Unit IV: Electromagnetic Induction and Alternating Currents **20 Periods**

Chapter–6: Electromagnetic Induction

Electromagnetic induction; Faraday's laws, induced EMF and current; Lenz's Law, Eddy currents. Self and mutual induction.

Chapter–7: Alternating Current

Alternating currents, peak and RMS value of alternating current/voltage; reactance and impedance; LC oscillations (qualitative treatment only), LCR series circuit, resonance; power in AC circuits, power factor, wattless current.

AC generator and transformer.

401. Define magnetic flux. Write its S.I. unit. Is it a scalar or vector quantity?

[**Ans. Magnetic flux** (ϕ) : It is defined as the total number of magnetic lines of force passing normally through a given surface

$$\phi = \vec{B}.\vec{A} = BA\ \cos\theta$$

It's S.I. is Weber (Wb). It is a scalar quantity

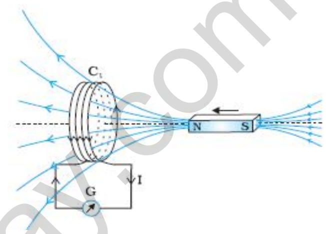
402. (i) What is electromagnetic induction ? **CBSE (AI)-2015**

(ii) Describe, with the help of a suitable diagram, how one can demonstrate that emf can be induced in a coil due to the change of magnetic flux.

[**Ans. (i) Electromagnetic Induction** : Whenever magnetic flux linked with a closed circuit is changed, an emf and hence a current is induced in the circuit. This phenomenon is known as electromagnetic induction.

(ii) Demonstration :

When a bar magnet is either pushed towards or pulled away from coil as shown, magnetic flux linked with the coil changes and galvanometer shows deflection. This shows that emf is induced



403. State Faraday's laws of electromagnetic induction. **CBSE (F)-2017,2009,(AI)-2016,2015**

[**Ans. Faraday's laws of electromagnetic Induction** :

(i) Whenever there is change in magnetic flux linked with a circuit, an emf is induced in the circuit. The induced emf lasts so long as the change in magnetic flux continues.

(ii) The magnitude of induced emf in a circuit is equal to time rate of change of magnetic flux linked with the circuit.

i,e, $e = -N\frac{d\phi}{dt} = -N\frac{\phi_2-\phi_1}{t}$

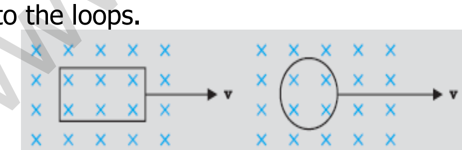
404. When a bar magnet is pushed towards or away from the coil connected to a galvanometer, pointer in galvanometer deflects. Identify the phenomenon causing this deflection and write the factors on which the amount and direction of the deflection depends. **CBSE (AI)-2016**

[**Ans. Phenomenon** : Electromagnetic induction

Factors : **(i)** Amount of deflection depends on the speed of movement of the magnet

(ii) Direction of deflection depends on the sense (towards or away) of the movement of the magnet

405. 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 **v.** In which loop do you expect the induced emf to be constant during the passage out of the field region? The field is normal to the loops. **NCERT-2017**



[**Ans.** In rectangular loop

Reason : In the case of circular loop, the rate of change of area of the loop during its passage out of the field region is not constant, hence induced emf will vary accordingly.

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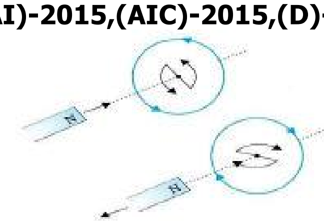
406. State Lenz's law. **CBSE (AI)-2015,(AIC)-2015,(D)-2014,2009**

[**Ans. Lenz's law** : The direction of induced current is such that it opposes the change in magnetic flux responsible for its production

407. Illustrate by giving an example, how Lenz's law helps in predicting the direction of the current in a loop in the presence of a changing magnetic flux ? **CBSE (AI)-2015,(AIC)-2015,(D)-2009**

[**Ans. Illustration** :

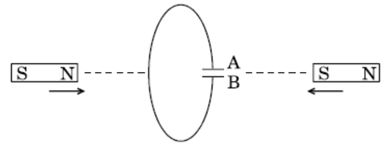
When north pole is moved towards loop, due to Lenz's Law loop will repel it by inducing current in anticlockwise direction. Similarly, when north pole is taken away current will be induced in clockwise direction.



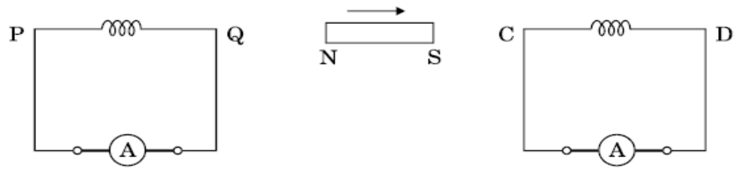
408. Predict the polarity of the capacitor in the situation described below : **CBSE (AI)-2017,2011**

[Ans. A – positive

B- negative



409. 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. **CBSE (AI)-2017,2012**

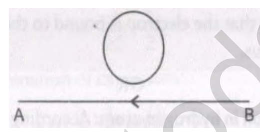


[Ans. Q to P through ammeter and D to C through ammeter

(**Alternatively:** Anticlockwise as seen from left in coil PQ clockwise as seen from left in coil CD

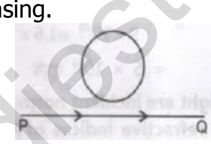
410. The electric current flowing in a wire in the direction from B to A is decreasing. Find out the direction of the induced current in the metallic loop kept above the wire as shown. **CBSE (AI)-2014**

[Ans. Clockwise



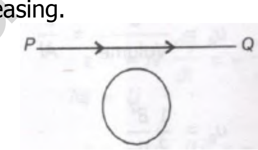
411. A conducting loop is held above a current carrying wire PQ' as shown in the figure. Depict the direction of the current induced in the loop when the current in the wire PQ' is constantly increasing. **CBSE (AI)-2014**

[Ans. Clockwise



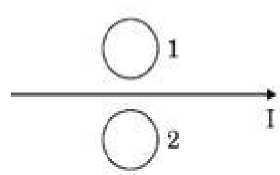
412. A conducting loop is held below a current carrying wire PQ' as shown in the figure. Predict the direction of the induced current in the loop when the current in the wire PQ' is constantly increasing. **CBSE (AI)-2014**

[Ans. Anticlockwise



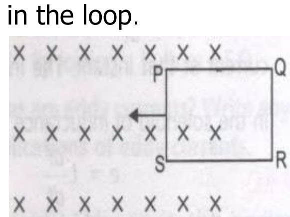
413. What is the direction of induced currents in metal rings 1 and 2 when current I in the wire is increasing steadily ?

[Ans. Clockwise in loop 1, anticlockwise in loop 2 **CBSE (AI)-2017**



414. The closed loop (PQRS) of wire is moved in to a uniform magnetic field at right angles to the plane of the paper as shown in figure. Predict the direction of the induced current in the loop. **CBSE (F)-2012**

[Ans. Anticlockwise



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415. A long straight current carrying wire passes normally through the centre of circular loop. If the current through the wire increases, will there be any induced emf in the loop ? Justify **CBSE (D)-2017**

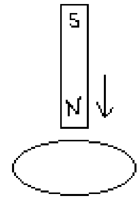
[Ans. No,

Reason : As the magnetic field due to current carrying wire will be in the plane of the circular loop, so magnetic flux will remain zero/ Magnetic flux does not change with the change of current

416. A bar magnet falls from height $'h'$ through a metal ring as shown in figure. **CBSE (AIC)-2001**

(i) Will its acceleration be equal to $'g'$?

(ii) What will happens if the ring in the above case is cut so as not to form a complete loop ? Justify your answer.



[Ans. (i) acceleration will be less than g ($a < g$)

Reason : as the magnet falls, magnetic flux inked with the metal ring increases. By the Lenz's law, induced current in the ring opposes the downward motion of the magnet

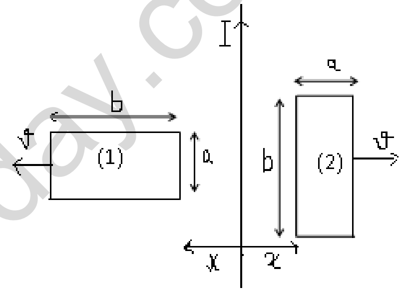
(ii) acceleration will be equal to g ($a = g$)

Reason : when the ring has a cut, emf will be induced but no induced current flows through it. Hence motion of the magnet is not opposed. Magnet will fall with acceleration equal to g

417. Figure shows two identical rectangular loops (1) and (2), placed on a table along with a straight long current carrying conductor between them. **CBSE (AI)-2005**

(i) What will be the direction of induced currents in the loops when they are pulled away from the conductor with the same velocity v ?

(ii) Will the emfs induced in the two loops be equal ? Justify your answer.



[Ans. (i) in loop (1) - Anticlockwise

in loop (2) – Clockwise

(ii) No, emf will not be equal because the rate of change of magnetic flux in the two loops are different

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418. What are eddy currents ? How are they produced ? **CBSE (AI)-2011,2009,(F)-2009,(AIC)-2006**

[Ans. Eddy currents : The induced circulating currents produced in the bulk piece of a conductor, when it is subjected to a changing magnetic flux, are known as eddy currents

Eddy currents are produced when a bulk conductor is placed in a changing magnetic field

419. Give two uses of eddy currents. **CBSE (AI)-2009**

[Ans. (i) magnetic braking in electric trains

(ii) to produce heat in induction furnaces

(iii) electro magnetic damping

420. Why eddy currents are considered undesirable ? **CBSE (AI)-2011,2009**

[Ans. Because (i) they heat up the metallic core and dissipate electrical energy in the form of heat.

(ii) they always oppose the motion.

421. How are eddy currents minimized ? **CBSE (AI)-2011,2009**

[Ans. (i) using laminating iron core

(ii) using slotted iron blocks

422. The motion of a copper plate is damped when it is allowed to oscillate between the two poles of a magnet. What is the cause of this damping ? **CBSE (AI)-2013**

[Ans. It is due to eddy currents produced in the plate

423. The motion of a copper plate is damped when it is allowed to oscillate between the two poles of a magnet. If the slots are cut in the plate, how will the damping be affected ? **CBSE (AI)-2013**

[Ans. The damping is due to eddy currents produced in the plate. Slots reduce eddy current hence damping will be less

424. A light metal disc on the top of an electromagnet is thrown up as the current is switched on. Why ? Give reason. **CBSE (AI)-2013**

[Ans. Due to eddy currents set up in the disc

Reason : As the current is switched on, eddy currents are set up in metal disc due to increasing magnetic flux. By Lenz's law lower face of the disc will have the same polarity as that on the top end of the Electromagnet, resulting in a repulsive force. Hence, it is thrown up

425. What is meant by self induction ?

[Ans. Self induction : When a changing current is passed through a coil, an emf is induced in the coil due to change in magnetic flux passing through it. This phenomenon is called self-induction.

426. Define self-inductance of a coil. Write its S.I. unit. **CBSE (AI)-2017,2015,2010,(D)-2009,(F)-2009**

[Ans. Self inductance : It is defined as the total magnetic flux linked with the coil, when unit current flows through it. Its S.I. unit is Henry (H)

427. What is meant by back emf ? When current in a coil changes with time, how is the back emf induced in the coil related to it ?

[Ans. Back emf :The self-induced emf in a coil due to changing current flowing through it, is called the back emf as it opposes any change in the current in a circuit ($e = -L\frac{dI}{dt}$) **CBSE (AI)-2008**

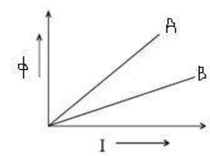
428. A plot of magnetic flux (ϕ) versus current (I) is shown in the figure for two inductors A and B, which of the two has larger value of self-inductance and why ? **CBSE (D)-2010**

[Ans. Inductor A

Reason : $\phi = L\,I \Rightarrow L = \frac{\phi}{I} = \text{slope}$

As $(slope)_A > (slope)_B$

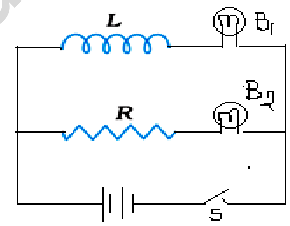
$\Rightarrow (L)_A > (L)_B$



429. Figure shows an inductor L and a resistor R connected in parallel to a battery through a switch. The resistance R is same as that of coil that makes L. Two identical bulbs are put in each arm of the circuit. **CBSE (AI)-2003**

(i) Which of the bulbs lights up earlier when S is closed ?

(ii) Will the two bulbs be equally bright after some time ? Give reason for your answer.



[Ans. (i) Bulb B_2 lights up earlier

Reason : induced emf across L opposes growth of current in B_1

(ii) yes, after some time both bulbs will be equally bright

Reason : after some time current reached its maximum value in L and self-induction plays no role

430. What is meant by mutual induction ?

[Ans. Mutual induction : When a changing current is passed through a coil, an emf is induced in the neighbouring coil due to change in magnetic flux passing through it. This phenomenon is called mutual-induction.

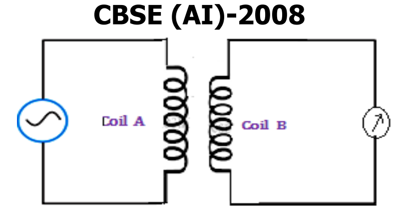
431. Define Mutual inductance of a coil. Write its S.I. unit. **CBSE (AI)-2015,2005,(D)-2009,(F)-2009**

[Ans. Mutual inductance : Mutual inductance of two coils may be defined as the total magnetic flux linked with one coil, when unit current flows through the other coil. Its S.I. unit is Henry (H)

432. The circuit arrangement given in the figure shows that when an a.c. passes through the coil A, the current starts Flowing in the coil B. **CBSE (AI)-2008**

(i) Name the underlying principle involved

(ii) Mention two factors on which the current produced in the coil B depends.



[Ans. (i) principle : Mutual induction

(ii) factors; (a) mutual inductance of two coils

(b) rate of change of current in coil A

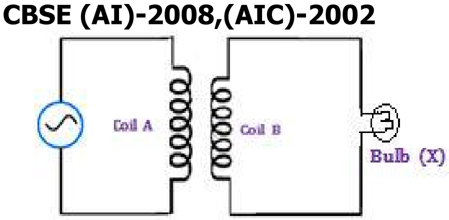
(c) resistance of coil B

433. Figure given below shows an arrangement by which current flows through the bulb (X) connected with coil B, when a.c. is passed through coil A. Explain the following observations : **CBSE (AI)-2008,(AIC)-2002**

(i) Bulb lights up

(ii) Bulb gets dimmer if coil B is moved upwards

(iii) If a copper sheet is inserted in the gap between the coils how the brightness of the bulb will change ?



[Ans. (i) bulb lights up due to induced current in coil B because of mutual induction

(ii) when coil B is moved upwards, flux linked with it decreases, induced current decreases so the bulb gets dimmer

(iii) eddy currents will be set up in the copper sheet, which will oppose the passage of magnetic flux. Induced emf in coil B de creases hence brightness s of bulb will decrease

435. The peak value of emf in an a.c. is E_0. Write its (a) rms and (b) average value over a complete cycle.

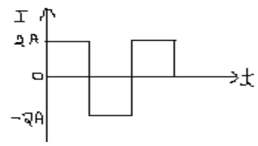
[Ans. (a) $E_{rms} = \frac{E_0}{\sqrt{2}}$ **(b)** Zero] **CBSE (F)-2001**

435. The instantaneous current from an a.c. source is $I = 5 \sin 314\, t$. What is the rms value of current ?

[Ans. $I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{5}{\sqrt{2}} = 0.707 \text{ X } 5 = 3.54 \; A$ **CBSE (DC)-2010**

436. Calculate the rms value of the alternating current shown in figure. **CBSE (D)-2001**

[Ans. $I_{rms} = \sqrt{\frac{I_1^2+I_2^2+I_3^2}{3}} = \sqrt{\frac{2^2+(-2)^2+2^2}{3}} = 2A$



437. (i) Define the term inductive reactance. Write its S.I. unit. **(AI)-2015,2011,(DC)-2008,(D)-2003**

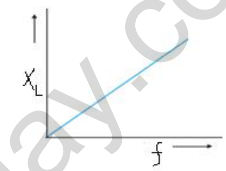
(ii) Show graphically the variation of inductive reactance with frequency of the applied alternating voltage.

[Ans. Inductive reactance (X_L) **:**

The obstruction offered by an inductor to the flow of alternating current through it, is called inductive reactance

$X_L = \omega L = 2\pi f L \quad \Rightarrow \quad X_L \propto f$

Its S. I. unit is Ohm (Ω)



438. (i) Explain the term capacitive reactance. Write its S.I. unit. **CBSE (AI)-2015,2011,(DC)-2008,(D)-2003**

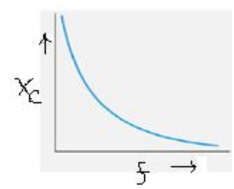
(ii) Show graphically the variation of capacitive reactance with frequency of the applied alternating voltage.

[Ans. Capacitive reactance (X_C) **:**

The obstruction offered by a capacitor to the flow of alternating current through it, is called capacitive reactance

$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C} \quad \Rightarrow \quad X_C \propto \frac{1}{f}$

Its S. I. unit is Ohm (Ω)



439. What is meant by impedance ? Write an expression for impedance of L-C-R circuit. What is it's S.I. unit ?

[Ans. Impedance (Z) **:**

The obstruction offered by the combination of resistance and effective reactance to the flow of alternating current through it, is called impedance

$Z = \sqrt{(R)^2 + (X_C - X_L)^2}$

Its S. I. unit is Ohm (Ω)

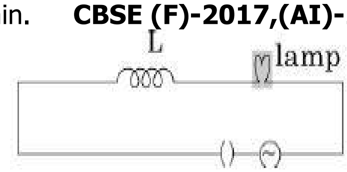
440. A lamp is connected in series with an inductor and an a.c. source. What happens to the brightness of the lamp when the key is plugged in and an iron rod is inserted inside the inductor ? Explain. **CBSE (F)-2017,(AI)-2016**

[Ans. Brightness decreases

Reason : When iron rod is inserted, inductance L increases

$\Rightarrow X_L = \omega L \;\&\; Z = \sqrt{R^2 + X_L^2}$ also decreases and current increases

Hence brightness $(I^2 Z)$ *increases.*



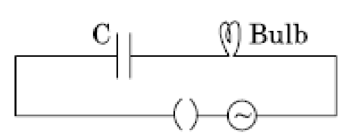
441. A bulb is connected in series with a variable capacitor and an a.c. source as shown. How the brightness of bulb changes on reducing the (a) capacitance and (b) frequency ? Justify your answer. **CBSE (AI)-2016,(D)-2010**

[Ans. (a) Brightness will decreases

Reason : When capacitance is reduced, reactance $(X_C = \frac{1}{\omega C})$ increases

$\Rightarrow Z = \sqrt{R^2 + X_C^2}$ also increases and current decreases

Hence brightness $(I^2 Z)$ *decreases*



(b) Brightness will decreases

Reason : When frequency is reduced, reactance $(X_C = \frac{1}{2\pi f C})$ increase.

$\Rightarrow Z = \sqrt{R^2 + X_C^2}$ also increases and current decreases

$I \;\; Z)$ *decreases* Hence brightness (^{2}

442. Define quality factor (Q-factor) and give its significance. What is its S.I. unit ? **CBSE (D)-2016,2013,(AI)-2015**

[Ans. Quality factor: It is defined as the ratio of resonant frequency to the frequency band width of the resonant curve

i,e, $Q = \frac{\omega_0}{2\Delta\omega} = \frac{\omega_0 L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}$

Significance : It gives the sharpness of resonance. For larger value of Q, resonance will be sharper and consequently the circuit will be more selective.

Unit : It has no unit

443. Name the factors on which Quality factors depends. **CBSE (D)-2009**

[Ans. Resonating frequency (ω_0) and band width ($2\Delta\omega$)

445. Why should the quality factor have high value in receiving circuits **CBSE (D)-2016,2013,(AI)-2015,(DC)-2014**

[Ans. For high value of Q, resonance will be sharper and consequently the circuit will be more selective

446. Define the term 'sharpness of resonance'. Under what condition, does a circuit become more selective ? **CBSE (F)-2016**

[Ans. Sharpness of resonance : The ratio of resonant frequency to the frequency band width of the resonant curve is the measure of sharpness of resonance (called Q-factor) and is given by

$$\frac{\omega_0}{2\Delta\omega} = \frac{\omega_0 L}{R} = Q$$

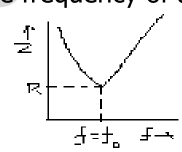
For high value of Q, resonance will be sharper and consequently the circuit will be more selective

447. (i) Mention the factors on which resonant frequency of a series LCR circuit depends. **CBSE (D)-2009,(AI)-2005**

(ii) Plot a graph showing the variation of impedance of a series LCR circuit with the frequency of applied a.c. source.

[Ans. (i) Factors : values of inductance L and capacitance C

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$



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448. Define the term power factor. State the condition under which it is (i) maximum and (ii) minimum. **CBSE (D)-2010**

[Ans. Power factor : It is the ratio of resistance to the impedance of an a.c. circuit

i,e, $\cos\phi = R/Z$

(i) when, $Z = R$, $\cos\phi = R/Z = 1 =$ maximum

i,e, when the circuit is purely resistive, power factor is maximum

(ii) when, $R = 0$, $\cos\phi = R/Z = 0 =$ minimum

i,e, when the circuit is purely inductive or capacitive, power factor is minimum]

449. Define the term 'Wattless current'. **CBSE (AI)-2015, (D)-2011**

[Ans. Wattless current : The current which flows in a circuit without consuming any electrical power is called Watt less current

In a purely inductive or capacitive circuit, $\cos\phi = R/Z = 0$

⇨ $\bar{P} = V_{rms}\ X\ I_{rms}\ X \cos 0 = 0$

450. The power factor of an a.c. circuit is 0.5. What is the phase difference between the voltage and current in the circuit ?

[Ans. 60^0 **Reason :** $\cos\phi = 0.5$ ⇨ $\phi = 60^0$ **CBSE (AI)-2016**

451. In a series LCR circuit, $V_L = V_C \neq V_R$. What is the value of power factor ? **CBSE (AI)-2015**

[Ans. $V_L = V_C$ ⇨ $IX_L = IX_C$ ⇨ $X_L = X_C$

⇨ $Z = \sqrt{(R)^2 + (X_C - X_L)^2} = R$ ⇨ Power factor, $\cos\phi = R/Z = 1$

452. In an a.c. circuit, the instantaneous voltage and current are $V = 200 \sin 300\,t$ Volt and $I = 8 \cos 300\,t$ Ampere respectively. Is the nature of the circuit is capacitive or inductive ? Give reason. **CBSE (AI)-2015**

[Ans. Capacitive, Reason : Given, $V = 200 \sin 300\,t$ & $I = 8 \cos 300\,t$ ⇨ $I = 8 \sin(300\,t + \pi/2)$

As the current leads voltage by phase angle $\pi/2$. Hence the circuit is Capacitive

453. Can the voltage drop across the inductor or the capacitor in a series LCR circuit be greater than the applied voltage of the a.c. source ? Justify your answer. **CBSE (D)-2005,2002**

[Ans. Yes, because in series LCR circuit, V_L or V_C are not in same phase, hence cannot be added like ordinary numbers

454. An a.c. source of voltage $V = V_0 \sin \omega t$ is connected one by one, to three circuit elements X, Y and Z. It is observed that the current flowing in them, **CBSE (AIC)-2008**
(i) is in phase with the applied voltage for element X
(ii) lags the applied voltage in phase by $\pi/2$, for element Y
(iii) leads the applied voltage in phase by $\pi/2$, for element Z.
Identify the three circuit elements.
[Ans. (i) X-Resistor (ii) Y- Inductor (iii) Z- capacitor

455. Write the principle of which a transformer works. **CBSE (AI)-2015,2014,2012,(F)-2008**
[Ans. It is based on the principle of **mutual induction**
i,e, whenever there is change in magnetic flux linked with a coil, an emf is induced in the neighbouring coil

456. Why cannot a transformer works on d.c. ? **CBSE (AI)-2015,(F)-2008, (DC)-2010**
OR
Why can not a transformer be used to step up d.c. voltage ?
[Ans. d.c. cannot produce a changing magnetic flux in the primary and hence no emf will be induced in the secondary

457. Why is the use of a.c. voltage is preferred over d.c. voltage ? Give two reasons. **CBSE (AI)-2014**
[Ans. 1. A.C. voltage can be steeped up & stepped down using a transformer, but same is not true for d.c. voltage
2. A.C. voltage can be converted in to d.c. voltage by using rectifier but d.c. voltage cannot be converted in to a.c. voltage

458. These days most of the electrical devices we use require a.c. voltage. Why ? **CBSE (AI)-2015**
[Ans. (a) It can be stepped up/ stepped down
(b) It can be converted in to d.c. (c) line loss can be minimized

459. In India, domestic power supply is at 220V,50Hz, while in U.S.A. it is 110V,50Hz. Give one advantage and one disadvantage of 220V supply over 110V supply. **CBSE (AI)-2004**
[Ans. Advantage – power loss at 220V supply is less than that at 110V.
Disadvantage- 220V is more dangerous than 110V because its peak value (311V) is more than peak value (155.5V) for 110V supply

460. Why is the core of a transformer is laminated ? **CBSE (DC)-2002**
[Ans. to minimize the energy losses due to eddy current

461. Mention the two characteristic properties of a material suitable for making core of a transformer. **CBSE (AI)-2012**
[Ans. (i) Low coercivity/ Low retentivity (ii) High permeability

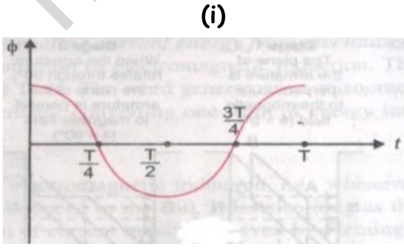
462. Why is the core of a transformer made of a magnetic material of high permeability ? **CBSE (DC)-2010**
[Ans. to increase the magnetic flux in the core, due to which flux leakage decreases & efficiency increases

463. Does a step up transformer violets the principle of conservation of energy ? **CBSE (D)-2011,(DC)-2009**
[Ans. No, In an ideal transformer input power is always equal to output power, due to which if voltage increases, current is reduced in same proportion

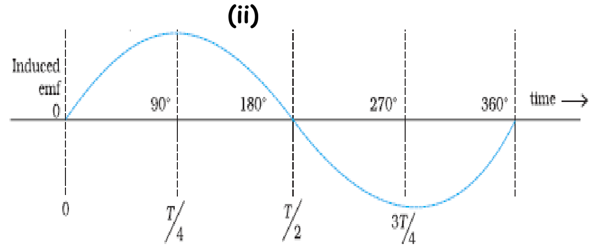
464. (i) What is the source of energy generation in an ac generator ? **CBSE (AI)-2011**
[Ans. Mechanical energy used in rotating the armature coil is the source of energy generation in an ac generator

465. (ii) Can the current produced by an ac generator be measured with a moving coil galvanometer ? **(D)-2007**
[Ans. No

465. Show a plot of variation of (i) magnetic flux and (ii) alternating emf versus time generated by a loop of wire rotating in a magnetic field in an ac generator. **CBSE (D)-2014**
[Ans. **(i)**



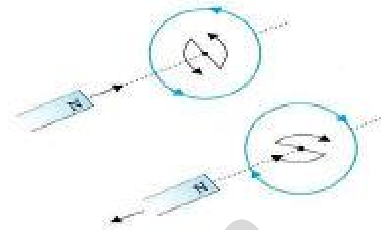
(ii)



466. Explain, with the help of a suitable example, how we can show that Lenz's law is a consequence of the principle of conservation of energy. **CBSE (F)-2017,(AI)-2015,(AIC)-2015,(D)-2009**

[Ans. Lenz's is a consequence of law of conservation of energy :

A bar magnet experiences a repulsive force when brought near a closed coil and attractive force when moved away from the coil, due to induced current. Therefore external work is required to be done in the process, which appears in the form of electrical energy.



In the absence of Lenz's law, no opposition by induced current and we would be obtaining electrical energy without doing any work, which is impossible. Thus, Lenz's law is in accordance with the principle of conservation of energy.

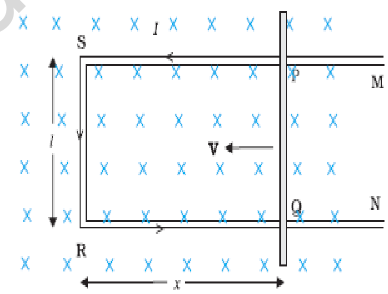
===

467. What is motional electromotive force (motional emf) ?

A rod of length l is moved horizontally with a uniform velocity $'v'$ in a direction perpendicular to its length through a region in which a uniform magnetic field is acting vertically downward. Derive the expression for the emf induced across the ends of the rod. **CBSE (D)-2014,2013**

[Ans. Motional emf : The emf induced across the ends of a conductor due to its motion in a magnetic field is called motional emf

Expression for motional emf :



Magnetic flux enclosed by loop PQRS

$\phi = BA = Blx$

Since X is changing with time, the rate of change of magnetic flux will induce an emf given by

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

⇨ $e = -\frac{d}{dt}(Blx) = Bl\left(-\frac{dx}{dt}\right)$

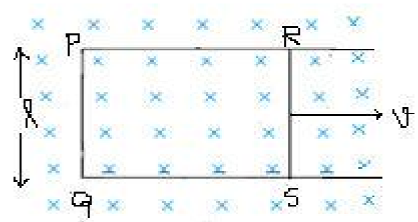
⇨ $e = Bl\,v$ Where $v = -\frac{dx}{dt}$, because velocity v is in decreasing direction of x

468. Figure shows a rectangular conducting loop $PQSR$ in which arm RS of length $'l'$ is movable. The loop is kept in a uniform magnetic field $'B'$ directed downwards perpendicular to the plane of the loop. The arm RS is moved with a uniform speed $'v'$. Deduce the expression for the : **CBSE (AI)-2009**

(a) emf induced across the arm $'RS'$

(b) external force required to move the arm, and

(c) power dissipated as heat.



[Ans. (i) Induced emf :

Magnetic flux enclosed by loop PQSR

$\phi = BA = Blx$

Since X is changing with time, the rate of change of magnetic flux will induce an emf given by

$|e| = \frac{d\phi}{dt} = \frac{d}{dt}(Blx) = Bl\left(\frac{dx}{dt}\right)$

⇨ $|e| = Bl\,v$

(ii) External force required to move the arm RS:

Induced current, $I = \frac{e}{R} = \frac{Blv}{R}$

⇨ External force required, $F = BIl\,\sin 90 = B\left(\frac{Blv}{R}\right)l = \frac{B^2l^2v}{R}$

(iii) Power dissipated as heat :

$P = I^2R = \left(\frac{Blv}{R}\right)^2 R = \frac{B^2l^2v^2}{R}$

469. Use the expression for Lorentz force acting on the charge carriers of a conductor to obtain the expression for the induced emf across the conductor of length l moving with velocity v through a magnetic field B acting perpendicular to its length. **CBSE (AI)-2015**

[Ans. Motional emf by using Lorentz's force:

Lorenz's force on any charge q in the rod

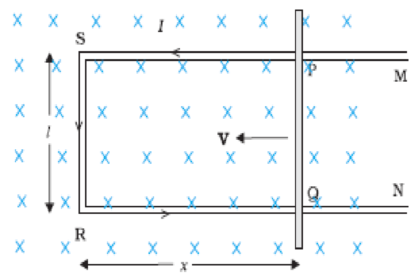
$F_m = Bqv$

This force will be towards Q

work done in moving the charge from P to Q

$W = F_m \, X \, l = Bqv\, l$

Now the induced emf = work done per unit charge



⇨ $e = \frac{W}{q} = \frac{Bqvl}{q}$

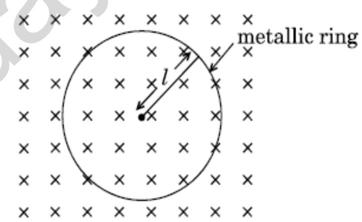
⇨ $e = Bl\, v$

470. A metallic rod of length 'l' is rotated with a frequency 'v', with one end hinged at the centre in a uniform magnetic field B as shown. Derive an expression for- **CBSE (AI)-2015, (AIC)-2014,(D)-2012,2008**

(a) induced emf and induced current in the rod

(b) magnitude and direction of the force acting on the rod

(c) power required to rotate the rod



[Ans. (a) As the rod is rotated, due to Lorentz force, free electrons in the rod move towards the outer end and get distributed over the ring. Thus, an emf is induced across the ends of the rod

induced emf across the length dl of the rod

$de = Bv\, dl = B(l\omega)\, dl = B\omega\, ldl$

⇨ $e = \int_0^l B\omega ldl = B\omega \int_0^l l\, dl\; e = B\omega \left[\frac{l^2}{2}\right]_0^l = \frac{1}{2}B\omega(l^2 - 0)$

⇨ $e = \frac{1}{2}B\omega l^2 = \frac{1}{2}B(2\pi v)l^2 = \pi v B l^2$

Induced current, $\mathrm{I} = \frac{e}{R} = \frac{1}{2}\frac{B\omega l^2}{R} = \frac{\pi v B l^2}{R}$

(b) Force on the rod, $F = BIl \sin 90 = B\left(\frac{1}{2}\frac{B\omega l^2}{R}\right) l = \frac{1}{2}\frac{B^2 l^3 \omega}{R} = \frac{\pi v B^2 l^3}{R}$

Direction of this force will be opposite to that of the Lorentz's force

(c) Power required to rotate the rod $P = \frac{e^2}{R} = \frac{\pi^2 v^2 B^2 l^4}{R}$

==

471. Describe briefly three main useful applications of eddy currents. **CBSE (F)-2015, (AI)-2010,2009**

[Ans. (i) Magnetic braking in trains:

In some electrically powered trains, strong electromagnets are situated above the rails. When the electromagnets are activated, the eddy currents induced in the rails oppose the motion of the train. As there are no mechanical linkages, the braking effect is smooth.

(ii) Electromagnetic damping:

Certain galvanometers have a fixed core made of nonmagnetic metallic material. When the coil oscillates, the eddy currents generated in the core oppose the motion and bring the coil to rest quickly.

(iii) Induction furnace: It is used to produce high temperatures and can be utilized to prepare alloys, by melting the constituent metals. A high frequency alternating current is passed through a coil which surrounds the metals to be melted. The eddy currents generated in the metals produce high temperatures sufficient to melt it.

(iv) Electric power meters: The shiny metal disc in the electric power meter rotates due to the eddy currents. Electric currents are induced in the disc by magnetic fields produced by sinusoidally varying currents in a coil

472. Derive the expression for the self-inductance of a long solenoid of cross sectional area A, length l, and having n turns per unit length. **CBSE (AIC)-13,(AI)-2005,(D)-2012,2009,2008**

[Ans. Self inductance of a long solenoid :

Let a current I is flowing through a long solenoid, then magnetic field at its centre

$$B = \mu_0 n I = \frac{\mu_0 N I}{l} \qquad [\because n = \frac{N}{l}]$$

⇨ magnetic flux linked with each turn of the solenoid

$$\phi = BA = \left(\frac{\mu_0 NI}{l}\right) A = \frac{\mu_0 N IA}{l}$$

⇨ $$L = \frac{N\phi}{I} = \frac{N}{I}\left(\frac{\mu_0 N IA}{l}\right) = \frac{\mu_0 N^2 A}{l}$$

⇨ $$L = \frac{\mu_0 (nl)^2 A}{l} = \mu_0 n^2 Al$$

If we fill the inside of the solenoid with a material of relative permeability μ_r, then

$$L = \mu_0 \mu_r n^2 Al = \mu_0 \mu_r n^2 \pi r^2 l$$

473. Derive an expression for the self-inductance of a circular aired coil. Name the three factors on which the self-inductance of a coil depends. **CBSE (AI)-2015**

[Ans. Self inductance of an aired coil :

magnetic field at the centre of circular coil

$$B = \frac{\mu_0 NI}{2r}$$

⇨ magnetic flux linked with each turn of the coil

$$\phi = BA = \left(\frac{\mu_0 NI}{2r}\right)\pi r^2 = \frac{1}{2}\mu_0 \pi NIr$$

⇨ Self inductance of the coil

$$L = \frac{N\phi}{I} = \frac{N}{I}\left(\frac{1}{2}\mu_0 \pi NIr\right) = \frac{1}{2}\mu_0 \pi N^2 r$$

Factors on which self inductance of a coil depends :

(a) the number of turns in the coil

(b) the area of cross section of the coil (c) the permeability of the core material

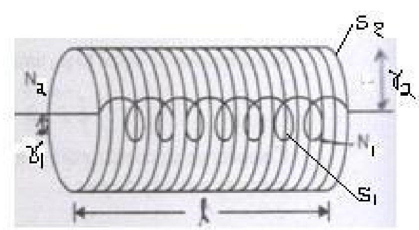
474. (i) Derive an expression for the mutual inductance of two long coaxial solenoids of same length wound one over the other. **CBSE (AI)-2017,2014,2009,(D)-2015,2012,2005,(F)-2013,2011**

(ii) Write the factors on which the mutual inductance of a pair of solenoids depends. **CBSE (AI)-2015**

[Ans. Mutual inductance between two co-axial long solenoids of same length wound over the other :

Magnetic field at the centre of solenoid S_2

$$B_2 = \mu_0 n_2 I_2 = \frac{\mu_0 N_2 I_2}{l}$$



Magnetic flux linked with each turn of inner solenoid S_1

$$\phi_1 = B_2 A_1 = \left(\frac{\mu_0 N_2 I_2}{l}\right) A_1 = \frac{\mu_0 N_2 I_2 A_1}{l}$$

Hence mutual inductance

⇨ $$M_{12} = \frac{N_1 \phi_1}{I_2} = \frac{N_1}{I_2}\left(\frac{\mu_0 N_2 I_2 A_1}{l}\right) = \frac{\mu_0 N_1 N_2 A_1}{l}$$

⇨ $$M_{12} = \frac{\mu_0 (n_1 l)(n_2 l) r_1^2}{l} = \mu_0 n_1 n_2 r_1^2 l$$

Similarly, $M_{21} = \mu_0 n_1 n_2 r_1^2 l$

⇨ $$M_{12} = M_{21} = M = \mu_0 n_1 n_2 r_1^2 l$$

If a medium of relative permeability μ_r is filled in between the solenoids then

$$M = \mu_0 \mu_r n_1 n_2 r_1^2 l$$

Factors on which mutual inductance of a pair of solenoids depends :

(i) number of turns and separation between two solenoids

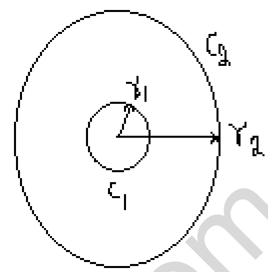
(ii) relative orientation of two solenoids

475. Two concentric circular coils, one of small radius r_1 and the other of large radius r_2 such that $r_1 \ll r_2$ are placed co-axially with centres coinciding. Obtain the mutual inductance of the arrangement. Give two factors on which the coefficient of mutual inductance between a pair of coils depends. **CBSE (AI)-2015,(D)-2015, (AIC)-2015**

[Ans. Mutual inductance between two co-axial with centres coinciding circular coils :

magnetic field at the centre of the outer coil

$$B_2 = \frac{\mu_0 N_2 I_2}{2r_2}$$



magnetic flux linked with inner coil

$$\phi_1 = B_2 A_1 = \left(\frac{\mu_0 N_2 I_2}{2r_2}\right) A_1$$

Hence mutual inductance

$$\Rightarrow \quad M_{12} = \frac{N_1 \phi_1}{I_2} = \frac{N_1}{I_2}\left(\frac{\mu_0 N_2 I_2}{2r_2}\right) A_1 = \frac{\mu_0 N_1 N_2 A_1}{2r_2}$$

$$\Rightarrow \quad M_{12} = \frac{\mu_0 N_1 N_2 \pi r_1^2}{2r_2}$$

Factors on which mutual inductance of a pair of a coil depends :

(i) number of turns and geometrical shape of two coils

(ii) relative orientation of two coils

476. In an experimental arrangement of two coils C_1 and C_2 placed co-axially parallel to each other, find the expression for the emf induced in the coil C_1(of N_1 turns)corresponding to the change of current I_2 in the coil C_2 (of N_2 turns). **CBSE (AI)-2015, (D)-2015**

[Ans. Induced emf in coil C_1 due to change in current through C_2

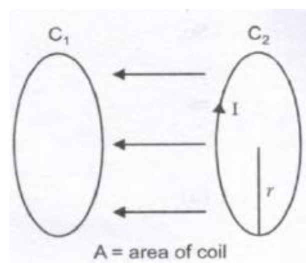
We have, $N_1 \phi_1 = M I_2$

For varying currents,

$$N_1\left(\frac{d\phi_1}{dt}\right) = M\left(\frac{dI_2}{dt}\right)$$

$$\Rightarrow \quad -e = M\left(\frac{dI_2}{dt}\right)$$

$$\Rightarrow \quad e = -M\left(\frac{dI_2}{dt}\right)$$]



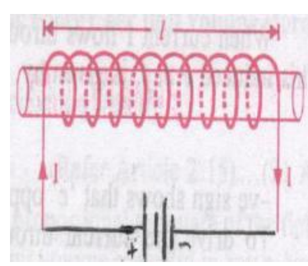
477. Obtain an expression for the energy stored in an inductor/coil/ solenoid of self-inductance 'L' when the current through it grows from zero to 'I'. **CBSE (AI)-2017,2015,2011,2008**

[Ans. <u>Energy stored in an inductor/coil/solenoid</u> :

When a current flows through an inductor/solenoid, work is done against back emf ($e = -L\frac{dI}{dt}$), which is stored as magnetic potential energy.

Rate of work done, when a current I is passing through the inductor

$$\frac{dW}{dt} = |e|\, I = \left(L\frac{dI}{dt}\right) I$$



$$\Rightarrow \quad W = \int_0^I L\, I\, dI = L\left[\frac{I^2}{2}\right]_0^I = \frac{1}{2} L\, I^2$$

$$\Rightarrow \quad \boxed{U = \frac{1}{2} L\, I^2}$$

But for a solenoid, $L = \frac{\mu_0 N^2 A}{l}$

$$\Rightarrow \quad U = \frac{1}{2}\left(\frac{\mu_0 N^2 A}{l}\right) I^2$$

478. An a.c. voltage $V = V_0 \sin \omega t$ is applied across a pure resistor of inductance R. Find an expression for the current flowing in the circuit and show mathematically that the current flowing through it is in phase with the applied voltage Also draw (a) phasor diagram (b) graphs of V and I versus ωt for the circuit. **CBSE (AIC)-2013**

[**Ans**. We have the applied a.c. voltage

$V = V_0 \sin \omega t$ -------(1)

By Kirchhoff's loop rule,

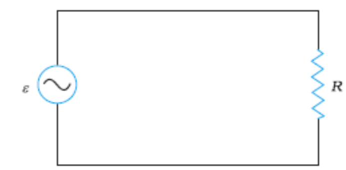
⇨ $IR = V_0 \sin \omega t$

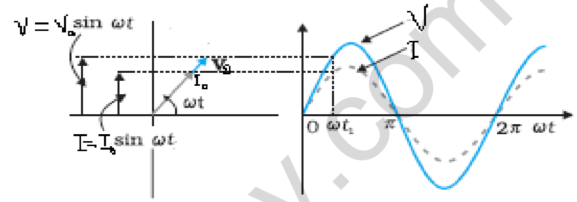
⇨ $I = \frac{V_0}{R} \sin \omega t$

⇨ $I = I_0 \sin \omega t$ -------(2)

Where $I_0 = \frac{V_0}{R}$ is the peak value of a.c.

From (1) & (2) we conclude that voltage and current are in the same phase





Phasor diagram V-I graph

479. For a given alternating current, $I = I_0 \sin \omega t$, Show that the average power dissipated in a resistor R over a complete cycle is $\frac{1}{2} I_0^2 R$. **CBSE (AI)-2013**

[**Ans**. We have, $I = I_0 \sin \omega t$

Average power dissipated per cycle

$$\overline{P} = \frac{1}{T}\int_0^T I^2 R\, dt = \frac{1}{T}\int_0^T (I_0 \sin \omega t)^2 R\, dt = \frac{I_0^2 R}{T}\int_0^T \sin^2 \omega t\, dt$$

⇨ $\overline{P} = \frac{I_0^2 R}{T}\int_0^T \left(\frac{1-\cos 2\omega t}{2}\right) dt$

⇨ $\overline{P} = \frac{I_0^2 R}{2T}\left[\int_0^T dt - \int_0^T \cos 2\omega t\, dt\right]$

⇨ $\overline{P} = \frac{I_0^2 R}{2T}[(T-0)]$ $\left[\because \int_0^T \cos 2\omega t\, dt = 0\right]$

⇨ $\overline{P} = \frac{1}{2} I_0^2 R$

480. An a.c. voltage $V = V_0 \sin \omega t$ is applied across a pure inductor of inductance L. Find an expression for the current flowing in the circuit and show mathematically that the current flowing through it lags behind the applied voltage by a phase angle of $\frac{\pi}{2}$. Also draw (a) phasor diagram (b) graphs of V and I versus ωt for the circuit.

CBSE (F)-2017,(AI)-2015,2011,(DC)-2008,(D)-2003

[**Ans**. We have the applied a.c. voltage

$V = V_0 \sin \omega t$ -------(1)

By Kirchhoff's loop rule,

$V - L\frac{dI}{dt} = 0$

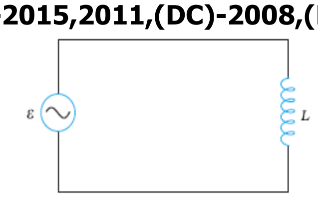
⇨ $\frac{dI}{dt} = \frac{V}{L} = \frac{V_0}{L} \sin \omega t$

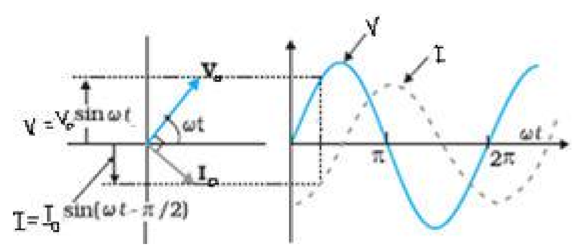
⇨ $\int dI = \frac{V_0}{L}\int \sin \omega t\ dt$

⇨ $\mathbf{I} = -\frac{V_0}{\omega L} \cos \omega t = -\mathbf{I_0} \cos \omega t$

⇨ $\mathbf{I} = \mathbf{I_0} \sin(\omega t - \frac{\pi}{2})$ ------(2)

Where, $I_0 = \frac{V_0}{\omega L}$ ------(3)





Obviously, effective resistance of the circuit known as inductive reactance (X_L) given by $X_L = \omega L = 2\pi f L$

From (1) & (2) we conclude that current in the circuit lags behind the voltage in phase by $\frac{\pi}{2}$

481. An a.c. voltage $V = V_0 \sin \omega t$ is applied across a pure capacitor of capacitance C. Find an expression for the current flowing in the circuit and show mathematically that the current flowing through it leads the applied voltage by a phase angle of $\frac{\pi}{2}$. Also draw (a) phasor diagram (b) graphs of V and I versus ωt for the circuit.

CBSE (AI)-2015,2011,(D)-2015,2003,(F)-2014

[**Ans**. We have the applied a.c. voltage

$V = V_0 \sin \omega t$ -------(1)

By Kirchhoff's loop rule,

$\frac{q}{C} = V_0 \sin \omega t$

⇨ $\mathbf{I} = \frac{dq}{dt} = \frac{d}{dt}(CV_0 \sin \omega t)$

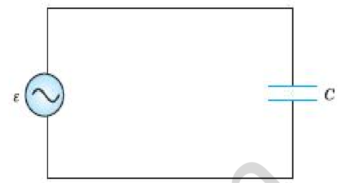
⇨ $\mathbf{I} = \omega C\, V_0 \cos \omega t = \frac{V_0}{1/\omega C} \cos \omega t$

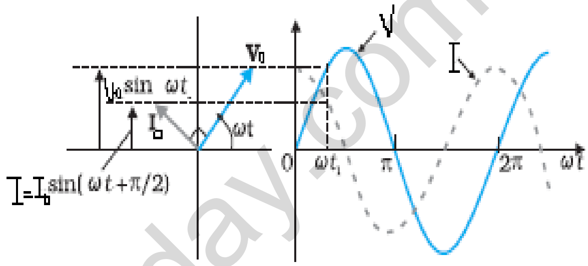
⇨ $\mathbf{I} = \mathbf{I_0} \cos \omega t = \mathbf{I_0} \sin(\omega t + \frac{\pi}{2})$ ------(2)

Where, $I_0 = \frac{V_0}{1/\omega C}$ ------(3)

Obviously, effective resistance of the circuit known as capacitive reactance (X_C) given by

$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$





Phasor diagram V-I graph

From (1) & (2) we conclude that current in the circuit Leads the voltage in phase by $\frac{\pi}{2}$

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482. When an a.c. source is connected to an ideal inductor show that the average power supplied by the source over a complete cycle is zero. Also plot a graph showing the variation of voltage, current, power and flux in one cycle.

CBSE (F)-2017,(D)-2016,(AI)-2015

[**Ans**. We have, $V = V_0 \sin \omega t$

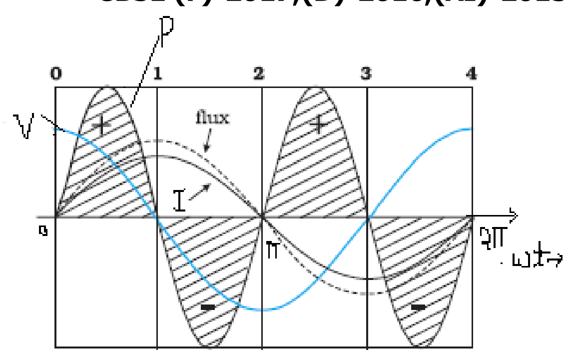
& $\mathrm{I} = \mathrm{I_0} \sin(\omega t - \frac{\pi}{2}) = -\,\mathrm{I_0} \cos \omega t$

Average power per cycle

$\overline{P} = \frac{1}{T}\int_0^T V \times I\, dt = \frac{1}{T}\int_0^T V_0\, I_0 \sin \omega t \cos \omega t\; dt$

⇨ $\overline{P} = \frac{V_0\, I_0}{2T}\int_0^T \sin 2\omega t\; dt$

⇨ $\overline{P} = 0$ $[\because \int_0^T \sin 2\omega t\; dt = 0]$



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483. When an a.c. source is connected to a pure capacitor show that the average power supplied by the source over a complete cycle is zero. Also plot a graph showing the variation of voltage, current, power and flux in one cycle.

CBSE (AIC)-2017,(D)-2016,(AI)-2015

[**Ans**. We have, $V = V_0 \sin \omega t$

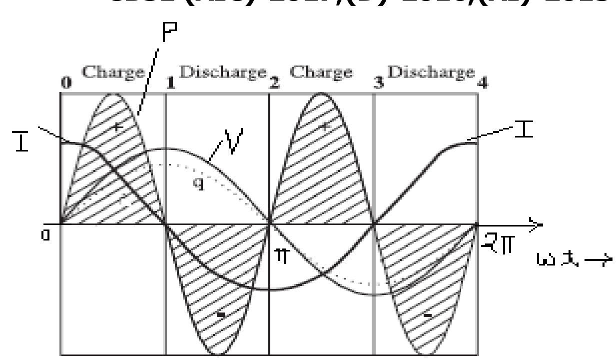
& $\mathrm{I} = \mathrm{I_0} \sin(\omega t + \frac{\pi}{2}) = \mathrm{I_0} \cos \omega t$

Average power per cycle

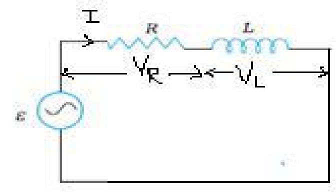
$\overline{P} = \frac{1}{T}\int_0^T V \times I\, dt = \frac{1}{T}\int_0^T V_0\, I_0 \sin \omega t \cos \omega t\; dt$

⇨ $\overline{P} = \frac{V_0\, I_0}{2T}\int_0^T \sin 2\omega t\; dt$

⇨ $\overline{P} = 0$ $[\because \int_0^T \sin 2\omega t\; dt = 0]$



484. An alternating voltage $V = V_0 \sin \omega t$ is applied to a series combination of a resistor and an inductor. Using phasor diagram, derive expressions for impedance, instantaneous current and its phase relationship to the applied voltage. Also draw graphs of V and I versus ωt for the circuit. **CBSE (AIC)-2014**



[**Ans. AC through LR circuit :**

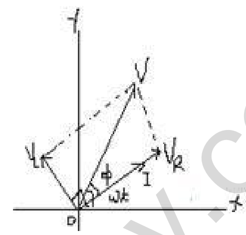
We have the applied voltage

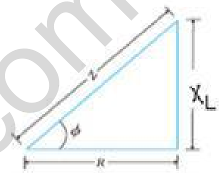
$V = V_0 \sin \omega t$ -------(1)

From phasor diagram

$$\boldsymbol{V} = \sqrt{V_R^2 + V_L^2} = \sqrt{(IR)^2 + (I X_L)^2} = I\sqrt{(R)^2 + X_L^2}$$

⇨ $\boldsymbol{I} = \frac{V}{\sqrt{R^2 + X_L^2}}$





Obviously, effective resistance of the circuit, known as impedance is given by

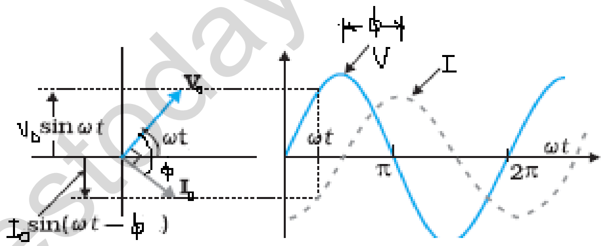
$$Z = \sqrt{R^2 + X_L^2}$$

Obviously, $\mathrm{I} = \mathrm{I}_0 \sin(\omega t - \phi)$ ----(2)

Where, $\tan\phi = \frac{V_L}{V_R} = \frac{I_0 X_L}{I_0 R} = \frac{X_L}{R} = \frac{\omega L}{R}$

⇨ $\phi = \tan^{-1}\left(\frac{\omega L}{R}\right)$

From (1) & (2) we conclude that current in the circuit lags behind the voltage in phase by ϕ.



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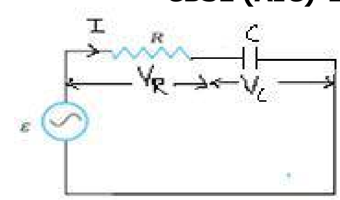
485. An alternating voltage $V = V_0 \sin \omega t$ is applied to a series combination of a resistor and a capacitor. Using phasor diagram, derive expressions for impedance, instantaneous current and its phase relationship to the applied voltage. Also draw graphs of V and I versus ωt for the circuit. **CBSE (AIC)-2014**



[**Ans. AC through CR circuit :**

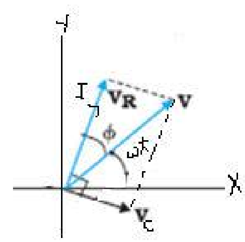
We have the applied voltage

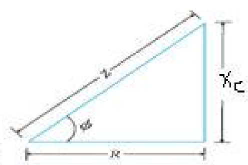
$V = V_0 \sin \omega t$ --------(1)

From phasor diagram

$$\boldsymbol{V} = \sqrt{V_R^2 + V_C^2} = \sqrt{(IR)^2 + (I X_C)^2} = I\sqrt{(R)^2 + X_C^2}$$

⇨ $\boldsymbol{I} = \frac{V}{\sqrt{R^2 + X_C^2}}$





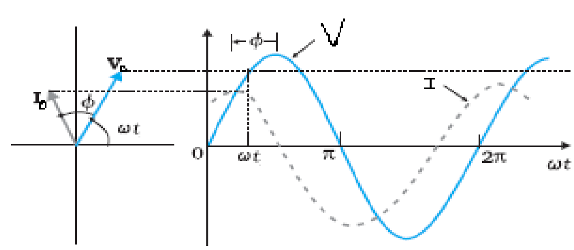
Obviously, effective resistance of the circuit, known as impedance is given by

$$Z = \sqrt{R^2 + X_C^2}$$

Obviously, $\mathrm{I} = \mathrm{I}_0 \sin(\omega t + \phi)$ ----(2)

Where, $\tan\phi = \frac{V_C}{V_R} = \frac{I_0 X_C}{I_0 R} = \frac{X_C}{R} = \frac{1/\omega C}{R}$

⇨ $\phi = \tan^{-1}\left(\frac{1}{\omega CR}\right)$



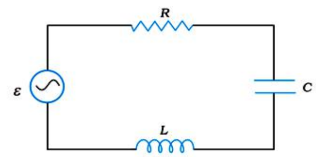
From (1) & (2) we conclude that current in the circuit lags behind the voltage in phase by ϕ

486. A series LCR circuit is connected to an a.c. source having voltage $V = V_0 \sin \omega t$. Using phasor diagram, derive expressions for impedance, instantaneous current and its phase relationship to the applied voltage. Also draw graphs of V and I versus ωt for the circuit **CBSE (AI)-2016**

[Ans. AC through LCR circuit :

We have the applied a.c. voltage

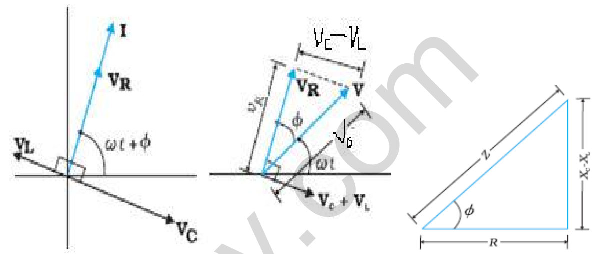
$V = V_0 \sin \omega t$ -------(1)



From phasor diagram

$$\boldsymbol{V} = \sqrt{V_R^2 + (V_C - V_L)^2} = \sqrt{(IR)^2 + (IX_C - IX_L)^2} = I\sqrt{R^2 + (X_C - X_L)^2}$$

$$\Rightarrow \boldsymbol{I} = \frac{V}{\sqrt{R^2 + (X_C - X_L)^2}}$$



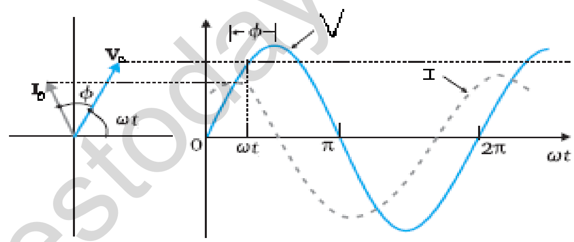
Obviously, effective resistance of the circuit, known as impedance is given by

$$Z = \sqrt{(R)^2 + (X_C - X_L)^2}$$

Obviously, $\mathrm{I} = \mathrm{I}_0 \sin(\omega t + \phi)$ ----(2)

Where, $\tan\phi = \frac{V_C - V_L}{V_R} = \frac{I_0 X_C - I_0 X_L}{I_0 R} = \frac{X_C - X_L}{R}$

$\Rightarrow \phi = \tan^{-1}\left(\frac{X_C - X_L}{R}\right)$



From (1) & (2) we conclude that current in the circuit leads the voltage in phase by ϕ.

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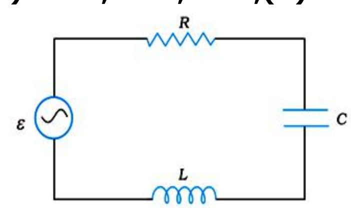
487. A voltage $V = V_0 \sin \omega t$ is applied to a series LCR circuit. Derive the expression for average power dissipated over a cycle. Under what condition is -

(i) no power is dissipated even though the current flows through the circuit,

(ii) maximum power dissipated in the circuit. **CBSE (AI)-2016,2015,2014,(D)-2016**

[Ans. We have the applied voltage



$V = V_0 \sin \omega t$

& $\mathrm{I} = \mathrm{I}_0 \sin(\omega t + \phi)$ Where, $\phi = \tan^{-1}\left(\frac{X_C - X_L}{R}\right)$

$\Rightarrow P = V \text{ X } I = V_0 \sin \omega t \text{ X } \mathrm{I}_0 \sin(\omega t + \phi)$

$\Rightarrow P = V_0 \mathrm{I}_0 \sin \omega t \text{ X } (\sin \omega t \cos \phi + \cos \omega t \sin \phi)$

$\Rightarrow P = V_0 \mathrm{I}_0 \left[\sin^2 \omega t \cos\phi + \frac{1}{2}\sin 2\omega t \sin\phi\right]$

Average power per cycle

$$\overline{P} = \frac{1}{T}\int_0^T P\, dt = \frac{1}{T}\int_0^T V_0 \mathrm{I}_0 \left[\sin^2 \omega t \cos\phi + \frac{1}{2}\sin 2\omega t \sin\phi\right] dt$$

$\Rightarrow \overline{P} = \frac{V_0 \mathrm{I}_0 \cos\phi}{T}\int_0^T \sin^2 \omega t\, dt + \frac{V_0 \mathrm{I}_0 \sin\phi}{2T}\int_0^T \sin 2\omega t\, dt$

$\Rightarrow \overline{P} = \frac{V_0 \mathrm{I}_0 \cos\phi}{T}\frac{T}{2} + 0$ $\left[\because \int_0^T \sin^2 \omega t\, dt = \frac{T}{2} \text{ \& } \int_0^T \sin 2\omega t\, dt = 0\right]$

$\Rightarrow \overline{P} = \frac{V_0 \mathrm{I}_0}{2}\cos\phi = \frac{V_0}{\sqrt{2}} \text{ X } \frac{I_0}{\sqrt{2}} \text{ X } \cos\phi$

$\Rightarrow$ $\boxed{\overline{P} = V_{rms} \text{ X } I_{rms} \text{ X} \cos\phi}$ Where, $\cos\phi = R/Z$ is called power factor

(i) For a pure inductive or capacitive circuit, $\phi = \frac{\pi}{2}$

$\Rightarrow \overline{P} = V_{rms} \text{ X } I_{rms} \text{ X} \cos\frac{\pi}{2} = 0$ which shows that, no power is dissipated even current flows through the circuit

(ii) at resonance when $X_L = X_C$, $\phi = 0$

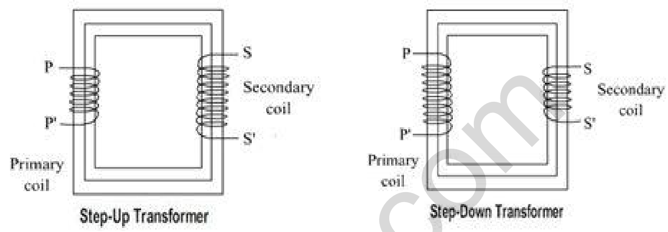
$\Rightarrow \overline{P} = V_{rms} \text{ X } I_{rms} \text{ X} \cos 0 = V_{rms} \text{ X } I_{rms}$ = maximum Which shows that at resonance m ax power is dissipated

488. Draw a schematic diagram of a step up/step down transformer. Explain its working principle. Deduce the expression for the secondary to primary voltage in terms of the number of turns in the two coils. In an ideal transformer, how is this ratio related to the currents in the two coils ?

CBSE (F)-2017,2012,2009,(AI)-2015,2010,(D)-2016

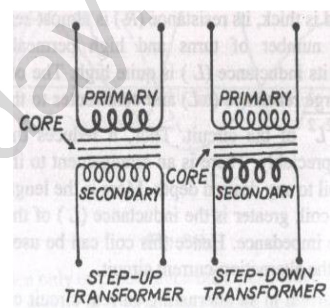
[**Ans. Transformer :** It is an electrical device which, which is used to increase or decrease the voltage in a.c. circuits.

Principle : It is based on the principle of **mutual induction,** i,e, whenever there is change in magnetic flux linked with a coil, an emf is induced in the neighbouring coil



Working :

When an alternating voltage is applied to the primary, magnetic flux linked with it changes which links to the secondary and induces an emf in it due to mutual induction.



Back emf induced in Primary

$$e_p = -N_p \frac{d\phi}{dt}$$

Similarly, emf induced in the secondary

$$e_s = -N_s \frac{d\phi}{dt}$$

⇨ $$\frac{e_s}{e_p} = \frac{-N_s \frac{d\phi}{dt}}{-N_p \frac{d\phi}{dt}} = \frac{N_s}{N_p} \qquad \text{---------(1)}$$

As the primary has negligible resistance, $e_p = V_p$ and if secondary is in an open circuit then $e_s = V_s$, Then from (1) we have

$$\frac{e_s}{e_p} = \frac{V_s}{V_p} = \frac{N_s}{N_p} = r \qquad \text{--------(2)}$$

Where, $r = \frac{N_s}{N_p}$, is called transformation ratio

Now, if the transformer is ideal, then

power input = power output

⇨ $V_P \times i_p = V_s \times i_s$

⇨ $\frac{i_s}{i_p} = \frac{V_P}{V_s} = \frac{N_P}{N_s} = \frac{1}{r}$

It shows that when voltage is stepped-up, the current is correspondingly reduced in the same ratio, and vice-versa

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489.(ii) Describe briefly any two energy losses, giving the reason of their occurrence in actual transformer. How are these reduced ?

CBSE (D)-2016, (AI)-2015, 2010, (F)-2012, 2009

[**Ans. Energy losses in a transformer :**

(i) Copper loss : Energy loss as heat due to resistance of primary and secondary is called copper loss and can be minimized by using thick copper wires

(ii) Iron loss : Energy loss as heat due to eddy currents in the iron core is called Iron loss and can be reduced by using a laminated iron core

(iii) Hysteresis loss: Magnetisation of iron core is repeatedly reversed by the alternating magnetic field and energy is lost in the form of heat in the core. This is called hysteresis loss and can be minimized by using a core of a material having low hysteresis loop.

(iv) Flux leakage : There is always some flux leakage; i,e, all of the flux due to primary does not passes through the secondary. It can be minimized by winding primary and secondary coils one over the other

490.(iii) How is the transformer used in large scale transmission and distribution of electrical energy over long distances ?

CBSE (AI)-2016,2010,2008,(AIC)-2014,(F)-2009

[**Ans.** (a) output voltage of the power generator is stepped-up so that current is reduced and as a result, line loss I^2R is also reduced

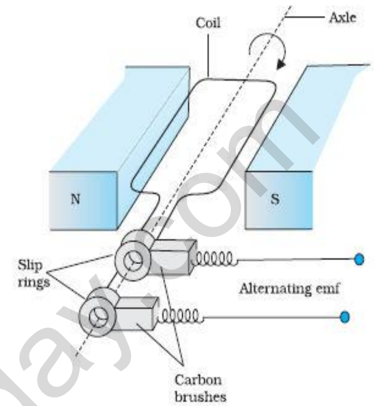
(b) It is then transmitted over long distances to an area sub-station, where voltage is stepped down.

491. (i) Explain with the help of a labelled diagram, the principle and working of an ac generator and obtain expression for the emf generated in the coil.
(ii) Draw a schematic diagram showing the nature of the alternating emf generated by the rotating coil in the magnetic field during one cycle. **CBSE (AI)-2016,2015,2011,(F)-2012,2009,(D)-2010,2007**

[**Ans. AC generator** : It is a device which converts mechanical energy in to electrical energy.

Principle : It is based on the principle of **electromagnetic induction**, i,e, whenever there is change in magnetic flux linked with a coil, an emf is induced in the coil

Working :



When the armature coil is rotated in a uniform magnetic field, effective area of coil ($A \cos\theta$) changes continuously due to which magnetic flux linked with it changes. Hence an emf is induced in the circuit and a current flows through the coil

At any instant the magnetic flux linked with the coil

$\phi = BA\cos\theta = BA\cos\omega t$

⇨ Induced emf in the coil

$e = -N\frac{d\phi}{dt} = -N\frac{d}{dt}(BA\cos\omega t)$

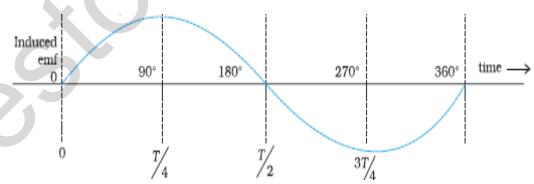
⇨ $e = -NBA(-\omega\sin\omega t) = NBA\omega\sin\omega t$

Obviously, when $\sin\omega t = 1$

$e = e_{max} = e_0 = NBA\omega$

⇨ $\boldsymbol{e = e_0 \sin\omega t}$

& $I = \frac{e}{R} = \frac{e_0}{R}\sin\omega t = I_0 \sin\omega t$



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492. In a series LCR circuit connected to an a.c. source of variable frequency and voltage $= V_0 \sin\omega t$, draw a plot showing the variation of amplitude of circuit current with angular frequency of applied voltage for two different values of resistance R_1 and R_2 ($R_1 > R_2$). Write the condition under which the phenomenon of resonance occurs. Answer the following using this graph: **CBSE (F)-2016,(AI)-2015,(DC)-2014,(D)-2013**
(a) In which case the resonance is sharper and why ?
(b) In which case the power dissipation is more and why ?
(c) Which one would be better suited for fine tuning in a receiver set ?

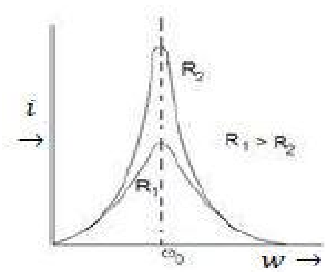
[**Ans. Resonance condition** : $X_L = X_C$ **or** $V_L = V_C$

(a) Sharper for R_2 **Reason** : Sharpness of resonance $= \frac{\omega_0 L}{R} \propto \frac{1}{R}$

(b) More power dissipation for R_2

Reason : At resonance, power dissipation$= \frac{V^2}{R} \propto \frac{1}{R}$ (for same V)

(c) for larger value of Q ($=\frac{\omega_0 L}{R} \propto \frac{1}{R}$), resonance will be sharper hence circuit with resistance R_2 would be better suited for tuning the receiver set]



493. In a series LR circuit $X_L = R$ and power factor of the circuit is P_1. When capacitor with capacitance C such that $X_L = X_C$ is put in series, the power factor becomes P_2. Calculate P_1/P_2. **CBSE (D)-2016, (AI)-2015**

[**Ans. For LR circuit power factor**

$$P_1 = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + X_L^2}} = \frac{R}{\sqrt{R^2 + R^2}} = \frac{R}{R\sqrt{2}} = \frac{1}{\sqrt{2}}$$

When $X_L = X_C$ is put in series, for LCR circuit power factor

$$P_2 = \frac{R}{Z} = \frac{R}{\sqrt{(R)^2 + (X_C - X_L)^2}} = \frac{R}{R} = 1 \quad ⇨ \quad \frac{P_1}{P_2} = \frac{1/\sqrt{2}}{1} = 1\ ]$$

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