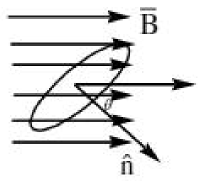
3. ELECTROMAGNETIC INDUCTION

SYNOPSIS

1. Magnetic flux :

i) The magnetic flux through a surface (of area $\vec{A}$) placed in a uniform magnetic field $\vec{B}$ is defined as $\varnothing = \vec{B}.\vec{A} = BA\cos\theta$

Where θ is the angle between $\vec{B}$ and $\vec{A}$



ii) Direction of $\vec{A}$ is in the direction of unit vector $(\hat{n})$ drawn perpendicular to the plane of the surface

2. Faraday's Laws :

i) Whenever there is a change of magnetic flux through a circuit, there will be an induced emf and this will last as long as the change persists

ii) The magnitude of induced emf is equal to the time rate of change of magnetic flux

Mathematically, $e = \frac{d\phi}{dt}$

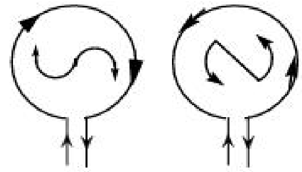
The negative sign indicates that the emf is induced so as to oppose the change of flux .

3. Lenz's Law :

i) "The polarity of the induced emf is such that it tends to produce a current which opposes the change that produces it"

Lenz's law is usually understood in terms of closed circuits and induced currents. If the circuit is open, we should think in terms of what would happen if it were closed and thus determine the polarity of induced emf.

ii) **Poles of a coil can be found.** If the current is clockwise the pole will be south, if the current is anti-clockwise, its pole will be north as in figure.



iii) Lenz's law is a consequence of law of conservation of energy.

iv) As $\phi = BAN\cos\theta$,

The change in flux can be caused by changing B (or) A (or) N (or) θ

v) Average induced emf when only 'B' is changed is given by

$$e = -A\,N\cos\theta\frac{(B_2 - B_1)}{(t_2 - t_1)}$$

Where B_1 & B_2 are the magnetic fields at instants t_1 & t_2 respectively .

If the plane of the coil perpendicular to magnetic field, $\theta = 0^0$

then $e = -AN\frac{(B_2 - B_1)}{(t_2 - t_1)}$

Instantaneous emf is given by

$$e = -AN\cos\theta\frac{dB}{dt}$$

vi) Average induced emf when only 'A' is changed is given by

$$e = -BN\cos\theta\frac{(A_2 - A_1)}{(t_2 - t_1)}$$

Where A_1 & A_2 are the areas of the coils at the instants t_1 & t_2 respectively. Instantaneous emf is given by

$$e = -BN\cos\theta\frac{dA}{dt}$$

vii) Average induced emf when only 'θ' is changed is given by

$$e = -BAN\frac{(\cos\theta_2 - \cos\theta_1)}{(t_2 - t_1)}$$

Where θ_1 & θ_2 are the angles made by $\overline{A}$ with $\overline{B}$. Instantaneous emf is given by

$$e = -BAN\frac{d(\cos\theta)}{dt}$$

If the coil is rotated with constant angular velocity 'ω' then

$$e = -BAN\frac{d(\cos\omega t)}{dt} = BAN\,\omega \sin\omega t$$

$\therefore$ $e = BAN\omega \sin \omega t$

If $\omega t = 90^0$, the plane is parallel to magnetic field and then induced emf is maximum.

Then $e_0 = BAN\omega$

$\therefore e = e_0 \sin\omega t$

This is the principle in **AC generator.**

viii) An ac generator converts mechanical energy into electrical energy. The device used for the purpose is called ac generator.

ix) The induced emf depends upon (i) strength of the magnetic field, (ii) area of the coil, (iii) speed of rotation, and (iv) the number of turns of the coil.

x) If the generator connected to a circuit of resistance 'R', current through the circuit is $i = \frac{e}{R} = \frac{BAN\omega}{R}\sin\omega t$

xi) Power delivered to the circuit is P = ei

xii) The flux change by changing the number of turns is practically difficult.

xiii) Current induced in a coil is given by $i = \frac{e}{R} = -\frac{1}{R}\frac{\Delta\varnothing}{\Delta t}$ But $i = \frac{q}{\Delta t}$ $\therefore q = -\frac{\Delta\varnothing}{R}$

i.e; Induced charge is independent of the time interval in which the change of flux is caused.

4. Motional EMF

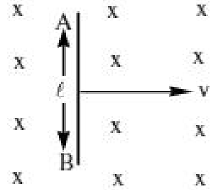
i) When a rod of length 'ℓ' is moved with a velocity 'v' perpendicular to its length in a uniform magnetic field B which is perpendicular to both its length as well as its velocity, then emf induced across its ends is given by $e = B\ell v$

ii) If the rod is moved making angle 'θ' with its length, then $e = B\ell v\sin\theta$

In vector form $e = \vec{B}.\left(\vec{l}\times\vec{v}\right)$

iii) **Fleming's right hand rule** is used to find the polarity of emf (or) current in the rod if the rod is connected to an external resistance.

Stretch the thumb, fore finger and middle finger such that they are mutually perpendicular and if thumb is in the direction of velocity, forefinger is in the direction of field, then middle finger gives the direction of induced current.



iv) In the above shown diagram, if the ends A and B of a rod are connected by a conducting wire, then current flows from B to A inside the rod. As the rod acts as a cell, and inside the cell the current flows from negative terminal to positive terminal, here B becomes –ve and A becomes +ve end.

v) If ends A and B are connected by an external resistance R, then current in the rod is given by

$$i = \frac{B\ell v}{R}$$

vi) Now, the force acting on the rod is given by $F = Bi\ell$

$$B\left(\frac{B\ell v}{R}\right)\ell = \frac{B^2\ell^2 v}{R}$$

vii) That is, we should apply a force of $\frac{B^2\ell^2 v}{R}$ on the rod, to move it with constant velocity.

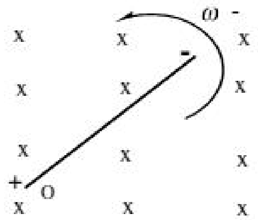
viii) The power applied by external agent in moving the rod with constant velocity is given by

$$p = Fv = \frac{B^2\ell^2 v^2}{R}$$

ix) If an irregular shaped conductor was moved in a uniform magnetic field, take effective length (vectorical sum of small current elements) of conductor to find emf. $e = B(l_{eff})v$

x) If a conducting disc of radius 'R' rotates with constant angular velocity 'ω' in a uniform magnetic field, which is perpendicular to the plane of disc, the emf between centre & rim is $e = \frac{1}{2}BR^2\omega$

xi) If a rod of length ℓ is rotated with a constant angular velocity 'ω' about an axis passing through its end (O) and perpendicular to its length and if a uniform magnetic field $\vec{B}$ is present perpendicular to it, then emf across its ends is given by $e = \frac{1}{2}B\ell^2\omega$



5. **Induced electric field :**

i) A time varying magnetic flux induces an emf and a current in conducting loop.

ii) The flow of charges in the loop is due to an electric field in it, called induced electric field, due to varying magnetic field.

iii) $\int \vec{E}.d\vec{\ell} = \frac{d\phi}{dt} \Rightarrow \int \vec{E}.d\vec{\ell} = A\left(\frac{dB}{dt}\right)$

iv) Induced electric field are non-conservative fields and these lines of forces form closed loops.

v) Induced electric field due to varying magnetic fields established even in the absence of any material objects, called vortex field (or) space electric field.

Eddy Currents

vi) When bulk pieces of conductors are subjected to changing magnetic flux, induced currents are produced in them.

vii) The flow patterns of induced currents resemble the swirling eddies in water. This effect was discovered by Foucault and these currents are called *eddy currents (or) Foucault currents.*

viii) A copper plate is allowed to swing like a simple pendulum between the pole pieces of a strong magnet , its motion is damped and the plate comes to rest in the magnetic field due to eddy currents in the plate.

Advantages :

Eddy currents are used in

(a) Magnetic braking in trains:

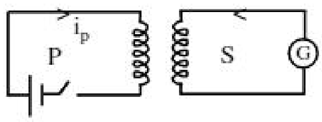
(b) Electromagnetic damping:

(c) Induction furnace:

(d) Electric power meters:

6. **Mutual Induction :**

i) When current in one coil changes, magnetic flux linked with the second coil placed near by it also changes. Then emf induced in secondary is called mutually induced emf and the phenomenon is called mutual induction.



ii) If 'ip' is current flowing in the primary coil, 'ϕ_S' is magnetic flux linked with secondary coil, then

$\phi_s \propto i_p$

$$\Rightarrow \phi_s = M i_p , \qquad \therefore M = \frac{\phi_s}{i_p}$$

Here 'M' is called coefficient of mutual induction or mutual inductance.

iii) Induced emf in secondary coil is

$$e = \frac{-d\phi}{dt} = -M\left(\frac{di_p}{dt}\right) \text{(or) } M = \frac{e}{-di_p / dt}$$

iv) Mutual Inductance depends mainly on geometry of the two circuits.

v) Mutual inductance increases with increase in number of turns in the coil.

vi) Mutual inductance decreases with increase in distance between the coils.

vii) Mutual inductance increases with increase in cross sectional area of coils.

viii) Mutual inductance increases with permeability of material of the core.

ix) Mutual inductance between two coils is maximum, if the angle between their axes is 0^0, and is minimum if the angle between their axis is 90^0

x) Consider two solenoids 1 and 2 with number of turns per unit length n_1 and n_2, with coil 1 inside coil 2 co - axially placed. Then mutual inductance between the coils is given by

$$M = \mu_0 n_1 n_2 \pi r_1^2 \ell$$

Where r_1 is radius of cross sections of inner coil and ℓ is the length of inner coil.

xi) If a magnetic material of relative permeability μ_r fills the space of inside solenoid, then

$$M = \mu_r \mu_0 n_1 n_2 \pi r_1^2 \ell$$

xii) The above expressions are true only if current is varied slowly so that expression for a magnetic field inside solenoid due to steady current $(B = \mu_0 ni)$ is applicable.

xiii) Mutual Inductance for the coil 1 due to 2 is equal to mutual inductance for the coil 2 due to 1 i.e ; $M_{12} = M_{21}$

xiv) If two circular coils, one of very small radius r_1 and the other of very large radius r_2 are placed co - axially with their centres coinciding, then mutual inductance of the system is given by

$$M = \frac{\mu_0 \pi r_1^2}{2r_2}$$

7. Self induction :

i) If current flowing in a coil changes, the magnetic flux linked with the coil changes. Then emf induced in the coil is called self induced emf and the phenomenon is called self induction.

ii) If 'i' is the current flowing through the coil and 'ϕ' is magnetic flux linked with the coil, then $\phi \propto i$

$$\Rightarrow \phi = L i , \quad \therefore L = \frac{\phi}{i}$$

Here 'L' is called coefficient of self induction of the coil or self inductance of the coil.

iii) Self induced e.m.f. is given by

$$e = \frac{-d\phi}{dt} = -L\frac{di}{dt}$$

iv) Self inductance of a coil is magnetic flux linked with the coil when unit current flows through it (or) emf induced in the coil when current changes in it at the rate of 1 A/sec.

v) S.I. Unit of self inductance : Henry.

vi) A coil having high self inductance is called inductor.

vii) For a long solenoid, where core consists of a magnetic material of relative permeability μ_r, $L = \mu_r \mu_0 n^2 A\ell$ Here A is area of cross section of solenoid, ℓ is the length and n is the number of turns per unit length

viii) Energy in a current carrying coil is stored in the form of magnetic field, and it is given by $U = \frac{1}{2}Li^2$ where 'i' is the current in the coil

ix) Energy stored in inductor is depends on i and independent of $\frac{di}{dt}$.

x) Power in an inductor depends on $\left(\frac{di}{dt}\right)$. $P = Li\left(\frac{di}{dt}\right)$.

xi) Magnetic energy density is energy stored per unit volume. $\frac{U}{V} = \frac{B^2}{2\mu_0}$

xii) The coefficient of self inductance of a coil is also numerically equal to twice the work required to establish a unit current in the coil.

xiii) The induced electric field is non conservative.

xiv) An inductor also has resistance. (one cannot have inductor without having resistance)

xv) An ideal inductor has no resistance.

xvi) One can have a resistance with or without inductance. A resistance without inductance is called noninductive resistance.

8. Relation between self inductance and mutual inductance :

If L_1, L_2 are coefficient of self inductances of two coils then coefficient of mutual inductance M is given by $M = k\sqrt{L_1 L_2}$ where k is coupling factor.

$k \le 1$.

k = 1 if the coils are wound one over the other.

9. Inductors in series and parallel :

Inductances are added in series or parallel like resistances i.e. $L_{series} = L_1 + L_2 + \ldots\ldots\ldots\ldots$

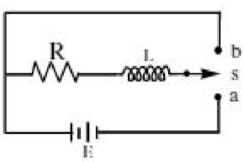
$$\frac{1}{L_{parallel}} = \frac{1}{L_1} + \frac{1}{L_2} + \ldots\ldots.$$

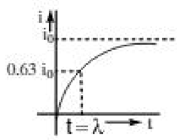
10. L.R. Circuits

Growth and decay of current in an inductor – Resistor (L – R) circuit

i) Growth of current

Consider a circuit shown in the diagram





a) When a switch S is connected to 'a' , the current in the circuit begins to increase from zero to a maximum value 'i_0'. The Inductor opposes the growth of the current.

$$\therefore E - L\frac{di}{dt} = Ri$$

where 'i' is the current in the circuit at any instant 't' and

$$i = i_0\left\{1 - e^{\frac{-t}{\lambda}}\right\}$$

Where i_0 is the maximum current.

Here $\lambda = \frac{L}{R}$ called **Inductive time constant**

b) At $t = \lambda$, $i = i_0\left(1 - \frac{1}{e}\right) = 0.63\, i_0$

c) Thus the inductive time constant of a circuit is defined as the time in which the current rises from zero to 63% of its final value.

d) Greater the value of 'λ' smaller will be the rate of growth of current.

e) Current reaches i_0 after infinite time.

f) when current attains maximum value, Inductor doesn't work.

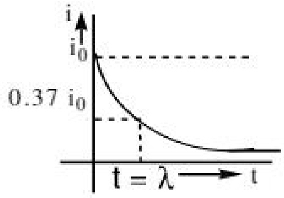
$$\therefore i_0 = \frac{E}{R}$$

ii) Decay of Current

a) When circuit is disconnected from the battery and switch 's' is connected to point 'b', the current now begins to fall. But inductor opposes decay of current $\therefore -L\frac{di}{dt} = Ri$

Where i is the current at any instant and $i = i_0 e^{\frac{-t}{\lambda}}$

where $t = \lambda = \frac{L}{R}$



b) At $t = \lambda$, $i = \frac{i_0}{e} = 0.37 i_0$

c) The inductive time constant (λ) can also be defined as the time interval during which the current decays to 37% of the maximum current.

d) For small value of 'L' , rate of decay of current will be large.

e) Current becomes zero after infinite time.

LECTURE SHEET

EXERCISE-I

(Magnetic flux, faraday's laws)

LEVEL-I (MAIN)

Straight Objective Type Questions

Magnetic flux, Faraday's law, lenz's law :

1. A coil of 100 turns and area 5 square centimetre is placed in a magnetic field B = 0.2T. The normal to the plane of the coil makes an angle of 60^0 with the direction of the magnetic field. The magnetic flux linked with the coil is

1) 5×10^{-3} Wb 2) 5×10^{-5} Wb 3) 10^{-2} Wb 4) 10^{-4} Wb

2. A magnetic field of 2×10^{-2}T acts at right angles to a coil of area 100cm^2 with 50 turns. If the average emf induced in the coil is 0.1V when it is removed from the field in time t. The value of 't'is

1) 0.1s 2) 0.01s 3) 1s 4) 20s

3. The magnetic flux of 500μ Wb passing through a 200 turn coil is reversed in 20×10^{-3} seconds. The average e.m.f. induced in the coil in volt is

1) 2.5 2) 5.0 3) 7.5 4) 10.0

4. A rectangular coil of 20 turns and area of cross section 25 cm^2 has a resistance of 100 ohm. If the magnetic field which is perpendicular to the plane of coil changes at the rate of 1000 tesla/sec, the current in the coil is

1) 1 amp 2) 0.5 amp 3) 5 amp 4) 50 amp

5. In a magnetic field of 0.05T, area of a coil changes from 101 cm^2 to 100 cm^2 without changing the resistance which is 2Ω. The amount of charg that flow during this period is

1) 2.5×10^{-6}C 2) 2×10^{-6}C 3) 10^{-6}C 4) 8×10^{-6}C

Numerical Type Questions

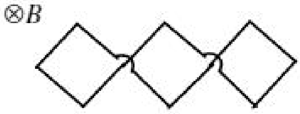
6. The number of turns in the coil of an ac generator is 5000 and the area of the coil is 0.25 m^2. The coil is rotated at the rate of 100 cycles/sec in a magnetic field of 0.2 T. The peak value of the emf (in kV) generated is

7. A circular coil of area 8m^2 and number of turns 20 is placed in a magnetic field of 2T with its plane perpendicular to it. It is rotated with an angular velocity of 20rev/s about its natural axis. The emf induced is

8. A coil having 500 square loops each of side 10 cm is placed normal to a magnetic flux which increases at the rate of 1.0 tesla/second. The induced e.m.f. in volts is

9. A coil of 40Ω resistance has 100 turns and radius 6 mm is connected to ammeter of resistance of 160 ohms. Coil is placed perpendicular to the magnetic field. When coil is taken out of the field, 32μC charge flows through it. The magnetic induction field strength (in Tesla) is

10. Three identical square loops are made of a single wire as shown. The magnetic field depending on time as $B = B_0t$ is present in the region as shown. The side of the square is a and resistance per unit length of the wire is λ. The induced current in the loop is $\frac{B_0a}{4k\lambda}$ where k = ____

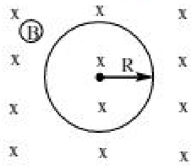


LEVEL-II (ADVANCED)

Straight Objective Type Questions

Magnetic flux, Faraday's laws of EMI

1. A conducting loop of radius R is present in a uniform magnetic field B perpendicular to the plane of ring. If radius R varies as a function of time t as $R = R_0 + t^2$. The emf induced in the loop is

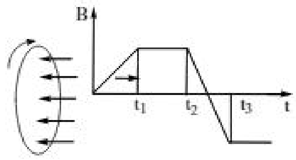


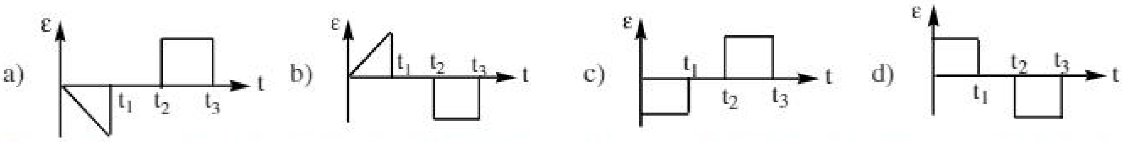
a) $2\pi Bt(R_0 + t^2)$ clockwise

b) $4\pi Bt^2(t^2 + R_0)$ anticlockwise

c) $4\pi Bt(t^2 + R_0)$ anticlockwise d) $4\pi Bt(t^2 + R_0)$ clockwise

2. A wire loop is placed in a region of time varying magnetic field which is oriented orthogonally to the plane of the loop as shown in the figure. The graph shows the magnetic field variation as the function of time. Assume the positive emf is the one which drives a current in the clockwise direction and seen by the observer in the direction of B. Which of the following graphs best represents the induced emf as a function of time.

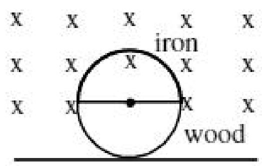




3. Figure shows a circular wheel of radius 10.0 cm whose upper half, is made of iron and the lower half of wood. The two junctions are joined by an iron rod. A uniform magnetic field B of magnitude 2.00×10^{-4}T exists in the space above the central line as suggested by the figure. The wheel is set into pure rolling on the horizontal surface. If it takes 2.00 seconds for the iron part to come down and the wooden part to go up, find the average emf induced during this period.

a) 1.25×10^{-7} V b) 1.57×10^{-6} V

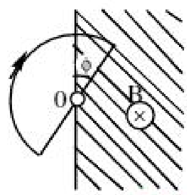
c) 5.57×10^{-6} V d) 3.57×10^{-7} V



4. A square loop of side l_0 is placed on a smooth horizontal surface, where a uniform, vertical magnetic field of constant magnitude B_0 exists. If the temperature of the surroundings changes as $\theta = a + bt$, where a and b are positive constants of appropriate dimensions, t is instant of time. The magnitude of emf linked with the loop at any instant t is (α is the coefficient of linear expansion of the material of the wire)

a) $B_0 l_0 b\alpha[a + b\alpha t]$ b) $2B_0 l_0^2 b\alpha[1 + b\alpha t]$ c) $B_0 l_0^2 \alpha[a + b\alpha t]$ d) $B_0 l_0^2 a\alpha[1 + b\alpha t]$

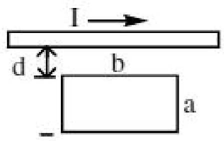
5. A wire loop enclosing a semi-circle of radius a is located on the boundary of a uniform magnetic field of induction B. At the moment t = 0, the loop is set into rotation with a constant angular acceleration α about an axis O coinciding with a line of vector B on the boundary. Find the emf induced in the loop as a function



of time t. The arrow in the figure shows the emf direction taken to be positive.

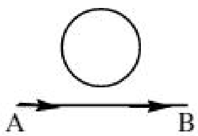
a) αBa^2t b) $\frac{\alpha Ba^2t}{4}$ c) $\frac{1}{2}\alpha Ba^2t$ d) $2\alpha Ba^2t$

6. A long straight wire is parallel to one edge as shown in fig. If the current in the long wire varies with time as $I = I_0e^{-t/\tau}$, what will be the induced emf in the loop?



a) $\frac{\mu_0 bI}{\pi\tau}\ln\left(\frac{d+a}{d}\right)$ b) $\frac{\mu_0 bI}{2\pi\tau}\ln\left(\frac{d+a}{d}\right)$ c) $\frac{2\mu_0 bI}{\pi\tau}\ln\left(\frac{d+a}{d}\right)$ d) $\frac{\mu_0 bI}{\pi\tau}\ln\left(\frac{d}{d+a}\right)$

7. In the arrangement shown in given figure current from A to B is increasing in magnitude. Induced current in the loop will



a) have clockwise direction

b) have anticlockwise direction

c) be zero

d) oscillate between clockwise and anticlockwise

8. Magnetic flux linked with a stationary loop of resistance 4Ω varies with respect to time during the time period 2 second, as follows: $\phi = 3t(2-t)$. Find the amount of heat generated (in joules) during that time.

a) 6 b) 8 c) 2 d) 1

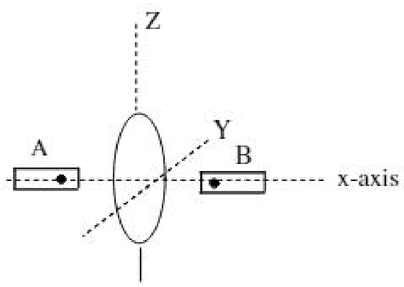
More than One correct answer Type Questions

9. A loop is fixed with its centre at origin, and lies in the yz plane. Two identical thin bar magnets are placed on x-axis at symmetric distances from the fixed loop as shown Dot indicates the north-pole of the magnet. Imagine the following situations .

Situation-1: The two magnets move towards the origin with equal uniform speeds

Situation-2 : The two magnets move towards the origin with unequal uniform speeds

Select the correct option(s) before any of the magnet crosses the origin.



a) The net induced current in the fixed loop is zero due to situation - 1

b) The net induced current in the loop is non-zero due to situation - 1

c) The net induced current in the fixed loop is zero due to situation - 2

d) The net induced current in the fixed loop is non-zero due to situation -2

Linked Comprehension Type Questions

Passage - I :

Two circular concentric conducting coils A and B have radii r,R (r being very small and r<<R) and number of turns n, 2n respectively.their planes are inclined at 60^0 to each other Now answer following parts

10. If coil A carries current i then Magnetic flux through coil B is

a) $\frac{\mu_0 \pi n^2 R^2 i}{2r}$ b) $\frac{\mu_0 \pi n^2 r^2 i}{2R}$ c) not possible to determine d) none of these

11. Amount of charge that will flow through any cross section of coil B (of resistance K) when current i in coil A is reversed in direction only will be

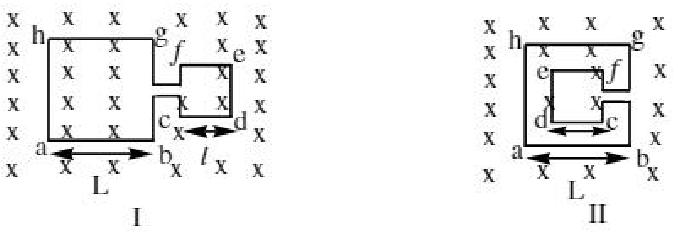
a) $\frac{\mu_0 \pi n^2 R^2 i}{Kr}$ b) $\frac{\mu_0 \pi n^2 R^2}{4Kr}$ c) $\frac{\mu_0 n r^2}{2KR}$ d) $\frac{\mu_0 n^2 r}{4K}$

12. If both the coils carry same current i then modulus of work done by an external agent in slowly rotating coil A by 180^0 about coinciding diameter of the coils is

a) $\frac{\mu_0^2 \pi n^3 r^2 i}{2R^2}$ b) $\frac{\mu_0^2 \pi n^3 i r^3}{3R^2}$ c) $\frac{\mu_0 \pi n^2 i^2 r^2}{R}$ d) none of these.

Passage - II :

The adjoining figure shows two different arrangements in which two square wire frames are placed in a uniform constantly decreasing magnetic field B.



13. The value of magnetic flux in each case is given by

a) Case I : $\phi = \pi (L^2 + l^2)B$; Case II: $\phi = \pi (L^2 - l^2)B$

b) Case I: $\phi = \pi (L^2 + l^2)B$; Case II: $\phi = \pi (L^2 + l^2)B$

c) Case I: $\phi = (L^2 + l^2)B$; Case II: $\phi = (L^2 - l^2)B$

d) Case I: $\phi = (L + l)^2B$; Case II: $\phi = \pi (L - l)^2B$

14. The direction of induced current in the case I is

a) from a to b and from c to d b) from a to b and from f to e

c) from b to a and from d to c d) from b to a and from e to f

15. The direction of induced current in the case II is

a) from a to b and from c to d b) from b to a and from f to e

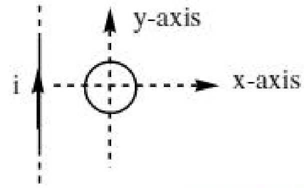
c) from b to a and from c to d d) from a to b and from d to c

16. If I_1 and I_2 are the magnitudes of induced current in the cases I and II, respectively, then

a) $I_1 = I_2$ b) $I_1 > I_2$ c) $I_1 < I_2$ d) nothing can be said

Matrix Matching Type Questions

17. A conducting circular rigid loop near a long straight current carrying wire as shown. Match the following table :



COLUMN - I	COLUMN - II
A) If current is increased	p) Inducedcurrent in the loop is clockwise
B) If current is decreased	q) Induced current in the loop is anticlockwise
C) If wire is moved away from the loop maintaining constant current	r) Wire will attract the loop and there will be a torque about y–axis
D) If wire is moved towards the wire maintaining constant current	s) Wire will repel the loop and there will be no torque about y–axis

18. Match the following

COLUMN - I	COLUMN - II
A) A metallic loop rotating about an axis parallel to the magnetic field	p) Conservation of energy
B) Lenz's law explains	q) Direction of magnetic field
C) If a current in the loop decreases	r) No emf is induced in the loop
D) Fleming's rule explains	s) emf is induced in the loop

EXERCISE-II

(Motional emf)

LEVEL-I (MAIN)

Straight Objective Type Questions

1. The wing span of an aeroplane is 20 metre. It is flying in a field, where the vertical component of magnetic field of earth is 5×10^{-5} tesla, with velocity 360 km/h. The potential difference produced between the blades will be

1) 0.10 V 2) 0.15 V 3) 0.20 V 4) 0.30V

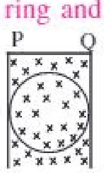
2. A copper disc of radius 0.1 m is rotated about its natural axis with 10 rps in a uniform magnetic field of 0.1 T with its plane perpendicular to the field. The emf induced across the radius of the disc is

1) $\pi \times 10\,V$ 2) $2\pi \times 10\,V$ 3) $\pi \times 10^{-2}\,V$ 4) $2\pi \times 10^{-2}\,V$

3. A wheel with 10 metallic spokes each 0.5m long is rotated with a speed of 120 rev/min in a plane normal to the earth's magnetic field at the place. If the magnitude of the field is 0.4 G, the induced e.m.f. between the axle and the rim of the wheel equal to

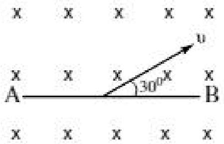
1) 1.256×10^{-3} V 2) 6.28×10^{-4} V 3) 1.256×10^{-4} V 4) 6.28×10^{-5} V

4. A vertical ring of radius r and resistance R falls vertically. It is in contact with two vertical rails which are joined at the top. The rails are without friction and resistance. There is a horizontal uniform magnetic field of magnitude B perpendicular to the plane of the ring and the rails. When the speed of the ring is υ, the current in the section PQ is



1) zero 2) $\frac{2Br\upsilon}{R}$ 3) $\frac{4Br\upsilon}{R}$ 4) $\frac{8Br\upsilon}{R}$

5. A conducting rod AB of length $l = 1$ m is moving at a velocity $\upsilon = 4$ m/s making an angle 30^0 with its length. A uniform magnetic field B = 2T exists in a direction perpendicular to the plane of motion. Then



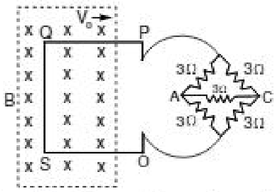
1) $V_A - V_B = 8V$ 2) $V_A - V_B = 4V$
3) $V_B - V_A = 8V$ 4) $V_B - V_A = 4V$

6. A copper rod of mass m slides under gravity on two smooth parallel rails l distance apart and set at an angle θ to the horizontal. At the bottom, the rails are joined by a resistance R. There is a uniform magnetic field perpendicular to the plane of the rails. The terminal velocity of the rod is

1) $\dfrac{mgR\cos\theta}{B^2\ell^2}$ 2) $\dfrac{mgR\sin\theta}{B^2\ell^2}$ 3) $\dfrac{mgR\tan\theta}{B^2\ell^2}$ 4) $\dfrac{mgR\cot\theta}{B^2\ell^2}$

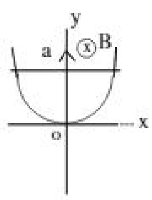
Numerical Type Questions

7. A square metal wire loop of side 10 cm and resistance 1Ω is moved with a constant velocity v_0 in a uniform magnetic field of induction B = 2 weber/m^2 as shown in the figure. The magnetic field lines are perpen-dicular to the plane of the loop (directed into the paper). The loop is connected to a network of resistors each of value 3Ω. The resistances of the lead wires OS and PQ are negligible. What should be the speed in (m/s) of the loop so as to have a steady current of 1 mA in the loop ?



8. A uniform magnetic field exists in region given by $\vec{B} = 3\hat{i} + 4\hat{j} + 5\hat{k}$. A rod of length 5 m is placed along y– axis is moved along x-axis with constant speed 1 m/sec. Then induced e.m.f. in the rod in volts is :

9. A wire is bent as a parabola $y = cx^2$ is located in a uniform magnetic field of magnitude B perpendicular to the xy plane as shown. At the instant t = 0 a long metal rod starts translating from the vertex of the parabola with a constant acceleration a along positive y–axis. The induced emf across the points of contact of the rod with the wire is given by $\varepsilon = 2By\sqrt{\dfrac{ka}{c}}$; where k = ___.



10. A 0.1m long conductor carrying a current of 50A is perpendicular to a magnetic field of 1.25mT. The mechanical power to move the conductor with a speed of $1ms^{-1}$ in mW.

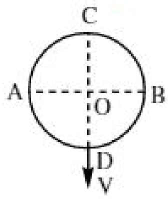
11. A conducting law of mass m and length l moves on two frictionless rails in the presence of a uniform magnetic field B_0 directed perpendicular to the plane of parallel rails. The rails are connected to a resistance R. The bar is given velocity V_0 to the right at t=0, the velocity of bar after 't'sec is given by $V = V_0 e^{-(B^2l^2t/kmR)}$. The value of 'k' is

LEVEL-II (ADVANCED)

Straight Objective Type Questions

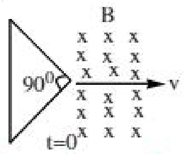
1. A vertical rod of length l is moved with constant velocity v towards East. The vertical component of the earth's magnetic field is B and the angle of dip is θ. The induced e.m.f. in the rod is:
a) $B \ell v \cot\theta$ b) $B \ell v \sin\theta$ c) $B \ell v \tan\theta$ d) $B \ell v \cos\theta$

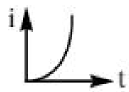
2. A vertical conducting ring of radius R falls vertically with a speed V in a horizontal uniform magnetic field B which is perpendicular to the plane of the ring :
a) A and B are at same potential
b) C and D are at same potential
c) current flows in clockwise direction
d) current flows in anticlockwise direction

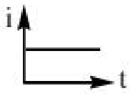


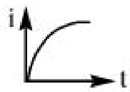
3. A square loop of area 2.5×10^{-3} m^2 and having 100 turns with a total resistance of 100 Ω is moved out of a uniform magnetic field of 0.40 T in 1 sec with a constant speed.Then work done, in pulling the loop is
a) zero b) 1 mJ c) 1 μJ d) 0.1 mJ

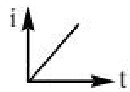
4. The figure shows an isosceles triangle wire frame with apex angle equal to $\frac{\pi}{2}$. The frame starts entering into the region of uniform magnetic field B with constant velocity v at t = 0. The longest side of the frame is perpendicular to the direction of velocity. If i is the instantaneous current through the frame then choose the alternative showing the correct variation of i with time.



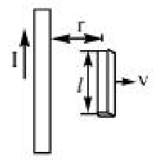
a) 

b) 

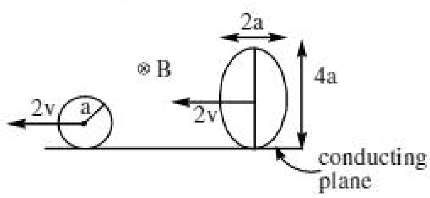
c) 

d) 

5. A conducting rod moves with constant velocity ϑ perpendicular to the long, straight wire carrying a current I as shown compute that the emf generated between the ends of the rod.
a) $\frac{\mu_0 \upsilon I l}{\pi r}$ b) $\frac{\mu_0 \upsilon I l}{2\pi r}$
c) $\frac{2\mu_0 \upsilon I l}{\pi r}$ d) $\frac{\mu_0 \upsilon I l}{4\pi r}$



6. A conducting circular ring and a conducting elliptical ring both are moving pure translationally in a uniform magnetic field of strength B as shown in figure on a horizontal conducting plane then potential difference between top most points of circle and ellipse is :



a) 12 va b) 4 vBa c) 8 vBa d) 2 vBa

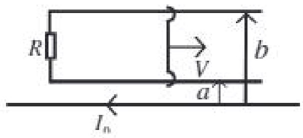
7. A square loop of side a and resistance R is moved in the region of uniform magnetic field B (loop remaining completely insidefield), with a velocity v through a distance x. The work done is :

a) $\frac{B\ell^2 vx}{R}$ b) $\frac{2B^2\ell^2 vx}{R}$ c) $\frac{4B^2\ell^2 vx}{R}$ d) none

8. A long straight wire carries a current I_0. At distances *a* and *b* from it there are two other wires, parallel to the former one, which are interconnected by a resistance R. A conector slides without friction along the wires with a constant velocity V. Assuming the resistances of the wires, the connector, the sliding contacts, and the self-inductance of the frame to be negligible, find the force required to maintain the connector's velocity constant.

a) $F=\left(\frac{\mu_0 I_0}{2\pi}\ln b/a\right)^2$ b) $F=\frac{V}{R}\left(\frac{\mu_0 I_0}{2\pi}\ln b/a\right)$

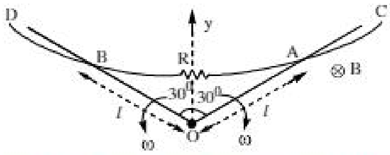
c) $F=\frac{V}{R}\left(\frac{\mu_0 I_0}{2\pi}\right)^2$ d) $F=\frac{V}{R}\left(\frac{\mu_0 I_0}{2\pi}\ln b/a\right)^2$



9. In figure there exists uniform magnetic field B into the plane of paper. Wire CD is in the shape of an arc and is fixed. OA and OB are the wires rotating with angular velocity w as shown in figure in the same plane as that of the arc about point O. If at some instant OA = OB = l and each wire makes angle q = 30° with y–axis, the current through resistance R is (wires OA and OB have no resistance)

a) Zero b) $\frac{B\omega\ell^2}{R}$

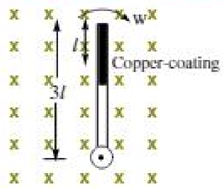
c) $\frac{B\omega\ell^2}{2R}$ d) $\frac{B\omega\ell^2}{4R}$



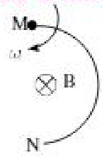
10. A wooden stick of length $3l$ is rotated about an end with constant angular velocity ω in a uniform magnetic field B perpendicular to the plane of motion. If the upper one third of its length is coated with copper, the potential difference across the whole length of the stick is

a) $\frac{9B\omega\ell^2}{2}$ b) $\frac{4B\omega\ell^2}{2}$

c) $\frac{5B\omega\ell^2}{2}$ d) $\frac{B\omega\ell^2}{2}$



11. A wire of length L is bent to form a semicircle. The wire rotates about its one end with angular velocity ω Axis of rotation being perpendicular to plane of the semi circle. In the space a uniform magnetic field B exists as shown. Then potential difference between M and N is

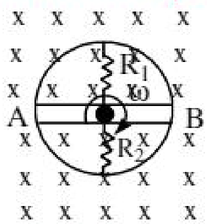


a) $\frac{B\omega L^2}{\pi^2}$ b) $\frac{2B\omega L^2}{\pi^2}$ c) $\frac{1}{2}B\omega L^2$ d) $\frac{1}{4}B\omega L^2$

12. AB is a resistanceless conducting rod which forms a diameter of a conducting ring of radius r rotating in a uniform magnetic field B as shown. The resistors R_1 and R_2 do not rotate. Then current through the resistor R_1 is :

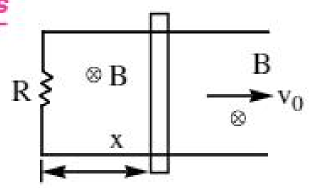
a) $\frac{B\omega r^2}{2R_1}$ b) $\frac{B\omega r^2}{2R_2}$

c) $\frac{B\omega r^2}{2R_1R_2}(R_1+R_2)$ d) $\frac{B\omega r^2}{2(R_1+R_2)}$



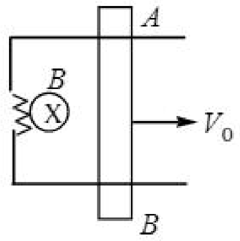
More than One correct answer Type Questions

13. A conducting rod of length l is moved at constant velocity v_0 on two parallel conducting, s mooth, fixed rails, that are placed in a uniform constant magnetic field B perpendicular to the plane of the rails as shown in figure. A resistance R is connected between the two ends of the rail. Then which of the following is/are correct?



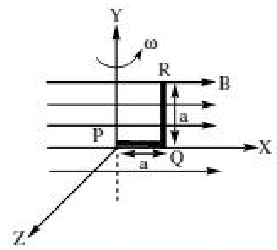
a) The thermal power dissipated in the resistor is equal to rate of work done by external person pulling the rod,
b) If applied external force is doubled then a part of external power increases the velocity of rod.
c) Lenz's law is not satisfied for direction of current in Loop.
d) If resistance R is doubled then power required to maintain the constant velocity v_0 becomes half.

14. A conducting rod AB of mass 'm' slides without friction over two long conducting horizontal rails separated by a distance 'l'. At the left rails are inter connected by a resistor R. The system is located in uniform magnetic field acting perpendicular to the plane of the loop. At the moment t = 0, the rod AB starts moving to the right with an initial velocity V_0. Neglect resistance of rails and self induction of the circuit



a) The rod covers a distance $\frac{mRV_0}{2B^2l^2}$ before stopping
b) The rod covers a distance $\frac{mRV_0}{B^2l^2}$ before stopping
c) The heat liberated in the resistor during motion of the rod is $\frac{1}{2}mV_0^2$
d) The heat liberated in the resistor during motion of the rod is $\frac{1}{4}mV_0^2$

15. In a region there exist a magnetic field B_0 along positive x-axis. A metallic wire of length 2a and one side along x-axis and one side parallel of y-axis is rotating about y-axis with a angular velocity w. Then at the instant shown.



a) Potential difference across PQ is zero
b) Potential difference across PQ is $\frac{1}{2}B_0\omega a^2$
c) Potential difference across QR is $\frac{1}{2}B_0\omega a^2$
d) Potential difference across QR is $B_0\omega a^2$

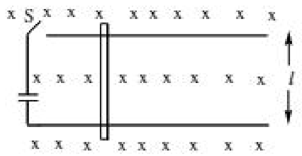
16. A flexible wire loop in the shape of a circle has a radius that grows linearly with time, as $r = r_0t$. There exists a time varying magnetic field in the region as $B=B_0t$, where B_0 and r_0 are positive constants with appropriate dimensions
a) The rate of change of induced emf varies linearly with time
b) The induced emf varies parabolically with time
c) The dimensional formula of $\frac{B_0}{r_0}$ is $M^1L^{-1}T^{-2}A^{-1}$
d) The dimensions of $\frac{B_0}{r_0}$ is independent of the physical quantity length

Linked Comprehension Type Questions

Passage :

One end of a horizontal track of separation l and negligible resistance is connected to a capacitor of capacitance C charged to voltage V_0. The inductance of the assembly is negligible. The system

is placed in a homogeneous, vertical magnetic field of induction B, as shown in the figure. A frictionless conducting rod of mass m and resistance R is placed perpendicularly onto the track . The polarity of the capacitor is such that the rod is repelled from the capacitor when the switch S is closed.



17. The maximum velocity of the rod V_{max} is

a) $\dfrac{BlCV_0}{m+B^2l^2C}$ b) $\dfrac{V_0}{Bl}$ c) $\dfrac{V_0}{m}$ d) $\dfrac{2BlCV_0}{2m+B^2l^2C}$

18. The minimum charge on the capacitor Q_{min} is

a) zero b) $\dfrac{CV_0}{2}$ c) $\dfrac{B^2l^2C^2V_0}{m+B^2l^2C}$ d) $\dfrac{2B^2l^2C^2V_0}{m+2B^2l^2C}$

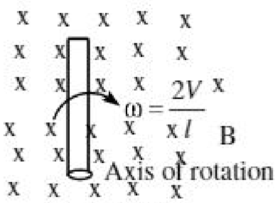
19. The heat generated in the system is

a) zero b) $\dfrac{1}{2}CV_0^2-\dfrac{Q_{min}^2}{2C}$

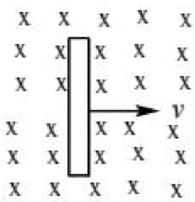
c) $\dfrac{1}{2}CV_0^2-\dfrac{1}{2}mV_{max}^2-\dfrac{Q_{min}^2}{2C}$ d) none of these

Matrix Matching Type Questions

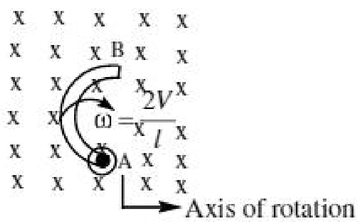
20. Consider four cases in which conducting wire element is moved with constant velocity 'v' or rotated with constant angular velocity ω in uniform and constant magnetic field 'B_0', which is same for all cases and extended upto infinity distance between points A and B directly in each case is 'l'. In case of pure rotation plane of rotation is perpendicular to direction of magnetic field. Potential difference between points B and A is $V_B - V_A$.



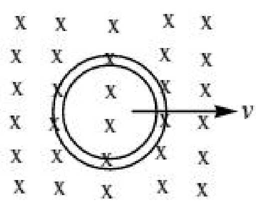
Pure rotation
Case - I



Pure translation
Case - II



Pure rotation
Case - III

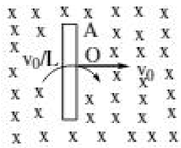


Pure translation
Case - IV

COLUMN-I	COLUMN-II
A) $V_B - V_A = Blv$	p) Case I
B) Rate of area swept by the conducting element $= \dfrac{dA}{dt} = Vl$	q) Case II
C) Uniform electric field in the conductor	r) Case III
D) When velocity or angular velocity remains constant, then the external force required is zero	s) Case IV

Integer Type Questions

21. A conducting rod of length L is moving on a horizontal smooth surface. Magnetic field in the region is vertically downward and of magnitude B_0. If centre of mass of the rod is translating with velocity v_0 and rod rotates about centre of mass with angular velocity v_0/L then potential difference between points O and A will be $\frac{x}{8}B_0v_0L$. Then x is ....



22. Two conducting rings P and Q of radii r and 2r rotate uniformly in opposite directions with centre of mass velocities 2v and v respectively on a conducting surface S. There is a uniform magnetic field of magnitude B perpendicular to the plane of the rings. The potential difference between the highest points of the two rings is_____Bvr

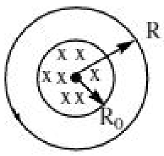
EXERCISE-III

(Induced Electric fields)

LEVEL-II (ADVANCED)

Straight Objective Type Questions

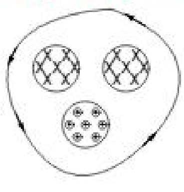
1. The magnetic field (B) within a cylindrical region of radius R_0 increases linearly with time. A concentric circle with radius $R > R_0$ is drawn as shown in the figure. The electric field (E) acting tangential to the circle satisfies



a) $E \propto R$ b) $E \propto \frac{1}{R}$ c) $E \propto \frac{1}{R^2}$ d) E = constant

2. Figure shows three regions of magnetic field, each of area A, and in each region magnitude of magnetic field decreases at a constant rate α. If $\vec{E}$ is induced electric field then value of line integral $\oint \vec{E}.d\vec{r}$ along the given loop is equal to

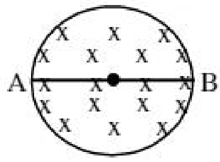
a) αA
b) $-\alpha A$
c) $3\alpha A$
d) $-3\alpha A$



3. A uniform circular ring of radius R, mass m has uniformly distributed charge q. The ring is free to rotate about its own axis (which is vertical) without friction. In the space, a uniform magnetic field B, directed vertically downwards, exists in a cylindrical region. Cylindrical region of magnetic field is coaxial with the ring and has radius 'r' greater than R. If magnetic field starts increasing at a constant rate $\frac{dB}{dt} = a$, angular acceleration of the ring will be

a) $\frac{qR}{2rm}\frac{dB}{dt}$ b) $\frac{q}{2m}\left(\frac{dB}{dt}\right)$ c) $\frac{qR}{rm}\frac{dB}{dt}$ d) $\frac{qR}{m}\left(\frac{dB}{dt}\right)$

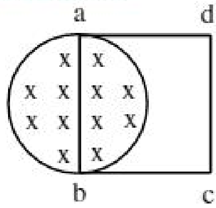
4. The radius of the circular conducting loop shown in figure is R.Magnetic field is decreasing at a constant rate α. Resistance per unit length of the loop is ρ. Then current in wire AB is : (AB is one of the diameters)



a) $\frac{R\alpha}{2\rho}$ from A to B b) $\frac{R\alpha}{2\rho}$ from B to A

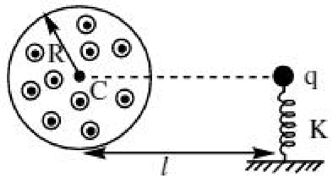
c) $\frac{2R\alpha}{\rho}$ from A to B d) zero

5. A uniform magnetic field B exists in a cylindrical region of radius 10 cm as shown in figure. A uniform wire of length 80 cm and resistance 4.0Ω is bent into a square frame and is place with one side along a diameter of the cylindrical region. If the magnetic field increases at a constant rate of 0.010 T/s, find the current induced in the frame.



a) 3.9×10^{-5}A b) 5×10^{-5}A c) 3.9×10^{5}A d) 1×10^{-6}A

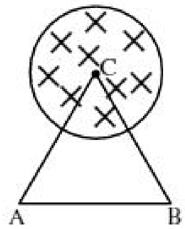
6. There is a horizontal cylindrical uniform but time varying magnetic field increasing at a constant rate $\frac{dB}{dt}$ as shown. A charged particle having charge q and mass m is kept in equilibrium, at the top of a spring of spring constant K in such a way that it is on the horizontal line passing through the center of the magnetic field as shown in figure. The compression in the spring will be



a) $\frac{1}{K}\left[mg-\frac{qR^2}{2\ell}\frac{dB}{dt}\right]$ b) $\frac{1}{K}\left[mg+\frac{qR^2}{\ell}\frac{dB}{dt}\right]$

c) $\frac{1}{K}\left[mg+\frac{2qR^2}{\ell}\frac{dB}{dt}\right]$ d) $\frac{1}{K}\left[mg+\frac{qR^2}{2\ell}\frac{dB}{dt}\right]$

7. A uniform magnetic field of intensity $B = C_1t + C_2$ is directed into the plane of the paper exists in the cylindrical region of radius r. Where C_1 and C_2 are positive constant and t is time in sec. A loop in form of an equilateral triangle ABC of side length 2r is placed such that vertex C lies on axis of cylindrical region and plane of loop is perpendicular to axis. Resistance of unit length of wire of loop = $\lambda\ \Omega/m$. Find the potential difference V_A - V_B at any t = t sec



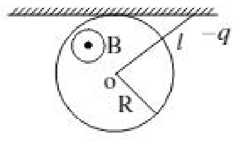
a) $+\frac{C_1\pi r^2}{6}$ b) $-\frac{C_1\pi r^2}{6}$

c) $+\frac{C_1\pi r^2}{9}$ d) $-\frac{C_1\pi r^2}{9}$

8. A time varying magnetic field directed out of the plane of the paper exists in a cylindrical region of radius R whose centre is at O. The rate of change of magnetic field is constant and equal to k(>0). A smooth rigid wall is tangential to this circular region. A charge '-q' is placed in a gravity free

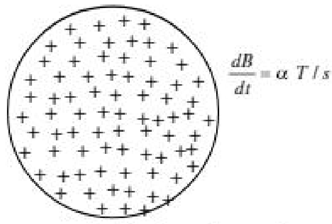
space nearest to the wall at a distance 'l' from the centre of cylindrical region as shown in figure. The net force on the charge is ($R << l$) (Including the normal reaction from the wall)

a) zero
b) $\frac{qR^2k}{2l}$
c) $\frac{qR^3k}{2l^2}$
d) $\frac{qR^3k}{l^2}$



More than One correct answer Type Questions

9. A time varying magnetic filed is present in a cylindrical region of radius R as shown in figure (cross-sectional view). B is increasing with time; mark out the correct statement(s) for the given situation, r being the distance from centre of cylindrical region.



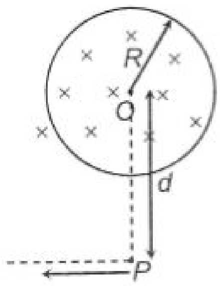
a) For $r < R$, the induced electric field is proportional to r.

b) For $r > R$, the induced electric field is proportional to $\frac{1}{r}$

c) For $r = R$, the induced electric field is maximum

d) If a coaxial "non-conducting" ring of radius $\frac{R}{2}$ is placed in the magnetic filed region, then emf induced in the ring is $\frac{\pi\alpha R^2}{4}$.

10. In a cylindrical region of radius R, there exists a time varying magnetic field B such that $\frac{dB}{dt} = K(>0)$. A charged particle having charge q is placed at the point P at a distance d(>R) from its centre O. Now, the particle is moved in the direction perpendicular to OP (see figure) by an external agent up to infinity so that there is no gain in kinetic energy of the charged particle. Choose the correct statement/s



a) Work done by external agent is $\frac{q\pi R^2}{4}k$ if $d = R$

b) Work done by external agent is $\frac{q\pi R^2}{8}k$ if $d = 4R$

c) Work done by external agent is $\frac{q\pi R^2}{4}k$ if $d = 4R$

d) Work done by external agent is $\frac{q\pi R^2}{4}k$ if $d = 6R$

Linked Comprehension Type Questions

Passage - I :

A thin non-conducting ring of mass m, radius a, carrying a charge q can rotate freely about its own axis which is vertical. At the initial moment the ring was at rest and no magnetic field was present. At instant $t = 0$, a uniform magnetic field is switched on which is vertically downwards and increase with time according to the law $B = B_0 t$. Neglecting magnetism induced due to rotational motion of the ring. Now answer the following questions.

11. The angular acceleration of the ring and its direction of rotation as seen from above:

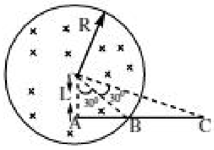
a) $\frac{Eq}{2ma}$ anti-clockwise b) $\frac{Eq}{ma}$ anti-clockwise c) $\frac{2Eq}{ma}$ clockwise d) $\frac{Eq}{ma}$ clockwise

12. The power developed by the forces acting on the ring, as a function of time:

a) $\frac{E^2q^2}{2m}t$ b) $\frac{E^2q^2}{m}t$ c) $\frac{2E^2q^2}{m}t$ d) $\frac{\sqrt{2}E^2q^2}{m}t$

Passage - II :

A metallic rod is placed with a part of it in a cylindrical region of radius R where a uniform but time varying magnetic field exist which is varying in magnitude (B)with rate $\frac{dB}{dt}=\alpha(\alpha>0)$, *then*



13. Induced potential difference between ponts A and B will be

a) $\frac{L^2\alpha}{2\sqrt{3}}$ b) $\frac{2L^2\alpha}{\sqrt{3}}$ c) $\frac{\sqrt{3}L^2\alpha}{2}$ d) zero

14. Potential difference between points B and C will be

a) zero b) $\frac{\pi R^2\alpha}{12}$ c) $\frac{\pi RL\alpha}{\sqrt{3}}$ d) $\frac{R^3\alpha}{\sqrt{3}L\pi}$

15. Magnitude of induced electric field intensity at a point distant 2L from axis of cylindrical region of magnetic field will be

a) $\frac{R^2\alpha}{4L}$ b) $L\alpha$ c) $\frac{R\alpha}{2}$ d) $\frac{L^2\alpha}{\sqrt{3}L}$

EXERCISE-IV

(Self induction, Mutual induction & Magnetic Energy density)

LEVEL-I (MAIN)

Straight Objective Type Questions

1. An e.m.f of 5 volt is produced by a self inductance, when the current changes at a steady rate from 3A to 2A in 1 millisecond. The value of self inductance is

1) Zero 2) 5H 3) 5000H 4) 5 mH

2. If a change in current of 0.01A in one coil produces a change in magnetic flux of 2×10^{-2} weber in the other coil, then the mutual inductance of the two coils in henry is

1) 0 2) 0.5 3) 2 4) 3

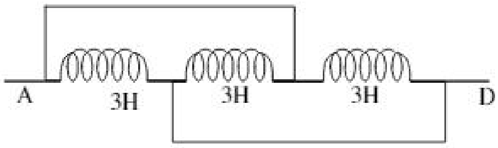
3. A 50 mH coil carries a current of 2 ampere. The energy stored in joules is

1) 1 2) 0.1 3) 0.05 4) 0.5

Numerical Type Questions

4. The number of turns of primary and secondary coils of a transformer are 5 and 10 respectively and the mutual inductance of the transformer is 25 henry. Now the number of turns in the primary and secondary of the tranformers are made 10 and 5 respectively. The mutual inductance of the transformer (in henry) will be :

5. The inductance between A and D is in Henry.



6. Two coaxial solenoids are made by winding thin insulated wire over a pipe of cross-sectional area A = 10 cm^2 and length = 20 cm. If one of the solenoid has 300 turns and the other 400 turns, their mutual inductance (in H) is $X\times10^{-4}$H. The value of 'X' is

7. A current of 2A is increasing at a rate of 4 A/s through a coil of inductance 2H. The energy stored in the inductor per unit time in J/sec.

LEVEL-II (ADVANCED)

Straight Objective Type Questions

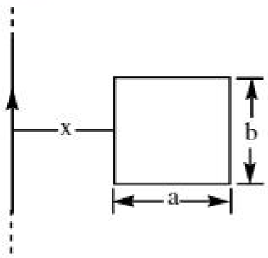
1. Mutual inductance of a pair of concentric conducing coils of radii a and b (b being very small and a >> b) with their planes inclined at 30^0 is given by

a) $\frac{\sqrt{3}\mu_0\pi b^2}{4a}$ b) $\frac{\mu_0\pi b^2}{4a}$ c) $\frac{\sqrt{3}\mu_0 b^2}{2\pi a}$ d) $\frac{\sqrt{3}\mu_0\pi b^2}{8a}$

2. The mutual inductance of the system of long straight conductor and the rectangular loop is

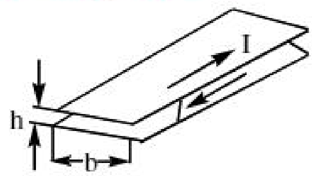
a) $\frac{\mu_0}{2\pi}a\ln\left(\frac{a+x}{a}\right)$ b) $\frac{\mu_0}{2\pi}b\ln\left(\frac{x+a}{x}\right)$

c) $\frac{\mu_0}{2\pi}b\ln\left(\frac{x+a}{a}\right)$ d) $\frac{\mu_0}{2\pi}a\ln\left(\frac{a+x}{x}\right)$



*3. Calculate the inductance of a unit lenght of a double tape line if the tapes are separated by a distance *h* which is considerably less than their width b, namely, b/h = 50.

a) 20 nH/m
b) 25 nH/m
c) 30 nH/m
d) 15 nH/m



4. A superconducting round ring of radius *a* and inductance L was located in a uniform magnetic field of induction B. The ring plane was parallel to the vector B, and the current in the ring was equal to zero. Then the ring was turned through 90^0 so that its plane became perpendicular to the field. Find the current induced in the ring after the turn.

a) $I=2\pi a^2B/L$ b) $I=\pi a^2B/2L$ c) $I=\pi a^2B/L$ d) $I=3\pi a^2B/2L$

5. In the above problem find the work performed during the turn.

a) $W=\frac{1}{2}\pi^2a^4B^2/L$ b) $W=\frac{1}{3}\pi^2a^4B^2/L$ c) $W=\frac{1}{3}\pi^2a^4B^2L$ d) $W=\frac{1}{2}\pi^2a^4B^2L$

*6. A long straight wire of circular cross-section is made of a non-magnetic material. The wire is of radius a. The wire carries a current I which is uniformly ditributed over its cross-section. The energy stored per unit lenght in the magnetic field contained within the wire is

a) $\frac{U}{l}=\frac{\mu_0 I^2}{8\pi}$ b) $\frac{U}{l}=\frac{\mu_0 I^2}{16\pi}$ c) $\frac{U}{l}=\frac{\mu_0 I^2}{4\pi}$ d) $\frac{U}{l}=\frac{\mu_0 I^2}{2\pi}$

*7. A long cylinder of radius a carrying a uniform surface charge rotates about its axis with an angular velocity ω. Find the magnetic field energy per unit length of the cylinder if the linear charge density equals λ and $\mu_r=1$.

a) $W_l=\mu_0\lambda^2\omega^2a^2/6\pi$ b) $W_l=\mu_0\lambda^2\omega^2a^2/8\pi$

c) $W_l=\mu_0\lambda\omega a/6\pi$ d) $W_l=\mu_0\lambda\omega a/8\pi$

8. A thin uniformly charged ring of radius a=10 cm rotates about its axis with an angular velocty $\omega=100\ \text{rad/s}$. Find the ratio of volume energy densities of magnetic and electric fields on the axis of the ring at a point moved from its centre by a distance $l = a$.

a) 2.1×10^{-15} b) 4.1×10^{-15} c) 6.1×10^{-15} d) 1.1×10^{-15}

Linked Comprehension Type Questions

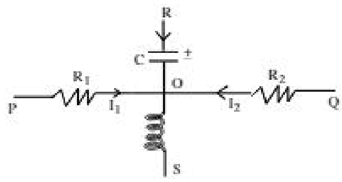
Passage :

$R_1=2\Omega, R_2=3\Omega$

$C=2F, L=4H$

$i_1=e^{-2t},\ i_2=4A$ *and*

$V_c=3e^{-2t}V$



9. Current through inductor (i_L) is

a) $(2-4e^{-2t})$ A b) $(4-2e^{-2t})$ A c) $(11e^{-2t}-4)$ A d) $4e^{-2t}$ A

10. Potential difference across inductor is (V_L)

a) $16e^{-2t}$ V b) $4e^{-2t}$ V c) $8e^{-2t}$ V d) $88e^{-2t}$ V

11. Potential difference between P and Q is (V_{PQ})

a) $(10e^{-2t}-12)$ V b) $(12e^{-2t}-10)$ V c) $(2e^{-2t}-12)$ V d) $12(e^{-2t}-1)$ V

12. Potential difference between P and R is

a) $7e^{-2t}$ V b) $-e^{-2t}$ V c) $5e^{-2t}$ V d) $10e^{-2t}$ V

EXERCISE-V

(L.R. Circuits)

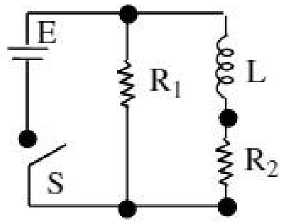
LEVEL-I (MAIN)

Straight Objective Type Questions

1. An ideal coil of 10 henry is joined in series with a resistance of 5 ohm and a battery of 5 volt. 2 second after joining, the current flowing in ampere in the circuit will be

1) e^{-1} 2) $(1-e^{-1})$ 3) $(1-e)$ 4) e

2. An inductor of inductance L = 400 mH and resistor of resistances $R_1 = 2\Omega$ and $R_2 = 2\Omega$ are connected to a battery of emf 12V as shown in the figure. The internal resistance of the battery is negligible. The switch S is closed at t = 0. The potential drop across L as a function of times is:

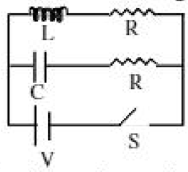


1) $\frac{12}{t}e^{-3t}V$ 2) $6\left(1-e^{-t/0.2}\right)V$ 3) $12e^{-5t}V$ 4) $6e^{-5t}V$

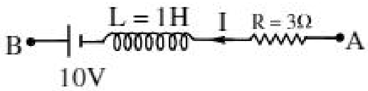
Numerical Type Questions

3. In a L–R decay circuit, the initial current is I. The total charge that has flown through the resistor till the energy in the inductor has reduced to one–fourth its initial value, is $\frac{LI}{XR}$. The value of 'X' is

4. In the circuit shown in the figure, $R=\sqrt{\frac{L}{C}}$. Switch S is closed at time t = 0. The current through C and L would be equal after a time t equal to CR log(P). The value of 'P' is



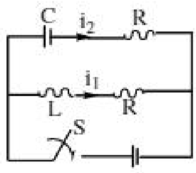
5. In the branch AB of a circuit, as shown in the figure, a current I = (10t + 5)A is flowing, where t is the time in second. At t = 0, the value of $(V_A - V_B)$ is (3x) volt. Find the value of 'x'.



6. An LR circuit is connected to a battery at time t = 0. The energy stored in the inductor reaches half its maximum value at time $\frac{L}{R}\log[X]$. The value of 'X' is

7. In an oscillating LC circuit the maximum charge on the capacitor is Q. The charge on the capacitor when the energy is stored equally between the electric and magnetic field is $\frac{Q}{\sqrt{N}}$. The value of 'N' is

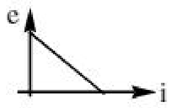
8. A pure inductor, pure capacitor and two pure equal resistors are connected as shown in the circuit, such that $L = 2R^2C$. At an instant t = 0 the switch is closed. If i_1 and i_2 are currents shown in the branches, at some instant of time $t = t_0$ the relation $\frac{di_1}{dt}+\frac{di_2}{dt}=0$ is satisfied. Then $t_0 = RC(\ln\sqrt{k})$; where k =

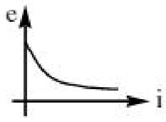


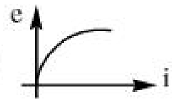
LEVEL-II (ADVANCED)

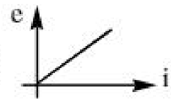
Straight Objective Type Questions

1. In an L-R circuit connected to a battery of constant e.m.f. E, switch S is closed at time t = 0. If e denotes the magnitude of induced e.m.f. across inductor and *i* the current in the circuit at any time t, then which of the following graphs shows the variation of e with *i* ?

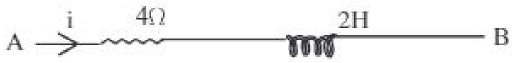
a) 

b) 

c) 

d) 

2. In the given branch $i = 10e^{-4t}$ A. Then

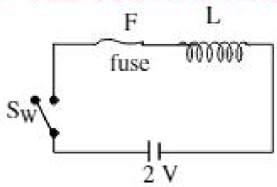


a) $V_L = 80e^{-4t}$ and $V_A - V_B = -40e^{-4t}$ b) $V_L = 80e^{-4t}$ and $V_A - V_B = 120e^{-4t}$

c) $V_L = 0$ and $V_A - V_B = -40e^{-4t}$ d) $V_L = 80e^{-4t}$ and $V_A - V_B = -80e^{-4t}$

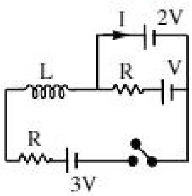
3. For L-R circuit, the time constant is equal to
   a) twice the ratio of the energy stored in the magnetic field to the rate of dissipation of energy in the resistance
   b) ratio of the energy stored in the magnetic field to the rate of dissipation of energy in the resistance
   c) half the ratio of the energy stored in the magnetic field to the rate of dissipation of energy in the resistance
   d) square of the ratio of the energy stored in the magnetic field to the rate of dissipation of energy in the resistance

4. In the circuit shown, the cell is ideal. The coil has an inductance of 4H and zero resistance. F is a fuse of zero resistance and will blow when the current through it reaches 5A. The switch is closed at t = 0. The fuse will blow :



a) just after t = 0 b) after 2s c) after 5s d) after 10s

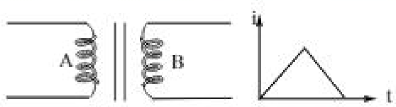
5. In the LR circuit shown, what is the variation of the current I as a function of time? The switch is closed at time t = 0.



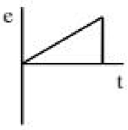
a) $\frac{V}{R}\left(1-e^{-\frac{Rt}{L}}\right)$ b) $\frac{V}{R}e^{-\frac{Rt}{L}}$

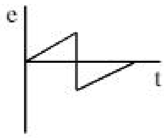
c) $-\frac{V}{R}e^{-\frac{Rt}{L}}$ d) None

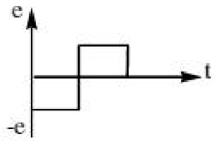
6 A and B are two coils placed closely as shown. The current in coil A varies as shown in the graph.

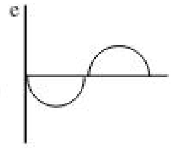


Then which of the following graphs gives the best representation of variation of induced emf in coil B ?

a) 

b) 

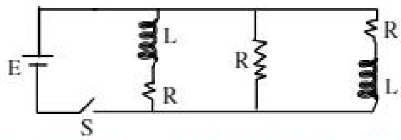
c) 

d) 

Linked Comprehension Type Questions

Passage - I :

The given circuit shows three identical resistors with resistance $R = 9\,\Omega$, two identical inductors with inductance $L = 2$ mH and an ideal battery with emf $E = 18V$.



7. The current through the battery just after the switch is closed will be
a) 6A b) 4A c) 2A d) 1A

8. The current through the battery long time after the switch has been closed will be
a) 6A b) 4A c) 2A d) 1A

9. The current through the middle resistor long time after the switch has been closed will be
a) 6A b) 4A c) 2A d) 1A

Passage - II :

An LC circuit has capacitance C_1 and inductance L_1. A second circuit has $C_2 = \frac{C_1}{2}$ and $L_2 = 2L_1$ and a third circuit has $C_3 = 2C_1$ and $L_3 = \frac{L_1}{2}$. Each is oscillatory circuit.

10. If in each case the capacitor was charged to same potential when connected to the inductor, maximum current will be generated in.
a) first circuit b) second circuit c) third circuit d) same in all circuit

11. Frequency of oscillation
a) is highest for first circuit b) is highest for second circuit
c) is highest for third circuit d) is same for all the three circuits

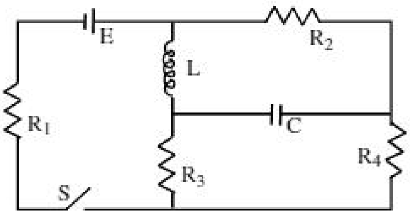
12. If I_1, I_2, I_3 are the maximum currents in those three circuits respectively
a) $I_1 > I_2 > I_3$ b) $I_3 > I_1 > I_2$ c) $I_3 > I_2 > I_1$ d) $I_1 < I_2 > I_3$

Matrix Matching Type Questions

13. Comparing L-C oscillations with the oscillations of spring -blocks system match the following table:

COLUMN - I (LC oscillations)	COLUMN - II (Spring - clock oscillations)
A) L	p) k
B) C	q) m
C) i	r) v
D) $\frac{di}{dt}$	s) x
	t) None

14. A circuit is shown in figure. At t = 0 a cell of emf 10 volt is connected and there is no initial charge on the capacitor and no initial current in any branch. Given $R_1 = R_2 = R_3 = R_4 = 1\Omega$, $C = 4\,\mu F$ and L = 2 mH. Match the column-I and column-II.



COLUMN - I	COLUMN - II
A) t = 0 current in R_1 (in amp) is	p) 2
B) t = ∞ current in R_1 (in amp)is	q) 4
C) t = charge on capacitor (in μC) is	r) 6
D) t = 0 potential differenceacross R_3 (in volt)	s) 8

KEY SHEET (LECTURE SHEET)

EXERCISE-I

LEVEL-I

1) **1** 2) **1** 3) **4** 4) **2** 5) **1** 6) **157.0** 7) **0.0** 8) **5.0** 9) **0.57** 10) **2.0**

LEVEL-II

1) **c** 2) **c** 3) **b** 4) **b** 5) **c** 6) **b** 7) **a** 8) **a** 9) **a,d** 10) **a** 11) **a** 12) **c** 13) **c** 14) **c** 15) **b** 16) **b** 17) **A-qs; B-ps; C-ps; D-qs** 18) **A-r; B-p; C-s; D-q**

EXERCISE-II

LEVEL-I

1) **1** 2) **3** 3) **4** 4) **4** 5) **2** 6) **2** 7) **0.02** 8) **25.0** 9) **2.0** 10) **6.25** 11) **1.0**

LEVEL-II

1) **a** 2) **b** 3) **d** 4) **d** 5) **b** 6) **b** 7) **d** 8) **d** 9) **b** 10) **c** 11) **b** 12) **a** 13) **b,d** 14) **b,c** 15) **a,d** 16) **a,b,c** 17) **a** 18) **c** 19) **c** 20) **A-pqrs; B-pqr; C-qs; D-qs** 21) **5** 22) **4**

EXERCISE-III

LEVEL-II

1) **b** 2) **b** 3) **b** 4) **d** 5) **a** 6) **d** 7) **d** 8) **c** 9) **a,b,c,d** 10) **a,c,d** 11) **b** 12) **b** 13) **a** 14) **b** 15) **a**

EXERCISE-IV

LEVEL-I

1) **4** 2) **3** 3) **2** 4) **25.0** 5) **1.0** 6) **7.53** 7) **16.0**

LEVEL-II

1) **a** 2) **b** 3) **b** 4) **c** 5) **a** 6) **b** 7) **b** 8) **d** 9) **c** 10) **d** 11) **c** 12) **b**

EXERCISE-V

LEVEL-I	1) 2	2) 3	3) 2.0	4) 2.0	5) 5.0	6) 3.41	7) 2.0	8) 16.0
LEVEL-II	1) a	2) a	3) a	4) d	5) c	6) c	7) c	8) a
	9) c	10) c	11) d	12) b	13) A-p; B-t; C-r; D-t			
	14) A-q; B-r; C-s; D-p							

PRACTICE SHEET

EXERCISE-I

(Magnetic flux, faraday's laws)

LEVEL-I (MAIN)

Straight Objective Type Questions

1. Magnetic flux ϕ (in weber) linked with a closed circuit of resistance 10 ohm varies with time t (in seconds) as $\phi = 5t^2 - 4t + 1$. The induced electromotive force in the circuit at t = 0.2 sec is
   1) 0.4 volts 2) – 0.4 volts 3) – 2.0 volts 4) 2.0 volts

2. A square coil of side 0.5 m has movable sides. It is placed such that its plane is perpendicular to uniform magnetic field of induction 0.2 T. If all the sides are allowed to move with a speed of $0.1 ms^{-1}$ for 4 sec outwards, average induced emf is
   1) Zero 2) 0.01V 3) 0.028V 4) 0.072V

3. A coil having n turns and resistance $R\Omega$ is connected with a galvanometer of resistance $4R\Omega$. This combination is moved in t second from field W_1 to W_2 weber. The induced current in circuit is :
   1) $\frac{n(W_2 - W_1)}{5Rt}$ 2) $\frac{W_2 - W_1}{5Rnt}$ 3) $\frac{n(W_2 - W_1)}{Rt}$ 4) $\frac{(W_2 - W_1)}{nRt}$

4. A very small circular loop of area 5×10^{-4} m^2 resistance 2Ω and negligible inductance is initially coplanar and concentric with a much larger fixed circular loop of radius 0.1m. A constant current of 1 ampere is passed in larger loop and smaller loop is rotated with a angular velocity 'ω' rads^{-1} about its diameter. The induced emf is ___ $\times 10^{-9}$ V
   1) $\pi\omega^2 \sin\omega t$ 2) $\frac{\pi\omega}{2}\sin\omega t$ 3) $\frac{\pi\omega}{8}\cos\omega t$ 4) $\pi\omega\sin\omega t$

Numerical Type Questions

5. A thin circular ring of area A is held perpendicular to an uniform magnetic field of induction B. A small cut is made in the ring and a galvanometer is connected across the ends such that the total resistance of the circuit is R. When the ring is suddenly squeezed to zero area, the charge flowing through the galvanometer is $\frac{BA}{NR}$. The value of 'N' is

6. A conducting metal circular-wire-loop of radius r is placed perpendicular to a magnetic field which varies with time as $B = B_0 e^{-t/\tau}$, where B_0 and τ are constant, at time t = 0. If the resistance of the loop is R then the heat generated in the loop after along time $(t \to \infty)$ is $\frac{\pi^2 r^a B_0^b}{2TR}$. The value of (a+b) is

LEVEL-II (ADVANCED)

Straight Objective Type Questions

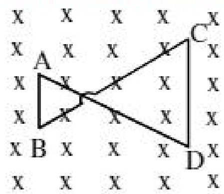
1. A conducting wire frame is placed in a magnetic field which is directed into the paper. The magnetic field is increasing at a constant rate. The directions of induced currents in wires AB and CD are

a) B to A and D to C

b) A to B and C to D

c) A to B and D to C

d) B to A and C to D



2. The e.m.f. induced in a coil of wire, which is rotating in a magnetic field, does not depend on

a) the angular speed of rotation
b) the area of the coil
c) the number of turns in the coil
d) the resistance of the coil

3. Two identical coaxial circular loops carry a current i each circulating in the same direction. If the loops approach each other

a) the current in each will decrease
b) the current in each will increase
c) the current in each will remain the same
d) the current in one will increase and in other will decrease

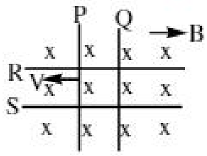
4. Two identical conductors P and Q are placed on two frictionless rails R and S in a uniform magnetic field directed into the plane. If P is moved in the direction shown in figure with a constant speed then rod Q

a) will be attracted towards P

b) will be repelled away from P

c) will remain stationary

d) may be repelled or attracted towards P



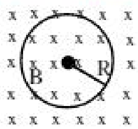
5. a conducting loop of radius R is present in a uniform magnetic field B perpendicular the plane of the ring. If radius R varies as a function of time 't', as $R = R_0 + t$. The e.m.f induced in the loop is

a) $2\pi (R_0 + t)B$ clockwise

b) $\pi (R_0 + t)B$ clockwise

c) $2\pi (R_0 + t)B$ anticlockwise

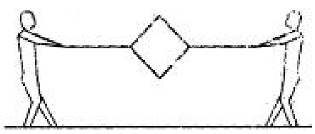
d) zero



Linked Comprehension Type Questions

Passage -I :

Figure shows a metallic square frame of edge a in a vertical plane. A uniform magnetic field B exists in the space in a direction perpendicular to the plane of the figure. Two boys pull the opposite corners of the square to deform it into a rhombus. They start pulling the corners at t=0 and displace the corners at a uniform speed u.



6. Find the induced emf in the frame at the instant when the angles at these corners reduce to 60^0.

a) 5 Bav
b) 2 Bav
c) 1 Bav
d) 1 Bav

7. In the above problem, find the induced current in the frame at this instant if the total resistance of the frame is R.

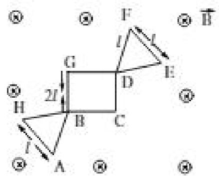
a) 3 Bav/R   b) 9 Bav/R   c) 2 Bav/R   d) 10 Bav/R

8. In the above problem, find the total charge which flows through a side of the frame by the time the square is deformed into a straight line.

a) $a\,{}^{B}\!/_{R}$ b) $a^2\,{}^{B^2}\!/_{R}$ c) $2a\,{}^{B}\!/_{R}$ d) $a^2\,{}^{B}\!/_{R}$

Passage - II :

Diagram shows one square metallic loop and two equilateral triangular metallic loops touching square metallic loop at points B and D.All metallic loops are present in a region of uniform but time varying magnetic field, which is increasing in magnitude (B) at a rate $\frac{dB}{dt}=\alpha$ resistance of each side of triangular or square loop is r. Magnetic field is perpendincualr to plane of each loop and points away from reader, then



9. Induced current in side BC is

a) $\frac{l^2\alpha}{r}$, along B to C   b) $\frac{l^2\alpha}{r}$, along C to B   c) $\frac{\sqrt{3}l^2\alpha}{4r}$, along B to C   d) not possible to determine

10. Induced current in side AB is

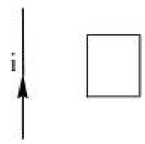
a) $\frac{l^2\alpha}{3r}$, along A to B   b) $\frac{l^2\alpha}{8r}$, along A to B   c) $\frac{l^2\alpha}{4\sqrt{3}r}$, along A to B   d) not possible to determine

11. Induced current in side DF is

a) $\frac{l^2\alpha}{\sqrt{2}r}$, along D to F   b) $\frac{4l^2\alpha}{\sqrt{3}r}$, along F to D   c) $\frac{l^2\alpha}{\sqrt{3}r}$, along D to F   d) $\frac{l^2\alpha}{4\sqrt{3}r}$ along F to D

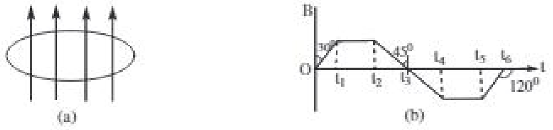
Matrix Matching Type Questions

12. A square loop is placed near a long straight current carrying wire as shown. Match the following table.



COLUMN - I	COLUMN - II
A) If current is increased	p) Induced current in loop is clockwise
B) If current is decreased	q) Induced current in loop is anticlockwise
C) If loop is moved away from the wire	r) wire will attract the loop
D) If loop is moved towards the wire	s) wire will repel the loop

13. A conducting loop is held in a magnetic field such that the field is oriented perpendicular to the area of the loop as shown in Fig-A. At Observer (Positive direction of field)



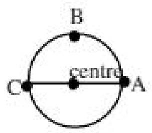
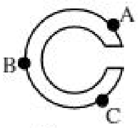
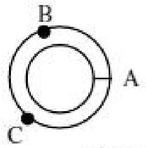
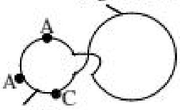
(a) (b)

any instant , magnetic flux density over the entire area has the same value but it varies with time as shown in Fig.B.

Match Column-I with Column-II

COLUMN - I	COLUMN - II
A) Induced current in the coil is in the clockwise sense	p) For $t_2 < t < t_3$
B) Induced current in the coil is in the anticlockwise sense	q) For $t_3 < t < t_4$
C) Induced current is zero	r) For $t_5 < t < t_6$
D) Induced current is maximum	s) For $t_4 < t < t_5$

14. Column-I shows thin plane conductors located in uniform magnetic field directed away from reader beyond the plane of paper. Column-II tells direction of resulting induced current in the conductors when magnetic field starts diministing.

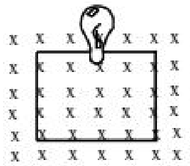
COLUMN - I	COLUMN - II
A) 	p) Clockwise current in part ABC
B) 	q) Anticlockwise current in part ABC
C) 	r) No current in part ABC
D) 	s) No current in some part of the conductor

Integer Type Questions

15. A coil having 100 turns and area of $0.001 m^2$ rotates freely about an axis passing through its diameter. The coil is placed perpendicular to a magnetic field of 1T. If the coil is rotated rapidly through an angle of 180^0, and resistance of that coil is 10Ω, the charge will flow through the coil is $z \times 10^{-2}$C. Find z.

16. A direct current I = 10 A flows in a long straight round conductor. Find the magnetic flux through a half of wire's cross-section per one meter of its length is ___ μwb/m

17. A square wire loop of 10.0 cm side lies at right angles to a uniform magnetic field of 20T. A 10 V light bulb is in a series with the loop as shown in the fig. The magnetic field is decreasing steadily to zero over a time interval Δt. The bulb will shine with full brightness if Δt is equal to k x 10ms. Find the value of k



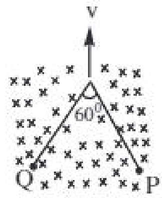
EXERCISE-II

(Motional emf)

LEVEL-I (MAIN)

Straight Objective Type Questions

1. A wire of length '2*l*' is bent at mid point so that angle between the two halves is 60^0. If it moves as shown with velocity 'v' in a magnetic field 'B'. The induced emf will be

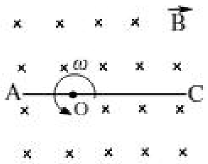


1) Blv, P at high potential and Q at low potential
2) 2Blv, P at high potential and Q at low potential
3) Blv, Q at high potential and P at low potential
4) 2Blv, from Q at high potential and P at low potential

2. A player with 3 m long iron rod runs towards east with a speed of 30 km/hr. Horizontal component of earth's magnetic field is 4×10^{-5} Wb/m^2. If he is running with rod in horizontal and vertical posistions, then the potential difference induced between the two ends of the rod in two cases will be

1) Zero in vertical position and 1×10^{-3} V in horizontal position
2) 1×10^{-3}V in vertical position and zero in horizontal position
3) Zero in both the cases
4) 1×10^{-3} in both the cases

3. A conducting rod AC of length 4 *l* is rotated about a point O in a uniform magnetic field $\vec{B}$ directed into the paper. AO = *l* and OC = 3*l*. Then

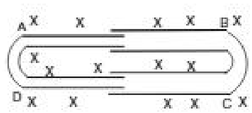


1) $V_A - V_0 = \dfrac{B\omega l^2}{2}$
2) $V_0 - V_C = \dfrac{9}{2}B\omega l^2$
3) $V_A - V_C = B\omega l^2$
4) $V_A - V_C = \dfrac{9}{2}B\omega l^2$

4. The perfect formula used for calculating induced e.m.f in a rod moving in a uniform magnetic field is

1) $e = \vec{B}.(\vec{l}\times\vec{v})$
2) $e = \vec{B}.(\vec{l}.\vec{v})$
3) $e = \vec{B}\times(\vec{l}.\vec{v})$
4) $e = \vec{B}\times(\vec{l}\times\vec{v})$

5. A conducting U–tube can slide inside another as shown in fig. maintaing electrical contacts between them. The magnetic field is perpendi-cular to plane of paper. If each tube move towards each other with constant speed υ, then emf induced in the circuit in terms of B, *l* and υ where *l* is the width of each tube.



1) Zero
2) $2B\ell\upsilon$
3) $B\ell\upsilon$
4) $-B\ell\upsilon$

Numerical Type Questions

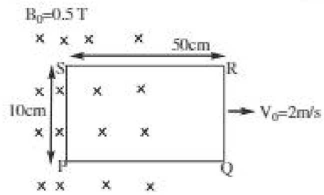
6. A thin wire of length of 2m is perpendicular to the XY-plane. It is moved with velocity $v = (2\hat{i}+3\hat{j}+\hat{k})ms^{-1}$ through a region of magnetic induction $B = (\hat{i}+2\hat{j})Wb/m^2$. Then, potential difference induced between the ends of the wire in voltes

7. A bicycle is resting on its stand in east-west direction and rear wheel is rotating at 100rpm. length of each spoke is 30cm, and vertical component of Earth's magnetism is 1.5×10^{-5}T. If the emf in induced in the spokes is $3\pi\times10^{-6}V$, then the angle of dip at that place is $\tan^{-1}\left[\frac{a}{b}\right]$. The value of (a+b) is

LEVEL-II (ADVANCED)

Straight Objective Type Questions

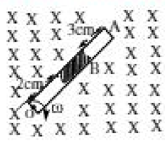
1. A rectangular loop PQRS (10cm × 50 cm) is placed in a plane perpendicular to uniform magnetic induction field B_0 = 0.5T and pulled out of the field region with a constant velocity V_0 = 2m/s. At a certain instant shown in the figure QR is out side the field region.



The resistance per unit length of the wire is $1\,\Omega/m$. $V_P - V_S$ will be

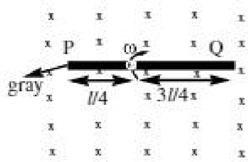
a) $\frac{11}{120}$V b) $\frac{-11}{120}$V c) $\frac{1}{120}$V d) $\frac{-1}{120}$V

2. A rod of length 10cm made up of conducting and non-conducting meterial (shaded part is non-conducting). The rod is rotated with constant angular velocity 10rad/s about point *O*, in constant magnetic field of 2T as shown in the figure. The induced emf between the points A and B of rod will be :



a) 0.029V b) 0.1V c) 0.051V d) 0.064V

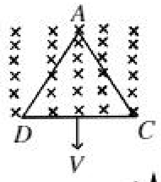
3. A conducting rod of length *l* is rotating with constant angular velocity ω about an axis OO' in a uniform magnetic field B as shown in figure. The emf induced between ends P and Q will be

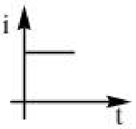
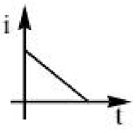
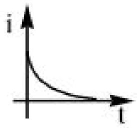
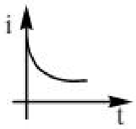


a) $\frac{1}{4}B\omega l^2$ b) $\frac{5}{10}B\omega l^2$

c) Zero d) $\frac{1}{2}B\omega l^2$

4. An equilateral triangular loop ADC of some finite magnetic field $\vec{B}$ as shown in the figure. At time t = 0, side DC of loop is at edge of the magnetic field. Magnetic field is perpendicular to the paper inwards (or perpendicular to the plane of the coil). The induced current versus time graph will be as

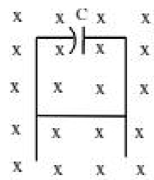


a) 
b) 
c) 
d) 

5. The magnetic field in a region is given by $\vec{B} = B_0\left(1+\frac{x}{a}\right)\hat{k}$. A square loop of edge - length d is placed with its edge along x & y axis. The loop is moved with constant velocity $\vec{V} = V_0\hat{i}$. The emf induced in the loop at that instant is

a) $\frac{V_0B_0d^2}{a}$ b) $\frac{V_0B_0d^2}{2a}$ c) $\frac{V_0B_0a^2}{d}$ d) None

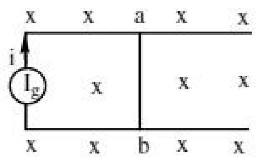
6. A wire of mass *m* and length *l* can slide freely on a pair of smooth, vertical rails. A magnetic field B exists in region in the direction perpendicular to the plane of the rails. The rails are connected at the top end by a capacitor of capacitance C. Find the acceleration of the wire neglecting any electric resistance.



a) $\frac{mg}{m+CB^2l^2}$ b) $\frac{mg}{m-CB^2l^2}$

c) $\frac{2mg}{m-CB^2l^2}$ d) $\frac{5mg}{m+CB^2l^2}$

7. The current generator I_g shown in figure, sends a constant current *i* through the circuit. The wire *ab* has a length *l* and mass *m* and can slide on the smooth, horizontal rails connected to I_g. The enitre system lies in a vertical magnetic field B. Find the velocity of the wire as a function of time.

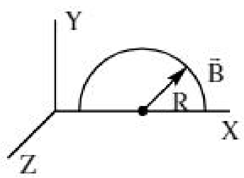


a) il Bt/m away from the generator b) 2il Bt/m away from the generator

c) 2il Bt/m towards the generator d) il Bt/2m towards the generator

More than One correct answer Type Questions

8. A semicircular conducting ring of radius R is placed in xy plane, as shown in the figure. A uniform magnetic field is set up along the x–axis. No emf will be induced in the ring. if



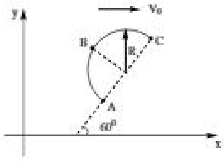
a) it moves along the x–axis

b) it moves along the y–axis

c) it moves along the z-axis

d) it remains stationary

9. A semicircular conducting metallic loop of radius R is moving in x-y plane in a region of uniform magnetic field given by $\vec{B} = B_0[\hat{i} + 2\hat{j} + 3\hat{k}]$ with velocity $\vec{V} = V_0\hat{i}$ as shown in diagram. Then



a) induced emf across its ends will be $3\sqrt{3}V_0B_0R$

b) potential of end C is less than potential of end A

c) point B and point C will be at same potential

d) we can get two points on loop which will be at same potential

10. A conducting loop rotates with constant angular velocity about its fixed diameter in a uniform magnetic field. Whose direction is perpendicular to that fixed diameter.

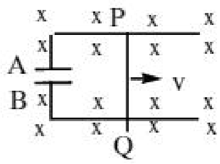
a) The emf will be maximum at the moment when flux is zero.

b) The emf will be '0' at the moment when flux is maximum.

c) The emf will be maximum at the moment when plane of the loop is parallel to the magnetic field

d) The phase difference between the flux and the emf is $\pi/2$

11. A conducting rod PQ of length L = 1.0 m is moving with a uniform speed v = 20 m/s in a uniform magnetic field B = 4.0 T directed into the paper. A capacitor of capacity C = 10 mF is connected as shown in figure. Then



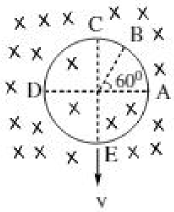
a) $q_A = +\ 800mC$ and $q_B = -\ 800mC$

b) $q_A = -\ 800mC$ and $q_B = +\ 800mC$

c) $q_A = 0 = q_B$

d) charged stored in the capacitor increases exponentially with time

12. A metallic ring of radius R is moving in a region of uniform magnetic field of magnitude B_0 with speed V as shown. then



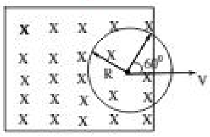
a) Potential difference between points A and B is $\dfrac{B_0RV}{2}$

b) Potential difference between points A and B is $\dfrac{B_0RV}{4}$

c) Potential difference between points C and D is B_0RV

d) Potential difference between points C and E is zero

13. A circular conducting loop of radius R and resistance per unit length λ is pulled out from a region of uniform magnetic field with constant velocity v. The situation shown in figure is at t = 0. Mark out the correct statement(s)



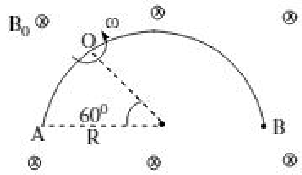
a) Just after t=0, i.e., the motion starts, the induced currrent in the loop is $\dfrac{\sqrt{3}Bv}{2\pi\lambda}$

b) Current will be induced in the loop for total time interval of $\dfrac{3R}{2v}$

c) Maximum induced current in loop is $\dfrac{Bv}{\pi\lambda}$ at $t=\dfrac{R}{2v}$

d) Induced current is in clockwise direction for t = 0 to $\dfrac{R}{2v}$ and there after it becomes in anti-clockwise direction

14. A semi circular rigid metallic wire, of radius R is rotating with constant angular speed ω about an axis passing through point O and perpendicular to the plane of the semicircular wire in a region of uniform magnetic field 'B_0' as shown then



a) Potential difference between points O and A is $\frac{B_0R^2\omega}{4}$

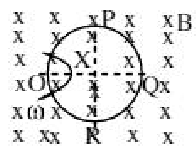
b) Potential difference between points O and B is $\frac{3B_0R^2\omega}{2}$

c) Electric Potential of point A is more than point B.

d) Potential difference between points A and B is $B_0R^2\omega$

Linked Comprehension Type Questions

Passage -I :



A conducting ring of radius a is rotated about a point O on its periphery as shown in the figure in a plane perpendicular to uniform magnetic field B which exists everywhere. The rotational velocity is ω.

15. Choose the correct statement(s) related to the potential of the points P, Q and R

a) $V_P - V_O > 0$ and $V_R - V_O < 0$
b) $V_P = V_R > V_O$
c) $V_O > V_P = V_Q$
d) $V_Q - V_P = V_P - V_O$

16. Choose the correct statement(s) related to the magnitude of potential differences

a) $V_P - V_0 = \frac{1}{2}B\omega a^2$
b) $V_P - V_Q = \frac{1}{2}B\omega a^2$
c) $V_Q - V_O = 2B\omega a^2$
d) $V_P - V_R = 2B\omega a^2$

17. Choose the correct statement(s) related to the induced current in the ring

a) Current flows from Q to P to O to R to Q
b) Current flows from Q to R to O to R to Q
c) Current flows from Q to P to O and from Q to R to O
d) No current flows

Passage -II :

A train of mass 100 tons (1 ton = 1000 kg) runs on a meter gauge track (distance between the two rails is 1 m.) The coefficient of friction between the rails and the train is 0.045. The train is powered by an electric engine of 90% efficiency. The train is moving with uniform speed of 72 Kmph at its highest speed limit. Horizontal and vertical component of earth's magnetic field are $B_H = 10^{-5}$ T and $B_v = 2 \times 10^{-5}$ T. Assume the body of the train and rails to be perfectly conducting.

18. The electrical power consumed by the train is

a) 1.11 MW
b) 1 MW
c) 0.50 MW
d) 0.90 MW

19. The potential difference between the two rails is

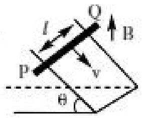
a) 0.1 mV
b) 0.2 mV
c) 0.4 mV
d) 0.8 mV

20. If now a resistor of 10^{-3} W is attached of between the two rails, the extra units of energy (electricity) consumed during a 324 km run of the train is (1 unit of power = 1 kW hour) (assume the speed of train to remain unchanged)

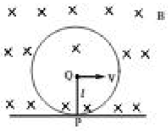
a) 8×10^{-4} KW hour
b) 8×10^{-5} KW hour
c) 8×10^{-6} KW hour
d) 8×10^{-7} KW hour

Matrix Matching Type Questions

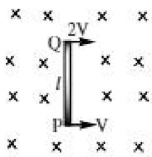
21. **COLUMN - I**

A) 

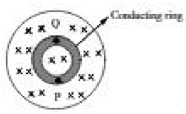
A conducting rod $PQ = l$ slides with constant velocity v down two parallel rails separated by distance 'l' and inclined at angle $\theta = 60^0$ to the horizontal. A uniform magnetic induction field B exists in vertically upward direction.

B) 

A conducting ring with a conducting spoke PQ= l rolls without sliding, the centre of the ring moves with constant velocity v. A uniform magnetic induction field B exists perpendicular to the plane of the ring as shown. At the position shown.

C) 

A conducting rod PQ=l moves in a plane perpendicular to uniform magnetic induction B with the velocities of the two ends as shown. At the position shown.

D) 

A magnetic induction varying with time T as $\frac{dB}{dT} = \alpha$ (constant) exists in a cylindrical region. A uniform conducting ring is placed inside the region as shown.

COLUMN - II

p) $V_P - V_Q = vBl/2$

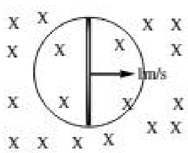
q) The magnitude of the electric field inside the rod/spoke/ring as we go from P to Q is constant

r) The magnitude of the electric field inside the rod/spoke/ring as go from P to Q increases.

s) The magnitude of the electric field inside the rod/spoke/ring is zero.

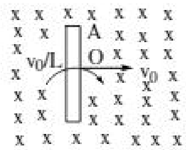
Integer Type Questions

22. A circular loop of radius 1m is kept in a magnetic field of strength 2T(plane of loop is perpendicular to the direction of magnetic field) .Resistance of the loop wire is $\frac{2}{\pi}\Omega/m$. A conductor of length 2m is sliding with a speed 1m/s as shown in the figure. Find the instantaneous force acting on the rod: [assume rod has negligible resistance]___x 2N

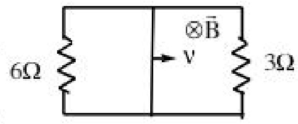


23. A rod of length 2m has translational velocity of 0.5 ms^{-1} in a direction making an angle of 30^0 with its length. The plane along which the rod is moving is normal to the magnetic field of induction 2T. The emf induced between the ends of the rod is

24. A conducting rod of length L is moving on a horizontal smooth surface. Magnetic field in the region is vertically downward and of magnitude B_0. If centre of mass of the rod is translating with velocity v_0 and rod rotates about centre of mass with angular velocity v_0/L then potential difference between points O and A will be $\frac{x}{8}B_0v_0L$. Then x is ....



25. A rectangular loop with a sliding connector of length $\ell = 1.0$m is situated in a uniform magnetic field B = 2T perpendicular to the plane of loop. Resistance of conector is $r = 2\Omega$ Two resistances of 6Ω and 3Ω are connected as shown in figure. The external force required to keep the connector moving with a constant velocity υ= 2 m/s is



*26. A metallic wire is initially at rest along the curve $y=\frac{\lambda}{\mu}\sin\left(\frac{\pi x}{\lambda}\right), x\in(0,2\lambda)$. It is moved along the x–y plane parallel to the line $x = y$, with a speed u. There is a uniform magnetic field $2B_0\hat{k}$ in the region. The maximum magnitude of induced emf between any two points on the wire is $\sqrt{\alpha}B_0\lambda u$. The value of α is

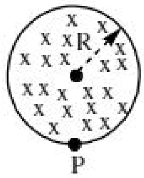
EXERCISE-III

(Induced Electric field)

LEVEL-II (ADVANCED)

Straight Objective Type Questions

1. A uniform magnetic field of induction B is confined to a cylindrical region of radius R. The magnetic field is increasing at a constant rate of dB/dt (tesla/second). An electron of charge q, placed at the point P on the periphery of the field experiences an acceleration :



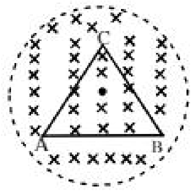
a) $\frac{1}{2}\frac{eR}{m}\frac{dB}{dt}$ towards left b) $\frac{1}{2}\frac{eR}{m}\frac{dB}{dt}$ towards right

c) $\frac{eR}{m}\frac{dB}{dt}$ towards left d) zero.

2. A non conducting ring having charge q uniformly distributed over its circumference is placed on a rough horizontal surface. A verical time varying magnetic field $B = 4t^2$ is switched on at time t = 0. Mass of the ring is m and radius is R. the ring starts rotating after 2 seconds. The coefficient of friction between the ring and the table is

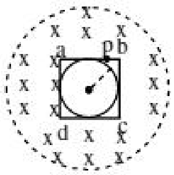
a) $\frac{4qR}{mg}$ b) $\frac{2qR}{mg}$ c) $\frac{8qR}{mg}$ d) $\frac{qR}{2mg}$

3. A triangular wire frame (each side = 2m) is placed in a region of time variant magnetic field having $dB/dt = \sqrt{3}$ T/s. The magnetic field is perpendicular to the plane of the triangle. The base of the triangle AB has a resistance 1Ω while the other two sides have resistance 2Ω each. The magnitude of potential difference between the points A and B will be



a) 0.4 V b) 0.6 V c) 1.2 V d) None

4. A uniform magnetic field B exists in a cylindrical region, shown dotted in figure. The magnetic field increases at a constant rate dB/dt. Consider a circle of radius r coaxial with the cylindrical region. Find the magnitude of the electric field E at a point on the circumference of the circle.

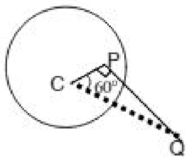


a) $\frac{r}{3}\frac{dB}{dt}$ b) $\frac{r}{2}\frac{dB}{dt}$ c) $\frac{dB}{dt}$ d) $\frac{r}{2}$

*5. A magnetic field, confined in a cylindrical region of radius R, is changing at the rate of $4Ts^{-1}$. A conducting rod PQ of length $\sqrt{\frac{3}{2}}R$ is placed in the region as shown. The induced emf across the rod will be

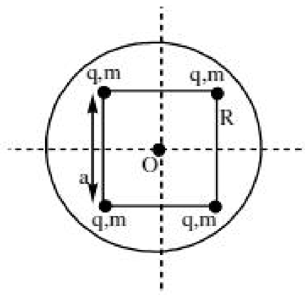
a) $\frac{R^2}{24}(\pi+6)$ b) $\frac{\pi R^2}{24}$

c) $\frac{\pi R^2}{6}$ d) $\frac{R^2}{6}(\pi+6)$



More than One correct answer Type Questions

6. Four identical charged particles each of mass 0.1 kg and charge 2C connected to each other via massless non-conducting rods of equal length. The whole arrangement is placed in a cylindrical region carrying a uniform magnetic field as shown in the figure (B_0=4T, a = 1m). Suddenly the magnetic field is switched off. Then choose the correct statement(s)



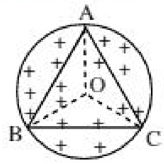
a) The angular momentum of the system is 8 Nm/s

b) The angular momentum of the system is $8\sqrt{2}$ Nm/s

c) Angular velocity of the system is 40 rad/s

d) The magnetic field at point O immediately after the magnetic field is switched off is non zero

7. In the figure shown there exists a uniform time varying magnetic field B = [(4 T/s) t + 0.3 T] in a cylindrical region of radius 4 m. An equilateral triangular conducting loop is placed in the magnetic field with its centroide on the axis of the field and its plane perpendicular to the field.



a) e.m.f. induced in any one rod is 16 V

b) e.m.f. induced in the complete ΔABC is $48\sqrt{3}$ V

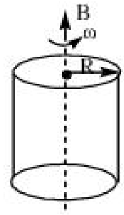
c) e.m.f. induced in the complete ΔABC is 48V

d) e.m.f. induced in any one rod is $16\sqrt{3}$

Linked Comprehension Type Questions

Passage :

A very long solid conducting cylinder of radius R is placed in a constant and uniform magnetic field B which is parallel to the axis of the cylinder. Now the cylinder is rotated with a constant angular velocity ω as shown in the figure. Charge and mass of electron can be taken as e and m respectively



8. The electric field inside the cylinder as a function of radial distance r is

a) $\left(\omega B - \frac{m\omega^2}{e}\right)r$ b) $E(r) = \frac{m\omega^2}{e}r$ c) $E(r) = \omega Br$ d) $E(r) = \left(\omega B + \frac{m\omega^2}{e}\right)r$

9. The potential difference between the axis of the cylinder and circumference is

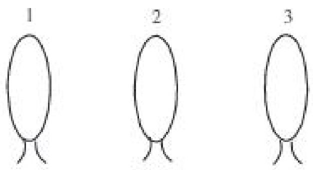
a) $\Delta V = \left(\omega B - \frac{m\omega^2}{e}\right)\frac{R^2}{2}$ b) $\Delta V = \frac{m\omega^2 R^2}{2}$ c) $\Delta V = \frac{\omega B R^2}{2}$ d) $\Delta V = \left(\omega B + \frac{m\omega^2}{e}\right)\frac{R^2}{2}$

10. The volume charge density of the cylinder is

a) $\omega B\varepsilon_0$ b) $\frac{m\omega^2}{e}\varepsilon_0$ c) $2\omega\varepsilon_0\left(B - \frac{m\omega}{e}\right)$ d) $\omega\varepsilon_0\left(B + \frac{m\omega}{e}\right)$

Matrix Matching Type Questions

11. Three coils are placed infront of each other as shown. Currents in 1 and 2 are in same direction, while that in 3 is in opposite direction, Match the following table :

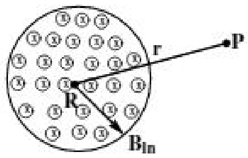


COLUMN - I	COLUMN - II
A) When current in 1 is increased	p) current in 1 will increase
B) When current in 2 is increased	q) current in 2 will increase
C) When current in 3 is increased	r) current in 3 will increase
	s) None

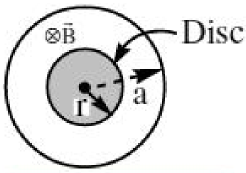
Integer Type Questions

12. A long solenoid of cross-sectional radius a = 10 cm has a thin insulated wire ring tightly put on its winding. One half of the ring has the resistance η-times that of the other half. The magnetic induction produced by the solenoid varies with time as B = bt where b = 4T/s (constant). Now the magnitude value of electric filed strength in the ring is found to be 10×10^{-2} N/C. Find the value of η.

13. For the situation shown in figure, the magnetic field changes according to the expression $B=(2t^3-4t^2+0.8T)$ and r=2R= 5cm. If the force on electron at P is zero at t = x/6sec, then, x is ....



14. A uniform disc of radius r and mass m is charged uniformly with the charge q. This disc is placed flat on a rough horizontal surface having coefficient of friction m. A uniform magnetic field is present in a circular region (a > r) but varying as kt^3 as shown in figure. Find the time in second after which the disc begins to rotate. (Given r = 1 m, m = 18 kg, q = 1C, m = 0.1m, K = 4, g = 10 m/s²)



EXERCISE-IV

(Self induction, Mutual induction & Magnetic Energy density)

LEVEL-I (MAIN)

Straight Objective Type Questions

1. A small square loop of wire of each side l is kept inside a large square loop of wire of each side 'L' (L > > l). The loops are coplanar and their centres coincide. The mutual inductance of the system is proportional to (current is in the outer loop)

1) l/L 2) $\frac{l^2}{L}$ 3) L/l 4) $\frac{L^2}{l}$

2. When current breaks in primary coil current reaches to zero in 10^{-4} second. Emf induced in the secondary coil is 20,000V and mutual inductance between the coils is 5H. The maximum current in the primary before the break is

1) 0.2 amp 2) 0.4 amp 3) 4 amp 4) 2amp

3. Two different coils have self – inductances L_1 = 8 mH and L_2 = 2 mH. The current in one coil is increased at a constant rate. The current in the second coil is also increased at the same constant rate. At a certain instant of time, the power given to the two coils is the same. At that time, the current, the induced voltage and the energy stored in the first coil are i_1, V_1 and W_1 respectively. Corresponding values for the second coil at the same instant are i_2, V_2 and W_2 respectively. Then :

a) $\frac{i_1}{i_2}=\frac{1}{4}$ b) $\frac{i_1}{i_2}=4$ c) $\frac{W_1}{W_2}=\frac{1}{4}$ d) $\frac{V_1}{V_2}=4$

1) a, d are true 2) c, d are true 3) a, c, d are true 4) Only b is true

Numerical Type Questions

4. The coefficient of neutral inductance of two circuits A and B is 3mH and their respective resistance are $10l$ and $4l$. The value of current (in A) should change in $0.02l$ in circuit A, so that to get current in B should be 0.006A is

5. The length of wire required to manufacture a solenoid of length and self inductance L is $\sqrt{\frac{XLl}{\mu_0}}$. The value of 'X' is

LEVEL-II (ADVANCED)

Straight Objective Type Questions

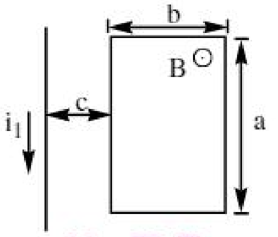
1. A long straight wire is placed along the axis of a circular ring of radius R. The mutual inductance of this system is

a) $\frac{\mu_0 R}{2}$ b) $\frac{\mu_0 \pi R}{2}$ c) $\frac{\mu_0}{2}$ d) 0

2. Two long parallel wires whose centres are at distance d apart carry equal currents in opposite directions. If the flux within wires is neglected, the inductance of such arrangement of wire of length l and radius a will be

a) $L = \frac{\mu_0 l}{2\pi}\log_e \frac{d-a}{a}$ b) $L = \frac{\mu_0 l}{\pi}\log_e \frac{d}{a}$ c) $L = \frac{\mu_0 l}{2\pi}\log_e \frac{a}{d}$ d) none

3. The mutual inductance between the rectangular loop and the long straight wire as shown in figure is M.



a) M = Zero b) $M = \frac{\mu_0 a}{4\pi}\ln\left(1+\frac{c}{b}\right)$

c) $M = \frac{\mu_0 b}{2\pi}\ln\left(\frac{a+c}{b}\right)$ d) $M = \frac{\mu_0 a}{2\pi}\ln\left(1+\frac{b}{c}\right)$

4. Two coil A and B have coefficient of mutual inductance M = 2H. The magnetic flux passing through coil A changes by 4 weber in 10 seconds due to the change in current in B. Then

a) change in current in B in this time interval is 0.5 A

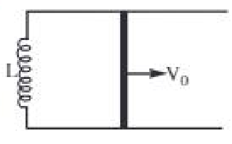
b) the change in current in B in this time interval is 2A

c) the change in current in B in this time interval is 8A

d) a change in current of 1A in coil A will produce a change in flux passing through B by 4 weber

More than One correct answer Type Questions

*5. A π shaped conductor containing an inductance L is placed with its plane perpendicular to a uniform magnetic field B .A conducting rod of mass m can slide freely on this conductor as shown in figure. At t = 0, the rod is imparted an initial velocity V_0. Then select correct option (s)



a) time period of oscillation of rod is $2\pi\sqrt{\frac{Lm}{B^2 l^2}}$

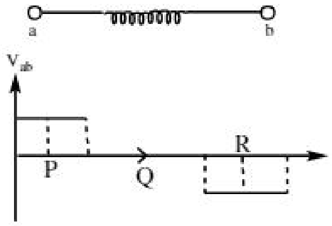
b) current (i) in the circuit as a function of time (t) is given by $i = \frac{m\omega V_0}{Bl}\sin\omega t\left(\text{where } \omega = \sqrt{\frac{B^2 l^2}{Lm}}\right)$

c) maximum acceleration of rod is $\sqrt{\frac{B^2 l^2 V_0^2}{Lm}}$

d) rod will perform simple harmonic motion.

Matrix Matching Type Questions

6. In the figure V_{ab} versus time graph along an inductor is shown. Match the following.



COLUMN - I	COLUMN - II
A) At P, if current is from b to a it must be	p) increasing
B) At Q, if current is from a to b it must be	q) decreasing
C) At R, if current is from a to b it must be	r) constant

Integer Type Questions

7. Two coils, 1 and 2 have a mutual inductance M = 5H and resistance $R = 10\Omega$ each. A current flows in ciol 1, which varies with time as: $I_1 = 2t^2$, where t is time. Find the total charge (in C) that has flown through coil 2 between t = 0 and t = 2s.

EXERCISE-V

(L.R. Circuits & L.C. Oscillations)

LEVEL-I (MAIN)

Straight Objective Type Questions

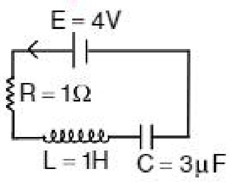
1. The time constant of an inductance coil is 3×10^{-3} s. When a $90\,\Omega$ resistance is joined in series, the time constant becomes 0.5×10^{-3} s. The inductance and resistance of the coil are

1) 54 mH; $18\,\Omega$ 2) 14 mH; $42\,\Omega$ 3) 42 mH; $14\,\Omega$ 4) 14 mH; $60\,\Omega$

2. An emf of 15 volt is applied in a circuit containing 5 henry inductance and 10 ohm resistance. The ratio of the currents in time $t = \infty$ and at t =1 second is :

1) $\frac{e^{1/2}}{e^{1/2}-1}$ 2) $\frac{e^2}{e^2-1}$ 3) $1 - e^{-1}$ 4) e^{-1}

3. The current in the given circuit is increasing with a rate 4 amp/s. The charge on the capacitor at an instant when the current in the circuit is 2 amp will be



1) $4\mu C$ 2) $5\mu C$ 3) $6\mu C$ 4) $3\mu C$

4. A coil of resistance 10 ohm and inductance 5 henry is connected to a 100 volt battery. Then, the energy stored in the coil. In the form of magnetic field (In steady state)

1) 250 J 2) 1000 J 3) 125 J 4) 750 J

5. Coil of inductance 300 mH and resistance $2\,\Omega$ is connected to a source of voltage 2V. The current reaches half of its steady state value in

1) 0.05 S 2) 0.1 S 3) 0.15 S 4) 0.3 S

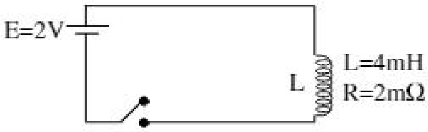
6. Two coils of self-inductane 2 mH and 8 mH are placed so close together that the effective flux in one coil is completely linked with the other. The mutual inductance between these coil is

1) 16 mH 2) 10 mH 3) 6 mH 4) 4 mH

Numerical Type Questions

7. A resistance with an inductor 8×10^{-2}H has same time costant as it has with a capacitor of $2\mu F$. The value of resistance in ohm is

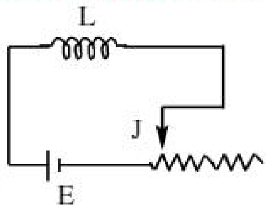
8. The cell in the circuit shown in figure is ideal. The coil has an inductance of 4mH and a resistance of $2m\Omega$. The switch is closed at t = 0. The amount of energy stored in the inductor at t = 2s is (take e = 3) in Joules.



LEVEL-II (ADVANCED)

Straight Objective Type Questions

1. In the circuit shown, the jockey J is pulled towards right so that the resistance in the circuit is increasing. Its value at some instant is R. Then current in the circuit at this instant will be



a) E/R b) < (E/R)

c) >(E/R)

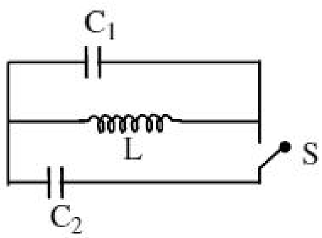
d) <(E/R) or > (E/R) depending on the value of L

2. An LR circuit with a battery is connected at t = 0. Which of the following quantities is not zero just after the connection

a) current in the circuit b) magnetic field energy in the inductor

c) power delivered by the battery d) emf induced in the inductor

3. At a moment (t = 0) when charge on capacitor C_1 is zero, the switch is closed. If I_0 be the current through inductor at that instant, for t > 0, [Initial charge on C_2 is also zero]



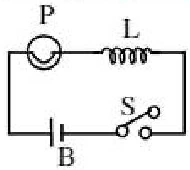
a) maximum current through inductor equals $I_0/2$.

b) maximum current through inductor equals $\frac{C_1 I_0}{C_1+C_2}$

c) maximum charge on $C_1 = \frac{C_1 I_0\sqrt{LC_1}}{C_1+C_2}$

d) maximum charge on $C_1 = I_0 C_1\sqrt{\frac{L}{C_1+C_2}}$

4. In figure, a lamp P is in series with an iron-core inductor L. When the switch S is closed, the brightness of the lamp rises relatively slowly to its full brightness than it would do without the inductor. This is due to



a) the low resistance of P
b) the induced-emf in L
c) the low resistance of L
d) the high voltage of the battery B

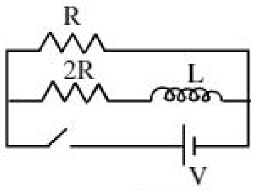
5. A capacitor of capacitance 2 mF is charged to a potential difference of 12 V. It is then connected across an inductor of inductance 0.6 mH. The current in the circuit when the potential difference across the capacitor is 6 V is :

a) 3.6 A b) 2.4 A c) 19 A d) 0.6 A

6. An induction coil stores 32 joules of magnetic energy and dissipates energy as heat at the rate of 320 watts, when a steady current of 4 amperes is passed through it. Find the time constant of the circuit when the coil is joined across a battery.

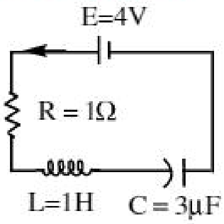
a) 0.2 s b) 0.1 s c) 0.3 s d) 0.4 s

7. The ratio of time constant in charging and discharging in the circuit shown in figure is



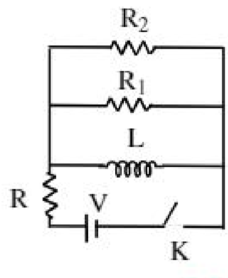
a) 1 : 1 b) 3 : 2 c) 2 : 3 d) 1 : 3

8. The current in the given circuit is increasing with a rate of 4 amp/s. The charge on the capacitor at an instant when the current in the circuit is 2 amp will be :



a) 4 μC b) 5 μC c) 6 μC d) none of these

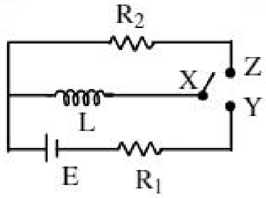
9. In the circuit shown, initially switch k is closed for long time. At time t = 0, switch k is open. Then total heat produced in resistor R_1 after opening the switch k is



a) $\frac{1}{2}\frac{LV^2}{R}$ b) $\frac{1}{2}\left(\frac{R_1}{R_1+R_2}\right)\frac{LV^2}{R^2}$

c) $\frac{1}{2}\left(\frac{R_2}{R_1+R_2}\right)\frac{LV^2}{R^2}$ d) zero

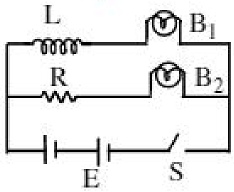
10. In the circuit shown, X is joined to Y for a long time, and then X is joined to Z. The total heat produced in R_2 is :



a) $\frac{LE^2}{2R_1^2}$ b) $\frac{LE^2}{2R_2^2}$

c) $\frac{LE^2}{2R_1R_2}$ d) $\frac{LE^2R_2}{2R_1^2}$

11. An inductor L, a resistance R and two identical bulbs B_1 and B_2 are connected to a battery through a switch S as shown in the figure. The resistance of coil having inductance L is also R. Which of the following statements gives the correct description of the happenings when the switch S is closed?



a) The bulb B_2 lights up earlier than B_1 and finally both the bulbs shine equally bright.

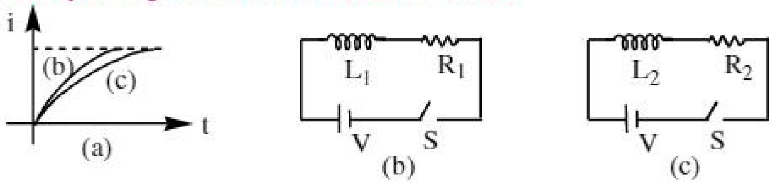
b) B_1 light up earlier and finally both the bulbs acquire equal brightness.

c) B_2 lights up earlier and finally B_1 shines brighter than B_2.

d) B_1 and B_2 light up together with equal brightness all the time.

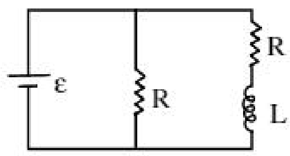
More than One correct answer Type Questions

12. Current growth in two L-R circuits (b) and (c) are as shown in figure (a). Let L_1, L_2, R_1 and R_2 be the corresponding values in two circuits. Then



a) $R_1>R_2$ b) $R_1=R_2$ c) $L_1>L_2$ d) $L_1<L_2$

13. In the circuit diagram shown



a) time constant is L/R

b) time constant is 2L/R

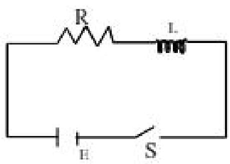
c) steady state current in inductor is 2e/R

d) steady state current in inductor is e/R

Linked Comprehension Type Questions

Passage - I :

An LR circuit consists of an inductance L and a resistance R connected in series through a battery of emf E. At time t = 0, the switch S is closed.



14. Work done by the battery during the time t = 0 to t = t

a) $\frac{E^2}{R}te^{-\frac{Rt}{L}}$ b) $\frac{E^2}{R}te^{-\frac{t}{RL}}$ c) $\frac{E^2}{R}\left\{t-\frac{L}{R}\left(1-e^{-\frac{Rt}{L}}\right)\right\}$ d) $\frac{E^2}{R}\left\{t+\frac{L}{R}\left(1-e^{-\frac{Rt}{L}}\right)\right\}$

15. The heat developed during this time is

a) $\frac{E^2}{R}\left\{t-\frac{L}{R}\left(1-e^{\frac{Rt}{L}}\right)\right\}$ b) $\frac{E^2}{R}\left\{t-\frac{L}{2R}\left(3-4e^{-\frac{Rt}{L}}+e^{\frac{-2Rt}{L}}\right)\right\}$

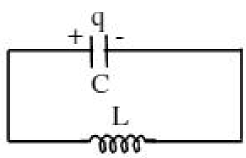
c) $\frac{E^2}{R}\left\{t+\frac{L}{R}\left(1-e^{\frac{Rt}{L}}\right)\right\}$ d) $\frac{E^2}{R}\left\{t-\frac{L}{2R}\left(1-2e^{\frac{Rt}{L}}+e^{\frac{-2Rt}{L}}\right)\right\}$

16. The magnetic field energy stored in the circuit at time t is

a) $\frac{LE^2}{R^2}\left(1-e^{\frac{-Rt}{L}}\right)^2$ b) $\frac{LE^2}{2R^2}\left(1-e^{\frac{-Rt}{L}}\right)$ c) $\frac{LE^2}{2R^2}\left(1+e^{\frac{-Rt}{L}}\right)^2$ d) $\frac{LE^2}{2R^2}\left(1-e^{\frac{-Rt}{L}}\right)^2$

Passage - II :

In an L-C circuit shown in figure :



$C=1F, L=4H$. *At time t = 0, charge in the capacitor is 4C and it is decreasing at a rate of* $\sqrt{5}\,C/s$.

17. Maximum charge in the capacitor can be :

a) 6 C b) 8 C c) 10 C d) 12 C

18. Charge in the capacitor will be maximum after time t = ... second

a) $2\sin^{-1}\left(\frac{2}{3}\right)$ b) $\pi-2\sin^{-1}\left(\frac{2}{3}\right)$ c) $2\tan^{-1}\left(\frac{2}{3}\right)$ d) none of these

19. Choose the correct option :

a) Maximum current in the circuit is 4A

b) When current is half its maximum value, charge in capacitor is less than half is maximum value

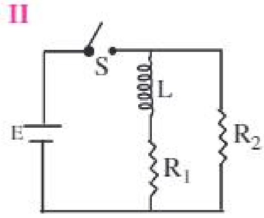
c) both (a) and (b) are correct

d) both (a) and (b) are wrong

Matrix Matching Type Questions

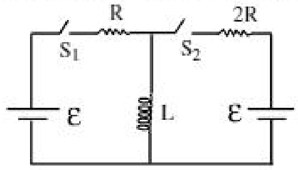
20. In the circuit shown in figure E = 18 V, L = 2H, $R_1 = 3\Omega$, $R_2 = 6\Omega$, switch S is closed at t = 0. Match the following;

COLUMN - I	COLUMN - II
A) Current through R_1 at t = 0	p) 6A
B) Current through R_1 at $t = \infty$	q) 3A
C) Current through R_2 at t = 0	r) Zero
D) Current through R_2 at $t = \infty$	s) Infinite



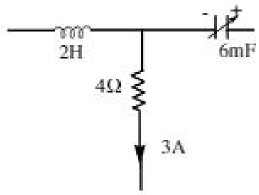
Integer Type Questions

21. In the circuit shown, switch S_2 remains closed for a long time, with S_1 open. It is given that $R = 10\Omega$, L = 1 mH and $\varepsilon = 3V$. Now switch S_1 is also closed. Immediately afterwards, if the magnitude of rate of change of current (in As^{-1}) in the inductor is 1000x, find x.



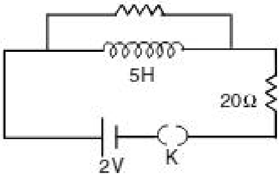
22. Figure shows a part of a bigger circuit. The capacity of the capacitor is 6mF and is decreasing at the constant rate 0.5 mFs^{-1}. The potential difference across the capacitor at the shown moment is changing as follows :

$$\frac{dV}{dt} = 2Vs^{-1}, \quad \frac{d^2V}{dt^2} = \frac{1}{2}Vs^{-2}$$



The current in the 4Ω resister is decreasing at the rate of 1mA/s. What is the potential difference in (mV) across the inductor at this moment.

23. Two resistances of 10Ω and 20Ω and an ideal inductor of inductance 5H are connected to a 2V battery through a key K, as shown in figure. The key is inserted at t = 0. What is the final value of current in the 10Ω resistor ?



KEY SHEET (PRACTICE SHEET)

EXERCISE-I

LEVEL-I

1) 4 2) 4 3) 1 4) 4 5) 1.0 6) 6.0

LEVEL-II

1) a 2) d 3) a 4) a 5) c 6) b 7) c 8) d
9) a 10) c 11) d 12) A-q,s; B-p,r; C-p,r; D-q,s
13) A-r; B-p,q; C-s; D-r 14) A-p,s; B-p; C-p,s; D-q 15) 2 16) 1
17) 2

EXERCISE-II

LEVEL-I

1) 3 2) 2 3) 2 4) 1 5) 2 6) 2.0 7) 7.0

LEVEL-II

1) b 2) c 3) a 4) b 5) a 6) a 7) a
8) a,b,c,d 9) a,b 10) a,b,d 11) a 12) a,c,d 13) a,b,c
14) b,c,d 15) b,d 16) c 17) d 18) b 19) c 20) d
21) A-p,q; B-p,r; C-p,r; D-q 22) 8 23) 1 24) 5 25) 2
26) 8

EXERCISE-III

LEVEL-II

1) a 2) c 3) a 4) b 5) d 6) a,b,c 7) b,d 8) d
9) d 10) d 11) A-r; B-r; C-p,q 12) 3 13) 8 14) 2

EXERCISE-IV

LEVEL-I

1) 2 2) 2 3) 3 4) 0.16 5) 12.56

LEVEL-II

1) d 2) a 3) d 4) b 5) a,b,c,d 6) A-q; B-r; C-q
7) 4

EXERCISE-V

LEVEL-I

1) 1 2) 2 3) 3 4) 1 5) 2 6) 4 7) 200.0 8) 888.8

LEVEL-II

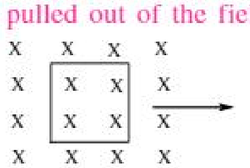
1) c 2) d 3) d 4) b 5) c 6) a 7) b 8) c
9) c 10) a 11) a 12) bd 13) ad 14) c 15) b 16) d
17) a 18) b 19) d 20) A-p; B-r; C-q; D-q 21) 2 22) 4
23) 0

ADDITIONAL PRACTICE EXERCISE

LEVEL-I (MAIN)

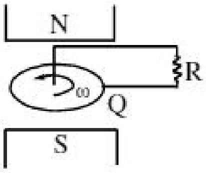
Straight Objective Type Questions

1. A square loop having n turns and an area A has a total resistance R. There is a uniform magnetic field 'B' normal to plane of the loop as shown. If the loop is pulled out of the field slowly and uniformly in time t, work done in pulling it out completely.



1) $\frac{nB^2A^2}{Rt}$ 2) $\frac{nB^2A}{Rt}$ 3) $\frac{nBA^2}{Rt}$ 4) $\frac{nB^2A^2}{R^2t}$

2. A metal disc rotates freely, between the poles of a magnet in the direction indicated. Brushes P and Q make contact with the edge of the disc and the metal axle. What current, if any, flows through R?



1) a current from P to Q

2) a current from Q to P

3) no current, because the emf in the disc is opposed by the back emf

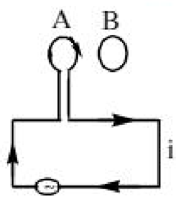
4) no current, because the emf induced in one side of the disc is opposed by the emf induced in the other side.

5) no current, because no radial emf is induced in the disc

3. A current carrying loop A has a small conducting wire loop B placed on its centre, with the two axes mutually perpendicular. If the current through A is varied, then

1) there is almost no current through B
2) loop B is attracted towards loop A
3) there is a torque on loop B
4) loop B is repelled by loop A

4. Two circular coils A and B are facing each other as shown in figure. The current i through A can be altered

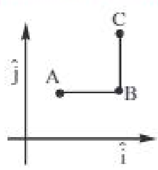


1) there will be repulsion between A and B if i is increased
2) there will be attraction between A and B if i is increased
3) there will be neither attraction nor repulsion when i is changed
4) attraction or repulsion between A and B depends on the direction of current. It does not depend whether the current is increased or decreased.

5. A metallic rod of length L and mass M is moving under the action of two unequal forces F_1 and F_2 (directed opposite to each other) acting at its ends along its length. Ignore gravity and any external magnetic field. If specific charge of electrons is (e/m), then the potential difference between the ends of the rod in steady state must be

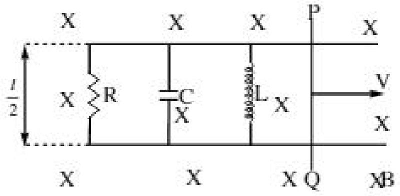
1) $|F_1 - F_2|\ mL/eM$ 2) $(F_1 - F_2)\ mL/eM$ 3) $[mL/eM] \ln [F_1/F_2]$ 4) None

6. There is a uniform magnetic field B normal to the xy plane. A conductor ABC has length AB = l_1, parallel to the x-axis, and length BC = l_2, parallel to the y-axis. ABC moves in the xy plane with velocity $v_x\hat{i} + v_y\hat{j}$. The potential difference between A and C is proportional to



1) $v_x l_1 + v_y l_2$ 2) $v_x l_2 + v_y l_1$ 3) $v_x l_2 - v_y l_1$ 4) $v_x l_1 - v_y l_2$

7. Consider the electric circuit shown in which a metallic rod PQ of length 'l' and zero resistance is moving with constant velocity 'V' on parallel ideal conducting rails in a region of uniform magnetic field 'B' then



1) Charge on capacitor will be BlVC 2) Current through resistor will be $\frac{\text{BlV}}{2\text{R}}$

3) Current through inductor will be Zero

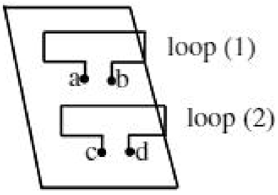
4) Current through inductor will be increasing at a rate $=\frac{\text{BlV}}{2\text{L}}$

LEVEL-II

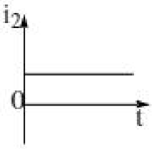
LECTURE SHEET (ADVANCED)

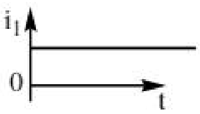
Straight Objective Type Questions

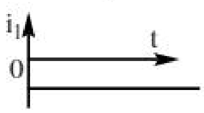
1. An electric current i_1 can flow either direction through loop (1) and induced current i_2 in loop (2). Positive i_1 is when current is from 'a' to 'b' in loop (1) and positive i_2 is when the current is from 'c' to 'd' in loop (2).

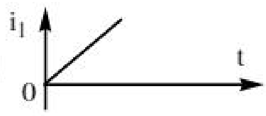


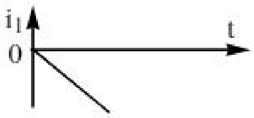
In an experiment, the graph of i_2 against time 't' is as shown below. Which one(s) of the following graphs could have caused i_2 to behave as give above.

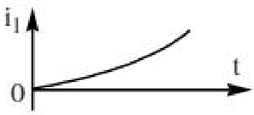


a) 

b) 

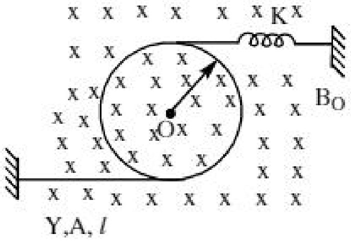
c) 

d) 

e) 

2. A uniform non-conducting circular disc of mass M and radius R charged uniformly with charge Q is free to rotate in horizontal plane about a vertical axis passing through its fixed centre O. A mass less spring of constant k and an elastic cord of length l, cross-sectional area A and young's modulus Y are attached to diametrically opposite points of the disc such that their lengths are parallel as

shown in the figure. Initially the spring is unstretched, the cord is just taut, and a uniform magnetic field B_0 exists in vertical direction. Now B_0 is switched off. Assuming B_0 is small enough for the oscillations to be small and simple harmonic, choose the correct options



a) The time period of oscillations is $T = 2\pi\sqrt{\dfrac{Ml}{2(Kl + YA)}}$

b) The time period of oscillations is $T = \pi\sqrt{\dfrac{Ml}{2(Kl + YA)}} + \pi\sqrt{\dfrac{M}{2K}}$

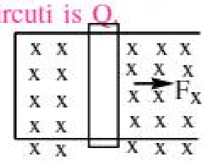
c) During the oscillations the maximum potential energy stored in the spring is $\dfrac{Q^2B_0^2R^2}{16M}$

d) During the oscillations the maximum elastic potential energy stored in the cord is $\dfrac{Q^2B_0^2R^2}{16M}$

3. A long single layer solenoid tightly wound of wire with resistivity $\rho = \dfrac{\pi}{2}\times 10^{-8}$ .ohm. m has n turns per unit length (n = 1000 per m). The thickness of wire insulation is negligible. The radius of solenoid is equal to a = 5 cm. If the phase difference between current and alternating voltage applied to the solenoid with frequency f = 100 Hz is (Take $\pi^2 = 10$)

a) $\dfrac{3\pi}{4}$ b) $\dfrac{3\pi}{2}$ c) $\dfrac{\pi}{4}$ d) $\dfrac{\pi}{2}$

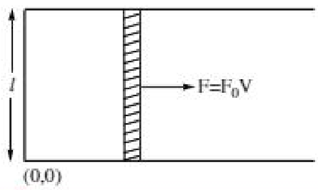
4. A rod closing the circuit shown in figure moves along a U shaped wire at a constant speed v under the action of the force F. The circuit is in a uniform magnetic field perpendicular to the plane. Calculate F if the rate of heat generation in the circuti is Q.



a) F = QV b) Q = Fv

c) F = $\dfrac{v}{Q}$ d) F= $\sqrt{Qv}$

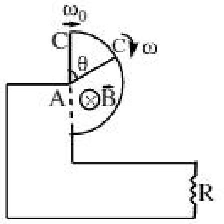
5. Two infinitely long parallel wires, having resistance per unit lenght λ are connected as shown in the figure. A slide wire of negligible resistance and having mass 'm' and length 'l' can slide between the parallel wires, without any frictional resistnce. If the system of wires is introduced to a magnetic field of intensity 'B' (directed into the plane of paper) a nd the slide wire is pulled with a force which varies with the velocity of the slide wire as F = F_0V, then find the velocity of the slide wire as a function of the distance x travelled. (The slide wire is initially at origin and has a velocity V_0)



a) $V_0 - \dfrac{F_0x}{m} + \dfrac{B^2l^2}{2\lambda m} ln\left(\dfrac{2x - l}{l}\right)$ b) $V_0 + \dfrac{F_0x}{m} + \dfrac{B^2l^2}{\lambda m} ln\left(\dfrac{2x - l}{l}\right)$

c) $V_0 + \dfrac{F_0x}{m} - \dfrac{B^2l^2}{2\lambda m} ln\left(\dfrac{2x + l}{l}\right)$ d) $V_0 + \dfrac{F_0x}{m} - \dfrac{B^2l^2}{\lambda m} ln\left(\dfrac{2x + l}{l}\right)$

*6. A conducting rod AC of mass m free to rotate in a horizontal plane about one end A over a semicircular conducting ring of radius 'a' is joined with an external resistance R as shown in figure. The resistance of the rod is r. The rod is given an initial angular velocity ω_0. A uniform magnetic field of magnitude B exists perpen-dicular to the plane of semicircular loop. Find the current in the circuit at an angle θ.



a) $\frac{Ba^2}{2(R+r)}\left[\omega_0-\frac{3B^2a^2\theta}{4m(R+r)}\right]$ b) $\frac{Ba^2}{2(R-r)}\left[\omega_0-\frac{B^2a^2\theta}{m(R-r)}\right]$

c) $\frac{Ba^2}{2(R-r)}\left[\omega_0-\frac{3B^2a^2\theta}{4m(R-r)}\right]$ d) $\frac{Ba^2}{(R-r)}\left[\omega_0-\frac{B^2a^2\theta}{4m(R-r)}\right]$

7. A ring of radius a = 50 mm made of thin wire of radius b = 1.0 mm was located in a uniform magnetic field with induction B = 0.5 mT so that the ring plane was perpendicular to the vector B. Then the ring was cooled down to a super-conducting state, and the magnetic field was switched off. Find the ring current after that. Note that the inductance of a thin ring along which the surface current flows is equal to $L=\mu_0 a\left(\ln\left(\frac{8a}{b}\right)-2\right)$.

a) 40 A b) 20 A c) 15.658A d) 50 A

8. A closed circuit consists of a source of constant emf ξ and a choke coil of inductance L connected in series. The active resistance of the whole circuit is equal to R. At the moment t = 0 the choke coil inductance was decreased abruptly η times. Find the current in the circuit as a function of time t. (During a stepwise change of inductance the total magnetic flux remains constant).

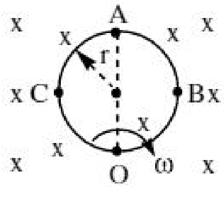
a) $I=\frac{\xi}{R}(1-(\eta+1)e^{-t\eta R/L})$ b) $I=\frac{\xi}{R}(1+(\eta-1)e^{-t\eta R/L})$

c) $I=\frac{\xi}{R}(2-(\eta+1)e^{-t\eta R/L})$ d) $I=\frac{\xi}{R}(2+(\eta-1)e^{-t\eta R/L})$

*9 There are two stationary loops with mutual inductance L_{12}. The current in one of the loops starts to be varied as $I_1=\alpha t$, where α is a constat, t is time. Find the time dependence $I_2(t)$ of the current in the other loop whose inductace is L_2 and resistance R.

a) $I_2=\frac{\alpha L_{12}}{R}(1-e^{-tR/L_2})$ b) $I_2=\frac{\alpha L_1}{R}\left(1-e^{-tR/L_1}\right)$ c) $I_2=\frac{\alpha L_{12}}{R}\left(1-e^{-tR/L_1}\right)$ d) $I_2=\frac{\alpha L_{12}}{R}\left(1+e^{-tR/L_1}\right)$

10. In figure, there is a conducting ring having resistance R placed in the plane of paper in a uniform magnetic field B_0. If the ring is rotating in the plane of paper about an axis passing through point O and perpendicular to the plane of paper with constant angular speed w in clockwise direction, wrong statement among the following is



a) Point A will be at higher potential than O.

b) The potential of point B and C will be same.

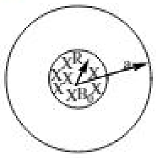
c) The current in ring will be zero.

d) The current in the ring will not be zero

11. A uniform magnetic induction field B_0 exists in a cylindrical region of radius R. A conducting ring of radius a (> R) is placed co-axially with the field region. The ring has mass 'm' and linear charge density λ. The angular velocity gained by the ring if the field is switched off is

a) $\frac{\lambda\pi B_0 a^2}{mR}$ b) $\frac{\lambda\pi B_0 a^2}{2mR}$

c) $\frac{\lambda\pi B_0 R^2}{ma}$ d) $\frac{\lambda\pi B_0 R^2}{2ma}$



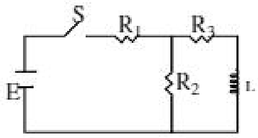
Linked comprehension type questions

Passage - I :

$E = 50V, R_1 = 10\Omega$

$R_2 = 20\Omega, R_3 = 30\Omega$

and $L = 2mH$



12. Current through R_1 immediately after switch S is closed is

a) 1A b) $\frac{5}{3}$A c) $\frac{2}{3}$A d) $\frac{1}{3}$A

13. Current through R_2, a long time after S is closed is

a) $\frac{25}{6}$A b) $\frac{50}{11}$A c) $\frac{25}{11}$A d) $\frac{15}{11}$A

14. After the steady state is attained, current through R_1 immediately after S is reopened is

a) zero b) 1A c) 2.3A d) 1.5A

15. After the steady state is attained, current through R_2 immediately after S is reopened is nearly

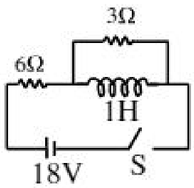
a) 0.31 A b) 0.71A c) 0.81A d) 0.91A

Passage - II :

In an L-R circuit current growth takes place according to the law :

$\mathbf{i = i_0(1 - e^{-t/\tau_L})}$ ***here i_0 is the steady state current (at $t \to \infty$) and is given by $\frac{V}{R}$. V is the applied voltage and R the resistance of circuit. $\tau_L = \frac{L}{R}$ is called time constant. Potential difference across inductor is given by $V_L = L\frac{di}{dt}$, where L is the inductance. At time t = 0, and inductor offers infinite resistance (in dc) and at $t = \infty$ it offers zero resistance. Time constant of a circuit can be obtained by $\tau_L = \frac{L}{R_{net}}$, where R_{net} is the net resistance across inductor after short circuiting the battery.***

In the circuit shown in figure switch S is closed at time t = 0.



16. Current i from the battery at time t is given by :

a) $3(1-e^{-2t})$ b) $3+e^{-2t}$ c) $3(1-e^{-t/9})$ d) $3-e^{-2t}$

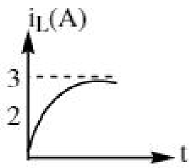
17. Potential difference across 3Ω resistance at time t is given by :

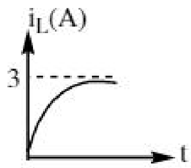
a) $9e^{-2t}$ b) $6e^{-2t}$ c) $3e^{-2t}$ d) $18(1-e^{-t/9})$

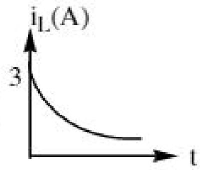
18. At what time current through 3Ω resistance and 1H inductor are equal ?

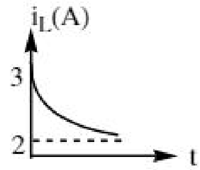
a) $\ln\sqrt{\frac{5}{3}}$ b) $\ln\left(\frac{8}{3}\right)$ c) $\ln\left(\frac{5}{3}\right)$ d) $\ln\sqrt{\frac{8}{3}}$

19. Taking current through the inductor left to right as positive current, current through inductor varies with time t as :

a) 

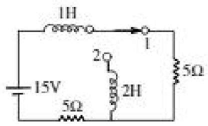
b) 

c) 

d) 

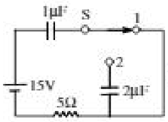
Matrix Matching Type Questions

20. **COLUMN-I** **COLUMN-I**

A) 

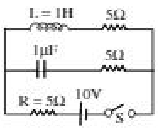
The circuit shown is in steady state The switch is shifted to position at t = 0

p) At t = 0 current through battery is 1A

B) 

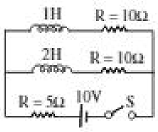
The circuit shown is in steady state The switch is shifted to position 2 at t = 0

q) At t = 0 current through battery is 0

C) 

The switch is closed at t = 0

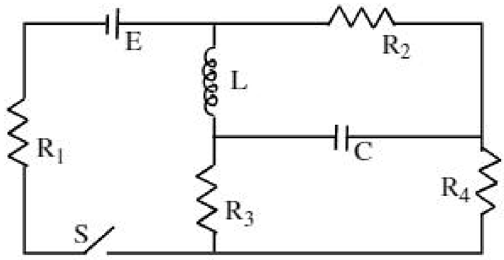
r) At $t\to\infty$ current through battery is 3A

D) 

The switch is closed at t = 0

s) At $t\to\infty$ current through battery is 1A.

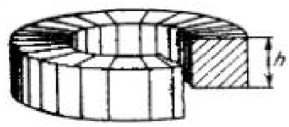
21. A circuit is shown in figure. At t = 0 a cell of emf 10 volt is connected and there is no initial charge on the capacitor and no initial current in any branch. Given $R_1 = R_2 = R_3 = R_4 = 1\Omega$, $C = 4\ \mu F$ and L = 2 mH. Match the column-I and column-II.



COLUMN - I	COLUMN - II
A) t = 0 current in R_1 (in amp) is	p) 2
B) $t = \infty$ current in R_1 (in amp)is	q) 4
C) t = charge on capacitor (in μC) is	r) 6
D) t = 0 potential differenceacross R_3 (in volt)	s) 8

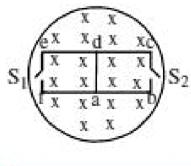
Integer Type Questions

22. Fig. shows a toroidal solenoid whose cross-section is rectangular. The magnetic flux through this cross-section, if the current through the winding equals I = 1.7 A, the total number of turns is N = 1000, the ratio of the outside diameter to the inside one is η =1.6, and the height is equal to h = 5cm is ____ μwb. $\left[ln 1.6 = \frac{8}{17}\right]$

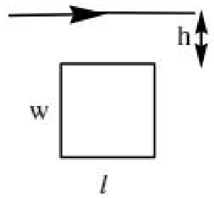


23. An electron is moving in a circular orbit of radius R with an angular acceleration α. A conducting loop of radius r is kept at the centre of the orbit (r <<R). The e.m.f induced in the smaller loop due to the motion of the electron is $\frac{\mu_0 e r^2}{kR}\alpha$. Find the value of k

24. The magnetic field in the cylindrical region shown in figure increases at a constant rate of 20.0 mT/s. Each side of the square loop *abcd* and *defa* has a length of 1.00 cm and a resistance of 4.00Ω. Find the current (magnitude and sense) in the wire *ad* if both S_1 and S_2 are closed.

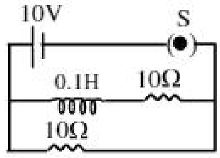


25. A relatively long straight conductor and a conducting rectangular loop lie in the same plane, as shown in figure, Taking $h = 0.4\ mm$, w = 1.3*mm* and $l = 2.7mm$, their mutual inductance is $261x\ pH$



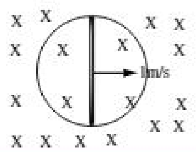
26. A coil of self inductance 50 henry is joined to the terminals of a battery of emf 2 volts through a resistance of 10 ohm and a steady current is flowing through the circuit. If the battery is now disconnected, the time in which the current will decay to 1/e of steady value is.

27. In the adjoining circuit, initially the switch S is open. The switch 'S' is closed at t = 0. The difference between the maximum and minimum currents that can flow in the circuit is ____ Amp.



28. In a spark plug which is connected to the secondary coil if transformer an emf 40000V is induced when in primary coil current changes from 4A to 0 in $10\mu s$. The self inductance of secondary coil is 1000H. Find the minimum value of self inductance of primary coil is $10^{-x}H$. Then find x.

29. A capacitor of capacity $2\mu F$ is charged to a potential difference of 12V. It is then connected across an inductor of inductance $6\mu H$. What is the current (inA) in the circuit at a time when the potential difference across the capacitor is 6.0 V ?



PRACTICE SHEET (ADVANCED)

Straight Objective Type Questions

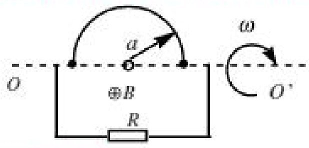
1. Magnetic energy stored in the magnetic field of infinitely long current carrying wire of current i in a cylindrical volume shell of radii R and 2 R, height h and axis coinciding with wire is

a) $\dfrac{\mu_0 i^2 h \log_e 2}{4\pi}$ b) $\dfrac{\mu_0 i^2 h \log_e\left(\dfrac{2+R}{R}\right)}{\pi}$ c) $\dfrac{\mu_0 i^2 R^2 \log_e 3}{4\pi h}$ d) none of these

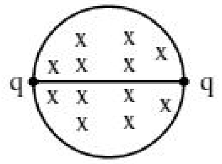
2. A wire shaped as a semi-circle of radius a rotates about an axis OO' with an angular velocity ω in a uniform magnetic field of induction B. The rotation axis is perpendicular to the field direction. The total resistance of the circuit is equal to R. Neglecting the magnetic field of the induced current, find the mean amount of thermal power being generated in the loop during a rotation period.

a) $(\pi\omega a^2 B)^2/R$ b) $\dfrac{1}{2}\dfrac{(\pi\omega a^2 B)^2}{R}$

c) $\dfrac{(\pi\omega a B)^2}{R}$ d) $\dfrac{1}{8}\dfrac{(\pi\omega a^2 B)^2}{R}$



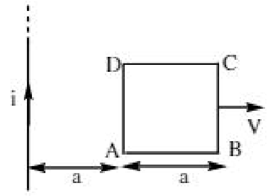
3. A cylindrical region of uniform magnetic field exists perpendicular to plane of paper which is increasing at a constant rate $\frac{dB}{dt} = \alpha$. The diameter of cylindrical region is l. A non–conducting rigid rod of length l having two charged particles is kept fixed on the diameter of cylindrical region w.r.t. inertial frame. If two charged particles having charges q each is kept fixed at the ends of the non-conducting rod. The net force on any one of the charges is



a) $\frac{q\ell\alpha}{4}$ b) $\frac{q\ell\alpha}{2}$

c) Zero d) $q\ell\alpha$.

4. Figure shows instantaneous position of a square metallic loop of side 'a' moving with constant velocity V in the magnetic field of infinitely long wire carrying current i. Resistance per unit length of square metallic loop is r. At this instant



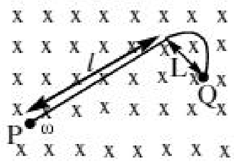
a) magnetic flux through square metallic loop due to magnetic field of infinitely long wire is $\frac{\mu_0 i a \log_e 2}{4\pi}$

b) Mutual inductance of a system of infinitely long wire and square loop is $\frac{\mu_0 a \log_e 2}{2\pi}$

c) Potential difference between points B and C is $\frac{5\mu_0 iV}{16\pi}$

d) Induced current in square metallic loop is $\frac{\mu_0 iV}{16\pi ar}$

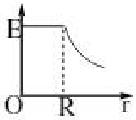
5. When a 'J' shaped conducting rod is rotating in its own plane with constant angular velocity w, about one of its end P, in a uniform magnetic field B directed normally into the plane of paper) then magnitude of emf induced across it will be

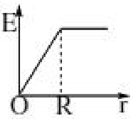


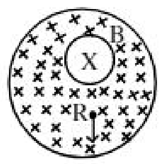
a) $Bw\sqrt{L^2 + l^2}$ b) $\frac{1}{2}B\omega L^2$

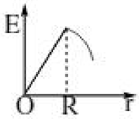
c) $\frac{1}{2}B\omega(L^2 + l^2)$ d) $\frac{1}{2}B\omega l^2$

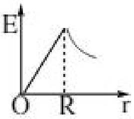
6. A uniform magnetic field is confined in cylindrical region of radius R. Induction of the magnetic field is increasing at a constant rate $\frac{dB}{dt} = \alpha$. Strength of induced electricfield varies with distance 'r' (fromthe axis of cylindrical region) according to graph

a) 

b) 



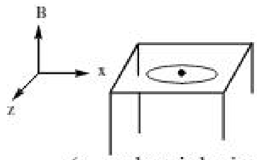
c) 

d) 

Linked Comprehension Type Questions

Passage -I :

A uniform conducting ring of mass π kg and radius 1 m is kept on smooth horizontal table. A uniform but time varying magnetic field $B = (\hat{i} + t^2\hat{j})$ Tesla is present in the region. (Where t is time in seconds). Resistance of ring is 2Ω. Then, (g =10 m/s^2)



(x - z plane is horizontal plane)

7. Net magnetic force (in Newton) on conducting ring as function of time is

   a) $2\pi^2 t$ b) $2\pi^2 t^2$ c) $2\pi^2 t^3$ d) zero

8. Time (in second) at which ring start toppling is

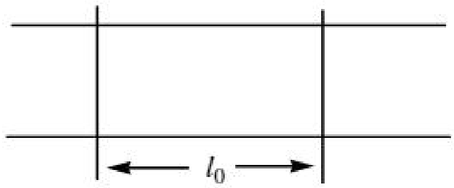
   a) $\frac{10}{\pi}$ b) $\frac{20}{\pi}$ c) $\frac{5}{\pi}$ d) $\frac{25}{\pi}$

9. Heat generated (in kJ) through the ring till the instant when ring start toppling is

   a) $\frac{1}{3\pi}$ b) $\frac{2}{\pi}$ c) $\frac{2}{3\pi}$ d) $\frac{1}{\pi}$

Passage - II :

Two conducting bars rest on two horizontal parallel conducting rails. The bars are perpendicular to the rails and parallel to each other as shown. The distance between bars is l_0.



At a certain moment a vertical upward magnetic field is switch on. The field quickly reaches its maximum value 'B_0' and remains constant. Mass of each rod is m, length of each rod is l and resistance of each rod is R.Neglect friction and resistance of the rails.

10. Under the given condition

    a) rods will keep on oscillating about their initial positions

    b) rods will start moving away from each other and finally stop

    c) rods will start moving towards each other and finally stop.

    d) rods will first come closer to each other and then again come to their initial position.

11. Find velocity gained by each rod at the moment magnetic field reaches its maximum value

    a) $\frac{l_0 B_0^2 l^2}{2MR}$ b) $\frac{l_0 B_0^2 l^2}{4MR}$ c) $\frac{l_0 B_0^2 l^2}{MR}$ d) $\frac{2l_0 B_0^2 l^2}{MR}$

12. Find minimum separation between rods in the mentioned situation

a) $\frac{l_0}{2}$ b) $\frac{l_0}{4}$ c) $\frac{l_0}{8}$ d) zero

KEY SHEET (ADDITIONAL PRACTICE EXERCISE)

LEVEL-I (MAIN)

1) **a** 2) **a** 3) **d** 4) **a** 5) **a** 6) **c** 7) **b,d**

LEVEL-II

LECTURE SHEET (ADVANCED)

1) **d** 2) **b,d** 3) **c** 4) **b** 5) **c** 6) **a** 7) **c** 8) **b** 9) **a** 10) **c**

11) **c** 12) **b** 13) **d** 14) **a** 15) **d** 16) **d** 17) **b** 18) **a** 19) **b**

20) **A-r; B-q; C-p; D-s** 21) **A-q; B-r; C-s; D-p** 22) **8** 23) **4** 24) **0** 25) **3**

26) **5** 27) **1** 28) **5** 29) **6**

PRACTICE SHEET (ADVANCED)

1) **a** 2) **d** 3) **a** 4) **b,c,d** 5) **c** 6) **d** 7) **d** 8) **a** 9) **c** 10) **c**

11) **b** 12) **a**