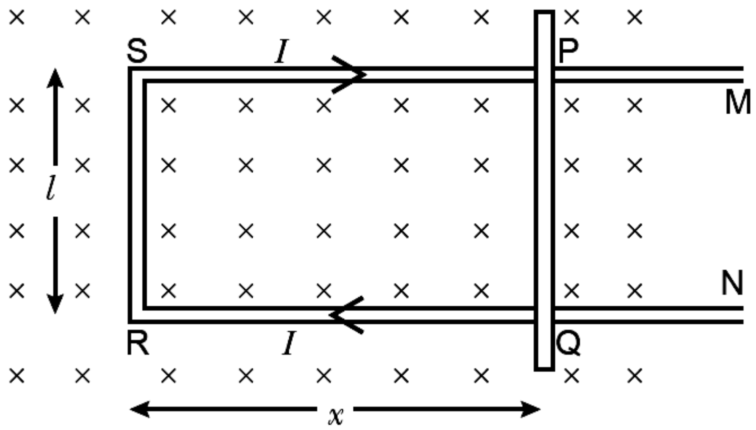
PRACTICE PAPER 06
CHAPTER 06 ELECTROMAGNETIC INDUCTION

SUBJECT: PHYSICS | **MAX. MARKS : 40**
CLASS : XII | **DURATION : 1½ hrs**

General Instructions:
(i). **All** questions are compulsory.
(ii). This question paper contains 2**0** questions divided into five Sections A, B, C, D and E.
(iii). **Section A** comprises of **10 MCQs** of **1 mark** each. **Section B** comprises of 4 questions of **2 marks** each. **Section C** comprises of 3 questions of **3 marks** each. **Section D** comprises of 1 question of **5 marks** each and **Section E** comprises of 2 Case Study Based Questions of **4 marks** each.
(iv). There is no overall choice.
(v). Use of Calculators is not permitted

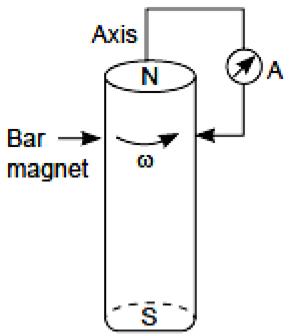
SECTION – A
Questions 1 to 10 carry 1 mark each.

1. Figure shows a rectangular conductor PSRQ in which movable arm PQ has a resistance 'r and resistance of PSRQ is negligible. The magnitude of emf induced when PQ is moved with a velocity v does not depend on



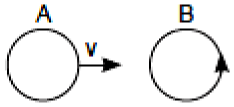
(a) magnetic field $\vec{B}$ (b) velocity field $\vec{v}$ (c) resistance (r) (d) length of PQ

2. A cylindrical bar magnet is rotated about its axis (Figure). A wire is connected from the axis and is made to touch the cylindrical surface through a contact. Then



(a) a direct current flows in the ammeter A.
(b) no current flows through the ammeter A.(c) an alternating sinusoidal current flows through the ammeter A with a time period T = $\frac{2\pi}{\omega}$.
(d) a time varying non-sinosoidal current flows through the ammeter A.

3. There are two coils A and B as shown in Figure. A current starts flowing in B as shown, when A is moved towards B and stops when A stops moving. The current in A is counterclockwise. B is kept stationary when A moves. We can infer that

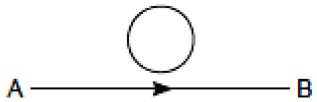


(a) there is a constant current in the clockwise direction in A.
(b) there is a varying current in A.
(c) there is no current in A.
(d) there is a constant current in the counterclockwise direction in A.

4. When current in a coil changes from 5 A to 2 A in 0.1 s, average voltage of 50 V is produced. The selfinductance of the coil is
(a) 1.67 H (b) 6 H (c) 3 H (d) 0.67 H

5. A coil of 100 turns carries a current of 5 mA and creates a magnetic flux of 10^{-5} weber. The inductance is
(a) 0.2 mH (b) 2.0 mH (c) 0.02 mH (d) 0.002 H

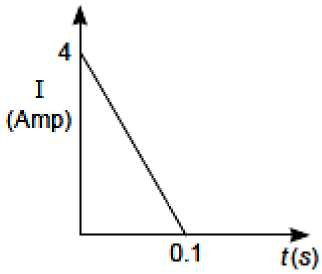
6. The current flows from A to B is as shown in the figure. The direction of the induced current in the loop is



(a) clockwise. (b) anticlockwise. (c) straight line. (d) no induced e.m.f. produced.

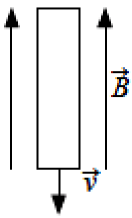
7. The self-inductance L of a solenoid of length l and area of cross-section A, with a fixed number of turns N increases as
(a) *l* and A increase. (b) *l* decreases and A increases.
(c) *l* increases and A decreases. (d) both l and A decrease.

8. In a coil of resistance 10 π, the induced current developed by changing magnitude of change in flux through the coil is weber is



(a) 8 (b) 2 (c) 6 (d) 4

In the following questions 9 and 10, a statement of assertion (A) is followed by a statement of reason (R). Mark the correct choice as:
(a) Both assertion (A) and reason (R) are true and reason (R) is the correct explanation of assertion (A).
(b) Both assertion (A) and reason (R) are true but reason (R) is not the correct explanation of assertion (A).
(c) Assertion (A) is true but reason (R) is false.
(d) Assertion (A) is false but reason (R) is true.



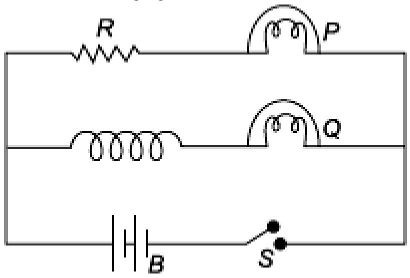
9. **Assertion (A):** In the given figure the induced emf across the ends of the rod is zero.
Reason (R): Motional emf is given by e = Bvl sin θ

10. **Assertion (A):** Mutual induction is the phenomenon in which the emf is induced in the coil due to change in magnetic flux it.
Reason (R): It follows law of conservation of energy.

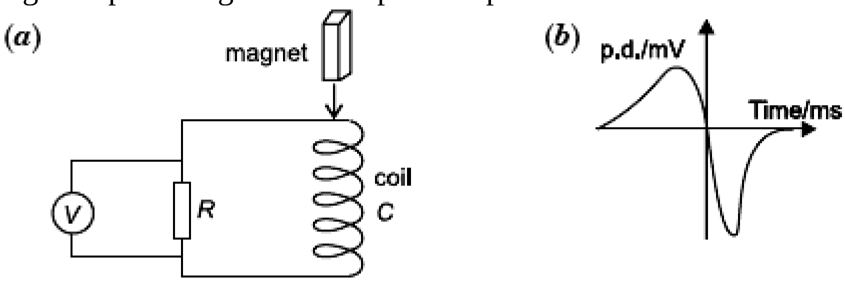
SECTION – B

Questions 11 to 14 carry 2 marks each.

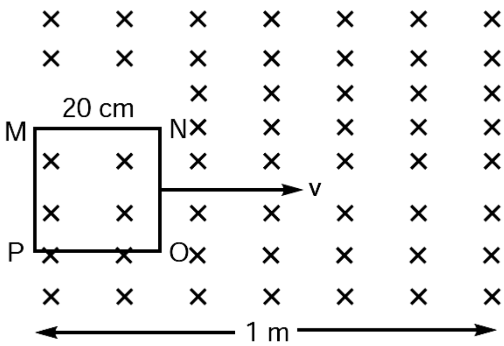
11. The given figure shows an inductor L and resistor R connected in parallel to a battery B through a switch S. The resistance of R is the same as that of the coil that makes L. Two identical bulbs, P and Q are put in each arm of the circuit as shown in the figure. When S is closed, which of the two bulbs will light up earlier? Justify your answer.



12. A bar magnet M is dropped so that it falls vertically through the coil C. The graph obtained for voltage produced across the coil vs time is shown in figure (b).
(i) Explain the shape of the graph.
(ii) Why is the negative peak longer than the positive peak?

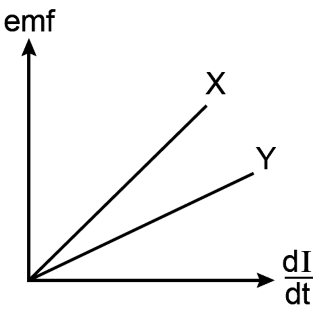


13. A square loop MNOP of side 20 cm is placed horizontally in a uniform magnetic field acting vertically downwards as shown in the figure. The loop is pulled with a constant velocity of 20 cms^{-1} till it goes out of the field.



(i) Depict the direction of the induced current in the loop as it goes out of the field. For how long would the current in the loop persist?
(ii) Plot a graph showing the variation of magnetic flux and induced emf as a function of time.

14. The figure shows the variation of induced emf as a function of rate of change of current for two identical solenoids X and Y. One is air cored and the other is iron cored. Which one of them is iron cored? why?

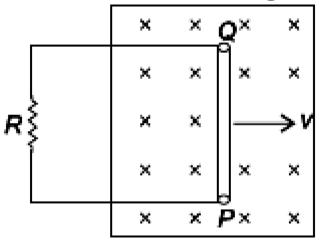


SECTION – C

Questions 15 to 17 carry 3 marks each.

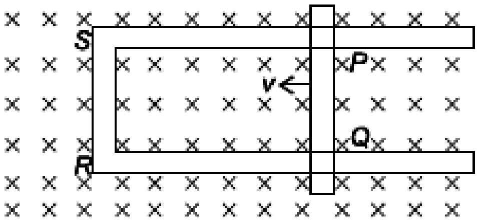
15. State Lenz's Law. Does it violate the principle of conservation of energy. Justify your answer.

16. A conducting rod, PQ, of length l, connected to a resistor R, is moved at a uniform speed, v, normal to a uniform magnetic field, B, as shown in the figure.



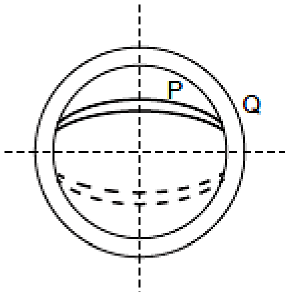
(i) Deduce the expression for the emf induced in the conductor.
(ii) Find the force required to move the rod in the magnetic field.
(iii) Mark the direction of induced current in the conductor.

17. Figure shows a rectangular loop conducting *PQRS* in which the arm *PQ* is free to move. A uniform magnetic field acts in the direction perpendicular to the plane of the loop. Arm *PQ* is moved with a velocity *v* towards the arm *RS*. Assuming that the arms *QR*, *RS* and *SP* have negligible resistances and the moving arm *PQ* has the resistance *r*, obtain the expression for (i) the current in the loop (ii) the force and (iii) the power required to move arm *PQ*.



OR

State Faraday's laws for electromagnetic induction. Two concentric magnetic coils P and Q are placed mutually perpendicular as shown in figure. When current is changed in any one coil, will the current induce in another coil, will the current induce in another coil? Justify your answer.



SECTION – D

Questions 18 carry 5 marks.

18. (a) Define mutual inductance and write its SI units.
(b) Derive an expression for the mutual inductance of two long co-axial solenoids of same length wound one over the other.
(c) In an experiment, two coils C_1 and C_2 are placed close to each other. Find out the expression for the emf induced in the coil C_1 due to a change in the current through the coil C_2.

OR

(i) Define coefficient of self-induction. Obtain an expression for self-inductance of a long solenoid of length l, area of cross-section A having N turns.

(ii) Calculate the self-inductance of a coil using the following data obtained when an AC source of frequency $\left(\frac{200}{\pi}\right)$ Hz and a DC source is applied across the coil.

AC Source		
S.No	**V (Volts)**	**I (A)**
1	3.0	0.5
2	6.0	1.0
3	9.0	1.5

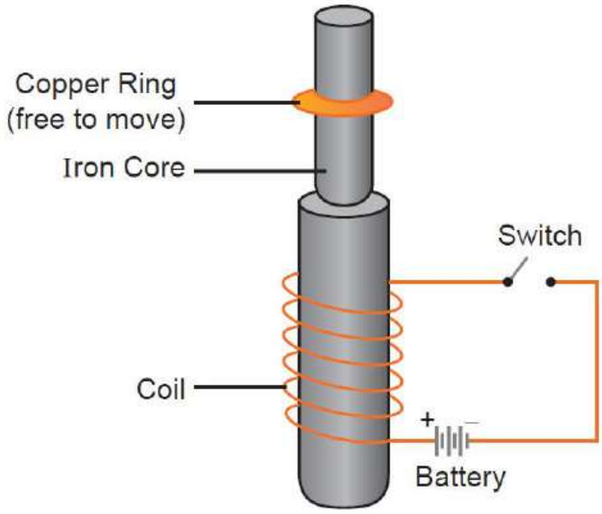
DC Source		
S.No	**V (Volts)**	**I (A)**
1	4.0	1.0
2	6.0	1.5
3	8.0	2.0

SECTION – E (Case Study Based Questions)

Questions 19 to 20 carry 4 marks each.

19. Electromagnetic Induction:

Consider the experimental set up shown in the figure. This jumping ring experiment is an outstanding demonstration of some simple laws of Physics. A conducting non-magnetic ring is placed over the vertical core of a solenoid. When current is passed through the solenoid, the ring is thrown off.



(i) The direction of induced current in the ring in jumping ring experiment is such that the polarity developed in the ring is same as that of the polarity on the face of the coil, then ring will jump up due to
(a) attractive force when the switch is closed in the circuit.
(b) repulsive force when the switch is closed in the circuit.
(c) attractive force when the switch is closed in the circuit.
(d) repulsive force when the switch is closed in the circuit.

(ii) What will happen if the terminals of the battery are reversed and the switch is closed?
(a) Ring will not be jump. (b) Ring will jump again.
(c) Current will not induced in the ring. (d) none of these

(iii) The jumping ring experiment based on which of the following law?
(a) Lenz's Law (b) Faraday's law (c) Snell's Law (d) both (a) and (b)

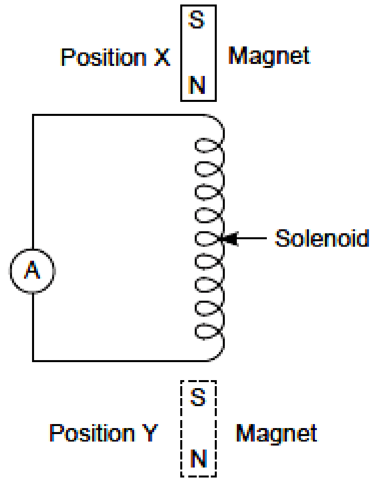
(iv) Two identical circular loops A and B of metal wire are lying on a table without touching each other. Loop A carries a current which increases with time. In response the loop B

(a) remains stationary.
(b) is attracted by loop A.
(c) is repelled by loop A.
(d) rotates about its centre of mass with centre of mass fixed.

OR

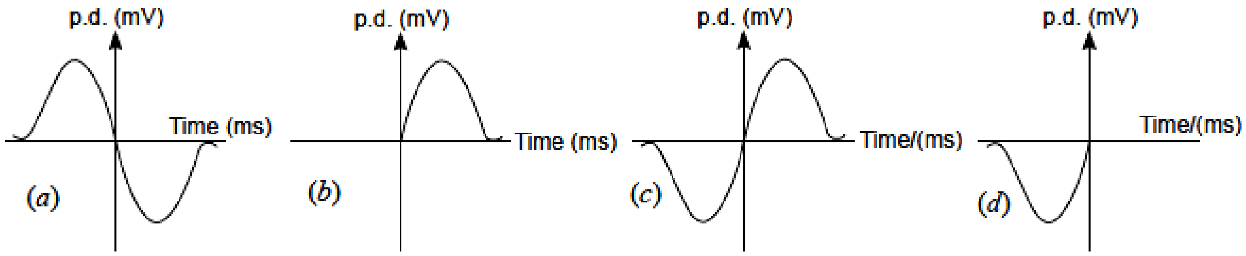
An emf of 200 V is induced in a circuit when current in the circuit falls from 5 A to 0 A in 0.1 second. The self-inductance of the circuit is
(a) 3.5 H (b) 3.9 H (c) 4 H (d) 4.2 H

20. A solenoid is held in a vertical position. The solenoid is connected to a sensitive, centre-zero ammeter.
A vertical bar magnet is held stationary at position X just above the upper end of the solenoid as shown. The magnet is released and it falls through the solenoid. During the initial stage of the fall, the sensitive ammeter shows a small deflection to the left



(i) Why does the ammeter show deflection?
(a) Due to induced current starts flowing in the solenoid
(b) Due to magnetic flux linked with the solenoid increases
(c) Due to magnetic flux linked with the solenoid becomes constant.
(d) Both (a) and (b).

(ii) Choose the correct graph for voltage produced across coil vs time



(iii) A magnet passes the middle point of the solenoid and continues to fall, it reaches position Y. What is observed on the ammeter as the magnet falls from middle point of the solenoid to position Y?
(a) Ammeter will show smaller deflection as change in magnetic flux is slower.
(b) Ammeter will show smaller deflection as change in magnetic flux is faster.
(c) Ammeter will show faster deflection as change in magnetic flux is slower.
(d) Ammeter will show faster deflection as the change in magnetic flux is faster.

(iv) Suggest the change in the apparatus that would increase the initial deflection of ammeter.
(a) By using stronger magnet
(b) By using solenoid of same length with more turns.
(c) By using solenoid wire of smaller resistance
(d) All of these

OR

(iv) Inductance plays the role of
(a) inertia (b) friction (c) source of emf (d) force

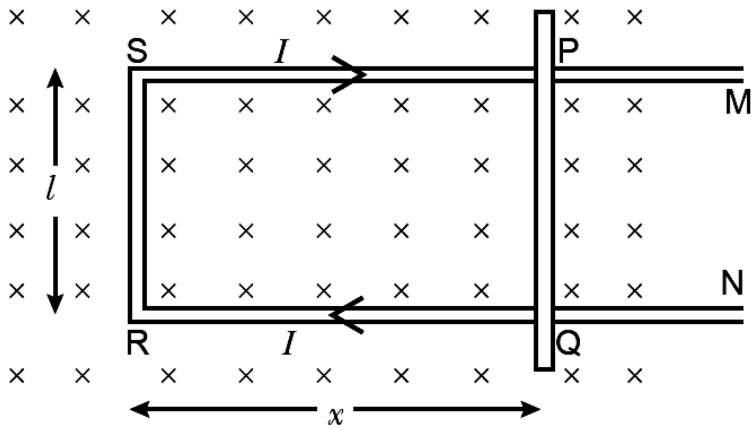
PRACTICE PAPER 06
CHAPTER 06 ELECTROMAGNETIC INDUCTION
(ANSWERS)

SUBJECT: PHYSICS **MAX. MARKS : 40**
CLASS : XII **DURATION : 1½ hrs**

General Instructions:
(i). **All** questions are compulsory.
(ii). This question paper contains 2**0** questions divided into five Sections A, B, C, D and E.
(iii). **Section A** comprises of **10 MCQs** of **1 mark** each. **Section B** comprises of 4 questions of **2 marks** each. **Section C** comprises of 3 questions of **3 marks** each. **Section D** comprises of 1 question of **5 marks** each and **Section E** comprises of 2 Case Study Based Questions of **4 marks** each.
(iv). There is no overall choice.
(v). Use of Calculators is not permitted

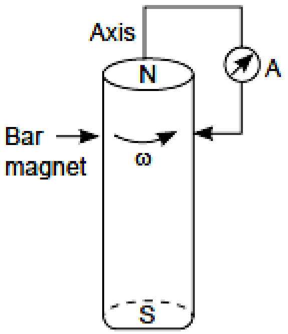
SECTION – A
Questions 1 to 10 carry 1 mark each.

1. Figure shows a rectangular conductor PSRQ in which movable arm PQ has a resistance ‘r and resistance of PSRQ is negligible. The magnitude of emf induced when PQ is moved with a velocity v does not depend on



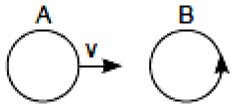
(a) magnetic field $\vec{B}$ (b) velocity field $\vec{v}$ (c) resistance (r) (d) length of PQ
Ans. (c) resistance (r)

2. A cylindrical bar magnet is rotated about its axis (Figure). A wire is connected from the axis and is made to touch the cylindrical surface through a contact. Then



(a) a direct current flows in the ammeter A.
(b) no current flows through the ammeter A.(c) an alternating sinusoidal current flows through the ammeter A with a time period T = $\frac{2\pi}{\omega}$.
(d) a time varying non-sinosoidal current flows through the ammeter A.
Ans. (a) a direct current flows in the ammeter A.

3. There are two coils A and B as shown in Figure. A current starts flowing in B as shown, when A is moved towards B and stops when A stops moving. The current in A is counterclockwise. B is kept stationary when A moves. We can infer that



(a) there is a constant current in the clockwise direction in A.
(b) there is a varying current in A.
(c) there is no current in A.
(d) there is a constant current in the counterclockwise direction in A.
Ans. (d) there is a constant current in the counterclockwise direction in A.

4. When current in a coil changes from 5 A to 2 A in 0.1 s, average voltage of 50 V is produced. The selfinductance of the coil is
(a) 1.67 H (b) 6 H (c) 3 H (d) 0.67 H
Ans. (a) 1.67 H

$$\because \varepsilon = -L\frac{dI}{dt}, \quad 50 = -L\frac{(2-5)}{0.1}$$

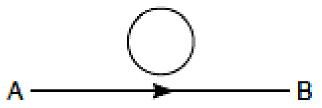
$$L = \frac{50 \times 0.1}{3} = \frac{5}{3} = 1.67 \text{ H}$$

5. A coil of 100 turns carries a current of 5 mA and creates a magnetic flux of 10^{-5} weber. The inductance is
(a) 0.2 mH (b) 2.0 mH (c) 0.02 mH (d) 0.002 H
Ans. (c) 0.02 mH

$$\because L = \frac{\phi}{NI} = \frac{10^{-5}}{100 \times 5 \times 10^{-3}} = \frac{10^{-4}}{5}\text{H} = \frac{10^{-1}}{5}\text{mH}$$

$$= 0.02 \text{ H}$$

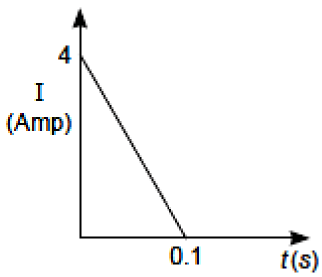
6. The current flows from A to B is as shown in the figure. The direction of the induced current in the loop is



(a) clockwise. (b) anticlockwise. (c) straight line. (d) no induced e.m.f. produced.
Ans. (a) clockwise.
By lenz's law, the induced current must produce inward flux to counter magnetic flux of AB. So induced current is clockwise in the loop.

7. The self-inductance L of a solenoid of length l and area of cross-section A, with a fixed number of turns N increases as
(a) *l* and A increase. (b) *l* decreases and A increases.
(c) *l* increases and A decreases. (d) both l and A decrease.
Ans. (b) *l* decreases and A increases.

8. In a coil of resistance 10 π, the induced current developed by changing magnitude of change in flux through the coil is weber is



(a) 8 (b) 2 (c) 6 (d) 4

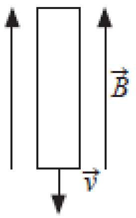
Ans. (b) 2

Charge, $q = It$ = Area under graph

$$q = \frac{\Delta\phi}{R}, \quad \Delta\phi = qR = 0.2 \times 10 = 2\ \text{W}$$

In the following questions 9 and 10, a statement of assertion (A) is followed by a statement of reason (R). Mark the correct choice as:
(a) Both assertion (A) and reason (R) are true and reason (R) is the correct explanation of assertion (A).
(b) Both assertion (A) and reason (R) are true but reason (R) is not the correct explanation of assertion (A).
(c) Assertion (A) is true but reason (R) is false.
(d) Assertion (A) is false but reason (R) is true.

9. Assertion (A): In the given figure the induced emf across the ends of the rod is zero.



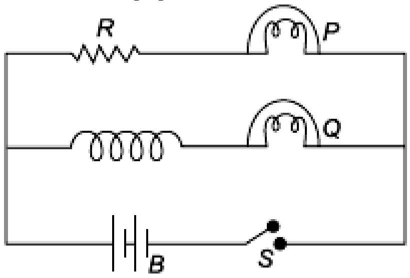
Reason (R): Motional emf is given by e = Bvl sin θ
Ans. (a) Both assertion (A) and reason (R) are true and reason (R) is the correct explanation of assertion (A).

10. Assertion (A): Mutual induction is the phenomenon in which the emf is induced in the coil due to change in magnetic flux it.
Reason (R): It follows law of conservation of energy.
Ans. (d) Assertion (A) is false but reason (R) is true.

SECTION – B

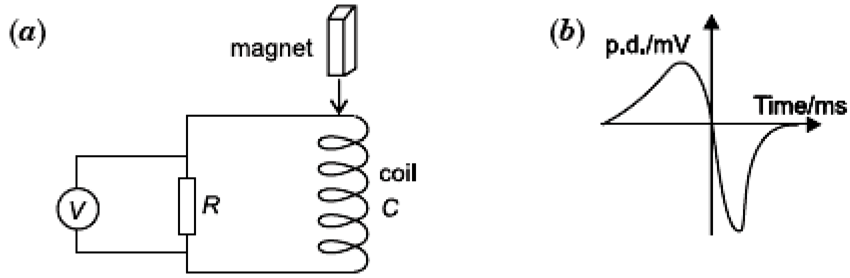
Questions 11 to 14 carry 2 marks each.

11. The given figure shows an inductor *L* and resistor *R* connected in parallel to *a* battery *B* through a switch *S*. The resistance of *R* is the same as that of the coil that makes *L*. Two identical bulbs, *P* and *Q* are put in each arm of the circuit as shown in the figure. When *S* is closed, which of the two bulbs will light up earlier? Justify your answer.



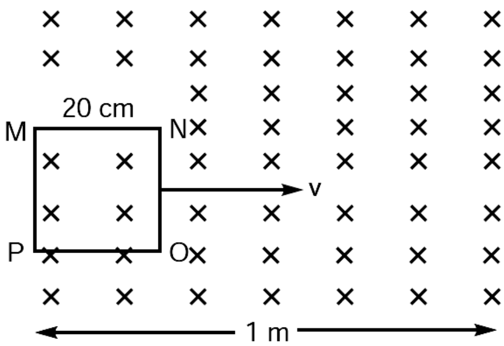
Ans. When switch *S* is closed, bulb *P* will light up earlier. Bulb *P* is connected in series with a resistor. So, the current in bulb *P* will instantly rise to its steady value. On the other hand, bulb *Q* is in series with an inductor. On closing the switch *S*, current in bulb *Q* will grow exponentially to its steady value which will be the same as for bulb *P*. This is due to the production of induced emf in the inductor. However, the steady state value of current will be the same in both the bulbs.

12. A bar magnet M is dropped so that it falls vertically through the coil C. The graph obtained for voltage produced across the coil vs time is shown in figure (b).
(i) Explain the shape of the graph.
(ii) Why is the negative peak longer than the positive peak?



Ans. (i) A magnet is moving towards the coil. Magnetic flux increases non-uniformly because the motion of the magnet is accelerated, an emf is induced. It increases, till the magnet reaches just above the coil. At this point, the emf attains its peak value.
While the magnet moves through the coil, the magnetic flux starts decreasing. With the flux, the induced emf also decreases and emf reduces to zero. Now, the magnet starts withdrawing itself from the coil. During this period, the magnetic flux again increases through the coil. Thus, the emf induced also increases, but this time opposite in the direction. The induced emf attains its maximum value, the moment magnet just comes out of the coil. After this, the magnet moves away from the coil. Thus, the magnetic flux through the coil decreases. The emf in the coil starts decreasing till it is reduced to zero.
(ii) The relative speed of recession of the magnet from the coil is more than the relative speed of approach of the magnet towards the coil. This is the reason why the negative peak is longer than the positive peak.

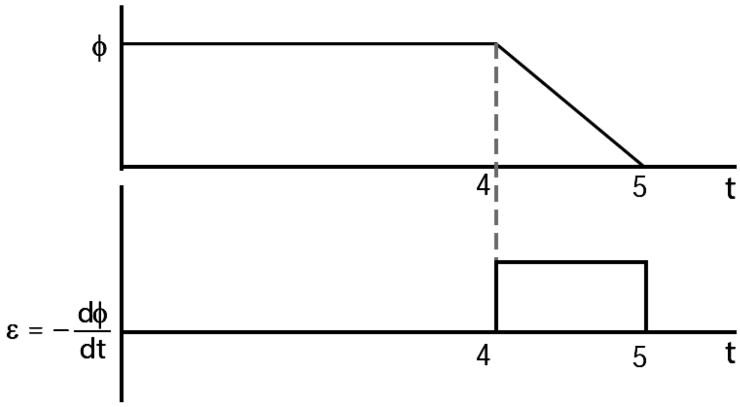
13. A square loop MNOP of side 20 cm is placed horizontally in a uniform magnetic field acting vertically downwards as shown in the figure. The loop is pulled with a constant velocity of 20 cms^{-1} till it goes out of the field.



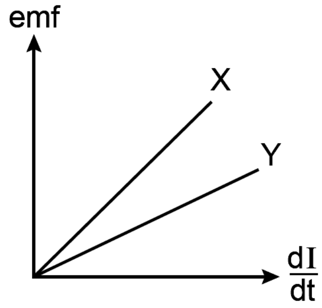
(i) Depict the direction of the induced current in the loop as it goes out of the field. For how long would the current in the loop persist?
(ii) Plot a graph showing the variation of magnetic flux and induced emf as a function of time.
Ans. (i) Clockwise MNOP.
v = 20 cm/s; d = 20 cm

Time taken by the loop to move out of magnetic field, t = $\frac{d}{v} = \frac{20}{20} = 1\text{sec}$

Induced current will last for 1 second till the length 20 cm moves out of the field.
(ii)



14. The figure shows the variation of induced emf as a function of rate of change of current for two identical solenoids X and Y. One is air cored and the other is iron cored. Which one of them is iron cored? why?



Ans. From the graph, slope = $\frac{\varepsilon}{\frac{dI}{dt}} = L$

Slope of X is more than that of Y. Hence X is iron-cored because inductance of iron cored coil is more than that of air-cored coil.

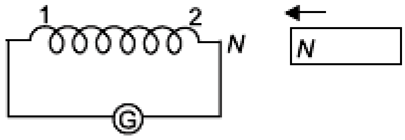
SECTION – C

Questions 15 to 17 carry 3 marks each.

15. State Lenz's Law. Does it violate the principle of conservation of energy. Justify your answer.
Ans. Lenz's Law: The current induced in a circuit always flows in such a direction that it opposes the change or the cause that produces it.

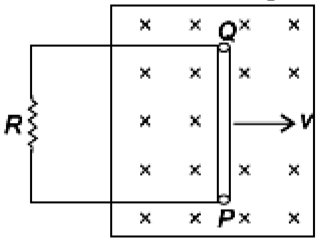
Mathematically, $\varepsilon = -\frac{d\phi}{dt}$

No, it does not violate the principle of conservation of energy.



Justification: Lenz's law complies with the principle of conservation of energy. For example, when the N-pole of a bar magnet is pushed into a coil as shown, the direction of induced current in the coil will be such that the end 2 of the coil will act as N-pole. Thus, work has to be done against the magnetic repulsive force to push the magnet into the coil. The electrical energy produced in the coil is at the expense of this work done.

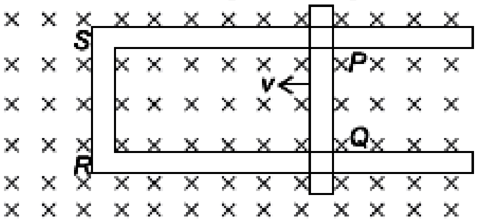
16. A conducting rod, PQ, of length l, connected to a resistor R, is moved at a uniform speed, v, normal to a uniform magnetic field, B, as shown in the figure.



(i) Deduce the expression for the emf induced in the conductor.
(ii) Find the force required to move the rod in the magnetic field.
(iii) Mark the direction of induced current in the conductor.
Ans. (i) Expression for the emf induced in the conductor
When the conductor PQ moves through the magnetic field, free charge carriers of the conductor experience a Lorentz force.

Consider a free charge q, in the conductor moving with speed v in the magnetic field. Lorentz force will act on the charge towards end Q of the conductor.
Its magnitude is given by
$F = qBv$ ($\because \theta = 90°$)
Work done in moving the charge from P to Q, $W = qvBl$
Since, emf is the work done per unit charge, $\varepsilon = W/q = Blv$
(ii) Force required to move the rod, $F = IlB$
When $I = \varepsilon/R = Blv/R$ then, $F = B^2l^2v / R$
(iii) The direction of induced current is determined by Faraday's right hand rule. It is from P to Q.

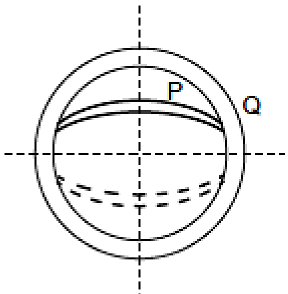
17. Figure shows a rectangular loop conducting *PQRS* in which the arm *PQ* is free to move. A uniform magnetic field acts in the direction perpendicular to the plane of the loop. Arm *PQ* is moved with a velocity *v* towards the arm *RS*. Assuming that the arms *QR*, *RS* and *SP* have negligible resistances and the moving arm *PQ* has the resistance *r*, obtain the expression for (i) the current in the loop (ii) the force and (iii) the power required to move arm *PQ*.



Ans. (i) An emf induced at the ends of the arm PQ is $\varepsilon = Blv$
(where l is the length of the arm PQ)
So, the current in the loop, $I = \dfrac{Blv}{R}$
(ii) The current flows through the arm PQ. A current-carrying wire experiences a force in the magnetic field.
$\therefore |\vec{F}| = |I(\vec{l} \times \vec{B})| = BIl\sin 90^0 = \dfrac{B^2l^2v}{R}$
(iii) Power dissipated, $P = Fv = \dfrac{B^2l^2v^2}{R}$

OR

State Faraday's laws for electromagnetic induction. Two concentric magnetic coils P and Q are placed mutually perpendicular as shown in figure. When current is changed in any one coil, will the current induce in another coil, will the current induce in another coil? Justify your answer.

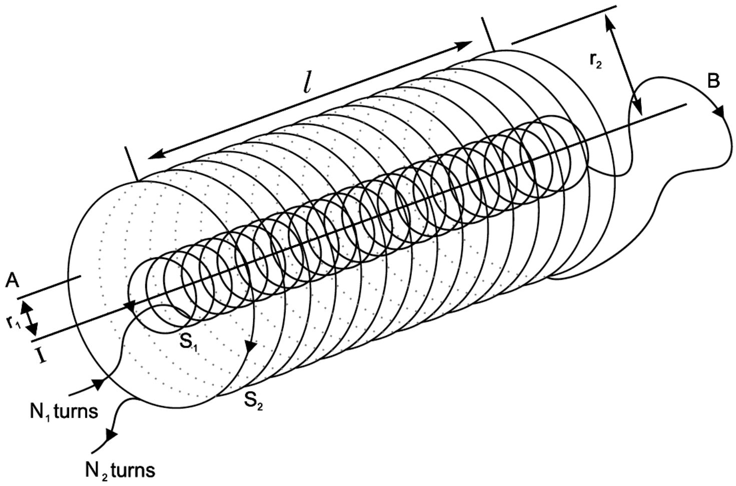


Ans. Faraday's laws:
(i) Whenever there is a change in the magnetic flux linked with a circuit, an induced emf is set up in it and lasts as long as the magnetic flux linked with it is changing.
(ii) The magnitude of the induced emf ε in a circuit is directly proportional to the rate of change of magnetic flux linked with the circuit. i. e. $\varepsilon \propto -\dfrac{d\phi}{dt}$
No, because if current flowing in 'P', magnetic flux of 'P' will be parallel to the surface of coil 'Q' and vice-versa. Hence no current will induce in another coil.

SECTION – D

Questions 18 carry 5 marks.

18. (a) Define mutual inductance and write its SI units.
(b) Derive an expression for the mutual inductance of two long co-axial solenoids of same length wound one over the other.
(c) In an experiment, two coils C_1 and C_2 are placed close to each other. Find out the expression for the emf induced in the coil C_1 due to a change in the current through the coil C_2.
Ans. (a) When current flowing in one of two nearby coils is changed, the magnetic flux linked with the other coil changes; due to which an emf is induced in it (other coil). This phenomenon of electromagnetic induction is called the mutual induction. The coil, in which current is changed is called the primary coil and the coil in which emf is induced is called the secondary coil.
The SI unit of mutual inductance is henry.



(b) Mutual inductance is numerically equal to the magnetic flux linked with one coil (secondary coil) when unit current flows through the other coil (primary coil).
Consider two long co-axial solenoids, each of length l. Let n_l be the number of turns per unit length of the inner solenoid S_1 of radius r_1, n_2 be the number of turns per unit length of the outer solenoid S_2 of radius r_2. Imagine a time varying current I_2 through S_2 which sets up a time varying magnetic flux ϕ_1 through S_1.

$\therefore\ \phi_1 = M_{12}(I_2)$ ...(i)

where, M_{12} = Coefficient of mutual inductance of solenoid S_1 with respect to solenoid S_2
Magnetic field due to the current I_2 in S_2 is $B_2 = \mu_0 n_2 I_2$

$\therefore$ Magnetic flux through S_1 is
$\phi_1 = B^2 A_1 N_1$

where, $N_1 = n_1 l$ and l = length of the solenoid

$\phi_1 = (\mu_0 n_2 I_2)(\pi r_1^2)(n_1 l) \Rightarrow \phi_1 = \mu_0 n_1 n_2 \pi r_1^2 l I_2$ ...(ii)

From equations (i) and (ii), we get $M_{12} = \mu_0 n_1 n_2 \pi r_1^2 l$ ...(iii)

Let us consider the reverse case.
A time varying current I_1 through S_1 develops a flux ϕ_2 through S_2.

$\phi_2 = M_{21}(I_1)$ ...(iv)

where, M_{21}= Coefficient of mutual inductance of solenoid S_2 with respect to solenoid S_1
Magnetic flux due to I_1 in S_1 is confined solely inside S_1 as the solenoids are assumed to be very long.
There is no magnetic field outside S_1 due to current I_1 in S_1.
The magnetic flux linked with S_2 is

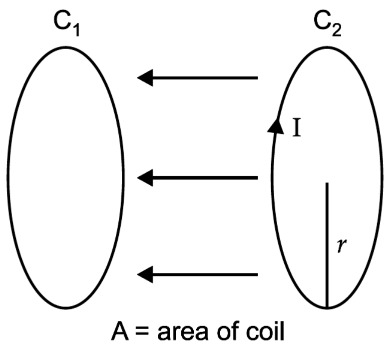
$\therefore\ \phi_2 = B_1 A_1 N_2 = (\mu_0 n_1 I_1)(\pi r_1^2)(n_2 l) \Rightarrow \phi_1 = \mu_0 n_1 n_2 \pi r_1^2 l I_1$ ...(v)

From equations (iv) and (v), we get $M_{21} = \mu_0 n_1 n_2 \pi r_1^2 l$ ...(vi)

From equations (iii) and (vi), we get $M_{12} = M_{21} = \mu_0 n_1 n_2 \pi r_1^2 l$

We can write the above equation as $M = \mu_0 \left(\frac{N_1}{l}\right)\left(\frac{N_2}{l}\right)\pi r_1^2 l \Rightarrow M = \frac{\mu_0 N_1 N_2 \pi r_1^2}{l}$

(c) When the current in coil C_2 changes, the flux linked with C_1 changes. This change in flux linked with C_1 induces emf in C_1.



Flux linked with C_1 = flux of C_2 = $\phi_{12} = B.A = \frac{\mu_0 I}{2r}.A$

Emf induced in C_1 = $\frac{d\phi_{12}}{dt} = \frac{d}{dt}\left(\frac{\mu_0 IA}{2r}\right) = \frac{\mu_0 A}{2r} \times \frac{dI}{dt}$

OR

(i) Define coefficient of self-induction. Obtain an expression for self-inductance of a long solenoid of length l, area of cross-section A having N turns.

(ii) Calculate the self-inductance of a coil using the following data obtained when an AC source of frequency $\left(\frac{200}{\pi}\right)$ Hz and a DC source is applied across the coil.

AC Source		
S.No	**V (Volts)**	**I (A)**
1	3.0	0.5
2	6.0	1.0
3	9.0	1.5

DC Source		
S.No	**V (Volts)**	**I (A)**
1	4.0	1.0
2	6.0	1.5
3	8.0	2.0

Ans. (i) Coefficient of self induction of a coil is equal to the amount of magnetic flux linked with the coil when unit current flows through the coil.

$$e = \frac{-d\phi}{dt} = -\frac{d}{dt}\text{LI}$$

or $$e = -\text{L}\frac{dI}{dt} \quad \text{or} \quad \text{L} = \frac{-e}{dI/dt}$$

Magnetic field B at any point inside the solenoid is constant.

$$\text{B} = \frac{\mu_0 NI}{l}$$

Magnetic flux through each turn, ϕ = B × area of a turn

$$\phi = \frac{\mu_0 NIA}{l} = \mu_0\left(\frac{N}{l}\right)IA$$

Magnetic flux linked with entire solenoid having N number of turns, $\phi = \frac{\mu_0 NIA}{l} \times N = \frac{\mu_0 N^2 IA}{l}$

As $\phi = LI \Rightarrow L = \frac{\mu_0 N^2 A}{l}$

(*ii*) For dc part $R = \frac{V}{I} = 4\ \Omega$ (in each case)

For ac part $f = \frac{200}{\pi}$ Hz

Total impedance

$$Z = 6\ \Omega \text{ (in each part)}$$

$X_L = \omega L = 2\pi f L = \sqrt{Z^2 - R^2} = \sqrt{6^2 - 4^2} = \sqrt{20}$

Thus, $2\pi f L = \sqrt{20}$

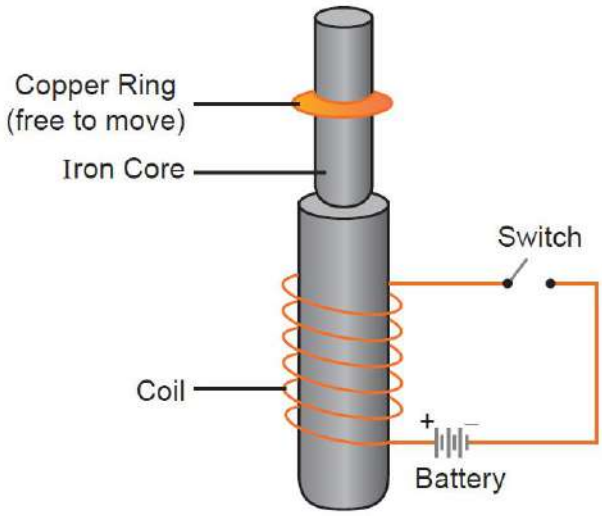
or $L = \frac{\sqrt{20}}{2\pi \times \frac{200}{\pi}} = \frac{\sqrt{20}}{400} = \frac{1}{20\sqrt{20}}$ H

SECTION – E (Case Study Based Questions)

Questions 19 to 20 carry 4 marks each.

19. Electromagnetic Induction:

Consider the experimental set up shown in the figure. This jumping ring experiment is an outstanding demonstration of some simple laws of Physics. A conducting non-magnetic ring is placed over the vertical core of a solenoid. When current is passed through the solenoid, the ring is thrown off.



(i) The direction of induced current in the ring in jumping ring experiment is such that the polarity developed in the ring is same as that of the polarity on the face of the coil, then ring will jump up due to

(a) attractive force when the switch is closed in the circuit.
(b) repulsive force when the switch is closed in the circuit.
(c) attractive force when the switch is closed in the circuit.
(d) repulsive force when the switch is closed in the circuit.

(ii) What will happen if the terminals of the battery are reversed and the switch is closed?

(a) Ring will not be jump. (b) Ring will jump again.
(c) Current will not induced in the ring. (d) none of these

(iii) The jumping ring experiment based on which of the following law?
(a) Lenz's Law (b) Faraday's law (c) Snell's Law (d) both (a) and (b)

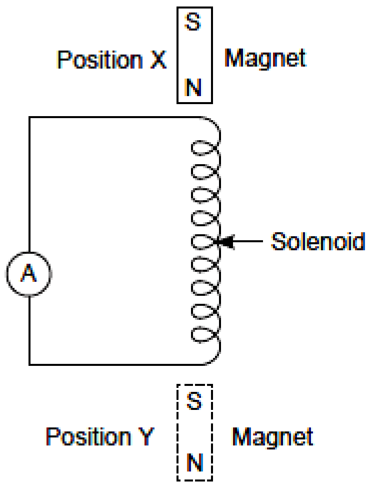
(iv) Two identical circular loops A and B of metal wire are lying on a table without touching each other. Loop A carries a current which increases with time. In response the loop B
(a) remains stationary.
(b) is attracted by loop A.
(c) is repelled by loop A.
(d) rotates about its centre of mass with centre of mass fixed.

OR

An emf of 200 V is induced in a circuit when current in the circuit falls from 5 A to 0 A in 0.1 second. The self-inductance of the circuit is
(a) 3.5 H (b) 3.9 H (c) 4 H (d) 4.2 H

Ans. (i) (b) The direction of induced current in the ring is such that the polarity developed in the ring is same as that of the polarity on the face of the coil, hence it will jump up due to repulsive force.
(ii) (b) The polarity of the induced current in the ring will get reversed on changing the terminals of the battery, so the ring will jump again.
(iii) (d) Lenz's law: It states that the polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produces it.
Faraday's law of EMI:
Whenever there is change in magnetic flux through a coil, an emf is induced.
The magnitude of the induced emf in a coil is equal to the time rate of change of change of magnetic flux through the coil.
(iv) (c) Opposite currents are induced in loops, so loops repel each other.
OR
(c) Self inductance, L = $\dfrac{e}{\dfrac{\Delta I}{\Delta t}} = \dfrac{200}{\dfrac{5}{0.1}} = \dfrac{200}{50} = 4H$

20. A solenoid is held in a vertical position. The solenoid is connected to a sensitive, centre-zero ammeter.

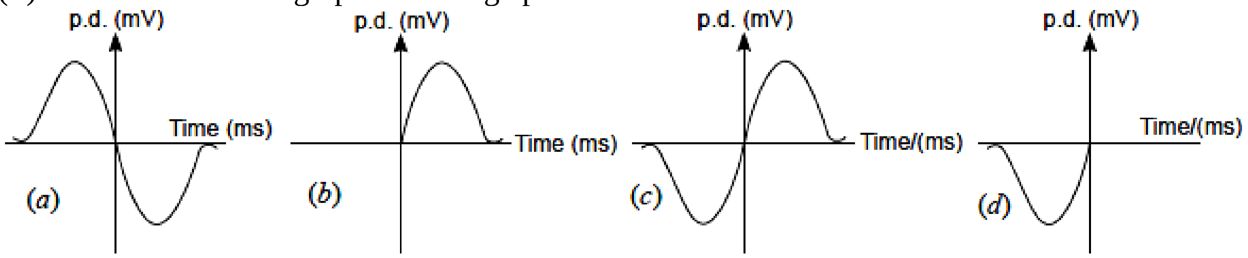


A vertical bar magnet is held stationary at position X just above the upper end of the solenoid as shown. The magnet is released and it falls through the solenoid. During the initial stage of the fall, the sensitive ammeter shows a small deflection to the left

(i) Why does the ammeter show deflection?
(a) Due to induced current starts flowing in the solenoid
(b) Due to magnetic flux linked with the solenoid increases
(c) Due to magnetic flux linked with the solenoid becomes constant.

(d) Both (a) and (b).

(ii) Choose the correct graph for voltage produced across coil vs time



(iii) A magnet passes the middle point of the solenoid and continues to fall, it reaches position Y. What is observed on the ammeter as the magnet falls from middle point of the solenoid to position Y?

(a) Ammeter will show smaller deflection as change in magnetic flux is slower.
(b) Ammeter will show smaller deflection as change in magnetic flux is faster.
(c) Ammeter will show faster deflection as change in magnetic flux is slower.
(d) Ammeter will show faster deflection as the change in magnetic flux is faster.

(iv) Suggest the change in the apparatus that would increase the initial deflection of ammeter.
(a) By using stronger magnet
(b) By using solenoid of same length with more turns.
(c) By using solenoid wire of smaller resistance
(d) All of these

OR

(iv) Inductance plays the role of
(a) inertia (b) friction (c) source of emf (d) force

Ans. (i) (d) Both (a) and (b).
(ii) (a)
(iii) (d) Ammeter will show faster deflection as the change in magnetic flux is faster.
(iv) (d) All of these

OR

(iv) (a) inertia