विध्न विचारत भीरु जन, नहीं आरम्भे काम, विपति देख छोड़े तुरंत मध्यम मन कर श्याम।
पुरुष सिंह संकल्प कर, सहते विपति अनेक, 'बना' न छोड़े ध्येय को, रघुबर राखे टेक।।

रचितः मानव धर्म प्रणेता
सद्गुरु श्री रणछोड़दासजी महाराज

STUDY PACKAGE

This is TYPE 1 Package please wait for Type 2

Subject : PHYSICS

Topic : E.M.I. & A.C.

TEKO CLASSES
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Index

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KEY CONCEPTS

When a conductor is moved across a magnetic field, an electromotive force (emf) is produced in the conductor. If the conductors forms part of a closed circuit then the emf produced caused an electric current to flow round the circuit. Hence an emf (and thus a current) is induced in the conductor as a result of its movement across the magnetic field. This is known as "**ELECTROMAGNETIC INDUCTION**."

1. **MAGNETIC FLUX** :

$\phi = \vec{B} \cdot \vec{A} = BA\cos\theta$ weber for uniform $\vec{B}$.

$\phi = \int \vec{B} \cdot d\vec{A}$ for non uniform $\vec{B}$.

2. **FARADAY'S LAWS OF ELECTROMAGNETIC INDUCTION** :

(i) An induced emf is setup whenever the magnetic flux linking that circuit changes.

(ii) The magnitude of the induced emf in any circuit is proportional to the rate of change of the magnetic flux linking the circuit, $\varepsilon \propto \frac{d\phi}{dt}$.

3. **LENZ'S LAWS** :

The direction of an induced emf is always such as to oppose the cause producing it .

4. **LAW OF EMI** :

$e = -\frac{d\phi}{dt}$. The negative sign indicated that the induced emf opposes the change of the flux .

5. **EMF INDUCED IN A STRAIGHT CONDUCTOR IN UNIFORM MAGNETIC FIELD** :

$E = BLV\sin\theta$ volt where

B = flux density in wb/m^2 ; L = length of the conductor (m) ;
V = velocity of the conductor (m/s) ;
θ = angle between direction of motion of conductor & B .

6. **COIL ROTATION IN MAGNETIC FIELD SUCH THAT AXIS OF ROTATION IS PERPENDICULAR TO THE MAGNETIC FIELD** :

Instantaneous induced emf. $E = NAB\omega\sin\omega t = E_0\sin\omega t$, where

N = number of turns in the coil ; A = area of one turn ;
B = magnetic induction ; ω = uniform angular velocity of the coil ;
E_0 = maximum induced emf.

7. **SELF INDUCTION & SELF INDUCTANCE** :

When a current flowing through a coil is changed the flux linking with its own winding changes & due to the change in linking flux with the coil an emf is induced which is known as self induced emf & this phenomenon is known as self induction . This induced emf opposes the causes of Induction. The property of the coil or the circuit due to which it opposes any change of the current coil or the circuit is known as **SELF – INDUCTANCE** . It's unit is Henry .

Coefficient of Self inductance $L = \frac{\phi_s}{i}$ or $\phi_s = Li$

L depends only on ;

(i) shape of the loop &

(ii) medium

i = current in the circuit .

ϕ_s = magnetic flux linked with the circuit due to the current i .

self induced emf $e_s = \frac{d\phi_s}{dt} = -\frac{d}{dt}(Li) = -L\frac{di}{dt}$ (if L is constant)

8. **MUTUAL INDUCTION** :

If two electric circuits are such that the magnetic field due to a current in one is partly or wholly linked with the other, the two coils are said to be electromagnetically coupled circuits . Than any change of current in one produces a change of magnetic flux in the other & the latter opposes the change by inducing an emf within itself . This phenomenon is called **MUTUAL INDUCTION** & the induced emf in the latter circuit due to a change of current in the former is called **MUTUALLY INDUCED EMF** . The circuit in which the current is changed, is called the primary & the other circuit in which the emf is induced is called the secondary. The co-efficient of mutual induction (mutual inductance) between two electromagnetically coupled circuit is the magnetic flux linked with the secondary per unit current in the primary.

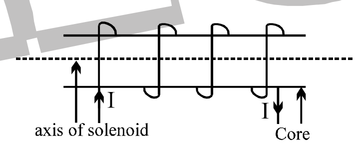
Mutual inductance = M = $\frac{\phi_m}{I_p} = \frac{\text{flux linked with secondary}}{\text{current in the primary}}$ mutually induced emf .

$E_m = \frac{d\phi_m}{dt} = -\frac{d}{dt}(MI) = -M\frac{dI}{dt}$ (If M is constant)

M depends on (1) geometery of loops (2) medium (3) orientation & distance of loops .

9. **SOLENOID** :

There is a uniform magnetic field along the axis the solenoid (ideal : length >> diameter)



$B = \mu\, ni$ where ;

μ = magnetic permeability of the core material ;

n = number of turns in the solenoid per unit length ;

i = current in the solenoid ;

Self inductance of a solenoid $L = \mu_0 n^2 A l$;

A = area of cross section of solenoid .

10. **SUPER CONDUCTION LOOP IN MAGNETIC FIELD** :

R = 0 ; ε = 0. Therefore ϕ_{total} = constant. Thus in a superconducting loop flux never changes. (or it opposes 100%)

11. (i) **ENERGY STORED IN AN INDUCTOR** :

$W = \frac{1}{2}LI^2$.

(ii) Energy of interation of two loops $U = I_1\phi_2 = I_2\phi_1 = MI_1I_2$, where M is mutual inductance .

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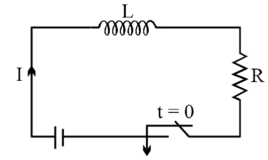
12. GROWTH OF A CURRENT IN AN L – R CIRCUIT :

$I = \frac{E}{R}\left(1 - e^{-Rt/L}\right)$. [If initial current = 0]



$\frac{L}{R}$ = time constant of the circuit .

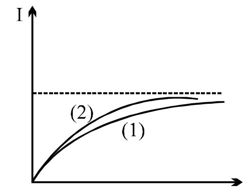
$I_0 = \frac{E}{R}$.

(**i**) L behaves as open circuit at $t = 0$ [If $i = 0$]

(**ii**) L behaves as short circuit at $t = \infty$ always .

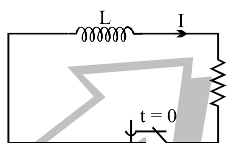
Curve (1) $\longrightarrow$ $\frac{L}{R}$ Large

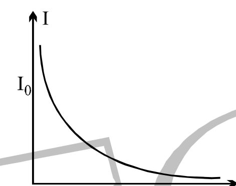
Curve (2) $\longrightarrow$ $\frac{L}{R}$ Small



13. DECAY OF CURRENT :

Initial current through the inductor = I_0 ; Current at any instant $i = I_0 e^{-Rt/L}$

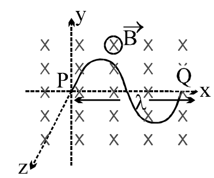




EXERCISE–I

Q.1 The horizontal component of the earth's magnetic field at a place is 3×10^{-4} T and the dip is $\tan^{-1}(4/3)$. A metal rod of length 0.25 m placed in the north-south position is moved at a constant speed of 10cm/s towards the east. Find the e.m.f. induced in the rod.

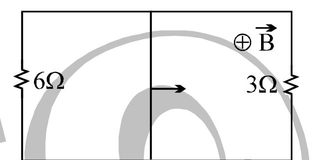
Q.2 A wire forming one cycle of sine curve is moved in x-y plane with velocity $\vec{V} = V_x\hat{i} + V_y\hat{j}$. There exist a magnetic field $\vec{B} = -B_0\hat{k}$. Find the motional emf develop across the ends PQ of wire.



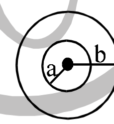
Q.3 A conducting circular loop is placed in a uniform magnetic field of 0.02 T, with its plane perpendicular to the field . If the radius of the loop starts shrinking at a constant rate of 1.0 mm/s, then find the emf induced in the loop, at the instant when the radius is 4 cm.

Q.4 Find the dimension of the quantity $\dfrac{L}{RCV}$, where symbols have usual meaining.

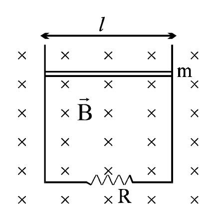
Q.5 A rectangular loop with a sliding connector of length $l = 1.0$ m is situated in a uniform magnetic field B = 2T perpendicular to the plane of loop. Resistance of connector is r = 2Ω. Two resistances of 6Ω and 3Ω are connected as shown in figure. Find the external force required to keep the connector moving with a constant velocity v = 2m/s.



Q.6 Two concentric and coplanar circular coils have radii a and b(>>a)as shown in figure. Resistance of the inner coil is R. Current in the outer coil is increased from 0 to i , then find the total charge circulating the inner coil.

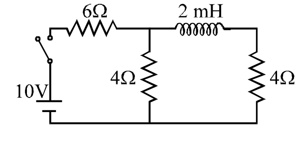


Q.7 A horizontal wire is free to slide on the vertical rails of a conducting frame as shown in figure. The wire has a mass m and length l and the resistance of the circuit is R. If a uniform magnetic field B is directed perpendicular to the frame, then find the terminal speed of the wire as it falls under the force of gravity.

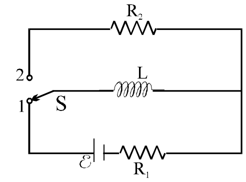


Q.8 A metal rod of resistance 20Ω is fixed along a diameter of a conducting ring of radius 0.1 m and lies on x-y plane. There is a magnetic field $\vec{B} = (50T)\hat{k}$. The ring rotates with an angular velocity $\omega = 20$ rad/sec about its axis. An external resistance of 10Ω is connected across the centre of the ring and rim. Find the current through external resistance.

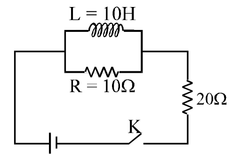
Q.9 In the given current, find the ratio of i_1 to i_2 where i_1 is the initial (at t = 0) current and i_2 is steady state (at $t = \infty$) current through the battery.



Q.10 In the circuit shown, initially the switch is in position 1 for a long time. Then the switch is shifted to position 2 for a long time. Find the total heat produced in R_2.



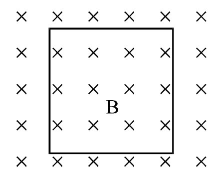
Q.11 Two resistors of 10Ω and 20Ω and an ideal inductor of 10H are connected to a 2V battery as shown. The key K is shorted at time $t = 0$. Find the initial ($t = 0$) and final ($t \to \infty$) currents through battery.



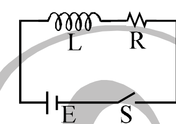
Q.12 There exists a uniform cylindrically symmetric magnetic field directed along the axis of a cylinder but varying with time as $B = kt$. If an electron is released from rest in this field at a distance of 'r' from the axis of cylinder, its acceleration, just after it is released would be (e and m are the electronic charge and mass respectively)

Q.13 An emf of 15 volt is applied in a circuit containing 5 H inductance and 10 Ω resistance. Find the ratio of the currents at time $t = \infty$ and $t = 1$ second.

Q.14 A uniform magnetic field of 0.08 T is directed into the plane of the page and perpendicular to it as shown in the figure. A wire loop in the plane of the page has constant area 0.010 m^2. The magnitude of magnetic field decrease at a constant rate of 3.0×10^{-4} Ts^{-1}. Find the magnitude and direction of the induced emf in the loop.



Q.15 In the circuit shown in figure switch S is closed at time $t = 0$. Find the charge which passes through the battery in one time constant.

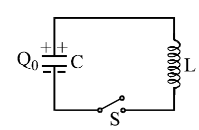


Q.16 Two coils, 1 & 2, have a mutual inductance = M and resistances R each. A current flows in coil 1, which varies with time as: $I_1 = kt^2$, where K is a constant and 't' is time. Find the total charge that has flown through coil 2, between $t = 0$ and $t = T$.

Q.17 In a L–R decay circuit, the initial current at $t = 0$ is I. Find the total charge that has flown through the resistor till the energy in the inductor has reduced to one–fourth its initial value.

Q.18 A charged ring of mass m = 50 gm, charge 2 coulomb and radius R = 2m is placed on a smooth horizontal surface. A magnetic field varying with time at a rate of (0.2 t) Tesla/sec is applied on to the ring in a direction normal to the surface of ring. Find the angular speed attained in a time $t_1 = 10$ sec.

Q.19 A capacitor C with a charge Q_0 is connected across an inductor through a switch S. If at $t = 0$, the switch is closed, then find the instantaneous charge q on the upper plate of capacitor.



Q.20 A uniform but time varying magnetic field $B = Kt - C$; $(0 \le t \le C/K)$, where K and C are constants and t is time, is applied perpendicular to the plane of the circular loop of radius 'a' and resistance R. Find the total charge that will pass around the loop.

Q.21 A coil of resistance 300Ω and inductance 1.0 henry is connected across an alternating voltage of frequency 300/2π Hz. Calculate the phase difference between the voltage and current in the circuit.

Q.22 Find the value of an inductance which should be connected in series with a capacitor of 5 μF, a resistance of 10Ω and an ac source of 50 Hz so that the power factor of the circuit is unity.

Q.23 In an L-R series A.C circuit the potential difference across an inductance and resistance joined in series are respectively 12 V and 16V. Find the total potential difference across the circuit.

Q.24 When 100 volt D.C. is applied across a coil, a current of one ampere flows through it, when 100 V ac of 50 Hz is applied to the same coil, only 0.5 amp flows. Calculate the resistance and inductance of the coil.

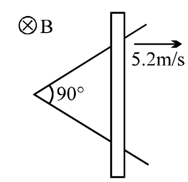
Q.25 A 50W, 100V lamp is to be connected to an ac mains of 200V, 50Hz. What capacitance is essential to be put in seirs with the lamp.

List of recommended questions from I.E. Irodov.

3.288 to 3.299, 3.301 to 3.309, 3.311, 3.313, 3.315, 3.316, 3.326 to 3.329, 3.331, 3.333 to 3.335, 4.98, 4.99, 4.100, 4.134, 4.135, 4.121, 4.124, 4.125, 4.126, 4.136, 4.137, 4.141, 4.144

EXERCISE–II

Q.1 Two straight conducting rails form a right angle where their ends are joined. A conducting bar contact with the rails starts at vertex at the time $t = 0$ & moves symmetrically with a constant velocity of 5.2 m/s to the right as shown in figure. A 0.35 T magnetic field points out of the page. Calculate:

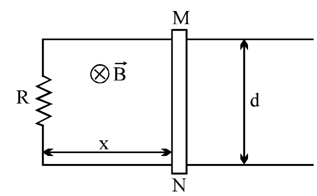


(i) The flux through the triangle by the rails & bar at $t = 3.0$ s.

(ii) The emf around the triangle at that time.

(iii) In what manner does the emf around the triangle vary with time .

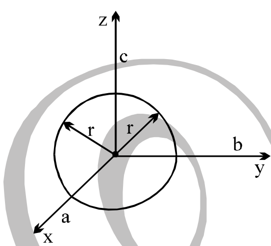
Q.2 Two long parallel rails, a distance l apart and each having a resistance λ per unit length are joined at one end by a resistance R. A perfectly conducting rod MN of mass m is free to slide along the rails without friction. There is a uniform magnetic field of induction B normal to the plane of the paper and directed into the paper. A variable force F is applied to the rod MN such that, as the rod moves, a constant current i flows through R. Find the velocity of the rod and the applied force F as function of the distance x of the rod from R



Q.3 A wire is bent into 3 circular segments of radius $r = 10$ cm as shown in figure . Each segment is a quadrant of a circle, ab lying in the xy plane, bc lying in the yz plane & ca lying in the zx plane.

(i) if a magnetic field B points in the positive x direction, what is the magnitude of the emf developed in the wire, when B increases at the rate of 3 mT/s ?

(ii) what is the direction of the current in the segment bc.



Q.4 Consider the possibility of a new design for an electric train. The engine is driven by the force due to the vertical component of the earths magnetic field on a conducting axle. Current is passed down one coil, into a conducting wheel through the axle, through another conducting wheel & then back to the source via the other rail.

(i) what current is needed to provide a modest 10 – KN force ? Take the vertical component of the earth's field be 10 μT & the length of axle to be 3.0 m .

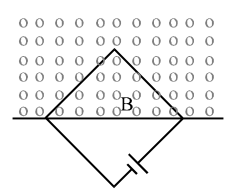
(ii) how much power would be lost for each Ω of resistivity in the rails ?

(iii) is such a train unrealistic ?

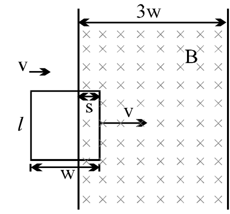
Q.5 A square wire loop with 2 m sides in perpendicular to a uniform magnetic field, with half the area of the loop in the field . The loop contains a 20 V battery with negligible internal resistance. If the magnitude of the field varies with time according to $B = 0.042 - 0.87$ t, with B in tesla & t in sec.

(i) What is the total emf in the circuit ?

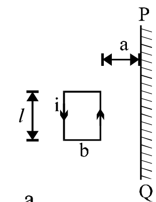
(ii) What is the direction of the current through the battery ?



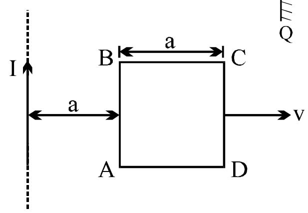
Q.6 A rectangular loop of dimensions l & w and resistance R moves with constant velocity V to the right as shown in the figure. It continues to move with same speed through a region containing a uniform magnetic field B directed into the plane of the paper & extending a distance 3 W. Sketch the flux, induced emf & external force acting on the loop as a function of the distance.



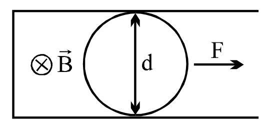
Q.7 A rectangular loop with current I has dimension as shown in figure . Find the magnetic flux ϕ through the infinite region to the right of line PQ.



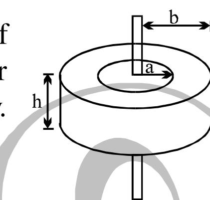
Q.8 A square loop of side 'a' & resistance R moves with a uniform velocity v away from a long wire that carries current I as shown in the figure. The loop is moved away from the wire with side AB always parallel to the wire. Initially, distance between the side AB of the loop & wire is 'a'. Find the work done when the loop is moved through distance 'a' from the initial position.



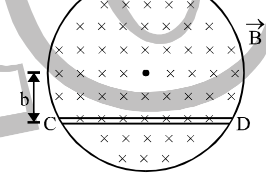
Q.9 Two long parallel conducting horizontal rails are connected by a conducting wire at one end. A uniform magnetic field B exists in the region of space. A light uniform ring of diameter d which is practically equal to separation between the rails, is placed over the rails as shown in the figure. If resistance of ring is λ per unit length, calculate the force required to pull the ring with uniform velocity v.



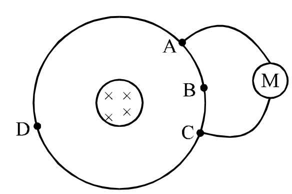
Q.10 A long straight wire is arranged along the symmetry axis of a toroidal coil of rectangular cross–section, whose dimensions are given in the figure. The number of turns on the coil is N, and permeability of the surrounding medium is unity. Find the amplitude of the emf induced in this coil, if the current $i = i_m \cos \omega t$ flows along the straight wire.



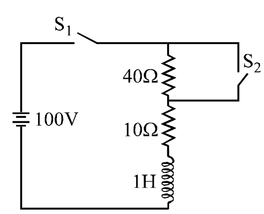
Q.11 A uniform magnetic field $\vec{B}$ fills a cylindrical volumes of radius R. A metal rod CD of length l is placed inside the cylinder along a chord of the circular cross-section as shown in the figure. If the magnitude of magnetic field increases in the direction of field at a constant rate dB/dt, find the magnitude and direction of the EMF induced in the rod.



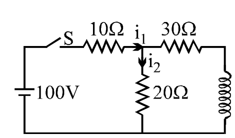
Q.12 A variable magnetic field creates a constant emf E in a conductor ABCDA. The resistances of portion ABC, CDA and AMC are R_1, R_2 and R_3 respectively. What current will be shown by meter M? The magnetic field is concentrated near the axis of the circular conductor.



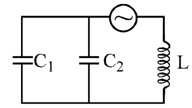
Q.13 In the circuit shown in the figure the switched S_1 and S_2 are closed at time t = 0. After time t = (0.1) ln 2 sec, switch S_2 is opened. Find the current in the circuit at time t = (0.2) ln 2 sec.



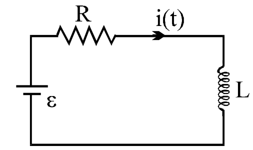
Q.14 Find the values of i_1 and i_2
(i) immediately after the switch S is closed.
(ii) long time later, with S closed.
(iii) immediately after S is open.
(iv) long time after S is opened.



Q.15 Consider the circuit shown in figure. The oscillating source of emf deliver a sinusoidal emf of amplitude e_{max} and frequency ω to the inductor L and two capacitors C_1 and C_2. Find the maximum instantaneous current in each capacitor.



Q.16 Suppose the emf of the battery, the circuit shown varies with time t so the current is given by $i(t) = 3 + 5t$, where i is in amperes & t is in seconds. Take R = 4Ω, L = 6H & find an expression for the battery emf as function of time.



Q.17 A current of 4 A flows in a coil when connected to a 12 V dc source. If the same coil is connected to a 12V, 50 rad/s ac source a current of 2.4 A flows in the circuit. Determine the inductance of the coil. Also find the power developed in the circuit if a 2500 μF capacitor is connected in series with the coil.

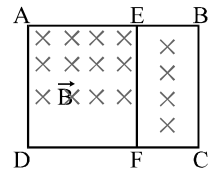
Q.18 An LCR series circuit with 100Ω resistance is connected to an ac source of 200 V and angular frequency 300 rad/s. When only the capacitance is removed, the current lags behind the voltage by 60°. When only the inductance is removed, the current leads the voltage by 60°. Calculate the current and the power dissipated in the LCR circuit.

Q.19 A box P and a coil Q are connected in series with an ac source of variable frequency. The emf of source at 10 V. Box P contains a capacitance of 1μF in series with a resistance of 32Ω coil Q has a self-inductance 4.9 mH and a resistance of 68Ω series. The frequency is adjusted so that the maximum current flows in P and Q. Find the impedance of P and Q at this frequency. Also find the voltage across P and Q respectively.

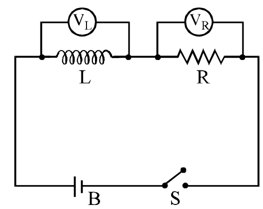
Q.20 A series LCR circuit containing a resistance of 120Ω has angular resonance frequency 4×10^5 rad s^{-1}. At resonance the voltages across resistance and inductance are 60 V and 40 V respectively. Find the values of L and C. At what frequency the current in the circuit lags the voltage by 45°?

EXERCISE–III

Q.1 A rectangular frame ABCD made of a uniform metal wire has a straight connection between E & F made of the same wire as shown in the figure. AEFD is a square of side 1 m & EB = FC = 0.5 m. The entire circuit is placed in a steadily increasing uniform magnetic field directed into the place of the paper & normal to it . The rate of change of the magnetic field is 1 T/s, the resistance per unit length of the wire is 1 Ω/m. Find the current in segments AE, BE & EF. [JEE '93, 5]

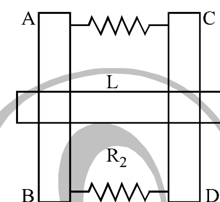


Q.2 An inductance L, resistance R, battery B and switch S are connected in series. Voltmeters V_L and V_R are connected across L and R respectively. When switch is closed:
(A) The initial reading in V_L will be greater than in V_R.
(B) The initial reading in V_L will be lesser than V_R.
(C) The initial readings in V_L and V_R will be the same.
(D) The reading in V_L will be decreasing as time increases.



[JEE'93, 2]

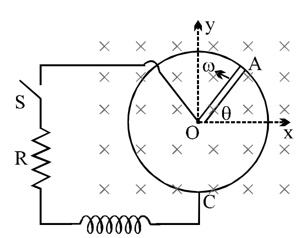
Q.3 Two parallel vertical metallic rails AB & CD are separated by 1 m. They are connected at the two ends by resistance R_1 & R_2 as shown in the figure. A horizontally metallic bar L of mass 0.2 kg slides without friction, vertically down the rails under the action of gravity. There is a uniform horizontal magnetic field of 0.6T perpendicular to the plane of the rails, it is observed that when the terminal velocity is attained, the power dissipated in R_1 & R_2 are 0.76 W & 1.2 W respectively. Find the terminal velocity of bar L & value R_1 & R_2. [JEE '94, 6]



Q.4 Two different coils have self inductance 8mH and 2mH. The current in one coil is increased at a constant rate. The current in the second coild is also increased at the same constant. 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: [JEE'94, 2]

(A) $\frac{I_1}{I_2} = \frac{1}{4}$ (B) $\frac{I_1}{I_2} = 4$ (C) $\frac{W_2}{W_1} = 4$ (D) $\frac{V_2}{V_1} = \frac{1}{4}$

Q.5 A metal rod OA of mass m & length r is kept rotating with a constant angular speed ω in a vertical plane about a horizontal axis at the end O. The free end A is arranged to slide without friction along a fixed conducting circular ring in the same plane as that of rotation. A uniform & constant magnetic induction $\vec{B}$ is applied perpendicular & into the plane of rotation as shown in figure. An inductor L and an external resistance R are connected through a switch S between the point O & a point C on the ring to form an electrical circuit. Neglect the resistance of the ring and the rod. Initially, the switch is open.

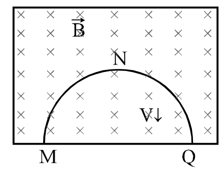


(a) What is the induced emf across the terminals of the switch ?
(b) (i) Obtain an expression for the current as a function of time after switch S is closed.
(ii) Obtain the time dependence of the torque required to maintain the constant angular speed, given that the rod OA was along the positive X-axis at t = 0. [JEE '95, 10]

Q.6 A solenoid has an inductance of 10 Henry & a resistance of 2 Ω. It is connected to a 10 volt battery. How long will it take for the magnetic energy to reach 1/4 of its maximum value ?

[JEE '96, 3]

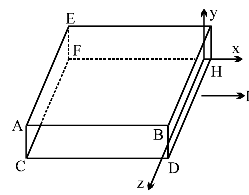
Q.7 Select the correct alternative.
A thin semicircular conducting ring of radius R is falling with its plane vertical in a horizontal magnetic induction $\vec{B}$. At the position MNQ the speed of the ring is v & the potential difference developed across the ring is :



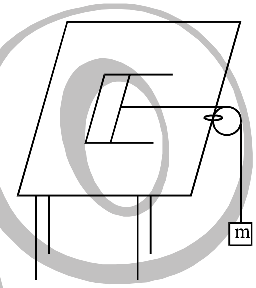
(A) zero
(B) $\frac{Bv\pi R^2}{2}$ & M is at higher potential
(C) π RBV & Q is at higher potential
(D) 2 RBV & Q is at higher potential

[JEE'96, 2]

Q.8 Fill in the blank.
A metallic block carrying current I is subjected to a uniform magnetic induction $B\hat{j}$. The moving charges experience a force $\vec{F}$ given by ______ which results in the lowering of the potential of the face ______.
[assume the speed of the carrier to be v] [JEE '96, 2]



Q.9 A pair of parallel horizontal conducting rails of negligible resistance shorted at one end is fixed on a table. The distance between the rails is L. A conducting massless rod of resistance R can slide on the rails frictionlessly. The rod is tied to a massless string which passes over a pulley fixed to the edge of the table. A mass m, tied to the other end of the string hangs vertically. A constant magnetic field B exists perpendicular to the table. If the system is released from rest, calculate:



(i) the terminal velocity achieved by the rod.
(ii) the acceleration of the mass at the instant when the velocity of the rod is half the terminal velocity.

[JEE '97, 5]

Q.10 A current $i = 3.36\,(1 + 2t) \times 10^{-2}$ A increases at a steady rate in a long straight wire. A small circular loop of radius 10^{-3} m is in the plane of the wire & is placed at a distance of 1 m from the wire. The resistance of the loop is 8.4×10^{-2} Ω. Find the magnitude & the direction of the induced current in the loop.

[REE '98, 5]

Q.11 Select the correct alternative(s). [JEE '98, 3 × 2 = 6 ,4×2=8]
(i) The SI unit of inductance, the Henry, can be written as :
(A) weber/ampere
(B) volt−second/ampere
(C) joule/(ampere)^2
(D) ohm−second

(ii) A small square loop of wire of side l is placed inside a large square loop of wire of side L $(L >> l)$. The loop are co-planar & their centres coincide. The mutual inductance of the system is proportional to :
(A) $\frac{\ell}{L}$ (B) $\frac{\ell^2}{L}$ (C) $\frac{L}{\ell}$ (D) $\frac{L^2}{\ell}$

(iii) A metal rod moves at a constant velocity in a direction perpendicular to its length . A constant, uniform magnetic field exists in space in a direction perpendicular to the rod as well as its velocity. Select the correct statement(s) from the following
(A) the entire rod is at the same electric potential
(B) there is an electric field in the rod
(C) the electric potential is highest at the centre of the rod & decreases towards its ends
(D) the electric potential is lowest at the centre of the rod & increases towards its ends.

(iv) An inductor of inductance 2.0mH,is connected across a charged capacitor of capacitance 5.0μF,and the resulting LC circuit is set oscillating at its natural frequency. Let Q denote the instantaneous charge on the capacitor, and I the current in the circuit .It is found that the maximum value of Q is 200 μC.

(a) when Q=100μC,what is the value of $|dI / dt|$?

(b) when Q=200 μC ,what is the value of I ?

(c) Find the maximum value of I.

(d) when I is equal to one half its maximum value, what is the value of $|Q|$

Q.12 Two identical circular loops of metal wire are lying on a table without touching each other. Loop-A carries a current which increases with time. In response, the loop-B [JEE '99]

(A) remains stationary (B) is attracted by the loop-A

(C) is repelled by the loop-A (D) rotates about its CM, with CM fixed

Q.13 A coil of inductance 8.4 mH and resistance 6Ω is connected to a 12V battery. The current in the coil is 1.0 A at approximately the time

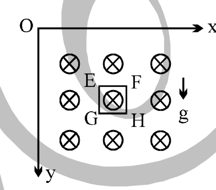
(A) 500 s (B) 20 s (C) 35 ms (D) 1 ms [JEE '99]

Q.14 A circular loop of radius R, carrying current I, lies in x-y plane with its centre at origin. The total magnetic flux through x-y plane is

(A) directly proportional to I (B) directly proportional to R

(C) directly proportional to R^2 (D) zero [JEE '99]

Q.15 A magnetic field $B = (B_0 y / a)\,\hat{k}$ is into the plane of paper in the +z direction. B_0 and a are positive constants. A square loop EFGH of side a, mass m and resistance R, in x-y plane, starts falling under the influence of gravity. Note the directions of x and y axes in the figure. Find



(a) the induced current in the loop and indicate its direction,

(b) the total Lorentz force acting on the loop and indicate its direction,

(c) an expression for the speed of the loop, $v(t)$ and its terminal value. [JEE '99]

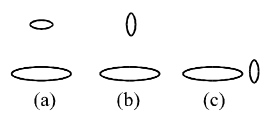
Q.16 Two circular coils can be arranged in any of the three situations shown in the figure. Their mutual inductance will be

(A) maximum in situation (a)

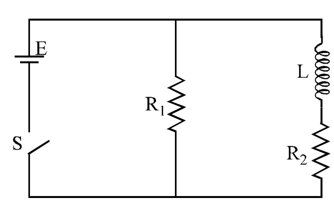
(B) maximum in situation (b)

(C) maximum in situation (c)

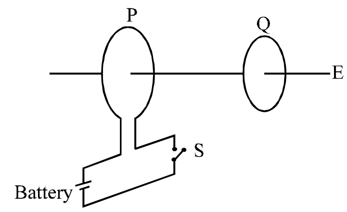
(D) the same in all situations [JEE '2001, (Scr)]



Q.17 An inductor of inductance L = 400 mH and resistors of resistances $R_1 = 2\Omega$ and $R_2 = 2\Omega$ are connected to a battery of e.m.f. E = 12V as shown in the figure. The internal resistance of the battery is negligible. The switch S is closed at time t = 0. What is the potential drop across L as a function of time? After the steady state is reached, the switch is opened. What is the direction and the magnitude of current through R_1 as a function of time? [JEE '2001]



Q.18 As shown in the figure, P and Q are two coaxial conducting loops separated by some distance. When the switch S is closed, a clockwise current I_P flows in P (as seen by E) and an induced current I_{Q1} flows in Q. The switch remains closed for a long time. When S is opened, a current I_{Q2} flows in Q. Then the directions of I_{Q1} adn I_{Q2} (as seen by E) are:

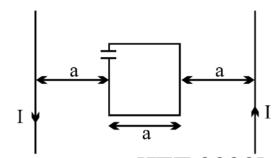


(A) respectively clockwise and anti-clockwise (B) both clockwise
(C) both anti-clockwise (D) respectively anti-clockwise and clockwise

[JEE 2002(Scr), 3]

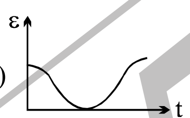
Q.19 A short -circuited coil is placed in a time varying magnetic field. Electrical power is dissipated due to the current induced in the coil. If the number of turns were to be quadrupled and the wire radius halved, the electrical power dissipated would be [JEE 2002(Scr), 3]
(A) halved (B) the same (C) doubled (D) quadrupled

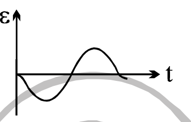
Q.20 A square loop of side 'a' with a capacitor of capacitance C is located between two current carrying long parallel wires as shown. The value of I in the is given as $I = I_0 \sin\omega t$.

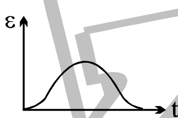


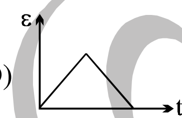
(a) calculate maximum current in the square loop.
(b) Draw a graph between charge on the lower plate of the capacitor v/s time. [JEE 2003]

Q.21 The variation of induced emf (ε) with time (t) in a coil if a short bar magnet is moved along its axis with a constant velocity is best represented as

(A)


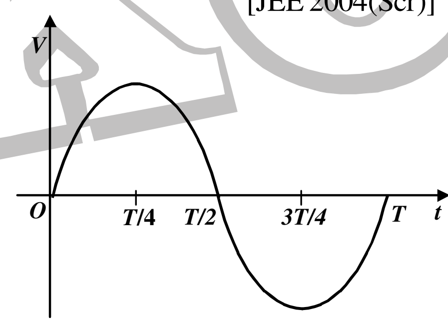
(B)


(C)


(D)


[JEE 2004(Scr)]

Q.22 In an LR series circuit, a sinusoidal voltage $V = V_0 \sin \omega t$ is applied. It is given that L = 35 mH, R = 11 Ω, $V_{rms} = 220$ V, $\frac{\omega}{2\pi} = 50$ Hz and $\pi = 22/7$. Find the amplitude of current in the steady state and obtain the phase difference between the current and the voltage. Also plot the variation of current for one cycle on the given graph. [JEE 2004]

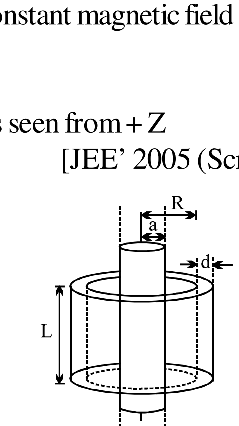


Q.23 An infinitely long cylindrical conducting rod is kept along + Z direction. A constant magnetic field is also present in + Z direction. Then current induced will be
(A) 0 (B) along +z direction
(C) along clockwise as seen from + Z (D) along anticlockwise as seen from + Z

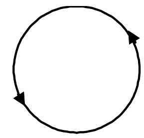
[JEE' 2005 (Scr)]

Q. 24 A long solenoid of radius a and number of turns per unit length n is enclosed by cylindrical shell of radius R, thickness d (d <<R) and length L. A variable current $i = i_0 \sin \omega t$ flows through the coil. If the resistivity of the material of cylindrical shell is ρ, find the induced current in the shell.

[JEE 2005]

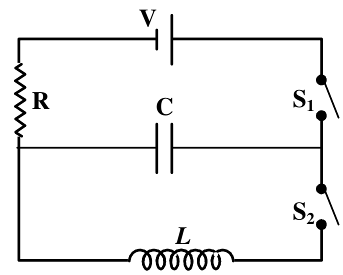


Q.25 In the given diagram, a line of force of a particular force field is shown. Out of the following options, it can never represent



(A) an electrostatic field
(B) a magnetostatic field
(C) a gravitational field of a mass at rest
(D) an induced electric field [JEE 2006]

Comprehension –I



The capacitor of capacitance C can be charged (with the help of a resistance R) by a voltage source V, by closing switch S_1 while keeping switch S_2 open. The capacitor can be connected in series with an inductor 'L' by closing switch S_2 and opening S_1.

Q.26 Initially, the capacitor was uncharged. Now, switch S_1 is closed and S_2 is kept open. If time constant of this circuit is τ, then
(A) after time interval τ, charge on the capacitor is CV/2
(B) after time interval 2τ, charge on the capacitor is $CV(1-e^{-2})$
(C) the work done by the voltage source will be half of the heat dissipated when the capacitor is fully charged.
(D) after time interval 2τ, charge on the capacitor is $CV(1-e^{-1})$ [JEE 2006]

Q.27 After the capacitor gets fully charged, S_1 is opened and S_2 is closed so that the inductor is connected in series with the capacitor. Then,
(A) at $t = 0$, energy stored in the circuit is purely in the form of magnetic energy
(B) at any time $t > 0$, current in the circuit is in the same direction
(C) at $t > 0$, there is no exchange of energy between the inductor and capacitor
(D) at any time $t > 0$, instantaneous current in the circuit may $V\sqrt{\frac{C}{L}}$ [JEE 2006]

Q.28 If the total charge stored in the LC circuit is Q_0, then for $t \geq 0$
(A) the charge on the capacitor is $Q = Q_0 \cos\left(\frac{\pi}{2} + \frac{t}{\sqrt{LC}}\right)$
(B) the charge on the capacitor is $Q = Q_0 \cos\left(\frac{\pi}{2} - \frac{t}{\sqrt{LC}}\right)$
(C) the charge on the capacitor is $Q = -LC\frac{d^2Q}{dt^2}$
(D) the charge on the capacitor is $Q = -\frac{1}{\sqrt{LC}}\frac{d^2Q}{dt^2}$ [JEE 2006]

<u>Comprehension –IV</u>

Magler Train: This train is based on the Lenz law and phenomena of electromagnetic induction. In this there is a coil on a railway track and magnet on the base of train. So as train is deviated then as is move down coil on track repel it and as it move up then coil attract it.

Disadvantage of magler train is that as it slow down the forces decreases and as it moves forward so due to Lenz law coil attract it backward.

Due to motion of train current induces in the coil of track which levitate it.

Q.29 What is the advantage of the train? [JEE 2006]

(A) Electrostatic force draws the train (B) Gravitational force is zero.

(C) Electromagnetic force draws the train (D) Dissipative force due to friction are absent

Q.30 What is the disadvantage of the train?

(A) Train experience upward force due to Lenz's law.

(B) Friction force create a drag on the train.

(C) Retardation

(D) By Lenz's law train experience a drag [JEE 2006]

Q.31 Which force causes the train to elevate up

(A) Electrostatic force (B) Time varying electric field

(C) magnetic force (D) Induced electric field [JEE 2006]

Q.32 Match the following Columns

Column 1	Column 2
(A) Dielectric ring uniformly charged	(P) Time independent electrostatic field out of system
(B) Dielectric ring uniformly charged rotating with angular velocity .	(Q) Magnetic field
(C) Constant current in ring i_0	(R) Induced electric field
(D) current i = i_0 cos ωt in ring	(S) Magnetic moment

[JEE 2006]

ANSWER KEY

EXERCISE–I

Q.1 $10\,\mu V$ Q.2 $\lambda V_y B_0$ Q.3 $5.0\,\mu V$ Q.4 I^{-1} Q.5 2 N

Q.6 $\frac{\mu_0 i a^2 \pi}{2Rb}$ Q.7 $\frac{mgR}{B^2 l^2}$ Q.8 $\frac{1}{3}$ A Q.9 0.8 Q.10 $\frac{LE^2}{2R_1^2}$

Q.11 $\frac{1}{15}$ A, $\frac{1}{10}$ A

Q.12 $\frac{erk}{2m}$ directed along tangent to the circle of radius r, whose centre lies on the axis of cylinder.

Q.13 $\frac{e^2}{e^2 - 1}$ Q.14 $3\mu V$, clockwise Q.15 $\frac{EL}{eR^2}$ Q.16 $kMT^2/(R)$ Q.17 $LI/2R$

Q.18 200 rad/sec Q.19 $q = Q_0 \sin\left(\sqrt{\frac{1}{LC}}\,t + \frac{\pi}{2}\right)$ Q.20 $C\pi a^2/R$ Q.21 $\pi/4$

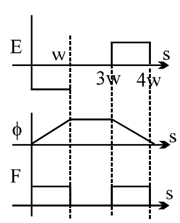
Q.22 $\frac{20}{\pi^2} \cong 2H$ Q.23 20 V Q.24 R = 100W, $\sqrt{3}/\pi$ Hz Q.25 C = 9.2 μF

EXERCISE–II

Q.1 (i) 85.22 Tm^2; (ii) 56.8 V; (iii) linearly Q.2 $\frac{I(R+2\lambda x)}{Bd}, \frac{2I^2 m\lambda(R+2\lambda x)}{B^2 d^2} + BId$

Q.3 (i) 2.4×10^{-5} V (ii) from c to b Q.4 (i) 3.3×10^{8} A, (ii) 1.0×10^{17} W, (iii) totally unrealistic

Q.5 21.74 V, anticlockwise Q.6



Q.7 $\phi = \frac{\mu_0}{2\pi} IL\, ln \frac{a+b}{a}$

Q.8 $\frac{\mu_0^2 I^2 a^2 V}{4\pi^2 R}\left[\frac{2}{3a} + \frac{2}{a}\ell n\frac{3}{4}\right] = \frac{\mu_0^2 I^2 a V}{2\pi^2 R}\left[\frac{1}{3} + \ell n\frac{3}{4}\right]$ Q.9 $\frac{4B^2 \nu d}{\pi\lambda}$ Q.10 $\frac{\mu_0 h\omega i_m N}{2\pi}\, ln\frac{b}{a}$

Q.11 $\frac{l}{2}\frac{dB}{dt}\sqrt{R^2-\frac{l^2}{4}}$ Q.12 $\frac{E\,R_1}{R_1R_2+R_2R_3+R_3R_1}$ Q.13 67/32 A

Q.14 (i) $i_1 = i_2 = 10/3$ A, (ii) $i_1 = 50/11$ A ; $i_2 = 30/11$ A, (iii) $i_1 = 0$, $i_2 = 20/11$ A, (iv) $i_1 = i_2 = 0$

Q.15 $C_2 = \frac{\varepsilon_{max}}{\left(1+\frac{C_1}{C_2}\right)\left(\omega L-\frac{1}{\omega(C_1+C_2)}\right)}$; $C_1 = \frac{\varepsilon_{max}}{\frac{C_2}{C_1}\left(1+\frac{C_1}{C_2}\right)\left(\omega L-\frac{1}{\omega(C_1+C_2)}\right)}$ Q.16 $42 + 20t$ volt

Q.17 0.08 H, 17.28 W Q.18 2A, 400W Q.19 77Ω, 97.6Ω, 7.7V, 9.76V

Q.20 0.2 mH, $\frac{1}{32}\mu F$, 8×10^5 rad/s

EXERCISE–III

Q.1 $I_{EA}=\frac{7}{22}$ A ; $I_{BE}=\frac{3}{11}$ A ; $I_{FE}=\frac{1}{22}$ A Q.2 A, D Q.3 $V = 1\ ms^{-1}$, $R_1 = 0.47\ \Omega$, $R_2 = 0.30\ \Omega$

Q.4 ACD

Q.5 (a) $E = \frac{1}{2}B\omega r^2$ (b) (i) $I = \frac{B\omega r^2\left[1-e^{-Rt/L}\right]}{2R}$, (ii) $\tau = \frac{mgr}{2}\cos\omega t + \frac{\omega B^2 r^4}{4R}(1-e^{-Rt/L})$

Q.6 $t = \frac{L}{R}\ln 2 = 3.47$ sec Q.7 D Q.8 $evB\hat{k}$, ABDC

Q.9 (i) $V_{terminal} = \frac{mgR}{B^2Z^2}$; (ii) $\frac{g}{2}$ Q.10 $1.6\pi\times10^{-13}$ A = 50.3 pA

Q.11 (i) A, B, C, D, (ii) B, (iii) B, (iv) (a) 10^4 A/s (b) 0 (c) 2A (d) $100\sqrt{3}\ \mu C$

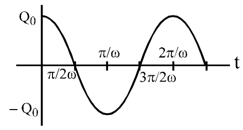
Q.12 C Q.13 D Q.14 D

Q.15 (a) $i = \frac{B_0 a v}{R}$ in anticlockwise direction, v = velocity at time t, (b) $F_{nett} = B_0^2 a^2 V/R$,

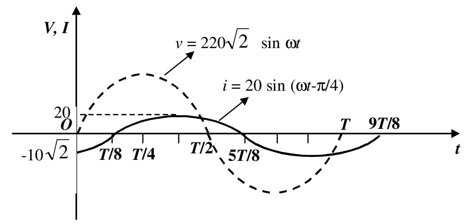
(c) $V = \frac{mgR}{B_0^2 a^2}\left(1-e^{-\frac{B_0^2 a^2 t}{mR}}\right)$

Q.16 A Q.17 $12e^{-5t}$, $6e^{-10t}$

Q.18 D Q.19 B

Q.20 (a) $I_{max} = \frac{\mu_0 a}{\pi} C I_0 \omega^2 ln 2$, (b) 

Q.21 B

Q.22 $20\,A, \frac{\pi}{4}, \therefore$ Steady state current $i = 20 \sin \pi\left(100t - \frac{1}{4}\right)$ 

Q.23 A Q.24 $I = \frac{(\mu_0 n i_0 \omega \cos \omega t)\pi a^2 (Ld)}{\rho 2\pi R}$

Q.25 A,C Q.26 B Q.27 D Q.28 C

Q.29 D Q.30 D Q.31 C

Q.32 (A) P; (B) P, Q, S; (C) Q,S ; (D) Q, R, S