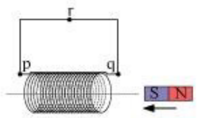
Class: 12
Subject: Physics
Topic: Electromagnetic induction
No. of Questions: 36

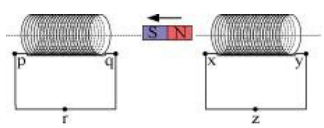
1. Predict the direction of induced current in the situations described by the following Figs. 6.18 (a) to (f).

Sol.

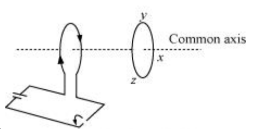
(a)



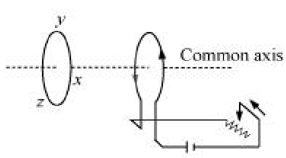
(b)



(c)

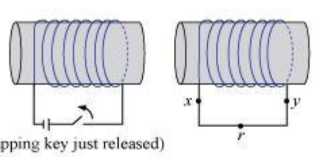


(d) (Tapping key just closed)



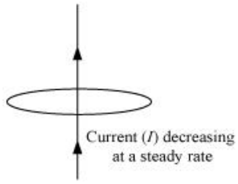
(Rheostat setting being changed)

(e)



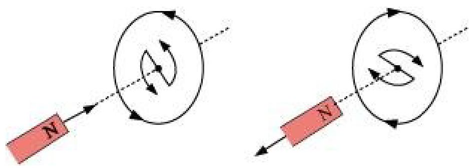
(Tapping key just released)

(f)



Sol.

The direction of the induced current in a closed loop is given by Lenz’s law. The given pairs of figures show the direction of the induced current when the North pole of a bar magnet is moved towards and away from a closed loop respectively.



Using Lenz’ rule, the direction of the induced current in the given situation can be predicated as follows:

The direction of the induced current is along **qrpq.**

The direction of the induced current is along **prqp.**

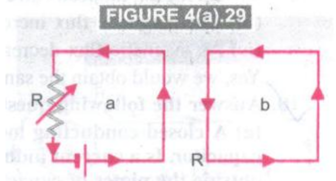
The direction of the induced current is along **yzxy.**

The direction of the induced current is along **xryx**.

No current is induced since the field lines are lying in the plane of the closed loop.

2. If resistance R in circuit ‘a’ of Fig. 4(a).29 be decreased, what will be the direction of induced current in the circuit ‘b’?

FIGURE 4(a).29



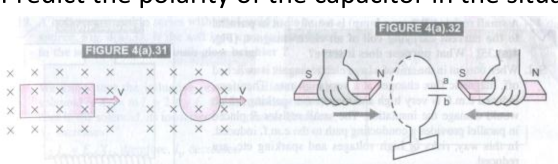
Sol.

When R is decreased, current in ‘a’ increases. An e.m.f. is induced in ‘b’ which opposes the increase of current in ‘b’. The induced current must, therefore, be anticlockwise.

3. A bar magnet falls through a metal ring. Will its acceleration be equal to ‘g’?
Sol.
No, acceleration of the magnet will not be equal to g. It will be less than ‘g’. This is because as the magnet falls, amount of magnetic flux linked with the ring changes. An induced current is developed in the ring which opposes the downward motion of the magnet. After the magnet has crossed the metal ring, amount of magnetic flux linked with the ring goes on decreasing. An induced current developes in the ring and opposes the fall of the magnet. Therefore, downward acceleration of the magnet continues to be less than ‘g’.

4. In the above problem, if the ring si cut somewhere, what would be the answer?
Sol.
If the metal ring is cut somewhere, e.m.f. will induced, but no induced current can flow. Therefore, there will be no opposing force on the falling magnet. Hence acceleration of falling magnet will remain equal to ‘g’ throughout.

5. Answer the following questions:
(a) A closed conducting loop move normal to the electric field between the plates of large capacitor. Is a current induced in the loop when it is (i) wholly inside the capacitor (ii) partially outside the plates of capacitor. Electric field is normal to the plane of the loop.
(b) A rectangular loop and a circular loop are moving out of a uniform magnetic field region to a field free region with a constant velocity, Fig. 4(a). 31. In which loop do you expect the induced e.m.f. to be constant during the passage out of the field region, the field is normal to the loops?
(c) Predict the polarity of the capacitor in the situation described by Fig. 4(a).32:



Sol.

(a) No, current is not induced by change in electric flux.
(b) The induced e.m.f. is expected to be constant in the case of a rectangular loop. In case of a circular loop, the rate of change of area of the loop during the passage out of the field region is not constant, whereas it is constant for rectangular loop, Fig. 4(a).31
(c) In the situation shown Fig. 4(a).32. a will become positive with respect to b, as current induced is in clockwise direction.

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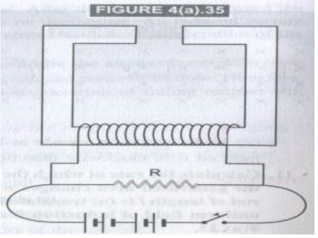
6. A small resistor R (say, a lamp) is usually put in parallel to the current carrying coil of an electromagnet, [Fig. 4(a).35]. What purpose does it serve?

FIGURE 4(a).35



Sol.

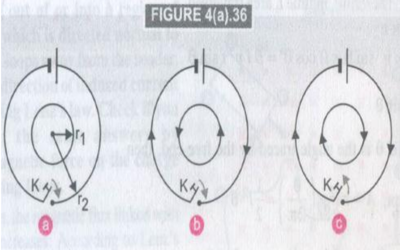
When current in the coil of large electromagnet is switched off, magnetic flux changes at a very high rate. Therefore, induced e.m.f. is very high and may cause sparking which would damage the insulation. The small resistor R placed in parallel provides a conducting path to the e.m.f. induced. In this way, risks of high voltages and sparking etc. Are reduced.

7. In co-axial concentric coils of radius r_1 and r_2 such that $r_1 << r_2$, Fig. 4(a).36, find direction of induced current when K is (i) pressed (ii) released.

Sol.

(i) When key K is pressed, current in outer coil increases from 0 to maximum. Current induced in inner coil opposes the growth of current in outer coil, by flowing in the opposite direction, i.e. in anticlockwise direction as shown in Fig. 4(a).36

FIGURE 4(a).36



(ii) When key K is released, current in outer coil decreases from maximum to zero. Current induced in inner coil opposes the decay of current in outer coil, by flowing in the same direction, i.e. in clockwise direction as shown in Fig. 4(a).36.

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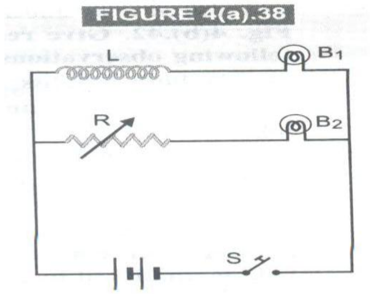
8. Answer the following questions:
Figure 4(a).38 shows an inductor L and resistance R connected in parallel to a battery through a switch. The resistance of R is the same as that of the coil that makes L. Two identical bulbs are put in each arm of the circuit. (i) Which of the bulb lights up earlier when S is closed? (ii) Will the bulb be equally bright after some time?

FIGURE 4(a).38



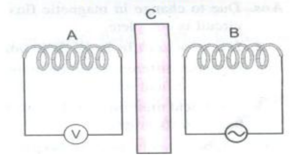
Sol.

(i) The bulb B_2 in arm R lights up earlier because induced e.m.f. across L opposes growth of current in B_1.

(ii) Yes, both the bulbs will be equally bright after some time. This is because once the current has reached its maximum value, self inductance play no role. Resistance of L and R is same: and both the bulbs are identical and are connected to same source of potential difference.

9. A coil A is connected to a voltmeter V and the other coil B to an alternating current source, Fig. 4(a).40. If a large copper sheet is placed between the two coils, how does the induced emf in coil A change due to current in coil B?

FIGURE 4(a).40



Sol.

In the absence of copper sheet, emf will be induced in coil A due to mutual induction between the two coils A and B. Voltmeter in coil A will show deflection as per the magnitude of emf induced.

When a copper sheet is placed between the two coils, eddy currents are set up in the sheet due to change in magnetic flux linked with C. Magnetic flux linked with coil A, due to coil B and due to opposing eddy currents in C will decrease. Therefore, rate of change of magnetic flux in A will decrease. Hence emf induced in A will decrease.

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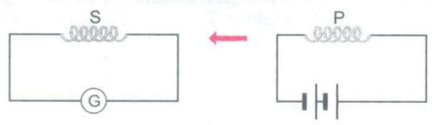
10. When primary coil P is moved towards secondary coil S, Fig. 4(b).41, the galvanometer shows momentary deflection. What can be done to have larger deflection in the galvanometer with same battery? State the related law?

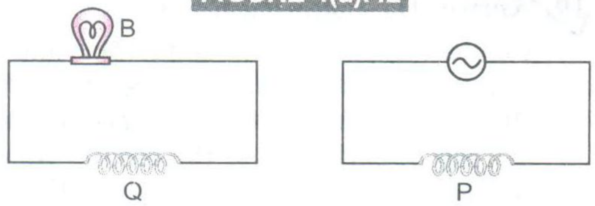
FIGURE 4(a).41



Sol.
To have deflection in the galvanometer with the same battery, coil P has to be moved faster towards. S.
The law governing this phenomenon is Faraday's 2nd law of electromagnetic induction.

11. A coil Q is connected to low voltage bulb B and placed near another coil P as shown in Fig. 4(b).42. Give reasons to explain the following observations:
(a) The bulb B lights
(b) Bulb gets dimmer if coil Q is moved towards left.

FIGURE 4(a).42



Sol.

(i) The bulb B lights on account of emf induced in coil Q due to mutual induction between P and Q.
(ii) (ii) When coil Q is moved towards left, magnetic flux linked with Q decreases, and may even reduce to zero at some distance. The emf induced may decrease and the bulb B gets dimmer.

12. A uniformly wound solenoid coil of self-inductance 1.8×10^{-4} H and resistance 6 Ω is broken up into two identical coils. These identical coils are then connected across a 12 V battery of negligible resistance. The time constant for the current in the circuit is

A. 0.3×10^{-4} s
B. 0.3×10^{-3} s
C. 0.3×10^{-2} s
D. 0.3 μs

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Right Answer Explanation:

Self inductance of each coil = $\frac{1}{2} \times (1.8 \times 10^{-4}) =$ 0.9×10^{-4} H. Resistance of each coil = $\frac{6}{2} = 3\ \Omega$.

When two such coils are connected in parallel, the self-inductance of the combination is $L = 0.45 \times 10^{-4}$ H and the resistance of the combination is $R = 1.5\ \Omega$.

$\therefore$ Time constant = $\frac{L}{R} = \frac{0.45 \times 10^{-4}}{1.5} = 0.3 \times 10^{-4}$ s

Hence the correct choice is (1).

13. A uniformly wound solenoid coil of self-inductance 1.8×10^{-4} H and resistance 6 Ω is broken up into two identical coils. These identical coils are then connected across a 12 V battery of negligible resistance, the steady current through the battery is

A. 8 μA
B. 0.8 A
C. 8 mA
D. 8 A

Right Answer Explanation:

Steady current $I_0 = \frac{V}{R} = \frac{12}{1.5} = 8$ A which is choice (4).

14. A square loop of side l, mass m and resistance R falls vertically into a uniform magnetic field directed perpendicular to the plane of the coil. The height h through which the loop falls, so that it attains terminal velocity on entering the region of magnetic field is given by

A. $\frac{mgR}{2Bl}$
B. $\frac{m^2gR^2}{2B^2l^2}$
C. $\frac{mgR^2}{4B^3l^3}$
D. $\frac{m^2gR^2}{2B^4l^4}$

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Right Answer Explanation:

Velocity $v = \sqrt{2gh}$. Induced emf $e = Blv = Bl\sqrt{2gh}$.

Therefore, the induced current in the loop is

$$I = \frac{Bl\sqrt{2gh}}{R}$$

$\therefore$ Force $F = BIl = \dfrac{B^2l^2\sqrt{2gh}}{R}$

The loop will attain terminal velocity if this force equals mg, i.e. if

$$\frac{B^2l^2\sqrt{2gh}}{R} = mg$$

which gives $h = \dfrac{m^2gR^2}{2B^4l^4}$

15. The mutual inductance between two planar concentric rings of radii r_1 and r_2 (with $r_1 > r_2$) placed in air is given by

A. $\dfrac{\mu_0\pi r_2^2}{2r_1}$

B. $\dfrac{\mu_0\pi r_1^2}{2r_2}$

C. $\dfrac{\mu_0\pi(r_1 + r_2)^2}{2r_1}$

D. $\dfrac{\mu_0\pi(r_1 + r_2)^2}{2r_2}$

Right Answer Explanation:

Magnetic field due to the larger coil at its centre is

$$B = \frac{\mu_0 I}{2r_1}$$

where I is the current in the larger coil. Flux through the inner coil is

$$\phi = B \times \pi r_2^2 = \frac{\mu_0 I}{2r_1} \times \pi r_2^2$$

But $\phi = MI$. Therefore

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

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16. A small square loop of wire of side l is placed inside a large square loop of wire of side L (L >> l). The loops are coplanar and their centres coincide. The mutual inductance of the system is proportional to

A. $\frac{l}{L}$

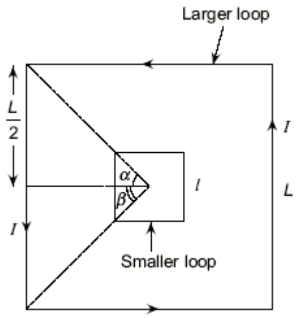
B. $\frac{l^2}{L}$

C. $\frac{L}{l}$

D. $\frac{L^2}{l}$

Right Answer Explanation:

Refer to figure. The magnetic field due a current I in the large loop at its centre is



$$B = 4 \text{ times that due to one side}$$
$$= 4 \times \frac{\mu_0}{4\pi} \frac{I}{(L/2)} (\cos\alpha + \cos\beta)$$
$$= \frac{2\mu_0 I}{\pi L} (\cos 45° + \cos 45°)$$
$$= \frac{2\sqrt{2}\mu_0 I}{\pi L} \quad (\because \alpha = \beta = 45°)$$

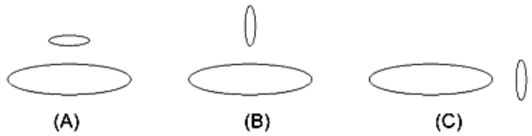
The magnetic flux that links the larger loop with the smaller loop of side l ($l << L$) is

$$\phi_{12} = Bl^2 = \frac{2\sqrt{2}\mu_0 I l^2}{\pi L}$$

$\therefore$ Mutual inductance $M_{12} = \frac{\phi_{12}}{I} = \frac{2\sqrt{2}\mu_0}{\pi}\left(\frac{l^2}{L}\right)$

i.e. $M_{12} \propto \frac{l^2}{L}$, which is choice (2).

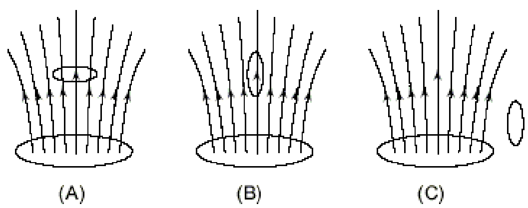
17. Two circular coils can be arranged in any of the three situations shown in the figure. Their mutual inductance will be



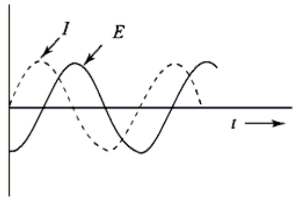
A. maximum in situation (A)
B. maximum in situation (B)
C. maximum in situation (C)
D. the same in all situations

Right Answer Explanation:

The mutual inductance between the two coils in orientation (A) is the maximum since the flux linkage in (A) is the maximum as shown in fig.



18. . When an A.C. source of e.m.f. $E = E_0 \sin(100t)$ is connected across a circuit, the phase difference between the e.m.f. E and the current I in the circuit is observed to be $\pi/4$, as shown in the figure below. If the circuit consists possibly only of R-C or R-L or L-C in series, what will be the relation between the two elements of the circuit?



A. R = 1 kΩ, C = 10 μF
B. R = 1 kΩ, C = 1 μF
C. R = 1 kΩ, L = 10 H
D. R = 1 kΩ, L = 1 H

Right Answer Explanation:

Given $E = E_0 \sin(100\,t)$. Comparing this with $E = E_0 \sin \omega t$, we have $\omega = 100$ rad s^{-1}. It follows from the figure that the current leads the e.m.f. which is true only for *R-C* circuit, and not for *R-L* circuit. Hence the circuit does not contain an inductor. Thus choices (3) and (4) are not possible. For *R-C* circuit, the phase difference between *E* and *I* is given by

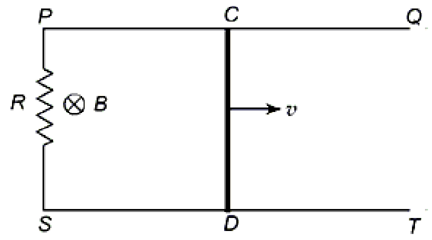
$$\tan \phi = \frac{1}{\omega RC} \qquad \text{(i)}$$

Given $\phi = \pi/4$. Also $\omega = 100$ rad s^{-1}. Using these values in (i), we get

$$\tan\left(\frac{\pi}{4}\right) = \frac{1}{100\,RC} \quad \text{or} \quad RC = \frac{1}{100}$$

This relation between *R* and *C* is satisfied by choice (1) and not choice (2). Hence the correct choice is (1).

19. Two parallel wires PQ and ST, placed a distance w apart are connected by a resistor R as shown in the figure and placed in a magnetic field B which is perpendicular to the plane containing the wires. A rod CD connects the two wires. The power spent to slide the rod CD with a velocity v along the wires is (neglect the resistance of the wires and the rod)



A. $\frac{Bwv}{R}$

B. $\frac{Bwv}{R^2}$

C. $\frac{(Bwv)^2}{R}$

D. $\left(\frac{Bwv}{R}\right)^2$

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Right Answer Explanation:

When wire CD is made to slide on wires PQ and ST, the flux linked with the circuit changes with time and hence an emf is induced in the circuit, which is given by

$$|e| = \frac{d\phi}{dt} = \frac{d}{dt}(BA) = B\frac{dA}{dt}$$

If wire CD moves a distance dx is time dt, then $A = wdx$ (here $w = CD$) and

$$|e| = B\frac{d}{dt}(wdx) = Bw\frac{dx}{dt} = Bwv$$

The induced current is

$$I = \frac{e}{R} = \frac{Bwv}{R}$$

This current is caused by the motion of wire CD. From Lenz's law, the current I opposes the motion of wire CD. Therefore, work has to be done to slide the wire CD. Now, the magnetic force on wire CD (of length w) is

$$F = BIw = B\left(\frac{Bwv}{R}\right)w = \frac{B^2w^2v}{R} \quad (1)$$

Work done in sliding wire CD through a small distance dx in time dt is

$$dW = Fdx$$

Therefore, the work done per second is

$$P = \frac{dW}{dt} = F\frac{dx}{dt} = Fv$$

Using (1), we get

$$P = \frac{B^2w^2v^2}{R}$$

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20. An air plane, with 20 m wingspread is flying at 250 ms^{-1} parallel to the earth's surface at a place where the horizontal component of earth's magnetic field is 2 × 10^{-5} T and angle of dip is 60°. The magnitude of the induced emf between the tips of the wings is

A. $\frac{1}{10}$ V
B. $\frac{\sqrt{2}}{10}$ V
C. $\frac{\sqrt{3}}{10}$ V
D. $\frac{1}{5}$ V

Right Answer Explanation:
As the air plane is flying horizontally parallel to the earth's surface, the flux linked with it will be due to the vertical component B_V of the earth's field.
Now

$$B_V = B_H \tan\theta = 2 \times 10^{-5} \times \tan 60^\circ$$
$$= 2\sqrt{3} \times 10^{-5}\ \text{Wbm}^{-2}$$

$\therefore$ Induced emf is $|e| = B_V l v = 2\sqrt{3} \times 10^{-5} \times 20 \times 250$

$= \frac{\sqrt{3}}{10}$ V, which is choice (3).

21. A coil of metal wire is kept stationary with its plane perpendicular to a uniform magnetic field directed along the positive x-axis. The current induced in the coil

A. circulates in anti-clockwise direction when viewed from the x-axis
B. circulates in clockwise direction when viewed from the x-axis
C. is perpendicular to the direction of the magnetic field
D. is zero

Right Answer Explanation:
If the coil is not moved in a magnetic field, the magnetic flux linked with the coil does not change. Hence, no emf or current is induced in the coil. Thus, the correct choice is (4).

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22. In a car spark coil, an emf of 40,000 volts is induced in its secondary windings when the current in its primary winding changes from 4 A to zero in 10 μs. The mutual inductance between the primary and the secondary windings of the spark coil is

A. 0.1 H
B. 0.3 H
C. 0.2 H
D. 0.4 H

Right Answer Explanation:

$$e = -M\frac{\Delta I}{\Delta t}$$

or $$M = -\frac{e\Delta I}{\Delta I} = -\frac{40{,}000\times(10\times10^{-6})}{(-4-0)}$$

$$= 0.1 \text{ H}$$

The correct choice is (1).

23. In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of 2.0 $\times$ 10^{10} Hz. What is the wavelength of the wave?

A. cm
B. 1.5 cm
C. cm
D. cm

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Right Answer Explanation:

$$\lambda = \frac{c}{v} = \frac{3\times10^8}{2.0\times10^{10}} = 1.5\times10^{-2}\text{ m} = 1.5\text{ cm, which}$$

is choice (2)

24. In Q. 12, if the peak value of the electric field is 60 Vm^{-1}, the average energy density (in Jm^{-3}) of the magnetic field of the wave will be (given $\mu_0 = 4\pi\times10^{-7}$ Fm^{-1})

A. $2\pi\times10^{-7}$
B. $4\pi\times10^{-7}$
C. $\frac{1}{2\pi}\times10^{-7}$
D. $\frac{1}{4\pi}\times10^{-7}$

Right Answer Explanation:

$$B_0 = \frac{E_0}{c} = \frac{60}{3\times10^8} = 2.0\times10^{-7}\ \text{T}$$

$$u_m = \frac{B_0^2}{4\mu_0} = \frac{\left(2.0\times10^{-7}\right)^2}{4\times4\pi\times10^{-7}} = \frac{1}{4\pi}\times10^{-7}\ \text{Jm}^{-3}$$

Hence the correct choice is (4).

25. An electromagnetic wave is produced by oscillating electric and magnetic fields **E** and **B**. Choose the only incorrect statement from the following.

A. **E** is perpendicular to **B**.
B. **E** is perpendicular to the direction of propagation of the wave.
C. **B** is perpendicular to the direction of propagation of the wave.
D. **E** is parallel to **B**.

Right Answer Explanation:
The only incorrect statement is choice (4).

26. Which of the following pairs of space and time varying **E** = ($\hat{i}E_x + \hat{j}E_y + \hat{k}E_z$) and **B** = ($\hat{i}B_x + \hat{j}B_y + \hat{k}E_z$) would generate a plane electromagnetic wave travelling in the z-direction?

A. E_x, B_z
B. E_y, B_z
C. E_z, B_x
D. E_x, B_y

Right Answer Explanation:
The correct choice is (4).

27. What is the self inductance of an air – core solenoid, 3.14 m long, cross-sectional area 10^{-3} m^2 and having 500 turns?

A. 0.1 mH
B. 0.2 mH
C. 0.3 mH
D. 0.4 mH

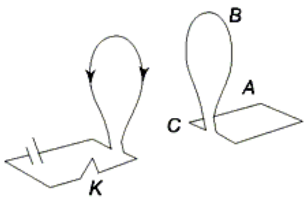
Right Answer Explanation:

$$L = \frac{\mu_0 N^2 A}{l} = \frac{4\pi\times10^{-7}\times(500)^2\times10^{-3}}{3.14}$$

$$= 10^{-4}\ \text{H} = 0.1\ \text{mH}$$

Hence the correct choice is (1).

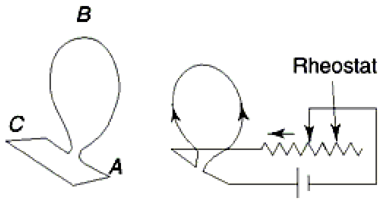
28. The figure below shows two coils placed close to each other. When the key K is pressed so that a current starts building up in one of the coils, then



A. a current flows along ABC in the other coil
B. a current flows along CBA in the other coil
C. no current flows in the other coil
D. an alternating current flows in the other coil

Right Answer Explanation:
When the key is pressed, a current starts building up in the coil and the magnetic flux through the neighbouring coil increases. By Lenz's law, the induced current in this coil must oppose this increase in flux. Hence the induced current must flow in the anti-clockwise direction, i.e. along *ABC*.

29. The figure below shows two coils placed close to each other. When the current through one coil is decreased gradually by shifting the position of the rheostat, then



A. a current flows along ABC in the other coil
B. a current flows along CBA in the other coil
C. no current flows in the other coil
D. an alternating current flows in the other coil

Right Answer Explanation:
As the rheostat is being shifted, the resistance in series with the coil is decreasing and the curren in the coil is increasing. Hence, the magnetic flux through the neighbouring coil increases. By Lenz's law, the induced current in the coil must oppose the increase in flux. Therefore, the induced current must flow in the clockwise direction, i.e. along CBA. Hence, the correct choice is (2).

30. If the flux of magnetic induction through a coil of resistance R and having n turns changes from ϕ_1 to ϕ_2, then the magnitude of the charge that passes through the coil is

A. $\frac{(\phi_2 - \phi_1)}{R}$

B. $\frac{n(\phi_2 - \phi_1)}{R}$

C. $\frac{(\phi_2 - \phi_1)}{nR}$

D. $\frac{nR}{(\phi_2 - \phi_1)}$

Right Answer Explanation:

Induced emf is $|e| = n\,\frac{\Delta\Phi}{\Delta t}$. Now

$$\Delta q = I\,\Delta t$$

$$= \frac{e}{R}\,\Delta t = \frac{n\Delta\Phi}{R\Delta t} \times \Delta t = \frac{n\Delta\Phi}{R}$$

$$= \frac{n(\Phi_2 - \Phi_1)}{R}$$

31. A metallic wheel with 8 metallic spokes, each of length r, is rotating at an angular frequency w in a plane perpendicular to the magnetic field B. The magnitude of the induced emf between the axle and the rim of the wheel is

A. $\frac{1}{2}\omega r^2 B$

B. $2\,\omega r^2 B$

C. $4\,\omega r^2 B$

D. $8\,\omega r^2 B$

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Right Answer Explanation:

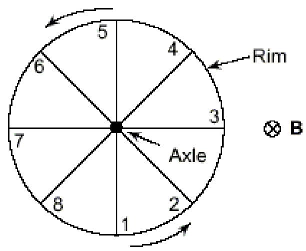
Refer to figure. Let ν be the frequency of rotation. The time taken for 1 full rotation is $T = 1/\nu$. Therefore, rate of change of area is

$$\frac{A}{T} = \frac{\pi r^2}{T} = \pi r^2 \nu$$

Now, the emf induced between the axle and rim is $e = B \times$ rate of change of area

$$= B \times \pi r^2 \nu = \frac{1}{2} B r^2 \omega \quad (\because \omega = 2\pi\nu)$$

Since the same emf is produced between the ends of each spoke, and these emfs are in parallel as is evident from figure, the net emf between the axle and the rim of the wheel will be the same as that across each spoke. We notice that all the eight spokes are connected with one end at the rim and the other at the axle. Hence the magnitude of the net emf between the axle and the rim is independent of the number of spokes.



32. A uniformly wound solenoid coil of self-inductance 1.8 $\times$ 10^{-4} H and resistance 6 Ω is broken up into two identical coils. These identical coils are then connected across a 12 V battery of negligible resistance. The time constant for the current in the circuit is

A. 0.3 $\times$ 10^{-4} s
B. 0.3 $\times$ 10^{-3} s
C. 0.3 $\times$ 10^{-2} s
D. 0.3 μs

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Right Answer Explanation:

Self inductance of each coil = $\frac{1}{2} \times (1.8 \times 10^{-4}) =$ 0.9×10^{-4} H. Resistance of each coil = $\frac{6}{2} = 3\ \Omega$.

When two such coils are connected in parallel, the self-inductance of the combination is $L = 0.45 \times 10^{-4}$ H and the resistance of the combination is $R = 1.5\ \Omega$.

$\therefore$ Time constant = $\frac{L}{R} = \frac{0.45 \times 10^{-4}}{1.5} = 0.3 \times 10^{-4}$ s

Hence the correct choice is (1).

33. A uniformly wound solenoid coil of self-inductance 1.8 $\times$ 10^{-4} H and resistance 6 Ω is broken up into two identical coils. These identical coils are then connected across a 12 V battery of negligible resistance, the steady current through the battery is

A. 8 μA
B. 0.8 A
C. 8 mA
D. 8 A

Right Answer Explanation:

Steady current $I_0 = \frac{V}{R} = \frac{12}{1.5} = 8$ A which is choice (4).

34. A square loop of side l, mass m and resistance R falls vertically into a uniform magnetic field directed perpendicular to the plane of the coil. The height h through which the loop falls, so that it attains terminal velocity on entering the region of magnetic field is given by

A. $\frac{mgR}{2Bl}$
B. $\frac{m^2gR^2}{2B^2l^2}$
C. $\frac{mgR^2}{4B^3l^3}$
D. $\frac{m^2gR^2}{2B^4l^4}$

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Right Answer Explanation:

Velocity $v = \sqrt{2gh}$. Induced emf $e = Blv = Bl\sqrt{2gh}$.

Therefore, the induced current in the loop is

$$I = \frac{Bl\sqrt{2gh}}{R}$$

$\therefore$ Force $F = BIl = \dfrac{B^2 l^2 \sqrt{2gh}}{R}$

The loop will attain terminal velocity if this force equals mg, i.e. if

$$\frac{B^2 l^2 \sqrt{2gh}}{R} = mg$$

which gives $h = \dfrac{m^2 g R^2}{2B^4 l^4}$

35. The mutual inductance between two planar concentric rings of radii r_1 and r_2 (with $r_1 > r_2$) placed in air is given by

A. $\dfrac{\mu_0 \pi r_2^2}{2r_1}$

B. $\dfrac{\mu_0 \pi r_1^2}{2r_2}$

C. $\dfrac{\mu_0 \pi (r_1 + r_2)^2}{2r_1}$

D. $\dfrac{\mu_0 \pi (r_1 + r_2)^2}{2r_2}$

Right Answer Explanation:

Magnetic field due to the larger coil at its centre is

$$B = \frac{\mu_0 I}{2r_1}$$

where I is the current in the larger coil. Flux through the inner coil is

$$\phi = B \times \pi r_2^2 = \frac{\mu_0 I}{2r_1} \times \pi r_2^2$$

But $\phi = MI$. Therefore

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

36. A small square loop of wire of side l is placed inside a large square loop of wire of side L (L >> l). The loops are coplanar and their centres coincide. The mutual inductance of the system is proportional to

A. $\frac{l}{L}$

B. $\frac{l^2}{L}$

C. $\frac{L}{l}$

D. $\frac{L^2}{l}$

Right Answer Explanation:

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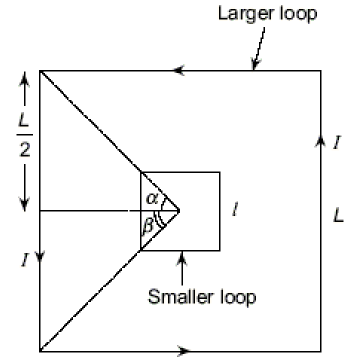
Refer to figure. The magnetic field due a current I in the large loop at its centre is



$$B = 4 \text{ times that due to one side}$$
$$= 4 \times \frac{\mu_0}{4\pi}\frac{I}{(L/2)}(\cos\alpha + \cos\beta)$$
$$= \frac{2\mu_0 I}{\pi L}(\cos 45° + \cos 45°)$$
$$= \frac{2\sqrt{2}\mu_0 I}{\pi L} \quad (\because \alpha = \beta = 45°)$$

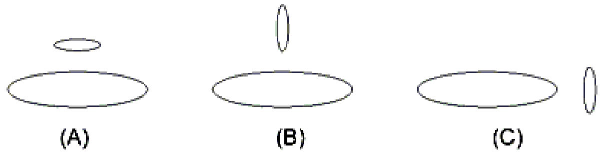
The magnetic flux that links the larger loop with the smaller loop of side l ($l << L$) is

$$\phi_{12} = Bl^2 = \frac{2\sqrt{2}\mu_0 I l^2}{\pi L}$$

$\therefore$ Mutual inductance $M_{12} = \dfrac{\phi_{12}}{I} = \dfrac{2\sqrt{2}\mu_0}{\pi}\left(\dfrac{l^2}{L}\right)$

i.e. $M_{12} \propto \dfrac{l^2}{L}$, which is choice (2).

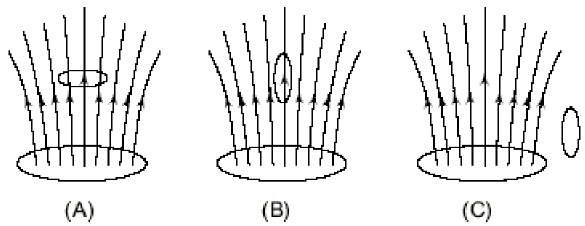
26. Two circular coils can be arranged in any of the three situations shown in the figure. Their mutual inductance will be



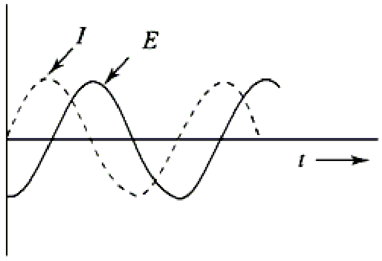
A. maximum in situation (A)
B. maximum in situation (B)
C. maximum in situation (C)
D. the same in all situations

Right Answer Explanation:

The mutual inductance between the two coils in orientation (A) is the maximum since the flux linkage in (A) is the maximum as shown in fig.



27. When an A.C. source of e.m.f. $E = E_0 \sin(100t)$ is connected across a circuit, the phase difference between the e.m.f. E and the current I in the circuit is observed to be $\pi/4$, as shown in the figure below. If the circuit consists possibly only of R-C or R-L or L-C in series, what will be the relation between the two elements of the circuit?



A. R = 1 kΩ, C = 10 μF
B. R = 1 kΩ, C = 1 μF
C. R = 1 kΩ, L = 10 H
D. R = 1 kΩ, L = 1 H

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Given $E = E_0 \sin(100\,t)$. Comparing this with $E = E_0 \sin \omega t$, we have $\omega = 100$ rad s^{-1}. It follows from the figure that the current leads the e.m.f. which is true only for R-C circuit, and not for R-L circuit. Hence the circuit does not contain an inductor. Thus choices (3) and (4) are not possible. For R-C circuit, the phase difference between E and I is given by

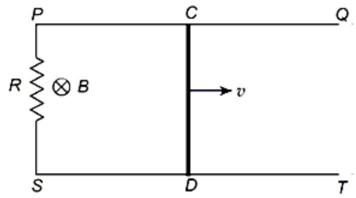
$$\tan \phi = \frac{1}{\omega RC} \qquad \text{(i)}$$

Given $\phi = \pi/4$. Also $\omega = 100$ rad s^{-1}. Using these values in (i), we get

$$\tan\left(\frac{\pi}{4}\right) = \frac{1}{100\,RC} \quad \text{or} \quad RC = \frac{1}{100}$$

This relation between R and C is satisfied by choice (1) and not choice (2). Hence the correct choice is (1).

28. Two parallel wires PQ and ST, placed a distance w apart are connected by a resistor R as shown in the figure and placed in a magnetic field B which is perpendicular to the plane containing the wires. A rod CD connects the two wires. The power spent to slide the rod CD with a velocity v along the wires is (neglect the resistance of the wires and the rod)



A. $\frac{Bwv}{R}$

B. $\frac{Bwv}{R^2}$

C. $\frac{(Bwv)^2}{R}$

D. $\left(\frac{Bwv}{R}\right)^2$

Right Answer Explanation:

When wire CD is made to slide on wires PQ and ST, the flux linked with the circuit changes with time and hence an emf is induced in the circuit, which is given by

$$|e| = \frac{d\phi}{dt} = \frac{d}{dt}(BA) = B\frac{dA}{dt}$$

If wire CD moves a distance dx is time dt, then $A = wdx$ (here $w = CD$) and

$$|e| = B\frac{d}{dt}(wdx) = Bw\frac{dx}{dt} = Bwv$$

The induced current is

$$I = \frac{e}{R} = \frac{Bwv}{R}$$

This current is caused by the motion of wire CD. From Lenz's law, the current I opposes the motion of wire CD. Therefore, work has to be done to slide the wire CD. Now, the magnetic force on wire CD (of length w) is

$$F = BIw = B\left(\frac{Bwv}{R}\right)w = \frac{B^2w^2v}{R} \quad (1)$$

Work done in sliding wire CD through a small distance dx in time dt is

$$dW = Fdx$$

Therefore, the work done per second is

$$P = \frac{dW}{dt} = F\frac{dx}{dt} = Fv$$

Using (1), we get

$$P = \frac{B^2w^2v^2}{R}$$

29. An air plane, with 20 m wingspread is flying at 250 ms^{-1} parallel to the earth's surface at a place where the horizontal component of earth's magnetic field is 2×10^{-5} T and angle of dip is 60°. The magnitude of the induced emf between the tips of the wings is

A. $\frac{1}{10}$ V
B. $\frac{\sqrt{2}}{10}$ V
C. $\frac{\sqrt{3}}{10}$ V
D. $\frac{1}{5}$ V

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Right Answer Explanation:

As the air plane is flying horizontally parallel to the earth's surface, the flux linked with it will be due to the vertical component B_V of the earth's field.

Now

$$B_V = B_H \tan\theta = 2\times10^{-5}\times\tan 60^\circ$$
$$= 2\sqrt{3}\times10^{-5}\ \text{Wbm}^{-2}$$

$\therefore$ Induced emf is $|e| = B_V lv = 2\sqrt{3}\times10^{-5}\times20\times250$

$= \frac{\sqrt{3}}{10}\text{V}$, which is choice (3).

30. A coil of metal wire is kept stationary with its plane perpendicular to a uniform magnetic field directed along the positive x-axis. The current induced in the coil

A. circulates in anti-clockwise direction when viewed from the x-axis
B. circulates in clockwise direction when viewed from the x-axis
C. is perpendicular to the direction of the magnetic field
D. is zero

Right Answer Explanation:

If the coil is not moved in a magnetic field, the magnetic flux linked with the coil does not change. Hence, no emf or current is induced in the coil. Thus, the correct choice is (4).