emf induced across the rod?

Ans. Lorentz force acting on the free charge carrier of conducting wire hence polarity developed across it.

40. Predict the polarity of the capacitor in the situation described in the figure below.

Ans. Plate *a* will be positive with respect to '*b*'. When the observer is looking from the side of moving bar magnet.



41. A circular coil rotates about its vertical diameter in a uniform horizontal magnetic field. What is the average emf induced in the coil?

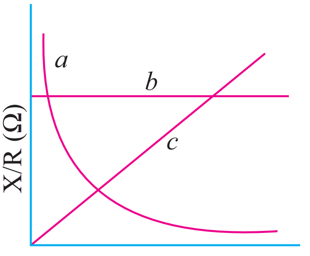
Ans. Zero

42. Define RMS Value of Current.

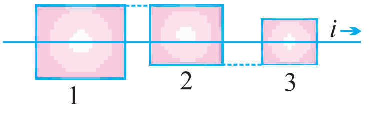
Ans. RMS value of ac is defined as that value of direct current which produces the same heating effect in a given resistor as is produced by the given alternating current when passed for the same time.

$$I_{rms} = \frac{I_0}{\sqrt{2}} = 0.707\ I_0$$

43. In given figure three curves *a, b* and *c* shows variation of resistance, (R) capacitive reactance (x_c) and inductive (x_L) reactance with frequency. Identify the respective curves for these.



44. A long straight wire with current *i* passes (without touching) three square wire loops with edge lengths 2L, 1.5L and L. The loops are widely spaced (so as do not affect one another). Loops 1 and 3 are symmetric about the long wire. Rank the loops according to the size of the current induced in them if current *i* is (a) constant and (b) increasing.



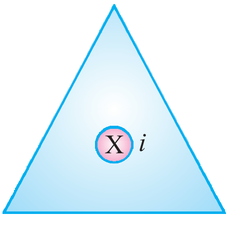
Ans. (a) No induced current

(b) Current will be induced only in loop 2.

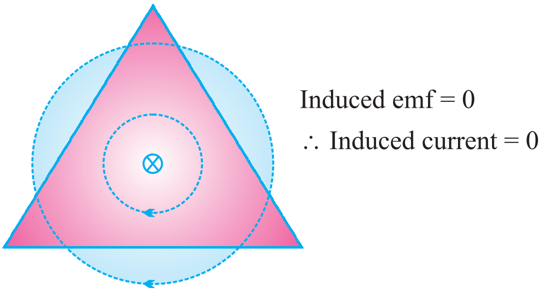
45. In an L–C circuit, current is oscillating with frequency 4×10^6 Hz. What is the frequency with which magnetic energy is oscillating?

Ans. $\upsilon_m = 2\upsilon = 8 \times 10^6$ Hz.

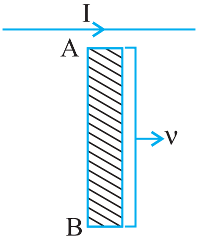
46. A current carrying wire (straight) passes inside a triangular coil as shown in figure. The current in the wire is perpendicular to paper inwards. Find the direction of induced current in the loop if current in the wire is increasing with time.



Ans. Magnetic field line are tangential to the triangular plane $\theta = 90^\circ$ so $\phi = 0$

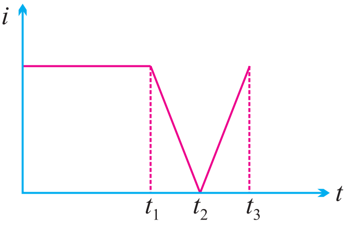


47. Wire carrying a study current and rod AB are in the same plane the rod move parallel to wire with velocity v then which end of the rod is at higher potential.



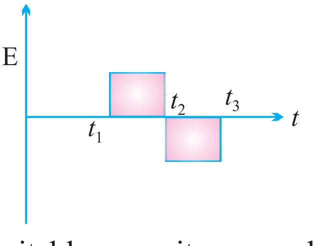
Ans. End A will be at higher potential.

48. The current i in an induction coil varies with time t according to the graph



Draw the graph of induced e.m.f. with time.

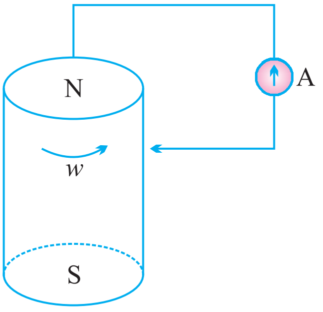
Ans.



49. Can a capacitor of suitable capacitance replace an inductor in an AC circuit?

Ans. Yes, because average power consumed in both is least while controlling an AC.

50. In the given figure,



a cylinderical bar magnet is rotated about its axis. A wire is connected from the axis and is made to touch the cylinderical surface through a contact. Then, current in the Ammeter is.....

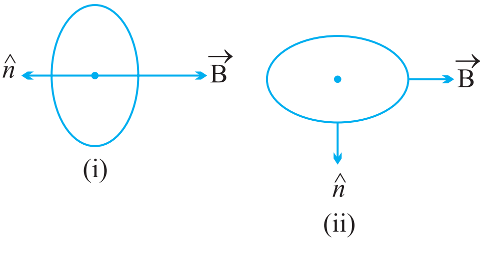
Ans. When cylinderical bar magnet is rotated about its axis, no change in magnetic flux linked with the circuit take place hence no e.m.f. is induced hence no current flows through the ammeter (A)

SHORT ANSWERS QUESTIONS (2 MARKS)

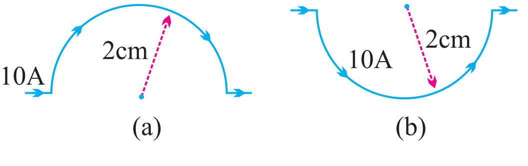
1. Write the four measures that can be taken to increase the sensitivity of galvanometer.

2. A galvanometer of resistance 120Ω gives full scale deflection for a current of 5mA. How can it be converted into an ammeter of range 0 to 5A? Also determine the net resistance of the ammeter.

3. A current loop is placed in a uniform magnetic field in the following orientations (1) and (2). Calculate the magnetic moment in each case.



4. A current of 10A flows through a semicircular wire of radius 2 cm as shown in figure (a). What is direction and magnitude of the magnetic field at the centre of semicircle? Would your answer change if the wire were bent as shown in figure (b) ?



5. A proton and an alpha particle of the same enter, in turn, a region of uniform magnetic field acting perpendicular to their direction of motion. Deduce the ratio of the radii of the circular paths described by the proton and alpha particle.

6. Why does the susceptibility of dimagnetic substance independent of temperature ?

Ans. As there is no permanent dipoles in dimagnetic substance, so, there is no meaning of randomness of dipoles on increasing temp.

7. Mention two properties of soft iron due to which it is preferred for making electromagnet.

Ans. Low retentivity, low coercivity

8. A magnetic dipole of magnetic moment M is kept in a magnetic field B. What is the minimum and maximum potential energy? Also give the most stable position and most unstable position of magnetic dipole.

9. What will be (i) Pole strength, (ii) Magnetic moment of each of new piece of bar magnet if the magnet is cut into two equal pieces :

   (a) normal to its length?

   (b) along its length?

10. A steady current I flows along an infinitely long straight wire with circular cross-section of radius R. What will be the magnetic field outside and inside the wire at a point r distance far from the axis of wire?

11. A circular coil of n turns and radius R carries a current I. It is unwound and rewound to make another square coil of side 'a' keeping number of turns and current same. Calculate the ratio of magnetic moment of the new coil and the original coil.

12. A coil of N turns and radius R carries a current I. It is unwound and rewound to make another coil of radius R/2, current remaining the same. Calculate the ratio of the magnetic moment of the new coil and original coil.

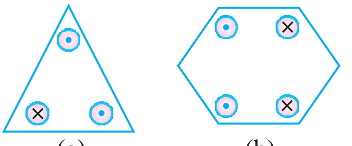
13. At a place horizontal component of the earths magnetic field is B and angle of dip at the place is 60°. What is the value of horizontal component of the earths magnetic field.

   (i) at Equator; (ii) at a place where dip angle is 30°

14. A galvanometer coil has a resistance G. 1% of the total current goes through the coil and rest through the shunt. What is the resistance of the shunt in terms of G?

15. Prove that magnetic moment of a hydrogen atom in its ground state is $eh/4\pi m$. Symbols have their usual meaning.

16. Each of conductors shown in figure carries 2A of current into or out of page. Two paths are indicated for the line integral $\oint \vec{B}.\vec{dl}$. What is the value of the integral for the path (a) and (b).



(a) (b)

17. What is the radius of the path of an electron (mass 9×10^{-31} kg and charge 1.6×10^{-19} C) moving at a speed of 3×10^7 m/s in a magnetic field of 6×10^{-4} T perpendicular to it? What is its frequency? Calculate its energy in keV. (1 eV = 1.6×10^{-19} J).

Ans. Radius, $r = mv/(qB)$

$= 9.1 \times 10^{-31}$ kg $\times 3 \times 10^7$ ms^{-1}/(1.6×10^{-19} C $\times 6 \times 10^{-4}$ T) = 20 cm

$\nu = v/(2\pi r) = 1.7 \times 10^7$ Hz

$E = (1/2)mv^2 = (1/2)\, 9 \times 10^{-31}$ kg $\times 9 \times 10^{14}$ m^2/s^2

$= 40.5 \times 10^{-17}$ J $= 4 \times 10^{-16}$ J = 2.5 keV.

18. Why is it necessary for voltmeter to have a higher resistance?

Ans. Since voltmeter is to be connected across two points in parallel, if it has low resistance, a part of current will pass through it which will decrease actual potential difference to be measured.

19. Can d.c. ammeter use for measurement of alternating current?

Ans. No, it is based on the principle of torque. When ac is passing through it (of freq. 50 Hz). It will not respond to frequent change in direction due to inertia hence would show zero deflection.

20. Define the term magnetic dipole moment of a current loop. Write the expression for the magnetic moment when an electron revolves at a speed 'v', around an orbit of radius 'r' in hydrogen atom.

Ans. The product of the current in the loop to the area of the loop is the magnetic dipole moment of a current loop.

The magnetic moment of electron

$$\bar{\mu} = -\frac{e}{2}\left(\vec{r} \times \vec{v}\right) = -\frac{e}{2m_e}\left(\vec{r} \times \vec{p}\right) = -\frac{e}{2m_e}\vec{\ell}$$

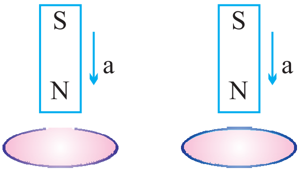
21. An ac source of rms voltage V is put across a series combination of an inductor L, capacitor C and a resistor R. If V_L, V_C and V_R are the rms voltage across L, C and R respectively then why is $V \neq V_L + V_C + V_R$? Write correct relation among V_L, V_C and V_R.

Ans. Hint :

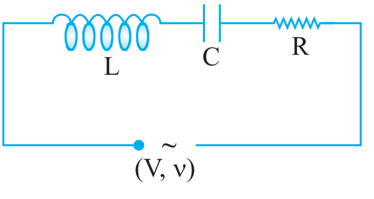
V_L, V_C and V_R are not in the same phase

$V_L + V_C + V_R > V$

22. A bar magnet is falling with some acceleration '*a*' along the vertical axis of a coil as shown in fig. What will be the acceleration of the magnet (whether $a > g$ or $a < g$ or $a = g$) if (a) coil ends are not connected to each other? (b) coil ends are connected to each other?



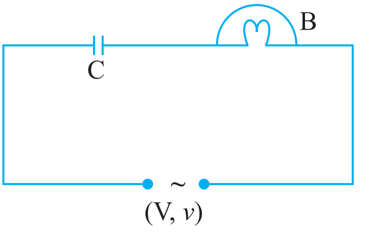
23. The series L–C–R circuit shown in fig. is in resonance state. What is the voltage across the inductor?



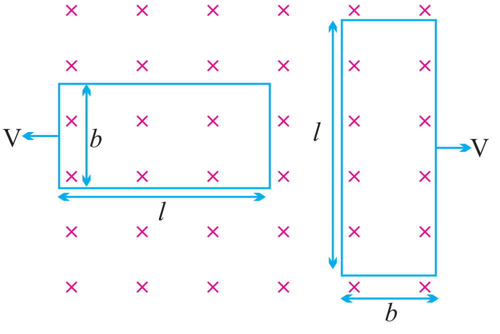
Ans. [Hint $V_L = I X_L$ where $I = \frac{V}{R}$]

24. The division marked on the scale of an a.c. ammeter are not equally spaced. Why?

25. Circuit shown here uses an air filled parallel plate capacitor. A mica sheet is now introduced between the plates of capacitor. Explain with reason the effect on brightness of the bulb B.



26. In the figure shown, coils P and Q are identical and moving apart with same velocity V. Induced currents in the coils are I_1 and I_2. Find I_1/I_2.



27. An electron moving through magnetic field does not experience mgnetic force, under what conditions is this possible ?

Ans. when electron moving parallel to magnetic field.

28. A 1.5 µF capacitor is charged to 57V. The charging battery is then disconnected, and a 12 mH coil is connected in series with the capacitor so that LC Oscillations occur. What is the maximum current in the coil? Assume that the circuit has no resistance.

29. The self inductance of the motor of an electric fan is 10H. What should be the capacitance of the capacitor to which it should be connected in order to impart maximum power at 50Hz?

30. A galvanometer needs 50mV for full scale deflection of 50 Divisions. Find it voltage sensitivity. What must be its resistance if its current sensitivity is 1 Div/A.

Ans. $V_s = \dfrac{\theta}{V} = \dfrac{50\text{Div}}{50\text{mv}} = 10^3 \text{ div}/\, v$ $\qquad I_s \rightarrow$ Current sensitivity

$R_g = \dfrac{I_S}{V_S} = 10^{-3}\text{w}$ $\qquad V_S \rightarrow$ Voltage sensitivity

31. How does an inductor behave in an AC circuit at very high frequency? Justify.

32. An electric bulb is connected in series with an inductor and an AC source. When switch is closed. After sometime an iron rod is inserted into the interior of inductor. How will the brightness of bulb be affected? Justify your answer.

Ans. Decreases, due to increase in inductive reactance.

33. Show that in the free oscillation of an LC circuit, the sum of energies stored in the capacitor and the inductor is constant with time.

Ans. Hint : $U = \frac{1}{2}LI^2 + \frac{1}{2}\frac{q^2}{c}$

34. Show that the potential difference across the LC combination is zero at the resonating frequency in series LCR circuit

Ans. Hint : P.d. across L is $= IX_L$

P.D. across C is $= IX_C$

$\Rightarrow \quad V = IX_L - IX_C$

at resonance $X_L = X_C$

$\Rightarrow \quad V = O.$

34. When a large amount of current is passing through solenoid, it contract, explain why ?

Ans. Current in two consecutive turns being in same direction make them to form unlike poles together hence, they attract each other.

35. for circuits used for transmitting electric power, a low power factor implies large power loss in transmission. Explain.

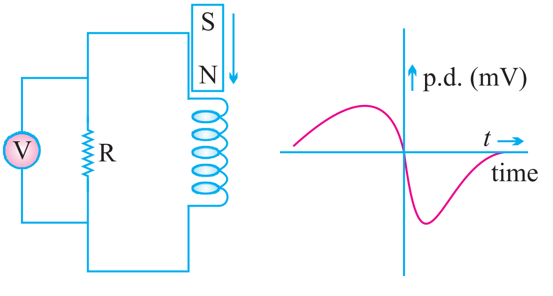
$\therefore \quad P = VI \cos \theta$

$$I = \frac{P}{V\cos\theta}$$

If $\cos \phi$ is low I will be high $\Rightarrow$ Large power loss.

36. An applied voltage signal consists of a superposition of DC Voltage and an AC Voltage of high frequency. The circuit consists of an inductor and a capacitor in series. Show that the DC signal will appear across C where as AC signal will appear across L.

37. A bar magnet M is dropped so that is falls vertically through the coil C. The graph obtained for voltage produced across the coil Vs time is shown in figure.



(i) Explain the shape of the graph.

(ii) Why is the negative peak longer than the positive peak ?

Ans. (i) When the bar magnet moves towards the coil magnetic flux passing through the coil increases as velocity of magnet increases in downward direction, e.m.f. induced also increases, due to formation of similar pole repulsive force decreases the rate of increase of flux.

(ii) once the magnet has passed through the coil, flux decreases in downward direction but $\frac{d\phi}{dt}$ increases as self induced e.m.f. in the coil maintains its flux in the same direction. Thus due to the addition of self induced e.m.f. in same direction according to Lenz's law.

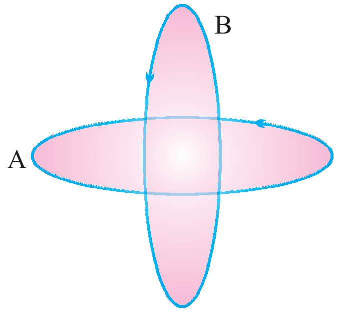
38. What is the significance of Q-factor in a series LCR resonant circuit ?

39. How does mutual inductance of a pair of coils kept coaxially at a distance in air change when

(i) the distance between the coils is increased?

(ii) an iron rod is kept between them?

40. Two circular conductors are perpendicular to each other as shown in figure. If the current is changed in conductor B, will a current be induced in the conductor A,



41. What is a radial magnetic field? Why is it required in a galvanometer ?

Ans. Using concave shaped pole of magnet and placing soft iron cylinderical core, A magnetic field, having field lines along radii is called as radial magnetic field.

To make Torque independent of 'θ' (constant) radial magnetic field is required $\tau = NIAB \sin \theta$

for radial Magnetic Field $\theta = 90°$

$\tau = NIAB$. (independent of θ)

42. The hysterisis loop of material depends not only on the nature of material but also on the history of its magnetization cycles. Suggest a use of this property of material.

Ans. The value of magnetization is record/memory of its cycles of magnetisation. If information bits can be made correspond to these cycles, the system displaying such hysterisis loop can act as a device for storing information's.

43. A wire in the form of a tightly wound Solenoid is connected to a DC source, and carries a current. If the coil is stretched so that there are gaps between successive elements of the spiral coil, will the current increase or decrease ? Explain ?

Ans. When the coil is stretched so that there are gaps between successive elements of the spiral coil *i.e.* the wires are pulled apart which lead to the flux leak through the gaps. According to Lenz's law, the e.m.f. produced must oppose this decrease, which can be done by an increase in current. So, the current will increase.

44. Show that the induced charge does not depend upon rate of change of flux.

Ans.

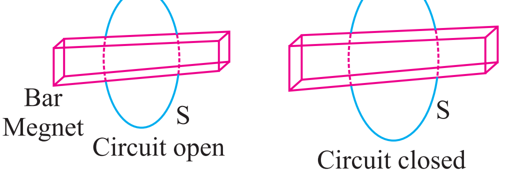
$$|E| = N\frac{d\phi}{dt}$$

$$i = \frac{E}{R} = \frac{N}{R}\frac{d\phi}{dt}$$

$$\frac{dq}{dt} = \frac{N}{R}\frac{d\phi}{dt}$$

$$\therefore \quad dq = \frac{N}{R}d\phi$$

45. Consider a magnet surrounded by a wire with an on/off switch S (figure). If the switch is thrown from the 'off' position (open circuit) to the 'on' position (Closed circuit) will a current flow in the circuit ? Explain.



Ans. ϕ = BA cos θ so flux linked will change only when either B or A or the angle between B and A change.

When switch is thrown from off position to the on position, then neither B nor A nor the angle between A and B change. Thus there is no change in magnetic flux linked with the coil, hence no electromotive force (e.m.f.) is produced and consequently no current will flow in the circuit.

Short answers Questions (3 marks)

1. Derive the expression for force between two infinitely long parallel straight wires carrying current in the same direction. Hence define 'ampere' on the basis of above derivation.
2. Define (i) Hysterisis (ii) Retentivity (iii) Coercivity
3. Distinguish between diamagnetic, paramagnetic and ferromagnetic substances in terms of susceptibility and relative permeability.
4. Name all the three elements of earth magnetic field and define them with the help of relevant diagram.
5. Describe the path of a charged particle moving in a uniform magnetic field with initial velocity
   (i) parallel to (or along) the field.
   (ii) perpendicular to the field.
   (iii) at an arbitrary angle θ ($0^\circ < \theta < 90^\circ$).
6. Obtain an expression for the magnetic moment of an electron moving with a speed 'v' in a circular orbit of radius 'r'. How does the magnetic moment change when :
   (i) the frequency of revolution is doubled?
   (ii) the orbital radius is halved?
7. State Ampere, circuital law. Use the law to obtain an expression for the magnetic field due to a toroid.
8. Obtain an expression for magnetic field due to a long solenoid at a point inside the solenoid and on the axis of solenoid.
9. Derive an expression for the torque on a magnetic dipole placed in a magnetic field and hence define magnetic moment.
10. Derive an expression for magnetic field intensity due to a bar magnet (magnetic dipole) at any point (i) Along its axis (ii) Perpendicular to the axis.
11. Derive an expression for the torque acting on a loop of N turns of area A of each turn carrying current I, when held in a uniform magnetic field B.
12. How can a moving coil galvanometer be converted into a voltmeter of a given range. Write the necessary mathematical steps to obtain the value of resistance required for this purpose.

13. A long wire is first bent into a circular coil of one turn and then into a circular coil of smaller radius having n turns. If the same current passes in both the cases, find the ratio of the magnetic fields produced at the centres in the two cases.

Ans. When there is only one turn, the magnetic field at the centre,

$$B = \frac{\mu_0 I}{2a}$$

$$2\pi a' \times n = 2\pi a \Rightarrow a' = a/n$$

The magnetic field at its centre, $B_1 = \frac{\mu_0 n I}{2a/n} = \frac{\mu_0 n^2 I}{2a} = n^2 B$

The ratio is, $B_1/B = n^2$

14. Obtain an expression for the self inductance of a straight solenoid of length l and radius r ($l >> r$).

15. Distinguish between : (i) resistance and reactance (ii) reactance and impedance.

16. In a series L–C–R circuit X_L, X_C and R are the inductive reactance, capacitive reactance and resistance respectively at a certain frequency f. If the frequency of a.c. is doubled, what will be the values of reactances and resistance of the circuit?

Ans. [Hint : $X_L = \omega L$, $X_C = \frac{1}{\omega C}$, R independent]

17. What are eddy currents? Write their any four applications.

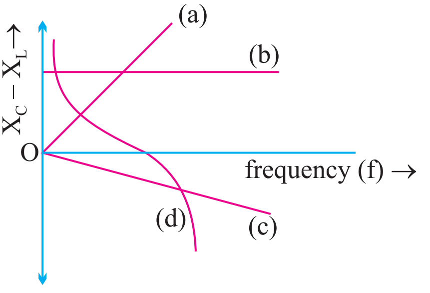
18. In a series L–R circuit, $X_L = R$ and power factor of the circuit is P_1. When capacitor with capacitance C such that $X_L = X_C$ is put in series, the power factor becomes P_2. Find P_1/P_2.

Ans. [Hint $P = \cos\theta = \frac{R}{Z}$]

19. Instantaneous value of a.c. voltage through an inductor of inductance L is $e = e_0 \cos \omega t$. Obtain an expression for instantaneous current through the inductor. Also draw the phasor diagram.

20. In an inductor of inductance L, current passing is I_0. Derive an expression for energy stored in it. In what forms is this energy stored?

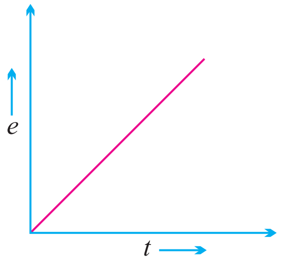
21. Which of the following curves may represent the reactance of a series LC combination.



22. A sinusoidal e.m.f. device operates at amplitude E_0 and frequency ν across a purely (1) resistive (2) capacitive (3) inductive circuit. If the frequency of driving source is increased. How would (a) amplitude E_0 and (b) amplitude I_0 increase, decrease or remain same in each case?

23. A conducting rod held horizontally along East-West direction is dropped from rest at certain height near Earth's surface. Why should there be an induced e.m.f. across the ends of the rod? Draw a graph showing the variation of e.m.f. as a function of time from the instant it begins to fall.

Ans. Hint : $e = Blv$ and $v = gt$



24. In an LC circuit, resistance of the circuit is negligible. If time period of oscillation is T then :

(i) at what time is the energy stored completely electrical

(ii) at what time is the energy stored completely magnetic

(iii) at what time is the total energy shared equally between the inductor and capacitor.

Ans. (i) $t = 0, T/2, 3T/2, \ldots\ldots\ldots$

(ii) $t = T/4, 3T/4, 5T/4 \ldots\ldots\ldots\ldots$

(iii) $t = \frac{T}{8}, \frac{3T}{8}, \frac{5T}{8}, \ldots\ldots\ldots$

25. An alternating voltage of frequency f is applied across a series LCR circuit. Let f_r be the resonance frequency for the circuit. Will the current in the circuit lag, lead or remain in phase with the applied voltage when (i) $f > f_r$ (ii) $f < f_r$ (iii) $f = f_r$? Explain your answer in each case.

Ans. (i) Current will lag because.

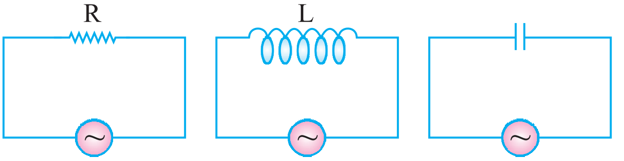
$V_L < V_C$ Hence $V_L - V_C > O$

(ii) Current will lead, because.

$V_L < V_C$ Hence $V_L - V_C < O$

(iii) In phase

26. Figure (a), (b), (c) show three alternating circuits with equal currents. If the frequency of alternating emf be increased, what will be the effect on current in the three cases? Explain.



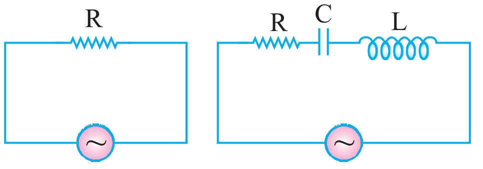
(a) (b) (c)

Ans. (i) No effect, R is not affected by frequency.

(ii) Current will decrease as X_L increase.

(iii) Current will increase as X_C decrease.

27. Study the circuit (a) and (b) shown in the figure and answer the following questions.



(a) (c)

(a) Under which condition the rms current in the two circuits to be the same?

(b) Can the r.m.s. current in circuit (b) larger than that of in (a) ?

Ans. $I_{rms(a)} = \dfrac{V_{rms}}{R} = \dfrac{V}{R}$ $I_{rms(b)} = \dfrac{V_{rms}}{Z} = \dfrac{V}{\sqrt{R^2 + (X_L - X_C)^2}}$

(a) $I_{rms(a)} = I_{rms(b)}$

when $X_L = X_c$ (resonance condition)

$$\frac{I_{rms(a)}}{I_{rms(b)}} = \frac{Z}{R} = 1$$

(b) As $z \geq R$

$$I_{rms(a)} \geq I_{rms(b)}$$

No, the rms current in circuit (b), cannot be larger than that in (a).

28. Can the instantaneous power output of an AC source ever be negative ? Can average power output be negative ? Justify your answer.

Ans. Yes, Instantaneous power output of an AC source can be negative.

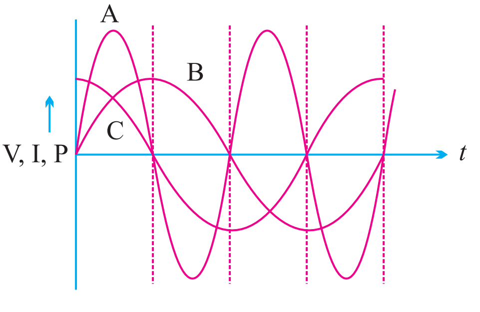
Instantaneous power output $P = EI = \frac{E.I.}{2}[\cos\phi - \cos(2\omega t + \phi)]$

No, $P_{avc} = V_{rms} I_{rms} \cos f$

$P_{avc} > 0$

$\cos\phi = \frac{R}{Z} > 0$

29. A device 'X' is connected to an AC source. The variation of voltage, current and power in one complete cycle is shown in fig.



(a) Which curves shows power consumption over a full cycle?

(b) What is the average power consumption over a cycle?

(c) Identify the device X if curve B shows voltage.

Ans. (a) A (a curve of power have a max. Amplitude of V and I)

(b) Zero.

(c) as average power is zero the device is a capacitor.

LONG ANSWER QUESTIONS (5 MARKS)

1. How will a diamagnetic, paramagnetic and a ferromagnetic material behave when kept in a non-uniform external magnetic field? Give two examples of each of these materials. Name two main characteristics of a ferromagnetic material which help us to decide suitability for making. (i) Permanent magnet (ii) Electromagnet.

2. State Biot-Savart law. Use it to obtain the magnetic field at an axial point, distance d from the centre of a circular coil of radius 'a' and carrying current I. Also compare the magnitudes of the magnetic field of this coil at its centre and at an axial point for which the value of d is $\sqrt{3a}$.

3. Write an expression for the force experienced by a charged particle moving in a uniform magnetic field B. With the help of diagram, explain the principle and working of a cyclotron. Show that cyclotron frequency does not depend on the speed of the particle.

***4.** Write the principle, working of a moving coil galvanometer with the help of neat labelled diagram. What is the importance of radial field and phosphor bronze used in the construction of moving coil galvanometer?

5. Draw a labelled diagram to explain the principle and working of an a.c. generator. Deduce the expression for emf generated. Why cannot the current produced by an a.c. generator be measured with a moving coil ammeter?

6. Explain, with the help of a neat and labelled diagram, the principle, construction and working of a transformer.

7. An L–C circuit contains inductor of inductance L and capacitor of capacitance C with an initial charge q_0. The resistance of the circuit is negligible. Let the instant the circuit is closed be $t = 0$.

(i) What is the total energy stored initially?

(ii) What is the maximum current through inductor?

(iii) What is the frequency at which charge on the capacitor will oscillate?

(iv) If a resistor is inserted in the circuit, how much energy is eventually dissipated as heat?

8. An a.c. $i = i_0 \sin \omega t$ is passed through a series combination of an inductor (L), a capacitor (C) and a resistor (R). Use the phasor diagram to obtain expressions for the (a) impedance of the circuit and phase angle between voltage across the combination and current passed in it. Hence show that the current

(i) leads the voltage when $\omega < \frac{1}{\sqrt{LC}}$

(ii) is in phase with voltage when $\omega = \frac{1}{\sqrt{LC}}$.

9. Write two differences in each of resistance, reactance and impedance for an ac circuit. Derive an expression for power dissipated in series LCR circuit.

NUMERICALS

1. An electron travels on a circular path of radius 10 m in a magnetic field of 2×10^{-3} T. Calculate the speed of electron. What is the potential difference through which it must be accelerated to acquire this speed? **[Ans.** Speed = 3.56×10^9 m/s; V = 3.56×10^7 volts**]**

2. A charge particle of mass m and charge q entered into magnetic field B normally after accelerating by potential difference V. Calculate radius of its circular path. **[Ans.** $r = \frac{1}{B}\sqrt{\frac{2mv}{q}}$ **]**

3. Calculate the magnetic field due to a circular coil of 500 turns and of mean diameter 0.1m, carrying a current of 14A (i) at a point on the axis distance 0.12 m from the centre of the coil (ii) at the centre of the coil. **[Ans.** (i) 5.0×10^{-3} Tesla; (ii) 8.8×10^{-2} Tesla**]**

4. An electron of kinetic energy 10 keV moves perpendicular to the direction of a uniform magnetic field of 0.8 milli tesla. Calculate the time period of rotation of the electron in the magnetic field. **[Ans.** 4.467×10^{-8} s.**]**

5. If the current sensitivity of a moving coil galvanometer is increased by 20% and its resistance also increased by 50% then how will the voltage sensitivity of the galvanometer be affected? **[Ans.** 25% decrease**]**

6. A uniform wire is bent into one turn circular loop and same wire is again bent in two circular loop. For the same current passed in both the cases compare the magnetic field induction at their centres.

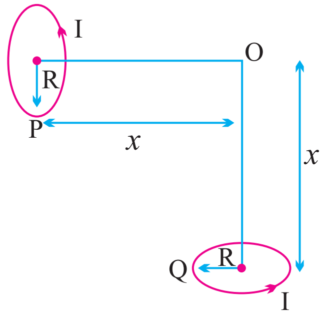
[Ans. Increased 4 times**]**

7. A horizontal electrical power line carries a current of 90A from east to west direction. What is the magnitude and direction of magnetic field produced by the power line at a point 1.5 m below it?

[**Ans.** 1.2×10^{-5} T South ward**]**

8. A galvanometer with a coil of resistance 90Ω shows full scale deflection for a potential difference 25mV. What should be the value of resistance to convert the galvanometer into a voltmeter of range 0V to 5V. How should it be converted? **[Ans.** 1910 Ω in series]

9. Two identical circular loops P and Q carrying equal currents are placed such that their geometrical axis are perpendicular to each other as shown in figure. And the direction of current appear's anticlockwise as seen from point O which is equidistant from loop P and Q. Find the magnitude and direction of the net magnetic field produced at the point O.



$\tan\theta = \frac{B_2}{B_1} = 1, \theta = \pi/4.$ [**Ans.** $\frac{\mu_0 I R^2 \sqrt{2}}{2(R^2 + x^2)^{3/2}}$]

10. A cyclotron's oscillator frequency is 10 MHz. What should be the operating magnetic field for accelerating protons, if the radius of its dees is 60 cm ? What is the kinetic energy of the proton beam produced by the accelerator? Given $e = 1.6 \times 10^{-19}$ C, $m = 1.67 \times 10^{-27}$ kg. Express your answer in units of MeV [1MeV = 1.6×10^{-13} J].

[Ans. B = 0.656T, E_{max} = 7.421 MeV]

11. The coil of a galvanometer is 0.02×0.08 m^2. It consists of 200 turns of fine wire and is in a magnetic field of 0.2 tesla. The restoring torque

constant of the suspension fibre is 10^{-6} Nm per degree. Assuming the magnetic field to be radial.

(i) What is the maximum current that can be measured by the galvanometer, if the scale can accommodate 30° deflection?

(ii) What is the smallest, current that can be detected if the minimum observable deflection is 0.1°?

[Ans. (i) 4.69×10^{-4} A; (ii) 1.56×10^{-6} A**]**

12. A voltmeter reads 5V at full scale deflection and is graded according to its resistance per volt at full scale deflection as $5000\Omega V^{-1}$. How will you convert it into a voltmeter that reads 20V at full scale deflection? Will it still be graded as $5000\ \Omega V^{-1}$? Will you prefer this voltmeter to one that is graded as $2000\ \Omega V^{-1}$? **[Ans.** $7.5 \times 10^4\ \Omega$**]**

13. A short bar magnet placed with its axis at 30° with an external field 1000G experiences a torque of 0.02 Nm. (i) What is the magnetic moment of the magnet. (ii) What is the work done in turning it from its most stable equilibrium to most unstable equilibrium position?

[Ans. (i) 0.4 Am^2; (ii) 0.08 J**]**

14. What is the magnitude of the equatorial and axial fields due to a bar magnet of length 4 cm at a distance of 40 cm from its mid point? The magnetic moment of the bar magnet is a $0.5Am^2$.

[Ans. $B_E = 7.8125 \times 10^{-7}$ T; $B_A = 15.625 \times 10^{-7}$ T**]**

15. What is the magnitude of magnetic force per unit length on a wire carrying a current of 8A and making an angle of 30° with the direction of a uniform magnetic field of 0.15T?

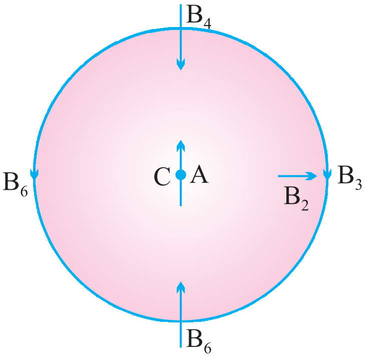
16. Two moving coil galvanometers, M_1 and M_2 have the following specifications.

$R_1 = 10\Omega$, $N_1 = 30$, $A_1 = 3.6 \times 10^{-3} m^2$, $B_1 = 0.25T$

$R_2 = 14\Omega$, $N_2 = 42$, $A_2 = 1.8 \times 10^{-3} m^2$, $B_2 = 0.50T$

Given that the spring constants are the same for the two galvanometers, determine the ratio of (a) current sensitivity (b) voltage sensitivity of M_1 & M_2. **[Ans.** (a) 5/7 (b) 1:1**]**

17. In the given diagram, a small magnetised needle is placed at a point O. The arrow shows the direction of its magnetic moment. The other arrows shown different positions and orientations of the magnetic moment of another identical magnetic needs B.



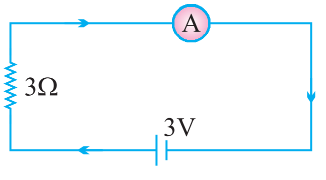
(a) In which configuration is the systems not in equilibrium?

(b) In which configuration is the system.

(i) stable and (ii) unstable equilibrium?

(c) Which configuration corresponds to the lowest potential energy among all the configurations shown?

18. In the circuit, the current is to be measured. What is the value of the current if the ammeter shown :

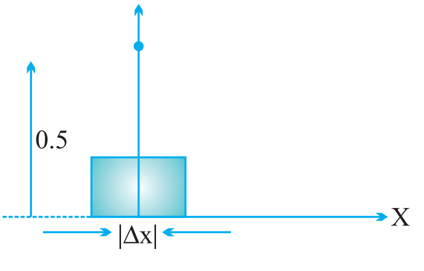


(a) is a galvanometer with a resistance $R_G = 60\ \Omega$,

(b) is a galvanometer described in (i) but converted to an ammeter by a shunt resistance $r_s = 0.02\Omega$

(c) is an ideal ammeter with zero resistance?

19. An element $\Delta I = \Delta x \cdot \hat{i}$ is placed at the origin and carries a large current I = 10A. What is the magnetic field on the y-axis at a distance of 0.5 m. $\Delta x = 1$ cm.



20. A straight wire of mass 200 g and length 1.5 m carries a current of 2A. It is suspended in mid-air by a uniform horizontal magnetic field B. What is the magnitude of the magnetic field?

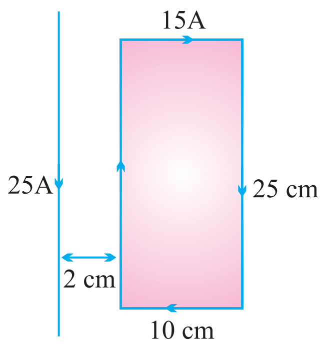
21. A rectangular loop of sides 25 cm and 10 cm carrying current of 15A is placed with its longer side parallel to a long straight conductor 2.0 cm apart carrying a current of 25A. What is the new force on the loop ? **[Ans.** 7.82×10^{-4} N towards the conductor**]**

Hint :

$$F_1 = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r_1} \times \ell = \frac{10^{-7} \times 2 \times 25 \times 15 \times 0.25}{0.02} = 9{\cdot}38 \times 10^{-4} \text{ N attractive}$$

$$F_2 = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r_2} \times \ell = \frac{10^{-7} \times 2 \times 25 \times 15 \times 0.25}{0.12} = 1.56 \times 10^{-4} \text{ N repulsive}$$

Net $F = F_1 - F_2 = 7.82 \times 10^{-4}$ N



22. In a chamber of a uniform magnetic field 6.5G is maintained. An electron is shot into the field with a speed of 4.8×10^6 ms^{-1} normal to the field. Explain why the path of electron is a circle.

(a) Determine the radius of the circular orbit ($e = 1.6 \times 10^{-19}$ C, $m_e = 9.1 \times 10^{-31}$ kg)

(b) Obtain the frequency of resolution of the electron in its circular orbit.

Hint : (a) $r = \dfrac{m_e v}{eB} = \dfrac{9.1 \times 10^{-31} \times 4.8 \times 10^6}{1.6 \times 10^{-19} \times 6.5 \times 10^{-4}} = 4.2$ cm

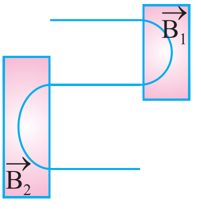
(b) frequency $\nu = \dfrac{1}{T} = \dfrac{eB}{2\pi m_e} = \dfrac{1.6 \times 10^{-19} \times 6.5 \times 10^{-4}}{2 \times 3.14 \times 9.1 \times 10^{-31}} = 18$ MHz

23. The horizontal and vertical components of earth's magnetic field at a place are 0.22G and 0.38G respectively. Calculate the angle of dip and resultant intensity of earth's field.

Hint : $\tan \delta = \frac{B_V}{B_H} = \frac{0.38}{0.22} = 1.73 = 60^\circ$, $B = \sqrt{B_H^2 + B_V^2} = 0.44$ G

24. Figure shows the path of an electron that passes through two regions containing uniform magnetic fields of magnitude B_1 and B_2. Its path in each region is a half circle. (a) which field is stronger? (b) What are the directions of two fields? (c) Is the time spend by the electron in the $\vec{B}_1$, region greater than, less than, or the same as the time spent in $\vec{B}_2$ region?

[Ans. (a) $B_1 > B_2$; (b) B_1 inward; B_2 outward (c) Time spent in B_1 < Time spent in B_2]



25. In a series C–R circuit, applied voltage is V = 110 sin 314*t* volt. What is the (i) The peak voltage (ii) Average voltage over half cycle ?

26. Magnetic flux linked with each turn of a 25 turns coil is 6 milliweber. The flux is reduced to 1 mWb in 0.5s. Find induced emf in the coil.

27. The current through an inductive circuit of inductance 4mH is $i = 12 \cos 300t$ ampere. Calculate :

(i) Reactance of the circuit.

(ii) Peak voltage across the inductor.

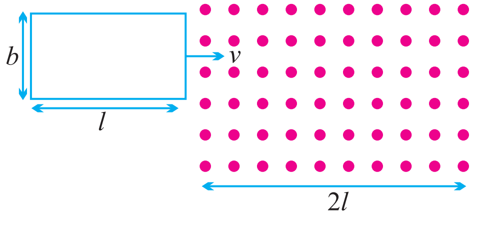
28. A power transmission line feeds input power at 2400 V to a step down ideal transformer having 4000 turns in its primary. What should be number of turns in its secondary to get power output at 240V?

29. The magnetic flux linked with a closed circuit of resistance 8Ω varies with time according to the expression $\phi = (5t^2 - 4t + 2)$ where ϕ is in milliweber and t in second. Calculate the value of induce current at $t = 15$ *s*.

30. A capacitor, a resistor and 4 henry inductor are connected in series to an a.c. source of 50 Hz. Calculate capacitance of capacitor if the current is in phase with voltage.

31. A series C–R circuit consists of a capacitance 16 mF and resistance 8Ω. If the input a.c. voltage is (200 V, 50 Hz), Calculate (i) voltage across capacitor and resistor. (ii) Phase by which voltage lags/leads current.

32. A rectangular conducting loop of length l and breadth b enters a uniform magnetic field B as shown below.



The loop is moving at constant speed v and at $t = 0$ it just enters the field B. Sketch the following graphs for the time interval $t = 0$ to $t = \frac{3l}{v}$.

(i) Magnetic flux versus time

(ii) Induced emf versus times

(iii) Power versus time

Resistance of the loop is R.

33. A charged 8mF capacitor having charge 5mC is connected to a 5mH inductor. What is :

(i) the frequency of current oscillations?

(ii) the frequency of electrical energy oscillations in the capacitor?

(iii) the maximum current in the inductor?

(iv) the magnetic energy in the inductor at the instant when charge on capacitor is 4mC?

34. A 31.4Ω resistor and 0.1H inductor are connected in series to a 200V, 50Hz ac source. Calculate

(i) the current in the circuit

(ii) the voltage (rms) across the inductor and the resistor.

(iii) is the algebraic sum of voltages across inductor and resistor more than the source voltage ? If yes, resolve the paradox.

35. A square loop of side 12 cm with its sides parallel to X and Y-axis is moved with a velocity of 8 cm/s in positive x-direction. Magnetic field exists in *z*-directions.

(i) Determine the direction and magnitude of induced emf if the field changes with 10^{-3} Tesla/cm along negative *z*-direction.

(ii) Determine the direction and magnitude of induced emf if field changes with 10^{-3} Tesla/s along +*z* direction.

Ans. (i) Rate of change of flux = induced emf

$$= (0.12)^2 \times 10^{-3} \times 8$$

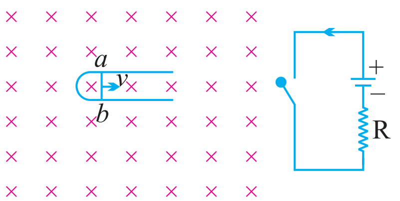
$$= 11.52 \times 10^{-5} \text{ Wb/s in } +z \text{ direction.}$$

(ii) Rate of change of flux = induced emf

$$= (0.12)^2 \times 10^{-3} \times 8$$

$$= 11.52 \times 10^{-5} \text{ Wb/s in } -z \text{ direction.}$$

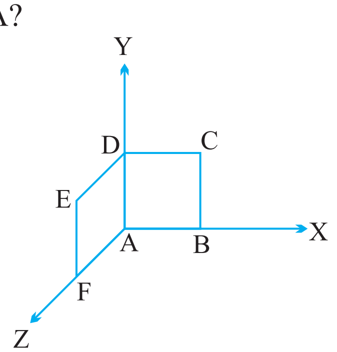
36. Figure shows a wire *ab* of length *l* which can slide on a U-shaped rail of negligible resistance. The resistance of the wire is R. The wire is pulled to the right with a constant speed *v*. Draw an equivalent circuit diagram representing the induced emf by a battery. Find the current in the wire.



$\varepsilon = Bvl$

$I = \varepsilon / r = \dfrac{Bvl}{R}$

37. A loop, made of straight edges has six corners at A(0, 0, 0), B(1, 0, 0), C(1, 1, 0), D(0, 1, 0), E(0, 1, 1) and F(0, 0, 1) a magnetic field $B = B_0 (\hat{i} + \hat{k})$ T is present in the region. Find the flux passing through the loop ABCDEFA?



Ans. Loop ABCDA lie in x-y plane whose area vector $A_1 = L^2\hat{k}$ where ADEFA lie in y-z plane where are vector $A_2 = L^2\hat{i}$

$\phi = B.A, \quad A = A_1 + A_2 = (L^2\hat{k} + L^2\hat{i})$

$B = B_0 \ (\hat{i}+\hat{k})(L^2\hat{k}+L^2\hat{i}) = 2 \ B_0L^2$ Wb.

38. A coil of 0.01 H inductance and 1Ω resistance is connected to 200V, 50 Hz AC supply. Find the impendence and time lag between maximum alternating voltage and current.

Ans. $$Z = \sqrt{R^2 + X_L^2} = \sqrt{R^2 + (2\pi f L)^2} = 3.3\Omega$$

$$\tan\phi = \frac{\omega L}{R} = \frac{2nfL}{R} = 3.14$$

$$\phi \cong 72^o$$

$$\text{Phase diff. } \phi = \frac{72\times\pi}{180}\text{rad.}$$

$$\omega = \frac{\Delta\phi}{\Delta t}, \text{ time lag } \Delta t = \frac{\phi}{\omega}$$

$$= \frac{72\pi}{180\times 2\pi\times 50} = \frac{1}{250} \text{ s}$$

39. An electrical device draws 2 KW power from AC mains (Voltage = 223V, $V_{rms} = \sqrt{50000V}$). The current differ (lags) in phase by ϕ $\left(\tan\phi = \frac{-3}{4}\right)$ as compared to voltage. Find

(a) R

(b) $X_C - X_L$

(c) I_m

Ans. P = 2KW = 2000W ; $\tan\phi = \frac{-3}{4}$; $I_m = I_0$? R = ? $X_C - X_L$ = ?

$$V_{rms} = V = 223V$$

$$Z = \frac{V^2}{P} = 25\Omega$$

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

$$625 = R^2 + (X_L - X_C)^2$$

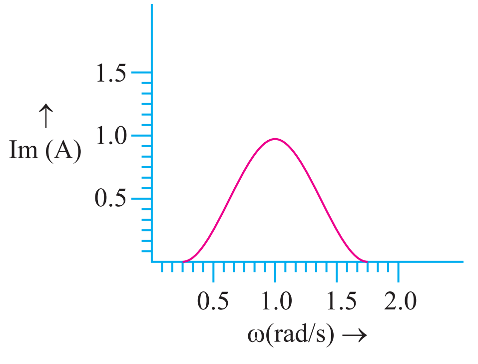
Again $$\tan \phi = \frac{X_L - X_C}{R} = \frac{3}{4}$$

$$X_L - X_C = \frac{3R}{4}$$

using this $R = 20\Omega$; $X_L - X_C = 15\Omega$, $I = \frac{V}{Z} = \frac{223}{25} = 8{\cdot}92$ A,

$$I_m = \sqrt{2}\ I = 12.6A$$

40. In a LCR circuit, the plot of I_{max} versus ω is shown in figure. Find the bandwith ?



Ans. $I_{rms} = \frac{I_{max}}{\sqrt{2}} = \frac{1}{\sqrt{2}} = 0.7$ At

from diagram $\omega_1 = 0.8$ rad/s

$\omega_2 = 1.2$ rad/s

$\Delta w = 1.2 - 0.8 = 0.4$ rad/s

41. An inductor of unknown value, a capacitor of 100μF and a resistor of 10Ω are connected in series to a 200V, 50Hz ac source. It is found that the power factor of the circuit is unity. Calculate the inductance of the inductor and the current amplitude.

Ans. $L = 0.10$ H, $I_0 = 28.3A$

42. A 100 turn coil of area 0.1 m^2 rotates at half a revolution per second. It is placed in a magnetic field of 0.01 T perpendicular to the axis of rotation of the coil. Calculate max. e.m.f. generated in the coil.

Ans. $\varepsilon_0 = 0.314$ Volt.

43. The magnetic flux linked with a large circular coil of radius R is 0.5×10^{-3} W*b*, when current of 0.5A flows through a small neighbouring coil of radius *r*. Calculate the coefficient of mutual inductance for the given pair of coils.

If the current through the small coil suddenly falls to zero, what would be the effect in the larger coil.

Ans. M = 1*m*H.

If the current through small coil suddenly falls to zero, [as, $e_2 = -M\frac{di_1}{dt}$] so initially large current is induced in larger coil, which soon becomes zero.

2 MARKS QUESTIONS

2. $S = \frac{I_g}{(I - I_g)}G = \frac{5\times10^{-3}}{5-5\times10^{3}} \times 120 = 0.12\Omega.$

3. (i) $-mB$ (ii) zero

4. (i) $B = \frac{10^{-7}\times\pi\times10}{2\times10^{-2}} = 5\pi \times 10^{-5}$ T (inwards).

(ii) B = 5p × 10^{-5} T (inwards).

5. $r_p = \frac{mv}{qB}$ and $r_\alpha = \frac{4mv}{(2q)B} = 2r_\alpha \Rightarrow \frac{r_p}{r_\alpha} = \frac{1}{2}$.

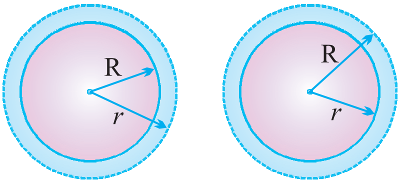
7. Low Retentivity and high permeability.

8. Minimum potential = – MB when θ = 0 (most stable position)

Maximum potential = MB when θ = 180º (most unstable position).

9. (a) Pole strength same; magnetic moment half.

(b) Pole strength half; magnetic moment half.



10. $$B\,(2\pi r) = \mu_0 \left[\frac{I}{\pi R^2}(\pi r^2)\right]$$

$$B = \left(\frac{\mu_0 I}{2\pi R^2}\right) r \qquad (R \geq r)$$

$$\oint \vec{B}.d\vec{l}. = \mu_0 I$$

$$\therefore \qquad B = \frac{\mu_0 I}{2\pi r} \qquad (r \geq R)$$

11. $M_1 = NI\pi R^2;\ M_2 = NIa^2 \quad \therefore \quad \frac{M_2}{M_1} = \frac{a^2}{R^2}$

$$2\pi r N = 4aN \Rightarrow a = \frac{\pi R}{2}$$

$$\frac{M_2}{M_1} = \pi/4$$

12. $$\frac{m_{new}}{m_{original}} = \frac{2I \times \pi\left(\frac{r}{2}\right)^2}{I \times \pi R^2} = \frac{1}{2} \quad (\text{As } N_2 = 2N_1)$$

13. 2B, $B\sqrt{3}$.

16. (a) $\oint \vec{B}.d\vec{l} = \mu_0 I = 2\mu_0$ Tm

(b) zero

22. (i) $a = g$ because the induced emf set up in the coil does not produce any current and hence no opposition to the falling bar magnet.

(ii) $a < g$ because of the opposite effect caused by induced current.

23. Current at resonance $I = \frac{V}{R}$.

$\therefore$ Voltage across inductor $V_L = I.X_L = I\omega L = \frac{V}{R}(2\pi\nu)$ L.

24. A.C. ammeter works on the principle of heating effect H α I^2.

25. Brightness of bulb depends on current. P α I^2 and

$$I = \frac{V}{Z} \text{ where } Z = \sqrt{X_c^2 + R^2} \text{ and}$$

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

$X_C \; \alpha \; \frac{1}{C}$, when mica sheet is introduced capacitance C increases

$\left(C = \frac{K \in_0 A}{d}\right)$,

X_C decreases, current increases and therefore brightness increases.

26. Current I = ε/R

In coil P, $I_1 = E_1/R = \frac{Bvb}{R}$

In coil Q, $I_2 = E_2/R = \frac{Bvl}{R}$ $\qquad I_2/I_2 = \frac{b}{l}$.

27. Electro magnetic energy is conserved.

$$\mu_E(\text{max}) = \mu_B(\text{max})$$

$$1/2\frac{Q^2}{C} = \frac{1}{2}LI^2$$

$$I = 637 \text{ mA}$$

28. 10^{-6} F.

40. No current is induced in coil A since angle is 90.

ANSWER FOR NUMERICALS

15. Force experienced by current carrying conductor in magnetic field.

$$F = \vec{IL} \times \vec{B} = IBL \sin\theta$$

Hence, force permit length, $f = \frac{F}{L}$ IB sin 30°

$= 8 \times 0.15 \times 1/2 = 0.6 \text{ Nm}^{-1}$

16. (a) Current sensitivity, $\frac{\phi}{I} = \frac{NBA}{K}$

Ratio of current Sensitivity $= \left(\frac{N_1B_1A_1}{K}\right) / \left(\frac{N_2B_2A_2}{K}\right)$

$= \frac{30 \times 0.25 \times 3.6 \times 10^{-3}}{42 \times 0.50 \times 1.8 \times 10^{-3}} = 5/7$

(b) Voltage sensitivity, $\frac{\phi}{V} = \frac{NBA}{kR}$

Ratio of voltage sensitivity $= \left(\frac{N_1B_1A_1}{kR_1}\right) / \left(\frac{N_2B_2A_2}{kR_2}\right)$

$= \frac{30 \times 0.25 \times 3.6 \times 10^{-3} \times 14}{42 \times 0.50 \times 1.8 \times 10^{-3} \times 10} = 1$

17. (a) For equilibrium, the dipole moment should be parallel or auto parallel to B. Hence, AB_1 and AB_2 are not in equilibrium.

(b) (i) for stable equilibrium, the dipole moments should be parallel, examples : AB_5 and AB_6 (ii) for unstable equilibrium, the dipole moment should be anti parallel examples : AB_3 and AB_4.

(c) Potential energy is minimum when angle between M and B is 0°, *i.e*, U = – MB Example : AB_6.

18. (a) Total resistance, $R_G + 3 = 63\Omega$.

Hence, $I = \frac{3V}{63\Omega} = 0.048A$

(b) Resistance of the galvanometer as ammeter is

$\frac{R_G r_S}{R_G r_S} = \frac{60\Omega \times 0.02\Omega}{(60 + 0.02)} = 0.02\Omega$

Total resistance $R = 0.02\Omega + 3\Omega = 3.02\Omega$

Hence, $I = \frac{3}{302} = 0.99A$.

(c) For the ideal ammeter, resistance is zero, the current, $I = 3/3 = 1.00A$.

19. From Biot-Savart's Law, $|\overrightarrow{d\beta}| = Id\ell \sin\theta / r^2$

$dI = \Delta x = 1$ cm $= 10^{-2}$ m, I = 10A, $r = y = 0.5$ m
$\mu_0/4\pi = 10^{-7}$ Tm/A, $\theta = 90°$ so $\sin\theta = 1$

$$|\overrightarrow{dB}| = \frac{10^{-7} \times 10 \times 10^{-2}}{25 \times 10^{-2}} = 4 \times 10^{-8} \text{ T along + z axis}$$

20. Force experienced by wire $F_m = BIl$ (due to map field)
The force due to gravity, $F_g = mg$

$$mg = BIl \Rightarrow B = mg/Il = \frac{0.2 \times 9.8}{2 \times 1.5} = 0.657 \text{ T}$$

[Earth's mag. field 4×10^{-5} T is negligible]

25. (i) $V_0 = 110$ volt

(ii) $V_{av1/2} = \frac{2V_0}{\pi} = \frac{2 \times 110 \times 7}{22} = 70$ volt.

26. Induced emf $\varepsilon = -N\frac{d\phi}{dt} = -25\frac{(1-6)\times 10^{-3}}{.5} = 0.25$ volt.

27. (i) Reactance $X_L = \omega L = 300 \times 4 \times 10^{-3} = 1.2\ \Omega$.

(ii) Peak Voltage $V_0 = i_0 X_L = 12 \times 1.2 = 14.4$ volt.

28. In ideal transformer $P_{in} = P_0$

$$V_P I_P = V_S I_S$$

$$\frac{V_S}{V_P} = \frac{I_P}{I_S} = \frac{N_S}{N_P} \qquad N_S = \left(\frac{V_S}{V_P}\right) N_P = \frac{240}{2400} \times 4000 = 400$$

29. Induced current $I = \varepsilon/R$

where $\varepsilon = \frac{-d\phi}{dt} = -10t + 4$

$\varepsilon = -10(15) + 4 = -146$ mV

where $\phi = 5t^2 - 4t + 2$ and $R = 8\Omega$

$$\therefore \quad I = -\frac{.146}{8} A = -.018A$$

30. When V and I in phase

$$X_L = X_C, \quad v = \frac{1}{2\pi}\frac{1}{\sqrt{LC}}$$

$$C = \frac{1}{4\pi^2 v^2 L} = \frac{1}{4\pi^2 \times 50 \times 50 \times \frac{4}{\pi^2}}$$

$$= 2.5 \times 10^{-5} = 25 \ \mu F.$$

31. Current in the circuit $I = \frac{V}{Z}$

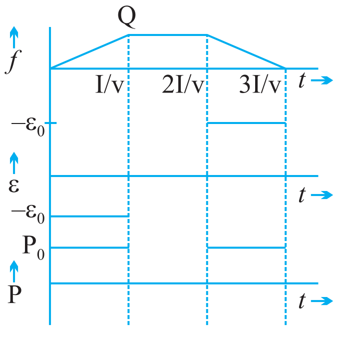
When $Z = \sqrt{X_C^2 + R^2}, \quad X_C = \frac{1}{\omega C} = \frac{1}{2\pi v C}$

Then total voltage across capacitor and resistor.

$$V_C = iX_C, \qquad V_R = IR.$$

(ii) $\tan\phi = \frac{X_C}{R}$ [V lags current]

32.



(i) $\phi = Blb$

(ii) $\varepsilon_0 = Bvb$

(iii) $P_0 = \frac{\varepsilon_0^2}{R}$

$$= \frac{B^2 v^2 b^2}{R}$$

33. (i) Frequency of current oscillations

$$v = \frac{1}{2\pi\sqrt{LC}}$$

(ii) Frequency of electrical energy oscillation $v_c = 2v$

(iii) Maximum current in the circuit $I_0 = \frac{q_0}{\sqrt{LC}}$

(iv) Magnetic energy in the inductor when charge on capacitor is $4m$C.

$$U_L = U - U_C = \frac{1}{2}\frac{q_0^2}{C} - \frac{1}{2}\frac{q^2}{C} = \frac{q_0^2 - q^2}{2C}$$

Here q_0 = 5mC; q = 4mC

34. Current in the circuit :

(i) $I = \frac{V}{Z}$, where $Z = \sqrt{X_L^2 + R^2}$

(ii) RMS voltage across L and R

$V_L = I \cdot X_L$; $V_R = IR$

(iii) $(V_L + V_R) > V$ because V_L and V_R are not in same phase.