CLASS – 12

WORKSHEET- ELECTROMAGNETIC INDUCTION

A. MAGNETIC FLUX

(1 Mark Questions)

1. When is the flux linked with a closed coil held in a magnetic field zero?

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_____

2. Name the SI units of (i) magnetic flux and (ii) magnetic induction (or magnetic flux density).

_____
_____

3. Write the dimensional formula of magnetic flux.

_____
_____

4. A square of side L meters lies in the x-y plane in a region, where the magnetic field is given by $B = B_0(2\hat{i} + 3\hat{j} + 4\hat{k})T$ where B_0 is constant. The magnitude of flux passing through the square is
(a) $2\ B_0\ L^2$ Wb. (b) $3\ B_0\ L^2$ Wb. (c) $4\ B_0\ L^2$ Wb. (d) $\sqrt{29}\ B_0\ L^2$ Wb

5. A loop, made of straight edges has six corners at A(0,0,0), B(L,O,0) C(L,L,0), D(0,L,0) E(0,L,L) and F(0,0,L). A magnetic field $B = B_0(\hat{i} + \hat{k})T$ is present in the region. The flux passing through the loop ABCDEFA (in that order) is
(a) $B_0\ L^2$ Wb. (b) $2\ B_0\ L^2$ Wb (c) $\sqrt{2}\ B_0\ L^2$ Wb. (d) $4\ B_0\ L^2$ Wb.

(2 Marks Questions)

6. A rectangular loop of area 20cm×30cm is placed in a magnetic field of 0.3T with its plane (i) normal to the field (ii) inclined 30° to the field and (iii) parallel to the field. Find the flux linked with the coil in each case. [Ans. 1.8×10^{-2}Wb, 0.9×10^{-2}Wb, zero]

7. Find the magnetic flux linked with a rectangular coil of size 6cm×8cm placed at right angle to a magnetic field of 0.5 Wbm^{-2}. [Ans. 2.4×10^{-3} Wb]

(3 Marks Questions)

8. A square coil of 600 turns each of side 20cm, is placed with its plane inclined at 30° to a uniform magnetic field of 4.5×10^{-4} Wbm^{-2}. Find the flux through the coil.
[Ans. 5.4×10^{-3} Wb]

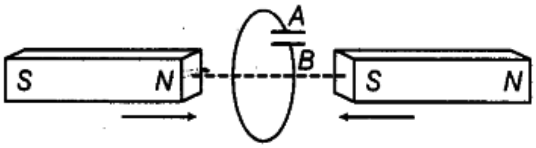
B. FARADAY'S LAW AND LENZ'S RULE

(1 Mark Questions)

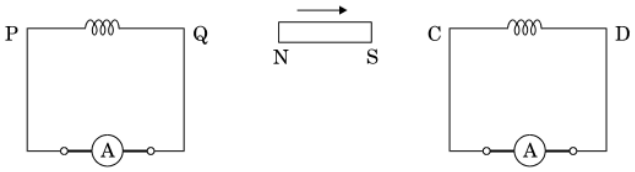
1. On what factors does the magnitude of the emf induced in the circuit due to magnetic flux depend?

2 A long straight current carrying wire passes normally through the centre of circular loop. If the current through the wire increases, will there be an induced emf in the loop? Justify.

3. Predict the polarity of the capacitor in the situation described below.



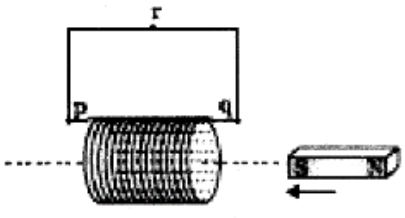
4. A bar magnet is moved in the direction indicated by the arrow between two coils PQ and CD. Predict the direction of the induced current in each coil.



5. State Lenz's law.

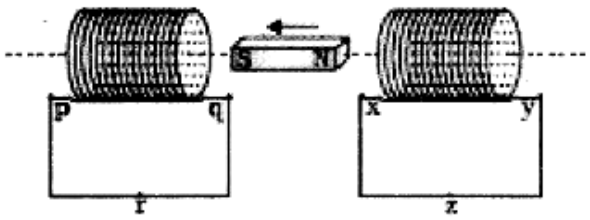
6. Predict the direction of induced current in the situations described by the following figures: (1 mark each)

(i)



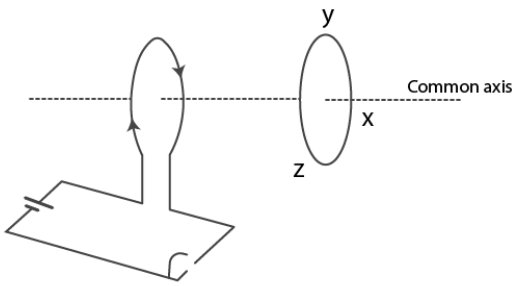
(a)

(ii)



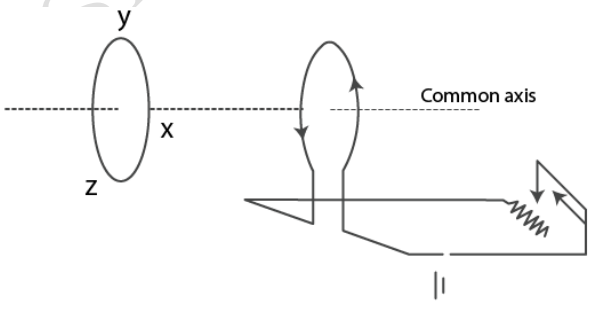
(b)

(iii)



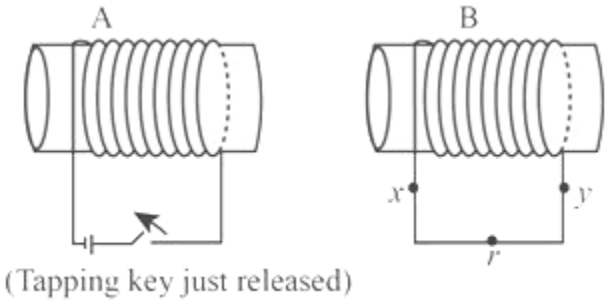
Tapping key just closed

(iv)

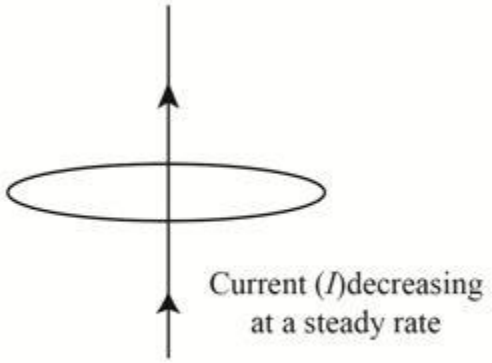


Rheostat setting being charged

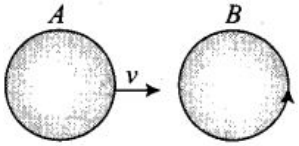
(v)



(vi)



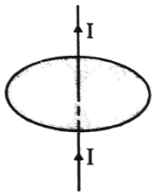
7. There are two coils A and B as shown in Figure. A current starts flowing in B as shown, when A is moved towards B and stops when A stops moving. The current in A is counterclockwise. B is kept stationary when A moves. We can infer that



(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.

(2 Marks Questions)

8. The current I in a wire passing normally though the centre of conducting loop is increasing at a constant rate. Will any current be induced in the loop?



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_____
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_____

9. Two identical loops, one of copper and another of aluminium are rotated with the same speed in the same magnetic field. In which case (i) the induced emf (ii) the induced current, will be more and why?

_____
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_____
_____

10. State Faraday's laws of electromagnetic induction. Express them mathematically.

_____
_____
_____
_____

11. State Lenz's law. On which law of conservation it is based?

_____
_____
_____
_____

12. A rectangular coil of N turns, area A is held in a uniform magnetic field B. If the coil is rotated at a steady angular speed ω, deduce an expression for the induced emf in the coil at any instant of time.

(3 Marks Questions)

13. A small piece of metal wire is dragged across the gap between the pole of a magnet is 0.5s. The magnetic flux between the pole pieces is known to be 8×10^{-4}Wb. Estimate the emf induced in the wire. [Ans. 1.6×10^{-3}V]

14. The magnetic flux through a coil perpendicular to the plane is varying according to the relation: $\phi = (5t^3 + 4t^2 + 2t - 5)\text{Wb}$
Calculate the induced current through the coil at t = 2s, if the resistance of the coil is 5Ω.

15. A 50 turn coil of area 500cm^2 is rotating at a rate of 50 rounds per second perpendicular to a magnetic field of 0.5 Wbm^{-2}. Calculate the maximum value of induced emf.

16. A long solenoid with 15 turns per cm has a small loop of area 20 cm^2 placed inside, normal to the axis of the solenoid. If the current carried by the solenoid changes steadily from 2A to 4A in 0.1s, what is the induced voltage in the loop while the current is changing. [Ans. 7.5×10^{-6} V]

17. We have an air-cored solenoid having a length of 30 cm, whose area is $\mathbf{25}\boldsymbol{cm^2}$ and a number of turns are 500. And the solenoid has carried a current of 2.5 A. Suddenly the current is turned off and the time is taken for it is $\mathbf{10^{-3}}$s. What would be the average value of the induced back-emf by the ends of the open switch in the circuit? (Neglect the variation in the magnetic fields near the ends of the solenoid.) [Ans. 6.54V]

(5 Marks Questions)

18. We have a powerful loudspeaker magnet and have to measure the magnitude of the field between the poles of the speaker. And a small search coil is placed normal to the field direction and then quickly removed out of the field region, the coil is of $\mathbf{2}\boldsymbol{cm^2}$ area and has 25 closely wound turns. Similarly, we can give the coil a quick **90∘** turn to bring its plane parallel to the field direction. We have measured the total charge flown in the coil by using a ballistic galvanometer and it comes to 7.5 mC. Total resistance after combining the coil and the galvanometer is **0.50Ω**. Estimate the field strength of the magnet. [Ans. 0.75 Wb m^{-2}]

C. MOTIONAL EMF

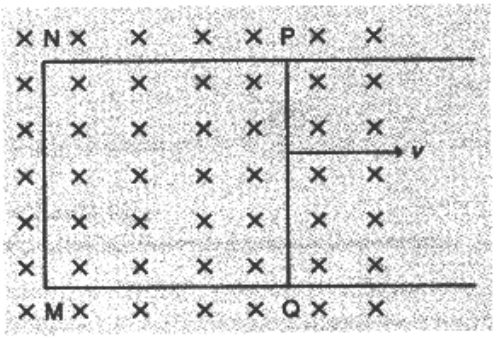
(1 Mark Questions)

1. A horizontal conducting rod 10m long extending from east to west is falling with a speed 5.0 ms^{-1} at right angles to the horizontal component of the Earth's magnetic field,0.3×10^{-4} Wb m^{-2}. Find the instantaneous value of the emf induced in the rod.

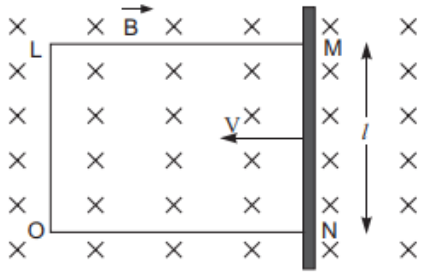
2 State the factors on which the induced emf in a coil rotating in a uniform magnetic field depends.

(2 Marks Questions)

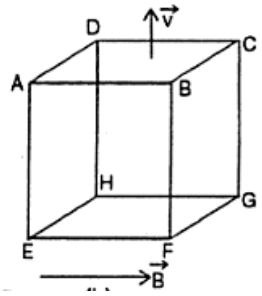
3. A rectangular loop PQMN with movable arm PQ of length 10cm and resistance 2Ω is placed in a uniform magnetic field of 0.1T acting perpendicular to the plane of the loop as shown in the figure. The resistances of the arms MN, NP and MQ are negligible. Calculate the (i) emf induced in the arm PQ and (ii) current induced in the loop when arm PQ is moved with velocity 20m/s.



4. A rectangular conductor LMNO is placed in a uniform field of 0.5T. The field is directed perpendicular to the plane of the conductor. When the arm MN of length of 20cm is moved towards left with a velocity of 10 ms^{-2}, calculate the emf induced in the arm. Given the resistance of the arm to be 5Ω (assuming that other arms are of negligible resistance) find the value of the current in the arm.



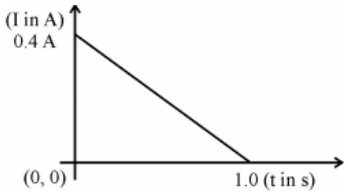
5. Twelve wires of equal lengths are connected in the form of a skeleton-cube which is moving with a velocity $\vec{v}$ in the direction of a magnetic field $\vec{B}$. Find the emf in each arm of the cube.



6. Prove that the magnitude of the emf induced in a conductor of length *l* when it moves at v m/s perpendicular to a uniform magnetic field B is B*l*v.

(3 Marks Questions)

7. When a conducting loop of resistance 10Ω and area $10cm^2$ is removed from an external magnetic field acting normally, the variation of induced current in the loop with time is shown in the figure.



Find the (i) total charge passed through the loop (ii) change in magnetic flux through the loop (iii) magnitude of the magnetic field applied.

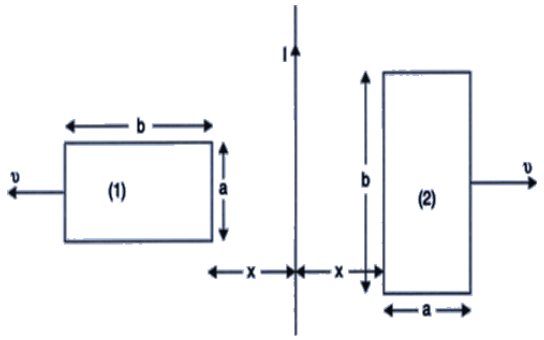
8. A 0.4m long straight conductor is moved in a magnetic field of induction 0.9 Wbm^{-2} with velocity of 7m/s. Calculate the maximum emf induced in the conductor. [Ans. 2.52V]

9. A rectangular wire loop of sides 8cm and 2cm with a small cut is moving out of a region of uniform magnetic field of magnitude 0.3T directed normal to the loop. What is the emf developed across the cut if the velocity of the loop is $1cms^{-1}$ in a direction normal to the (i) longer side (ii) shorter side of the loop? For how long does the induced voltage last in each case? [Ans. 2s, 8s]

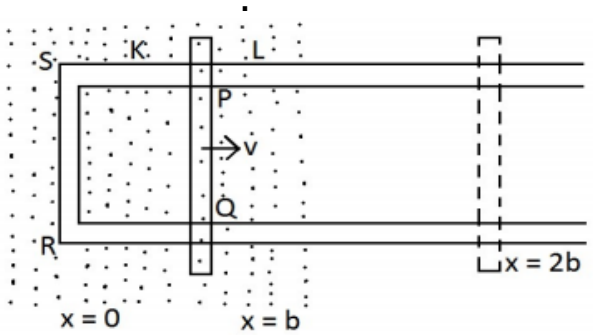
10. A jet plane is travelling towards the west at a speed of 1800 km/h. What is the voltage difference developed between the ends of the wing having a span of 25 m, if the Earth's magnetic field at the location has a magnitude of 5×10^{-4} T and the dip angle is 30°. [Ans. 3.1V]

(5 Marks Questions)

11. Figure shows two identical rectangular loops (1) and (2) placed on a table along with a straight lone current carrying conductor between them. (i) What will be the directions of the induced currents in the loops when they are pulled away from the conductor with same velocity v? (ii) Will the emfs induced in the two loops be equal. Justify your answer.



12. Refer to the figure. The arm PQ of the rectangular conductor is moved from x = 0 to the right side. The uniform magnetic field perpendicular to the plane and extends from x = 0 to x = b and is zero for x>b. Only the arm PQ possesses substantial resistance r. Consider the situation when the arm PQ is pulled outwards from x = 0 to x = 2b and is then moved back to x = 0 with constant speed v. Obtain expressions for the flux, the induced emf, the force necessary to pull the arm and the power dissipated as joule heat. Sketch the variation of these quantities with time.

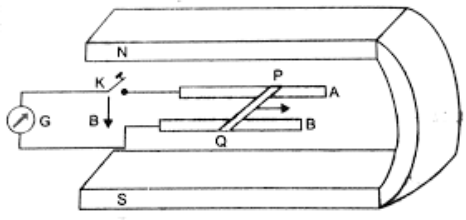


13. A circular coil of radius 8.0 cm and 20 turns is rotated about its vertical diameter with an angular speed of 50rads^{-1} in a uniform horizontal magnetic field of magnitude 3.0× 10^{-2} T. Obtain the maximum and average emf induced in the coil. If the coil forms a closed loop of resistance 10 Ω, calculate the maximum value of current in the coil. Calculate the average power loss due to Joule heating. Where does this power come from?

[Ans. 0.018 W]

14. A horizontal straight wire 10 m long extending from east to west is falling with a speed of 5.0 m s^{-1}, at right angles to the horizontal component of the earth's magnetic field, 0.30×10^{-4} Wb m^{-2}.
(a) What is the instantaneous value of the emf induced in the wire?
(b) What is the direction of the emf?
(c) Which end of the wire is at the higher electrical potential? [Ans. (a) 4.5×10^{-3}V]

15. In the given figure we have a metal rod PQ which is put on the smooth rails AB and these are kept in between the two poles of permanent magnets. All these three (rod, rails and the magnetic field) are in mutually perpendicular direction. There is a galvanometer 'G' connected through the rails by using a switch 'K'. Given, Rod's length = 15 cm, Magnetic field strength, B = 0.50 T, Resistance produced by the closed-loop 9.0$m\Omega$. Let's consider the field is uniform.



(i) Determine the polarity and the magnitude of the induced emf if we will keep the K open and the rod will be moved with the speed of 12 cm/s in the direction shown in the figure.
(ii) When the K was open is there any excess charge built up? Assume that K is closed then what will happen after it?

(iii) When the rod was moving uniformly and the K was open, then on the electron in the rod PQ there was no net force even though they did not experience any magnetic field because of the motion of the rod. Explain.

(iv) After closing the K, calculate the retarding force.

(v) When the K will be closed calculate the total external power which will be required to keep moving the rod with the same speed (12 cm/s)? and also calculate the power required when K will be closed.

(vi)What would be the power loss (in form of heat) when the circuit is closed? What would be the source of this power?

(vii) Calculate the emf induced in the moving rod if the direction of the magnetic field is changed from perpendicular to parallel to the rails?

[Ans. (i) 9.0 mV, (iv) 75×10^{-3}V, (v) 9.0×10^{-3}W, (vi) 9.0×10^{-3}W, (vii) 0]

D. SELF INDUCTANCE

(1 Mark Questions)

1. Define the term 'self-inductance' of a coil. Write its SI unit.

2 Define self-inductance. Give its SI units.

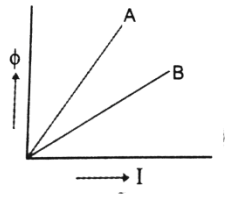
3. The self inductance L of a solenoid of length l and area of cross-section A, with a fixed number of turns N increases as
(a) *l* and A increase. (b) *l* decreases and A increases.
(c) *l* increases and A decreases. (d) both *l* and A decrease.

(2 Marks Questions)

4. A 12V battery connected to a 6□, 10H coil through a switch drives a constant current through the circuit. The switch is suddenly opened, if it takes 1ms to open the switch, find the average emf induced across the coil. [Ans. 20,000V]

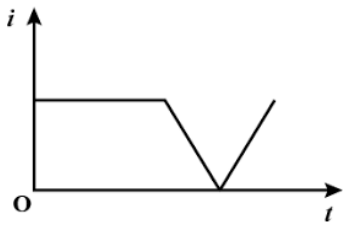
5. A coil of inductance 0.5H is connected to a 18V battery. Calculate the rate of growth of current. [Ans. 36 As^{-1}]

6. A plot of magnetic flux (ϕ) versus current (I) is shown in figure for inductors A and B. Which of the tow has greater value of self-inductance?



7. Current in a circuit falls from 5.0 A to 0.0 A in 0.1 s. If an average emf of 200 V induced, give an estimate of the self-inductance of the circuit.

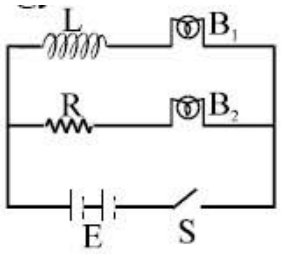
8. The current i in an induction coil varies with time t according to the graph Draw the graph of induced e.m.f. with time.



(3 Marks Questions)

9. The self inductance of an inductor coil having 100 turns is 20mH. Calculate the magnetic flux through the cross-section of the coil corresponding to a current of 4mA. Also, find the total flux. [Ans. 8×10^{-7} Wb, 8×10^{-5} Wb]

10. Figure shows an inductor L and a resistor R connected in parallel to a battery through a switch. The resistance of R is same as that of the coil that makes L. Two identical bulbs are put in each arm of the circuit.



(i) Which of the bulbs lights up bright when S is closed?
(ii) Will the two bulbs be equally bright after some time? Give reason for your answer.

11. Derive the expression for the self inductance of a long solenoid of cross-sectional area A and length l, having n turns per unit length.

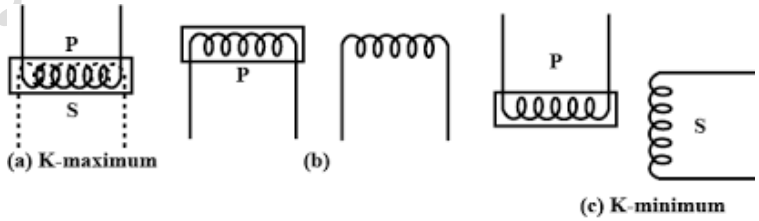
12. Derive the expression of energy across an Inductor.

E. MUTUAL INDUCTANCE

(1 Mark Questions)

1. Define mutual inductance.

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



(2 Marks Questions)

3. A large circular coil, of radius R and a small circular coil, of radius r, are put in vicinity of each other. If the coefficient of mutual induction, for this pair, equals 1mH, what would be the flux linked with the larger coil when a current of 0.5A flows through the smaller coil? [Ans. 5×10^{-4} Wb]

4. A pair of adjacent coils has a mutual inductance of 1.5 H. If the current in one coil changes from 0 to 20 A in 0.5 s, what is the change of flux linkage with the other coil? [Ans. 30 Wb]

5. There are two coils A and B seperated by some distance. If a current of 2 A flows through A, a magnetic flux of 10-2 Wb passes through B (no current through B). If no current passes through A and a current of 1 A passes through B, what is the flux through A?

(3 Marks Questions)

6. A pair of adjacent coils has a mutual inductance of 1.5H. If the current in one coil changes from 0 to 20A in 0.5s, what is the change of flux linkage with the other coil?

7. Define the term 'mutual inductance' between the two coils. Obtain the expression for mutual inductance of a pair of long coaxial solenoids each of length l and radii r_1 and r_2 ($r_2 >> r_1$). Total number of turns in two solenoids are N_1 and N_2 respectively.

F. EDDY CURRENT

(1 Mark Questions)

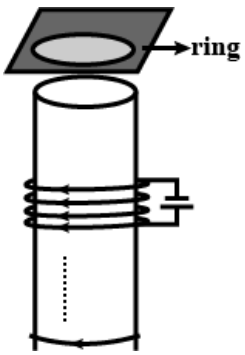
1. Give one example of use of eddy current.

2. A metallic piece gets hot when surrounded by a coil carrying high frequency alternating current. Why?

3. How are eddy currents reduced in a metallic core?

4. Why does a metallic piece become very hot when it is surrounded by a coil carrying high frequency alternating current?

5. Consider a metal ring kept (supported by a cardboard) on top of a fixed solenoid carrying a current I (see Figure). The centre of the ring coincides with the axis of the solenoid. If the current in the solenoid is switched off, what will happen to the ring?



6. Consider a metallic pipe with an inner radius of 1 cm. If a cylindrical bar magnet of radius 0.8cm is dropped through the pipe, it takes more time to come down than it takes for a similar unmagnetised cylindrical iron bar dropped through the metallic pipe. Explain.

(2 Marks Questions)

7. What are eddy currents? Write any two applications of eddy currents.

G. AC GENERATOR

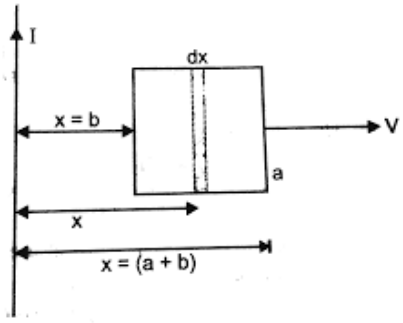
(5 Marks Questions)

1. (a) Draw a schematic diagram for an ac generator. Explain its working and obtain the expression for the instantaneous value of the emf in terms of the magnetic field B, number of turns N of the coil of the area A rotating with angular frequency ω. Show how an alternating emf is generated by a loop of wire rotating in a magnetic field.
(b) A circular coil of radius 10cm and 20 turns is rotated about its vertical diameter with angular speed of 50 rad s^{-1} in a uniform horizontal magnetic field of 3.0×10^{-2}T.
(i) Calculate the maximum and average emf induced in the coil.
(ii) If the coil forms a closed loop of resistance 10Ω, calculate the maximum current in the coil and the average power loss due to joule heating.

H. CHALLENGING PROBLEMS

1. An athlete peddles a stationary tricycle whose pedals are attached to a coil having 100 turns each of area $0.1m^2$. The coil, lying in the X-Y plane is rotated, in this plane, at the rate of 50 rpm, about the Y-axis, in a region where a uniform magnetic field $\vec{B} = (0.01)\hat{k}$ tesla , is present. Find the (i) maximum emf (ii) average emf, generated in the coil over one complete revolution. [Ans. 0.52V, 0]

2. (i) We are given a long straight wire and a square loop of given size (refer to figure). Find out an expression for the mutual inductance between both.
(ii) Now, consider that we passed an electric current through the straight wire of 50 A, and the loop is then moved to the right with constant velocity, v = 10 m/s.Find the emf induced in the loop at an instant where x = 0.2 m. Take a = 0.01 m and assume that the loop has a large resistance.

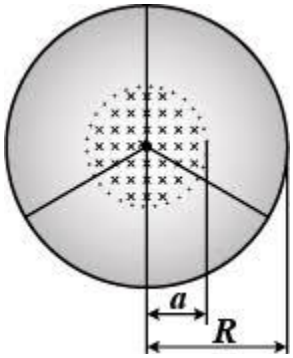


[Ans. (i) $\frac{\mu_0 Ia}{2\pi}\ln\left(1+\frac{a}{x}\right)$, (ii) 1.7×10^{-5}V]

3. A line charge λ per unit length is lodged uniformly onto the rim of a wheel of mass M and radius R. The wheel has light non-conducting spokes and is free to rotate without friction about its axis (see Fig.). A uniform magnetic field extends over a circular region within the rim. It is given by,

$\vec{B} = B_0\hat{k}\,[r \le a, a < R] = 0$ (otherwise)

What is the angular velocity of the wheel after the field is suddenly switched off?



4. A square loop having side 12 cm with its sides are parallel to x and y-axis moves with a velocity of 8 cm /s in the positive x-direction in a region which have a magnetic field in the direction of positive z-axis. The field is not uniform whether in case of its space or in the case of time. It has a gradient of 10^{-3} T cm^{-1} along the negative x-direction(i.e its value increases by $\mathbf{10^{-3}}\boldsymbol{T}$ as we move from positive to negative direction), and it is reducing in the case of time with the rate of $\mathbf{10^{-3}}\boldsymbol{Ts^{-1}}$. Calculate the magnitude and direction of induced current in the loop (Given: Resistance = $\mathbf{4.5}\ \boldsymbol{m\Omega}$). [Ans. 2.9×10^{-2} A]

SPACE FOR ROUGH WORK

SPACE FOR NOTES