UNIT – 4 ELCTROMAGNETIC INDUCTION AND ALTERNATING CURRENT

Short Answers (Book back)

1.What is meant by electromagnetic induction?

- Whenever the **magnetic flux** linked with a closed coil **changes**, an **emf is induced** and hence an electric current flows in the circuit.
- This current is called an induced current and the emf giving rise to such current is called an induced emf.
- This phenomenon is known as electromagnetic induction.

2.State Faraday's law of electro magnetic induction.

First law

Whenever **magnetic flux** linked with a closed circuit **changes**, an **emf is induced** in the circuit.

Second law

The **magnitude of induced emf** in a closed circuit is equal to the **rate of change of magnetic flux** linked with the circuit.

3.State Lenz's law

It states that the **direction of the induced current** is such that it always **opposes the cause responsible for its production**.

4.State Fleming's right hand rule

If the **index finger** points the **direction of the magnetic field** and the **thumb** indicates the **direction of motion of the conductor**, then the **middle finger** will indicate the **direction of the induced current**.

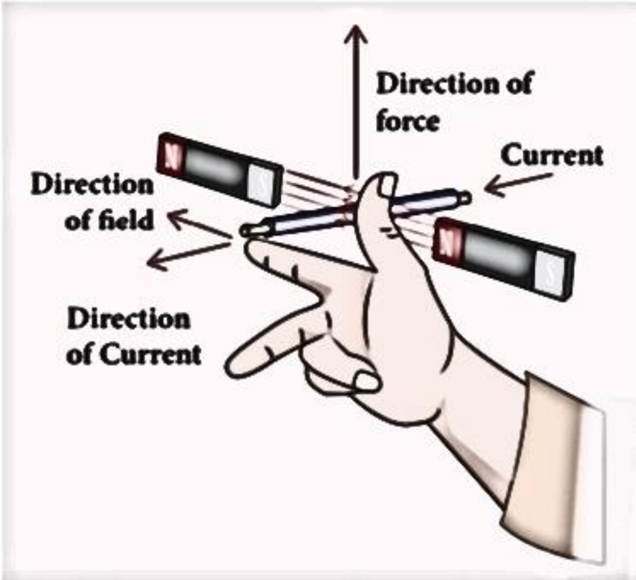


Figure 4.8 Fleming's right hand rule

5.How is Eddy current is produced ? How do they flow in a conductor

For **a conductor** in the form of a sheet or plate, an **emf is induced** when magnetic **flux** linked with it **changes**.

The induced **currents flow** in concentric **circular paths**

As these **electric currents** resemble **eddies** of water, these are known as **Eddy currents OR Foucault current**

6.Mention the ways of producing induced emf .

$$\varepsilon = \frac{d}{dt}(BA\cos\theta)$$

(i) By changing the magnetic field B
(ii) By changing the area A of the coil and
(iii) By changing the relative orientation θ of the coil with magnetic field

15.What are phasors ?

A sinusoidal alternating voltage (or current) can be represented by a **vector** which **rotates** about the **origin in anti-clockwise** direction at a **constant angular velocity ω**. Such a rotating vector is called a phasor.

16.Define electrical resonance

When the **frequency of the applied alternating source is equal to the natural frequency of the *RLC* circuit**, the current in the circuit reaches its maximum value.

Then the circuit is said to be in electrical resonance. The **frequency** at which **resonance takes place** is called **resonant frequency.**

17.What do you meant by resonant frequency ?

- When the **frequency of the applied alternating source (ω_r) is equal to the natural frequency of the *RLC* circuit** $\left(\frac{1}{\sqrt{LC}}\right)$, the current in the circuit reaches its maximum value.
- Then the circuit is said to be in electrical resonance. The **frequency** at which **resonance takes place** is called **resonant frequency.**

18.How will you define Q – factor

It is defined as the ratio of voltage across *L* or *C* to the applied voltage.

$$Q - \text{factor} = \frac{\text{Voltage across } L \text{ or } C}{\text{Applied voltage}}$$

19.What is meant by wattles current?

The current component **(I_{RMS} sin∅)** which has a **phase angle of π/2** with the voltage is called **reactive component.**

$P_{av} = V_{RMS} I_{RMS} \cos\emptyset \qquad \emptyset = \frac{\pi}{2}$

$P_{av} = 0$

So that it is also known as 'Wattless' current.

20.Give any one definition of power factor

I)Power factor = cos ϕ = cosine of the angle of lead or lag

II) Power factor = $\frac{R}{S} = \frac{RESIATANCE}{IMPEDANCE}$

III) Power factor = $\frac{VI\cos\emptyset}{VI} = \frac{\text{True power}}{\text{Apparent power}}$

21.What are LC oscillations

- Whenever energy is given to a circuit containing a pure inductor of inductance *L* and a capacitor of capacitance *C*, **the energy oscillates back and forth between the magnetic field of the inductor** and the electric field of the capacitor.
- Thus the electrical oscillations of definite frequency are generated. These oscillations are called *LC* oscillations.

Book inside Two marks

1.Define magnetic flux

It is defined as the **number of magnetic field lines** passing **through** that **area** normally

$\phi_B = \int \vec{B}.\vec{dA}$ = BA cosθ

Unit : $T\,m^2$ or Wb

2.What are the importance of electromagnetic induction

- Home appliances to huge factory machineries, from cell phone to computers and internet, from electric guitar to satellite communication, all need electricity for their operation.
- All these are met with the help of electric generators and transformers which function on electromagnetic induction.

3. A cylindrical bar magnet is kept along the axis of a circular solenoid is rotated about its axis, find out whether an electric current is induced in the coil.

- The **magnetic field** of a cylindrical magnet is **symmetrical about its axis.**
- As the **magnet** is rotated along the **axis of the solenoid**, there is **no induced current** in the solenoid because the **flux linked** with the solenoid does **not change** due to the rotation of the magnet.

4. A straight conducting wire is dropped horizontally from a certain height with its length along east – west direction. Will an emf be induced in it? Justify your answer.

Yes! An emf will be induced in the wire because it moves perpendicular to the horizontal component of Earth's magnetic field.

5.How does eddy current is minimized in transformer and electric motor

The core of the **transformer** is made up of **thin laminas insulated from one another**

while for **electric motor** the winding is made up of a **group of wires insulated** from one another

6.Define Electromotive force

It is the work done in moving unit electric charge around the circuit.

Unit ; $J\,C^{-1}$ or volt.

7.How will you induce emf by changing the magnetic field

The change in flux is brought about by

(i) relative motion between the circuit and the magnet

(ii) variation in current flowing through the nearby coil

8.What do you meant by A.C generator?

It is a device which **converts mechanical energy into electrical energy.**

9.How will you generate alternating emf

It is generated by **rotating a coil in a magnetic field or by rotating a magnetic field within a stationary coil.**

First method is used for **small AC generators**

Second method is employed for **large AC generators.**

- Thus the signal of that station alone is received.

18.Why resonance not occur in a *RL* and *RC* circuits.

- The phenomenon of electrical resonance is **possible** when the circuit **contains both *L* and *C*.**
- Only then the voltage across L and C cancel one another when V_L and V_C are 180° out of phase and the circuit becomes purely resistive.

19.What is meant by wattful current?

The component of current (**I_{RMS} cos∅**) which is in phase with the voltage is called active component.

$P_{av} = V_{RMS} I_{RMS} \cos\emptyset$ $\emptyset = 0$

$P_{av} = V_{RMS} I_{RMS}$

The power consumed by this current. So that it is also known as 'Wattful' current.

20.How LC oscillations become damped oscillations

- The **Joule heating and radiation of electromagnetic waves** from the circuit decrease the energy of the system.
- Therefore, the oscillations become damped oscillations.

Long answers question (Book back)

1.Establish the fact that the relative motion between the coil and the magnet induces an emf in the coil of closed circuit .

- When a bar magnet is placed close to a coil, some of the magnetic field lines of the bar magnet pass through the coil i.e., the magnetic flux is linked with the coil.
- When the bar magnet and the coil approach each other, the magnetic flux linked with the coil increases.
- So this increase in magnetic flux induces an emf and hence a transient electric current flows in the circuit in one direction
- At the same time, when they recede away from one another, the magnetic flux linked with the coil decreases.
- The decrease in magnetic flux again induces an emf in opposite direction and hence an electric current flows in opposite direction.
- So there is deflection in the galvanometer which indicates current is induced when when there is a relative motion between the coil and the magnet.

Whenever the magnetic flux linked with a closed coil changes, an emf (electromotive force) is induced and hence an electric current flows in the circuit. This current is called an induced current and the emf giving rise to such current is called an induced emf. This phenomenon is known as electromagnetic induction.

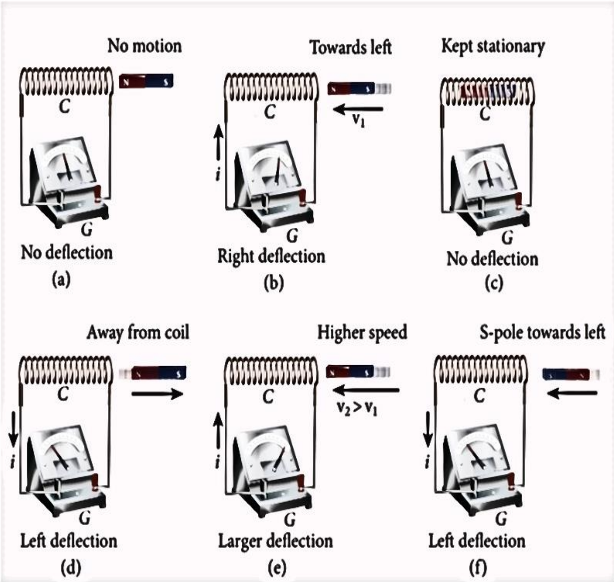


Figure 4.2 Faraday's first experiment

2.Give an illustration of determining direction of induced current by using Lenz's law

- Consider a uniform magnetic field, with its field lines perpendicular to the plane of the paper and pointing inwards.
- These field lines are represented by crosses (x)
- A rectangular metallic frame *ABCD* is placed in this magnetic field, with its plane perpendicular to the field. The arm *AB* is movable so that it can slide towards right or left.
- If the arm AB slides to our right side, the number of field lines (magnetic flux) passing through the frame *ABCD* increases and a current is induced.
- By Lenz's law, the induced current opposes this flux increase and it tries to reduce it by producing **another magnetic field pointing outwards i.e., opposite to the existing magnetic field.**

- Lorentz force creates accumulation of free electrons which produces a potential difference across the rod which in turn establishes an electric field $\vec{E}$ directed along BA.
- Due to the electric field the coulomb force starts acting on the free electrons along *AB* and is given by

$$\vec{F}_E = -e\vec{E}$$

- F_E increases as electric field increases as long as accumulation of electron at the end A continues
- At equilibrium, the magnetic Lorentz force and the coulomb force balance each other and no further accumulation of free electrons at the end *A* takes place.

$$|\vec{F}_B| = |\vec{F}_E|$$

$$|-e(\vec{v} \times \vec{B})| = |-e\vec{E}|$$

$$vB = E$$

The potential difference between two ends of the rod is

$$V = El$$

$$V = vBl$$

Thus the Lorentz force on the free electrons is responsible to maintain this potential difference and hence produces an emf.

$$\varepsilon = Blv$$

As this emf is produced due to the movement of the rod, it is often called as motional emf.

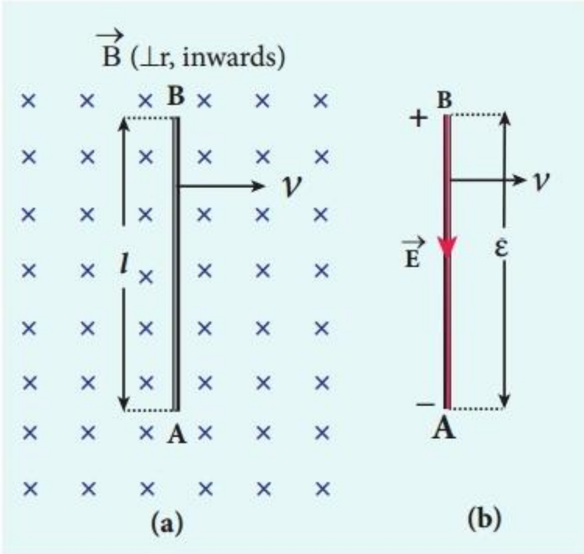


Figure 4.9 Motional emf from Lorentz force

5.Using Faraday's law of electromagnetic induction , derive an equation for motional emf

- Let us consider a rectangular conducting loop of width l in a uniform magnetic field $\vec{B}$ which is perpendicular to the plane of the loop and is directed inwards.
- A part of the loop is in the magnetic field while the remaining part is outside the field
- When the loop is pulled with a constant velocity $\vec{v}$ to the right, the area of the portion of the loop within the magnetic field will decrease.
- Thus, the flux linked with the loop will also decrease.
- According to Faraday's law, an electric current is induced in the loop which flows in a direction so as to oppose the pull of the loop.

x - length of the loop which is still within the magnetic field,

$A = lx$

$\phi_B = \int \vec{B}.\vec{dA}$ = BA $\cos\theta$ [$\theta = 0°$ $\cos 0 = 1$]

$= Blx$

$$\varepsilon = \frac{d\phi_B}{dt}$$

$$= Bl\frac{dx}{dt}$$

both B and *l* are constants.

$$\varepsilon = Blv$$

[$v = \frac{dx}{dt}$] velocity of loop

This emf is known **as motional emf since it is produced due to the movement of the loop** in the magnetic field.

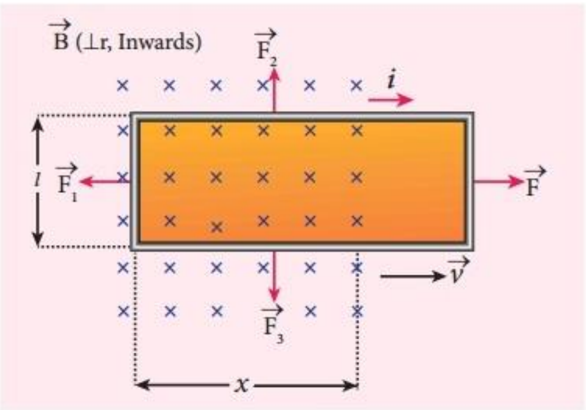


Figure 4.10 Motional emf from Faraday's law

6.Give the uses of Foucault current or Eddy current

i. Induction stove

ii. Eddy current brake

iii. Eddy current testing

iv. Electromagnetic damping

i. Induction stove

- **It is used to** cook the food quickly and safely with less energy consumption.
- Below the cooking zone, there is a tightly wound **coil of insulated wire.**
- The cooking pan made of suitable material, is placed over the cooking zone.
- When the stove is switched on, an **alternating current** flowing in the coil **produces high frequency alternating magnetic field** which induces very **strong eddy currents** in the cooking pan.

The eddy currents in the pan produce so much of **heat** due to **Joule heating** which is used to cook the food.

ii. Eddy current brake

- This eddy current braking system is generally used in **high speed trains** and **roller coasters**. **Strong electromagnets** are fixed just above the rails.
- To stop the train, **electromagnets are switched on.**
- The magnetic field of these magnets induces eddy currents in the rails which **oppose or resist the movement of the train.**
- This is **Eddy current linear brake.**

iii. Eddy current testing

- It is one of the **simple non–destructive** testing methods to find defects like surface cracks, air bubbles present in a specimen.
- A coil of insulated wire is given an **alternating electric current** so that it produces **an alternating magnetic field.**
- When this coil is brought near the test surface, **eddy current** is induced in the test surface.
- **The presence of defects** causes the **change in phase and amplitude** of

the eddy current that can be detected by some other means.

- In this way, the defects present in the specimen are identified

iv. Electromagnetic damping or dead beat galvanometer

- The armature of the galvanometer coil is wound on a soft iron **cylinder.**
- **Once the armature** is **deflected,** the relative motion between the soft iron cylinder and the **radial magnetic field induces eddy current** in the cylinder .
- **The damping force** due to the flow of eddy current **brings the armature to rest immediately** and then galvanometer shows a steady deflection.

7.Define self – inductance of a coil in terms of magnetic flux and induced emf

Self induction

The property of a coil which enables to produce an **opposing induced emf** in it when the **current** in the coil **changes** is called self induction.

self – inductance of a coil in terms of magnetic flux

When current I flows through a coil of N turns , the magnetic flux ϕ_B linked with the coil is proportional to current

$N\phi_B \;\alpha\; i$

$N\phi_B = Li$

L – Coefficient of self induction

$L = \frac{N\phi_B}{i}$

$i = 1A$

$L = N\phi_B$

Self-inductance or simply inductance of a coil is defined as the **flux linkage of the coil** when **1A current** flows through it.

self – inductance of a coil in terms of induced emf

When the current *i* changes with time, an emf is induced in it.

From Faraday's law of electromagnetic induction

$$\varepsilon = -\frac{d(N\phi_B)}{dt}$$

$$N\phi_B = Li$$

$$\varepsilon = -\frac{d(Li)}{dt}$$

$$\varepsilon = -L\frac{di}{dt}$$

$$L = \frac{-\varepsilon}{di/dt}$$

$$\frac{di}{dt} = 1\ A/s \text{ then}$$

L = $-\varepsilon$

Inductance of a coil is also defined as the **opposing emf** induced in the coil when the **rate of change of current** through the coil is **1 *A s*$^{-1}$**

8.How will you define the unit of inductance

Inductance is a scalar

$L = \frac{-\varepsilon}{di/dt}\left(\frac{Wb}{As^{-1}}\right)$

Therefore unit of inductance is Wb A^{-1} s

It is also measured in henry (H).

$\frac{di}{dt} = 1\ A/s$ **then L = $-\varepsilon$**

It is also measured in henry (H).

1 H = 1 Wb A^{-1} s or 1 V s A^{-1}

total number of turns N is given by $N = n\, l$) is

$N\phi_B = (nl)(\mu_0 ni)A$

$= (\mu_0 n^2 Al)i$ …….(2)

$N\phi_B = Li$ ………(3)

Comparing (1) & (2)

$Li = (\mu_0 n^2 Al)i$

$L = \mu_0 n^2 Al$

If the solenoid is filled with a dielectric medium of relative permeability

$L = \mu n^2 Al$ or $L = \mu_0\ \mu_r n^2 Al$

11.An inductor of inductance L carries an electric current I .How much energy is stored while establishing the current in it

- Whenever a current is established in the circuit, the inductance opposes the growth of the current.
- In order to establish a current in the circuit, **work** is done **against this opposition** by some external agency.
- This **work done** is stored as **magnetic potential energy.**

Let us assume that electrical resistance of the inductor is negligible and inductor effect alone is considered.

The induced emf at any instant *t* is

$\varepsilon = -L\frac{di}{dt}$…………(1)

Let dW be work done in moving a charge dq in a time dt against the opposition, then

$dW = Vdq$ ………….(2)

$V = -\varepsilon$ $dq = idt$

Sub V & dq values in (2) equation

$dW = = -\varepsilon\ idt$

Sub $\varepsilon = -L\frac{di}{dt}$ **in above equation**

$= -\ (-L\frac{di}{dt})\ idt$

$dW = Lidi$

On integration

$W = \frac{1}{2} Li^2$

This work done is stored as magnetic potential energy

$U_B = \frac{1}{2} Li^2$

The energy density is the energy stored per unit volume of the space and is given by

$u_B = \frac{U_B}{Al}$

$u_B = \frac{B^2}{2\mu_0}$

12.Show that the mutual inductance between a pair of coil is same ($M_{12} = M_{21}$)

<u>Mutual induction</u>

- When an **electric current** passing through a coil **changes** with time, an **emf** is induced in the **neighbouring coil.** This phenomenon is known as mutual induction and the emf is called mutually induced emf.

Consider two coils which are placed close to each other. If an electric current i_1 is sent through coil 1, the magnetic field produced by it is also linked with coil 2.

ϕ_{21} - magnetic flux linked with each turn of the coil 2 of N_2 turns due to coil 1.

$$N\phi_{21}\ \alpha\ i_1$$

$$N\phi_{21} = M_{21} i_1$$

M_{12} – mutual inductance of the coil 2 with respect to coil 1. It is also called as coefficient of mutual induction.

$$\varepsilon_2 = -\frac{d\,(N_2\,\phi_{21})}{dt}$$

Sub $N\phi_{21} = M_{12} i_1$ **in above equation**

$$\varepsilon_2 = -M_{21}\frac{di_1}{dt}$$

$$M_{21} = \frac{-\varepsilon_2}{\frac{di_1}{dt}}$$

$\frac{di_1}{dt} = 1\ As^{-1}$

Then $M_{12} = -\varepsilon_2$

Similarly

$$N\phi_{12} = M_{12} i_2$$

$$M_{12} = \frac{-\varepsilon_1}{\frac{di_2}{dt}}$$

M_{12} - mutual inductance of the coil 1 with respect to coil 2

$M_{12} = M_{21} = M$

13.How will you induce an emf by changing the area enclosed by the coil?

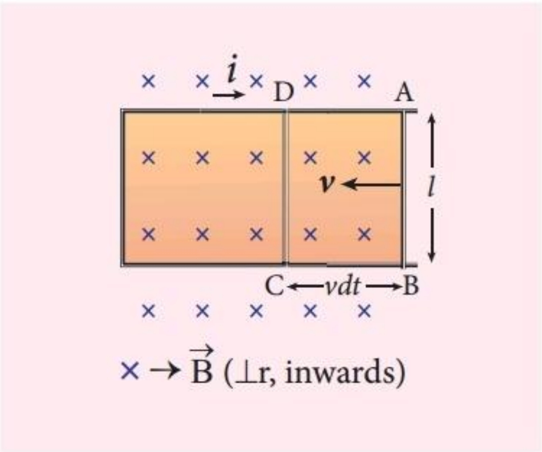


Figure 4.24 Induction of emf by changing the area enclosed by the loop

- Consider a conducting rod of length *l* moving with a velocity $\vec{v}$ towards left on a rectangular metallic framework .
- The whole arrangement is placed in a uniform magnetic field $\vec{B}$ whose magnetic lines are perpendicularly directed into the plane of the paper.
- As the rod moves from *AB* to *DC* in a time *dt*, the area enclosed by the loop and hence the magnetic flux through the loop decreases.

The change in magnetic flux in time dt is

$d\phi_B = B \times dA$

dA = area of ABCD

area of ABCD(rectangle) = l × b

v = dx/dt = b/dt (dx = b)

b = vdt

area of ABCD(rectangle) = l × vdt

$\frac{d\phi_B}{dt}$ = *Blv ……….. (1)*

As a result of change in flux , induced emf is generated in the loop

$\varepsilon = \frac{d\phi_B}{dt}$ ……….(2)

Comparing (1) & (2)

$$\varepsilon = Blv$$

This emf is motional emf .

14.Show mathematically that the rotation of a coil in a magnetic over one rotation induces an alternating emf of one cycle

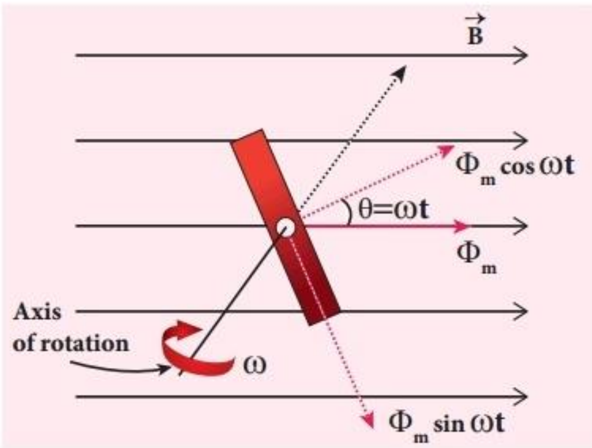


Figure 4.25(b) The coil has rotated through an angle θ = ωt

- Consider a rectangular coil of N turns kept in magnetic field $\vec{B}$.
- It is rotated in anticlockwise direction with an angular velocity ω about an axis perpendicular to field.
- **At time = 0**, the plane of the coil is perpendicular to the field and the flux linked with the coil has its maximum value ϕ_m = **BA**
- In a time *t* seconds, the coil is rotated through an angle (**θ = *ωt*)** in anti–clockwise direction.
- In this position, the flux linked is **Φ_m cos ωt**, a component of Φ_m **normal** to the plane of the coil
- The component parallel to the plane **(Φ_m sin ωt)** has no role in electromagnetic induction. Therefore, the flux linkage at this deflected position is

$N\phi_B = N\phi_M cos\omega t$

$$\varepsilon = -\frac{d}{dt}(N\phi_B)$$

$$\varepsilon = -\frac{d}{dt}(N\phi_m cos\omega t)$$
$$= N\phi_m \omega sin\omega t$$

- When the coil is rotated through **90º** from initial position, **sin ωt = 1**.
- Then the maximum value of induced emf is

$$\varepsilon = N\phi_m \omega sin\omega t$$

sin ωt = 1 → $\varepsilon_m = N\phi_m\omega$

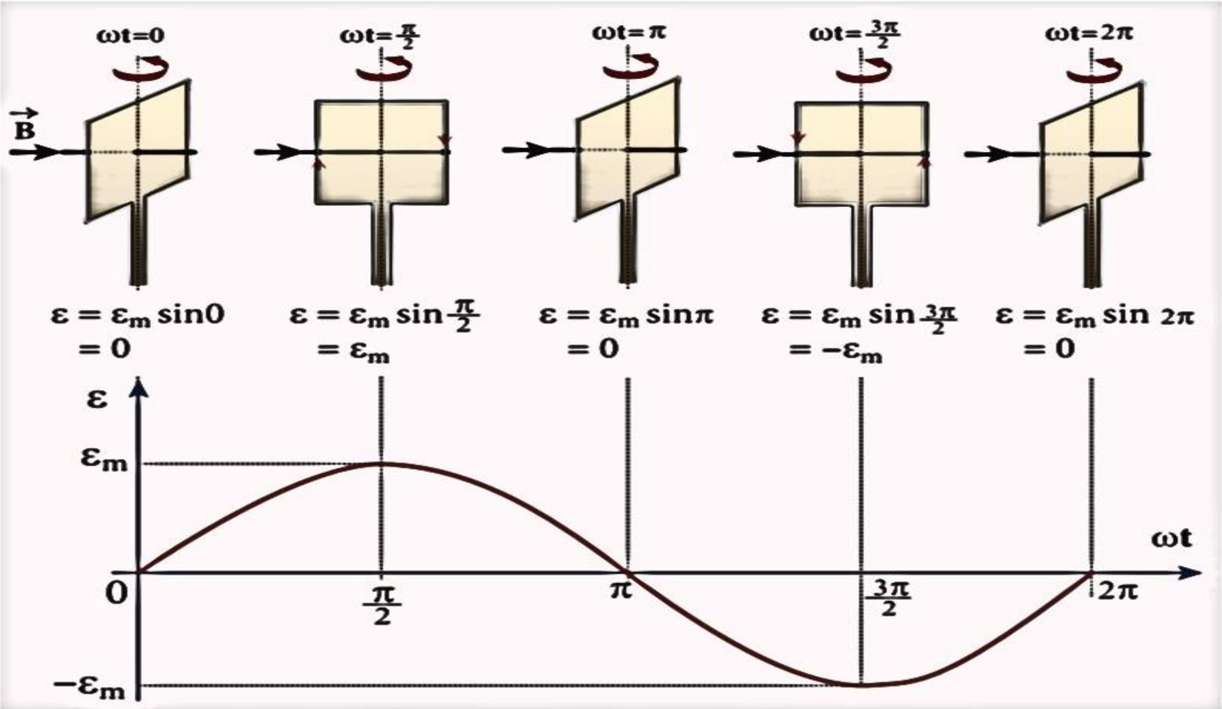
sub $\varepsilon_m = N\phi_m\omega$ in above equation

Therefore, the value of induced emf at that instant is then given by

$\varepsilon = \varepsilon_m sin\omega t$

- It is seen that the induced emf varies as sine function of the time angle *ωt*.
- The graph between induced emf and time angle for one rotation of coil will be a sine curve and the emf varying in this manner is called sinusoidal emf or alternating emf.
- If this alternating voltage is given to a closed circuit, a sinusoidally varying current flows in it.

This current is called alternating current & is given by $i = i_m sin\omega t$



15.Elaborate the standard construction details of AC generator

It consists of two major parts – **stator and rotor**

Stator – Stationary

Rotor – Rotates inside the stator

- Armature winding is mounted on stator
- Field magnet mounted on rotor

Construction details of

i)Stator

- The stationary part which has armature windings mounted in it is called stator.
- It has three components, namely stator **frame, stator core and armature winding**.

Stator frame

- This is the **outer frame** used for **holding stator core and armature windings** in proper position.
- Stator frame provides best ventilation with the help of holes provided in the frame itself

Stator core

- Stator core or armature core is **made** up of **iron or steel alloy**.
- It is a **hollow cylinder** and is **laminated** to minimize eddy current loss.
- The slots are cut on inner surface of the core to **accommodate armature windings**.

Armature winding

- Armature winding is the coil, wound on slots provided in the armature core.
- One or more than one coil may be employed, depending on the type of alternator.

Two types of windings

i) single-layer winding

ii) double-layer winding.

- In single-layer winding, a slot is **occupied by a coil as a single layer**.
- But in double-layer winding, the **coils are split into two layers** such as top and bottom layers

ii) Rotor

- Rotor contains **magnetic field windings**.
- The magnetic poles are magnetized by DC source.
- The ends of field windings are connected to a pair of slip rings, attached to a common shaft about which rotor rotates.
- Slip rings rotate along with rotor.
- To maintain connection between the DC source and field windings, two brushes are used which continuously slide over the slip rings.

2 types of rotors used in **alternators**

i) salient pole rotor and

ii) cylindrical pole rotor.

i) salient pole rotor

- The word salient means **projecting.**
- This rotor has a **number of projecting poles** having their bases riveted to the rotor.
- It is mainly used in **low-speed alternators.**

ii) cylindrical pole rotor.

- This rotor consists of a **smooth solid cylinder.** The slots are cut on the outer surface of the cylinder along its length.

induced **emf becomes zero**. This is represented by point B.

- The field magnet becomes again parallel to PQRS **for 270°** rotation of field magnet. The **induced emf is maximum but the direction is reversed**. Thus the current flows along SRQP. This is represented by point C.
- On completion of **360°**, the induced **emf becomes zero** and is represented by the point D. From the graph, it is clear that emf induced in PQRS is alternating in nature.

- Therefore, when field magnet completes one rotation, induced emf in PQRS finishes one cycle.
- The **frequency** of the induced emf depends on the **speed** at which the field magnet rotates.

(Draw the sine wave given in Q.no 14)

18.Explain the construction and working of transformer

Principle ; Mutual induction between two coils.

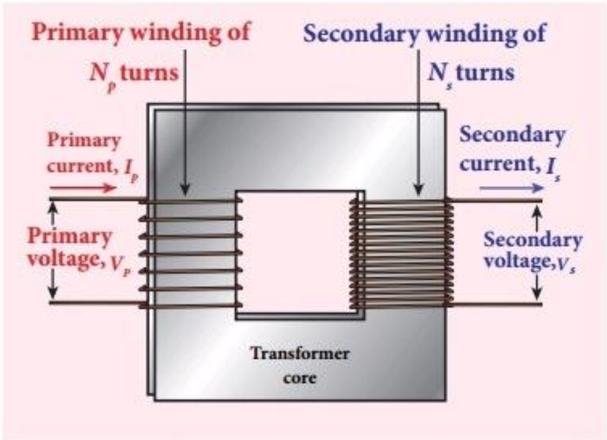


Figure 4.37(a) Construction of transformer

Construction

- There are **two coils of high mutual inductance** wound over the same transformer core.
- The core is **generally laminated** and is made up of a good magnetic material like silicon steel.
- The coil across which **alternating voltage is applied is called primary coil *P*** and the coil from which **output power is drawn out is called secondary coil *S*.**
- The assembled core and coils are kept in a container which is filled with suitable medium for better insulation and cooling purpose.
- Coils are **electrically insulated** but magnetically linked via transformer core

Working

- If the primary coil is connected to a source of alternating voltage, an alternating magnetic flux is set up in the laminated core.
- Rate at which magnetic flux changes through each turn is same for both primary and secondary coils.
- As a result of flux change, emf is induced in both primary and secondary coils.
- The emf induced in the primary coil ε_p is almost equal and opposite to the applied voltage v_p and is given by

$$V_P = \varepsilon_P = -N_P \frac{d}{dt}(N\phi_B) \quad \ldots\ldots\ldots.(1)$$

- The frequency of alternating magnetic flux in the core is same as the frequency of the applied voltage.
- Therefore, induced emf in secondary will also have same frequency as

that of applied voltage. The emf induced in the secondary coil ε_s is given by

$$\varepsilon_S = -N_S \frac{d}{dt}(N\phi_B)$$

N_P , N_S - number of turns in the primary and secondary coil

If the secondary circuit is open, then **$\varepsilon_s = \upsilon_s$** where υ_s is the voltage across secondary coil.

$$V_S = \varepsilon_S = -N_S \frac{d}{dt}(N\phi_B) \quad ....(2)$$

Dividing (2) by (1)

$$\frac{V_S}{V_P} = \frac{N_S}{N_P} = K$$

K – **voltage Transformer ratio**

For an ideal transformer,
Input power = Output power

$$v_P i_P = v_S i_S$$

$$\frac{V_S}{V_P} = \frac{N_S}{N_P} = \frac{I_P}{I_S} = K$$

<u>For step-up transformer</u>

K > 1 $V_S > V_P$ $I_S < I_P$

voltage is increased and the corresponding current is decreased.

<u>For step down transformer</u>

K < 1 $V_S < V_P$ $I_S > I_P$

voltage is decreased and the current is increased.

19.Mention the various energy losses in a transformer

i) Core loss or Iron loss

- This loss takes place in **transformer core.**
- **Hysteresis loss and eddy current loss** are known as core loss or Iron loss.
- When transformer core is magnetized and demagnetized repeatedly by the alternating voltage applied across primary coil, hysteresis takes place due to which some energy is lost in the form of heat.

<u>Hysteresis loss minimization</u> - using **steel of high silicon content i**n making transformer core.

Alternating magnetic flux in the core induces eddy currents in it. Therefore there is energy loss due to the flow of eddy current, called
eddy current loss.

<u>Eddy current minimization -</u> using very **thin laminations** of transformer core.

ii)Copper loss

- Transformer windings have electrical resistance.
- When an electric current flows through them, some **amount of energy is dissipated** due to **Joule heating.** This energy loss is called copper loss

<u>Copper loss minimization -</u> using **wires of larger diameter**.

iii) Flux leakage

Flux leakage happens when the magnetic lines of primary coil are not completely linked with secondary coil.

<u>Flux leakage minimization -</u> using **winding coils one over the other.**

21.Find out phase relationship between voltage and current in a pure inductor circuit

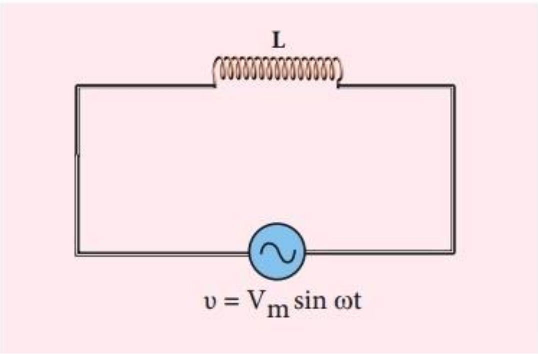


Figure 4.47 AC circuit with inductance

Consider a circuit containing a pure inductor of **inductance *L*** connected across an alternating voltage source).
The alternating voltage is given by the equation

V = V_m sinωt ………. (1)
The alternating current flowing through the inductor induces a self-induced emf or back emf in the circuit.

Back emf $\varepsilon = -L\frac{di}{dt}$ **…….(2)**
By applying Kirchoff's loop rule to the purely inductive circuit, we get

V + ε = 0

$V_m \sin \omega t - L\frac{di}{dt} = 0$

$V_m \sin\omega t = -L\frac{di}{dt}$

di $= \frac{V_m}{L}$ **sinωt dt**

Integrating both sides

I $= \frac{V_m}{L} \int$ **sinωtdt**

$= \frac{V_m}{L\omega}(-\cos \omega t)$ **+ constant**

The integration constant in the above equation is independent of time so integration constant is zero

I $= \frac{V_m}{L\omega}(\sin \omega t - \pi/2)$

I = I_m $(\sin \omega t - \pi/2)$ **………(3)**

where $\frac{V_m}{L\omega}$ **= I_m** the peak value of the alternating current in the circuit.

From (1) and (3) it is evident that current lags behind the applied voltage by π/2 in an inductive circuit.

Inductive reactance $X_L = \omega L$

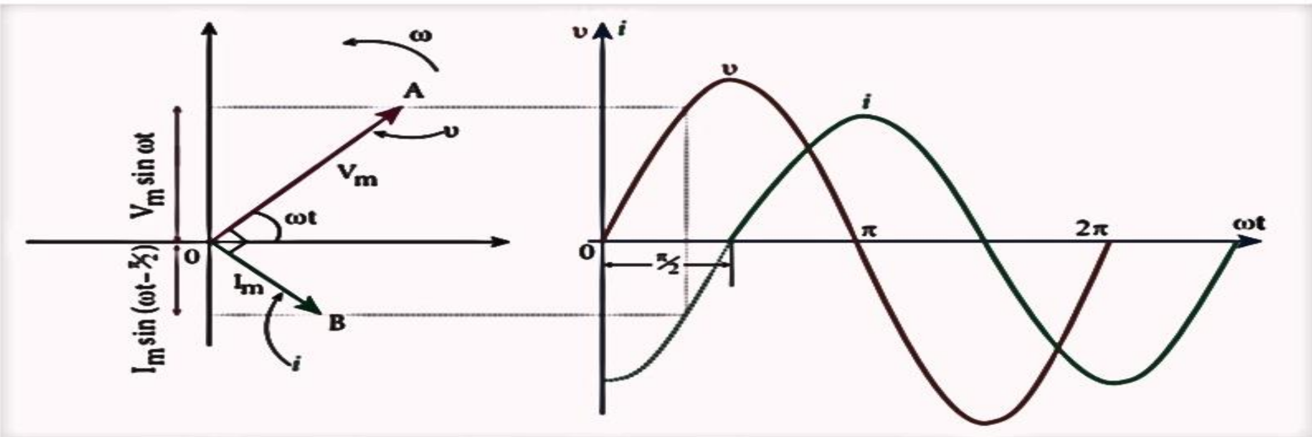


Figure 4.48 Phasor diagram and wave diagram for AC circuit with L

22.Derive an expression for phase angle between the applied voltage and current in a series RLC circuit

Consider a circuit containing a resistor of resistance *R*, a inductor of inductance *L* and a capacitor of capacitance *C* connected across an alternating voltage source

The applied alternating voltage is

$V = V_m \sin\omega t$ ………. (1)

Let *i* be the resulting circuit current in the circuit at that instant.

As a result, the voltage is developed across *R*, *L* and *C*.

Voltage across R (V_R) is in pahse with i
Voltage across L (V_L) Leads i by π/2
Voltage across C (V_C) Lags i by π/2

V_L & V_C are 180° out of phase with each other and the resultant of V_L and V_C is ($V_L - V_C$)

Assuming circuit to be predominantly inductive.

The applied voltage equals the vector sums of V_L , V_C , V_R

$OI = I_m$

$V_R = OA = I_m R$ $V_L = OB = I_m X_L$

$V_R = OC = I_m X_C$

By parallelogram law, the diagonal $\overrightarrow{OE}$ gives the resultant voltage υ of V_R and ($V_L - V_C$) and its length *OE* is equal to V_m.

Therefore,

$V_m^2 = V_R^2 + (V_L - V_C)^2$

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

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

$I_m = V_m / Z$

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

Z - impedance of the circuit which refers to the effective opposition to the circuit current by the series *RLC* circuit

From phasor diagram, the phase angle between *υ* and *i* is found out from the following relation

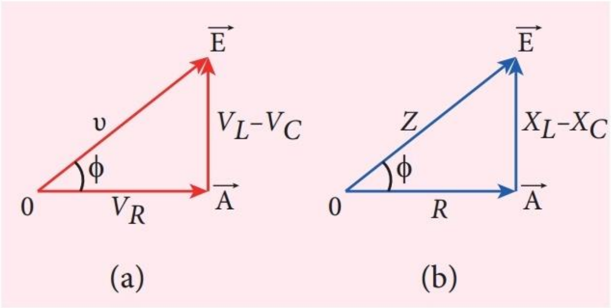


Figure 4.53 Voltage and impedance triangle when $X_L > X_C$

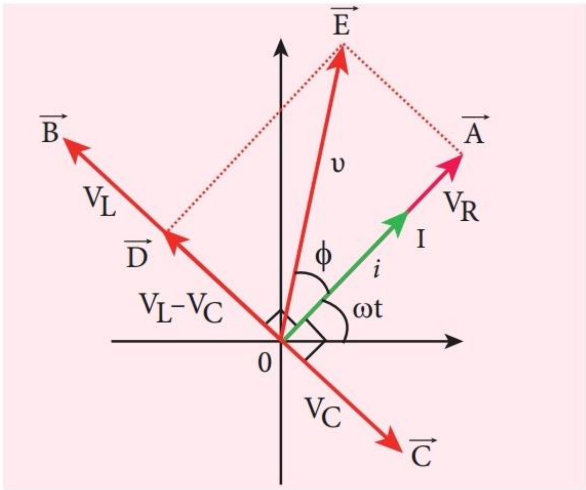


Figure 4.52 Phasor diagram for a series *RLC* – circuit when $V_L > V_C$

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

(ii) For **purely inductive** or capacitive circuit

$\emptyset = \pm\frac{\pi}{2}$ $\cos\pm\frac{\pi}{2} = 0$ $P_{av} = 0$

(iii)For **series RLC** circuit ,

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

$P_{av} = V_{RMS}\, I_{RMS} \cos\emptyset$

(iv) For series **RLC** circuit at **resonance**,

$\emptyset = 0$ $\cos\emptyset = 1$ $P_{av} = V_{RMS}\, I_{RMS}$

25.Show that the total energy is conserved during LC oscillations.

- During LC oscillations in LC circuits , the energy of the system oscillates between the electric field of the capacitor and the magnetic field of the inductor .
- These two forms of energy varies with times , the total energy remains constant.
- LC oscillations takes place in accordance with law of conservation of energy

Total energy **$U = U_E + U_B$**

$U_E = \frac{q^2}{2C}$ $U_B = \frac{Li^2}{2}$

$U = \frac{q^2}{2C} + \frac{Li^2}{2}$

Considering 3 different stages of LC oscillations and calculating the total energy of the system

Case (i) Charge in capacitor $q = Q_m$

Current through inductor i = 0

Total energy $U = \frac{Q_m^2}{2C} + 0 = \frac{Q_m^2}{2C}$ ……..(1)

Case (ii) Charge in capacitor q = 0

Current through inductor $i = I_m$

Total energy $U = 0 + ½\frac{LI_m^2}{2}$

$= \frac{LI_m^2}{2}$

$I_m = Q_m\,\omega$ where $\omega = \frac{1}{\sqrt{LC}}$

$I_m = Q_m \times \frac{1}{\sqrt{LC}}$

$U = \frac{Q_m^2}{2C}$ ………..(2)

Case (iIi) Charge in capacitor q = q

Current through inductor i = i

Total energy $U = \frac{q^2}{2C} + \frac{Li^2}{2}$

$q = Q_m \cos\omega t$ $i = -\frac{dq}{dt} = Q_m\,\omega \sin\omega t$

Negative sign in current indicates charge in capacitor decreases with time

$U = \frac{q^2}{2C} + \frac{Li^2}{2}$

$= \frac{Q_m^2 sin^2\omega t}{2C} + \frac{LQ_m^2 sin^2\omega t}{2LC}$ $(\omega = \frac{1}{\sqrt{LC}})$

$= \frac{Q_m^2(COS^2\omega t + sin^2\omega t)}{2C}$

$= \frac{Q_m^2}{2C}$ ……….(3)

From (1) , (2) , (3) it is clear that total energy of the system remains constant i.e conserved

Book inside Long answers

1. Calculate the Mutual inductance between two long co-axial solenoids

- Consider two long co-axial solenoids of same length l.
- The length of these solenoids is large when compared to their radii so that the magnetic field produced inside the solenoids is uniform and the fringing effect at the ends may be ignored.
- A_1 and A_2 - Area of cross section of the solenoids
- $A_1 > A_2$
- n_1 & n_2 - The turn density of these solenoids
- i_1 - current flowing through solenoid 1
- Then the magnetic field produced inside it is

$B_1 = \mu_o n_1 i_1$

As the field lines of B_1 are passing through the area bounded by solenoid 2 the magnetic flux is linked with each turn of solenoid 2 due to solenoid 1

$$\emptyset_{21} = B_1 A_2$$

Sub B_1 in above equation

$$\emptyset_{21} = (\mu_o n_1 i_1) A_2$$

The flux linkage of solenoid 2 with total turns N_2 is

$N_2 \emptyset_{21} = (\mu_o n_1 i_1)(n_2 l) A_2$ **where N_2 = nl**

$$= (\mu_o n_1 n_2 l A_2) i_1 \text{.......(1)}$$

$N_2 \emptyset_{21} = M_2 i_1$ ....(2)

Comparing (1) and (2)

$$M_2 i_1 = (\mu_o n_1 n_2 l A_2) i_1$$

$$M_2 = \mu_o n_1 n_2 l A_2$$

mutual inductance of the solenoid 2 with respect to solenoid 1 is

$M_2 = \mu_o n_1 n_2 l A_2$........(3)

similarly

i_2 - current flowing through solenoid 2

Then the magnetic field produced inside it is

$B_2 = \mu_o n_2 i_2$

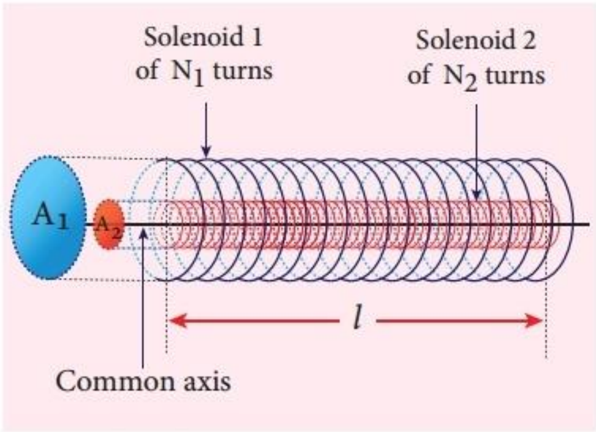


Figure 4.23 Mutual inductance of two long co-axial solenoids

As the field lines of B_2 are passing through the area bounded by solenoid 1

This magnetic field B_2 is uniform inside the solenoid 2 but outside the solenoid 2, it is almost zero. Therefore for solenoid 1, the area A_2 is the effective area over which the magnetic field B_2 is present; not area A_1.

the magnetic flux is linked with each turn of solenoid 1 due to solenoid 2

$$\emptyset_{12} = B_2 A_2$$

Sub B_1 in above equation

$$\emptyset_{12} = (\mu_o n_2 i_2) A_2$$

The flux linkage of solenoid 2 with total turns N_2 is

$N_1 \emptyset_{12} = (\mu_o n_2 i_2)(n_1 l) A_2$ **where N_1 = nl**

$$= (\mu_o n_1 n_2 l A_2) i_2 \text{.......(4)}$$

$N_1 \emptyset_{12} = M_1 i_2$........(5)

Comparing (4) and (5)

$$M_1 i_2 = (\mu_o n_1 n_2 l A_2) i_2$$

$$M_1 = \mu_o n_1 n_2 l A_2$$

mutual inductance of the solenoid 2 with respect to solenoid 1 is

$M_1 = \mu_o n_1 n_2 l A_2$........(6)

From (3) & (6)

$$M_1 = M_2 = M$$

2.Explain about three phase generator

Construction

- In three- phase AC generator, the **armature core has 6 slots**, cut on its inner rim.
- Each **slot is 60°** away from one another.
- Six armature conductors are mounted in these slots.
- The conductors **1 and 4** are **joined** in series to form **coil 1**.
- The conductors **3 and 6** form **coil 2** while the conductors **5 and 2** form coil **3**.
- So, these coils are rectangular in shape and are **120° apart** from one another.

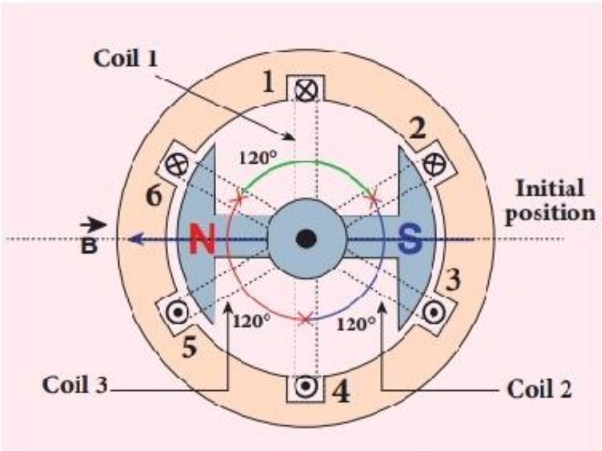


Figure 4.35 Construction of three-phase AC generator

Working

- The initial position of the field magnet is horizontal and field direction is perpendicular to the plane of the coil 1.
- As it is seen in single phase AC generator, when field magnet is rotated from that position in **clockwise direction**, alternating emf ε_1 in coil 1 begins a cycle from origin O.
- The corresponding cycle for alternating emf ε_2 **in coil 2** starts at point A after field magnet has rotated through 120°.
- Therefore, the phase difference between and is 120°. Similarly, emf ε_3 in coil 3 would begin its cycle at point B after 240° rotation of field magnet from initial position.
- Thus these **emf's** produced in the three phase AC generator have **120° phase difference between one another**.

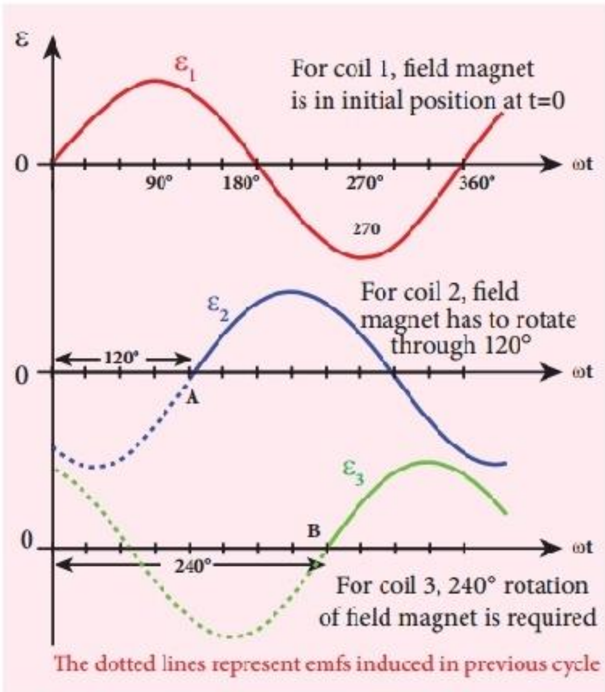


Figure 4.36 Variation of emfs ε_1, ε_2 and ε_3 with time angle.

4. Find out the phase relationship between voltage and current in pure capacitive circuit

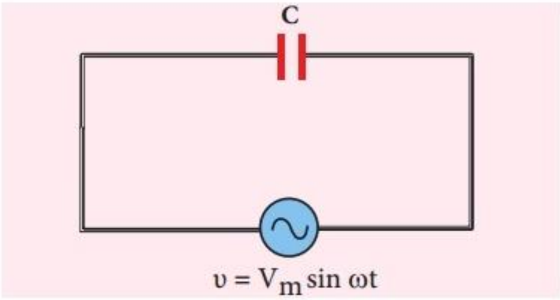


Figure 4.49 AC circuit with capacitance

- Consider a circuit containing a capacitor of capacitance *C* connected across an alternating voltage source
- The instantaneous value of the alternating voltage is given by

V = V_m sinωt ....(1)

q - instantaneous charge on the capacitor.

C = $\frac{q}{V}$

q = CV

= C V_m sinωt

$i = \frac{dq}{dt}$

$= \frac{d}{dt}(CV_m sin\omega t)$

$= CV_m \frac{d}{dt}(sin\omega t)$

$= \omega\, CV_m cos\omega t$

$= \frac{V_m}{1/C\omega}\sin(\omega t + \frac{\pi}{2})$

$I_m = \frac{V_m}{1/C\omega}$

$i = I_m \sin(\omega t + \frac{\pi}{2})$ **.........(2)**

From (1) & (2) it is clear that current leads the applied voltage $\frac{\pi}{2}$ by in a capacitive circuit.

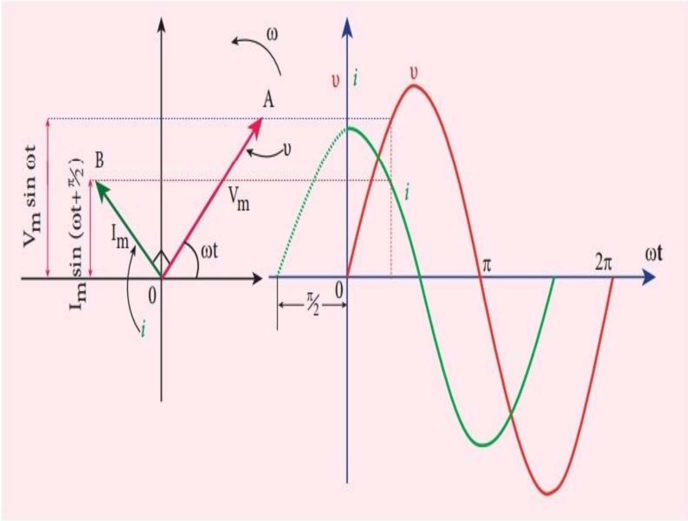


Figure 4.50 Phasor diagram and wave diagram for AC circuit with C

5.What are the Advantages and disadvantages of AC over DC

Advantages:

(i) The generation of **AC is cheaper** than that of DC.

(ii) When AC is **supplied** at **higher voltages,** the transmission losses are small compared to DC transmission.

(iii) **AC** can easily be **converted into DC** with the help of rectifiers.

Disadvantages:

(i) Alternating voltages **cannot** be used for certain applications e.g. **charging of batteries, electroplating, electric traction etc.**

(ii) At **high voltages**, it is more **dangerous** to work with AC than DC.

Unit – 5 ELECTROMAGNETIC WAVES

Book back Short answers

1.What is displacement current?

It can be defined as the current which comes into play in the region in which the **electric field** and the **electric flux are changing** with **time**

2.What are electromagnetic waves?

Electromagnetic waves are non-**mechanical waves** which **move** with **speed equals to the speed of light** (in vacuum).

3.Write down the integral form of modified Ampere's circuital law

$$\oint \vec{B}.d\vec{S} = \mu_0(I_c + I_d)$$

I_c - **Conduction current**

I_d – **Displacement current**

4.Explain the concept of intensity of electromagnetic waves

The energy crossing per unit area per unit time and perpendicular to the direction of propagation of electromagnetic wave is called the intensity.

Intensity = $\frac{Total\ electro\ magnetic\ energy\ (U)}{Surface\ area\ (A) \times time\ (t)}$

Intensity = $\frac{Power\ (P)}{Surface\ area\ (A)}$

5.What is Fraunhofer lines?

When the **spectrum obtained from the Sun** is examined, it consists of large number of **dark lines** (line absorption spectrum). These dark lines in the solar spectrum are known as **Fraunhofer lines**. The absorption spectra for various materials are compared with the

Book inside short answers

1.What is electromagnetic spectrum?

Electromagnetic spectrum is an orderly distribution of electromagnetic waves in terms of wavelength or frequency

2.What is dispersion of light

- A beam of white **light** made to pass through the **prism** , it is split into its **seven constituent colours** which can be viewed on the screen as **continuous spectrum.**
- This phenomenon is known as dispersion of light

3.What do you meant by spectrum

- A beam of white **light** made to pass through the **prism** , it is split into its **seven constituent colours** which can be viewed on the screen as **continuous spectrum.**
- This phenomenon is known as dispersion of light.
- Pattern of colours obtained on the screen after dispersion is called as spectrum

4. What is radiation pressure?

The force exerted by an electromagnetic wave on unit area of a surface is called radiation pressure.

5.What are the application of electromagnetic waves

Medical **- LASER surgery**,
Defence **- RADAR signals** and also in **fundamental scientific research**.

6.Derive the energy density of the electromagnetic wave

The energy density (energy per unit volume) associated with an electromagnetic wave propagating in vacuum or free space is

$$u = \frac{1}{2}\varepsilon_\circ E^2 + \frac{1}{2\mu_\circ}B^2$$

where, $\frac{1}{2}\varepsilon_\circ E^2 = u_E$ is the energy density in an electric field and $\frac{1}{2\mu_0}B^2 = u_B$ is the energy density in a magnetic field.

Since, $E = Bc \Rightarrow u_B = u_E$.

The energy density of the electromagnetic wave is

$$u = \varepsilon_0 E^2 = \frac{1}{\mu_0}B^2$$

7.What is pointing vector?

The rate of flow of energy crossing a unit area is known as pointing vector for electromagnetic waves

Unit : W m^{-2}.

$$\vec{S} = \frac{1}{\mu_0}(\vec{E} \times \vec{B}) = c^2\varepsilon_o(\vec{E} \times \vec{B})$$

8.What are uses of Fraunhofer lines?

Fraunhofer lines in the solar spectrum, which helps in identifying elements present in the **Sun's atmosphere**

Book back Long answers

1.Write down Maxwell equation in integral form.

1. First equation - Gauss's law.

It relates the net electric flux to net electric charge enclosed in a surface

$\oint \vec{E}.\vec{dA} = \frac{Q_{enclosed}}{\varepsilon_0}$ **(Gauss law)**

$Q_{enclosed}$ - Charge enclosed

$\vec{E}$ – Electric field

It means that isolated positive charge or negative charge can exist

2. Second equation has no name. But this law is similar to Gauss's law in electrostatics. So this law can also be called as Gauss's law in magnetism.

$\oint \vec{B}.\vec{dA} = 0$

$\vec{B}$**- Magnetic field**

It means that no isolated magnetic monopole exists

3. Third equation is Faraday's law of electromagnetic induction

$\oint \vec{E}.\vec{dl} = \frac{d}{dt}\phi_B$

$\vec{E}$ – Electric field

This equation implies that the line integral of the electric field around any closed path is equal to the rate of change of magnetic flux through the closed path bounded by the surface.

4. Fourth equation is **modified Ampere's circuital law**. This is also known as Ampere – Maxwell's law. This law relates the **magnetic field** around **any closed path** to the **conduction current and displacement current** through that path.

$$\oint \vec{B}.\vec{dl} = \mu_o I_{enclosed} + \mu_o\varepsilon_o \frac{d}{dt}\int_S \vec{E}.\vec{dA}$$

These four equations are known as Maxwell's equations in electrodynamics. This equation ensures the existence of electromagnetic waves.

2.Write short notes in a) microwave b) X-ray c)radio waves d)Visible light spectrum

a) Microwaves

- It is produced by **electromagnetic oscillators** in electric circuits.
- **Wavelength** range is 1×10^{-3} **m to** 3×10^{-1} **m**
- **Frequency** range is 3×10^{11} **Hz to** 1×10^{9} **Hz**.
- It obeys **reflection** and **polarization**.

Uses

Radar system for aircraft navigation, speed of the vehicle, microwave oven for cooking and very long distance wireless communication through satellites.

b)X – rays

- It is produced when there is a sudden deceleration of high speed electrons at high-atomic number target, and also by electronic transitions among the innermost orbits of atoms.
- The **wavelength** range 10^{-13} **m to** 10^{-8} **m**
- **Frequency** range are 3×10^{21} **Hz to** 1×10^{16} **Hz.**
- X-rays have **more penetrating power** than ultraviolet radiation.

Uses

X-rays are used extensively in studying structures of inner atomic electron shells and crystal structures.

It is used in detecting fractures, diseased organs, formation of bones and stones, observing the progress of healing bones. Further, in a finished metal product, it is used to detect faults, cracks, flaws and holes.

c)Radio waves

- It is **produced by oscillators** in electric circuits.
- **Wavelength** range is 1×10^{-1} **m to** 1×10^{4} **m Frequency** range is 3×10^{9} **Hz to** 3×10^{4} **Hz.**
- It obeys **reflection** and **diffraction**.

Uses

- Radio and television communication systems In cellular phones to transmit voice communication in the ultra high frequency band.

d) Visible light

- It is produced by **incandescent bodies** and also it is **radiated by excited atoms in gases.**
- **Wavelength** range is 4×10^{-7} **m to** 7×10^{-7} **m**
- **Frequency** range are 7×10^{14} **Hz to** 4×10^{14} **Hz**.
- It obeys the laws of reflection, refraction, interference, diffraction, polarization, photo-electric effect and photographic action.

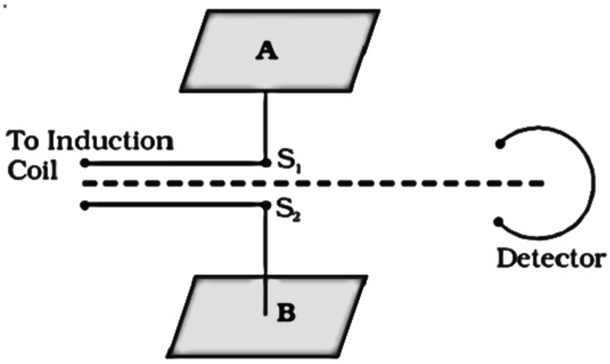
Uses

It can be used to study the structure of molecules, arrangement of electrons in external shells of atoms and sensation of our eyes.

3.Discuss briefly the experiment conducted by Hertz to produce and detect electromagnetic waves

Construction

- It consists of two metal electrodes which are made of small spherical metals .
- These are connected to larger spheres and the ends of them are connected to induction coil with very large number of turns.
- This is to produce very high electromotive force (emf).
- The coil is maintained at very high potential.



Working

- Due to high potential air between the electrodes gets ionized and spark (spark means discharge of electricity) is produced.
- The gap between electrode (ring type – not completely closed and has a small gap in between) kept at a distance also gets spark. This implies that the energy is transmitted from electrode to the receiver (ring electrode) as a wave, known as electromagnetic waves.

Conclusion

- If the receiver is rotated by 90° - then no spark is observed by the receiver.
- This confirms that electromagnetic waves are transverse waves as predicted by Maxwell.
- Hertz detected radio waves and also computed the speed of radio waves which is equal to the speed of light
- **(3×10^8 m s^{-1})**.

4. Explain the Maxwell's of Ampere's circuital law

- Consider a situation of 'charging a parallel plate capacitor .
- Assume that the medium in between the capacitor plates is a non-conducting medium.
- I_C - conduction current
- This current generates magnetic field around the wire connected across the capacitor.
- For computing the strength of magnetic field at a point, we use Ampere's circuital law which states that **The line integral of the magnetic field around any closed loop** is **equal to μ_0 times the net current I** threading through the area enclosed by the loop'.

- An Amperian loop drawn which encloses the surface S_1 to find magnetic field at a point P near the wire

$$\oint_l \vec{B}\cdot d\vec{l} = \mu_o I(t) \qquad (5.3)$$

where μ_o is the permeability of free space.

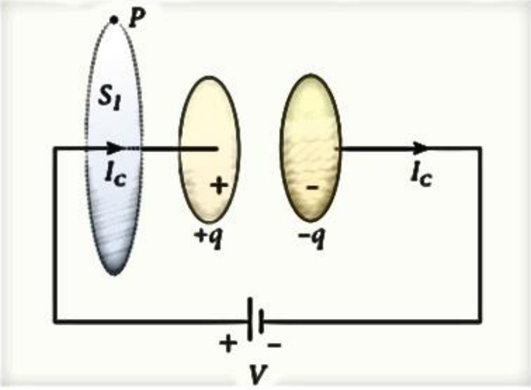


Figure 5.4 Applying Ampere's circuital law - loop enclosing surface

Same loop is enclosed by balloon shaped surface S_2

- Shape of the enclosing surfaces are different (first surface **(S_1)** is **circular in shape** and second one is **balloon shaped surface (S_2)**).

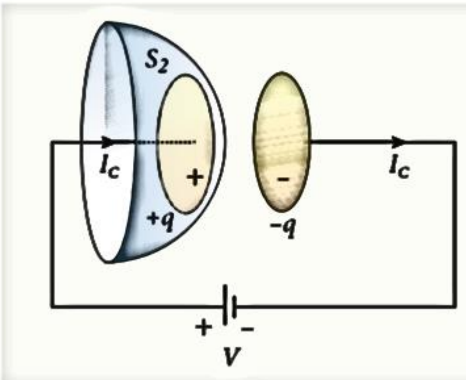


Figure 5.5 Applying Ampere's circu law - loop enclosing surface S2

- Ampere's law applied for a given closed loop does not depend on shape of the enclosing surface, the integrals will give the same answer.

$$\oint_{S_1} \vec{B}\cdot d\vec{l} = \mu_o I_c \qquad (5.4)$$

- The right hand side of equation is zero because the surface S_2 no where touches the wire carrying conduction current and further, there is no current in between the plates of the capacitor (there is a discontinuity).
- So the magnetic field at a point P is zero. Hence there is an inconsistency between equation (5.3) and equation (5.4).

J. C. Maxwell resolved this inconsistency as follows:

- Due to external source (battery or cell), the capacitor gets charged up because of current flowing through the capacitor. This produces an increasing electric field between the capacitor plates.
- The time varying electric flux (or time varying electric field) existing between the plates of the capacitor also produces a current known as displacement current.

From Gauss's law the electric flux between the plates of the capacitor

$\phi_E = \oiint \vec{E}.d\vec{A} = EA = \frac{q}{\varepsilon_0}$

Change in electric flux

$$\frac{d\phi_E}{dt} = \frac{1}{\varepsilon_0}\frac{dq}{dt} = \frac{1}{\varepsilon_0} I_d$$

$\varepsilon_0 \frac{d\phi_E}{dt} = I_d$

I_d – **Displacement current**

The **displacement current can be defined as the current which comes into play in the region in which the electric field and the electric flux are changing with time**.

Maxwell modified Ampere's law as

$$\oint \vec{B}.d\vec{S} = \mu_0 I$$

$$I = I_c + I_d$$

$$\oint \vec{B}.d\vec{S} = \mu_0 (I_c + I_d)$$

Constant current is applied , displacement current **I_d = 0 and hence I_c = I.**

Between the plates, the conduction current **I_c = 0 and hence I_d = I.**

5.Write down properties of electromagnetic waves

1) They are produced by any **accelerated charge**.

2) They do not **require any medium for propagation**. So it is a **non-mechanical wave**.

3) They are **transverse** in nature. Oscillating electric field vector, oscillating magnetic field vector and propagation vector (gives direction of propagation) are **mutually perpendicular to each other.**

4) Electromagnetic waves travel with speed which is equal to the speed of light in vacuum or free space, $c = \frac{1}{\sqrt{\mu_o \varepsilon_0}}$ = **$3 \times 10^{-}$ m s^{-1}**

5) They are **not deflected** by electric field or magnetic field.

6) They can show **interference, diffraction and can also be polarized**.

7) They also carry energy and momentum.The force exerted by an electromagnetic wave on unit area of a surface is called **radiation pressure**.

8) Electromagnetic waves carries not only energy and momentum but **also angular momentum.**

6.Discuss the source of electromagnetic waves

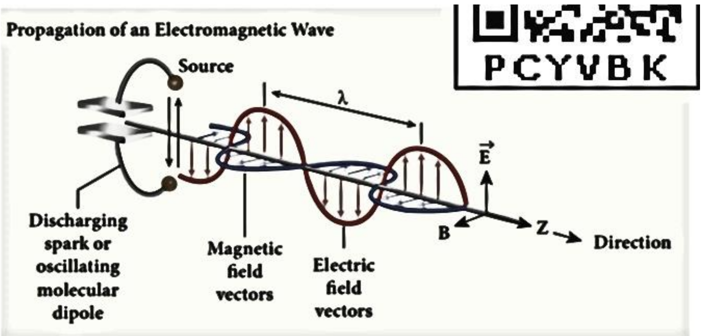


Figure 5.9 Oscillating charges - sources of electromagnetic waves

- When the charge moves with uniform velocity, it produces steady current which gives rise to magnetic field (not time dependent, only space dependent) around the conductor in which charge flows.
- If the charged particle accelerates, in addition to electric field it also produces magnetic field.
- Both electric and magnetic fields are time varying fields.
- Since the electromagnetic waves are transverse waves, the direction of

propagation of electromagnetic waves is perpendicular to the plane containing electric and magnetic field vectors.

- Any oscillatory motion is also an accelerating motion, so, when the charge oscillates (oscillating molecular dipole) about their mean position it produces electromagnetic waves.
- Suppose the electromagnetic field in free space propagates along *z* direction, and if the electric field vector points along y axis then the magnetic field vector will be mutually perpendicular to both electric field and the propagation vector direction, which means

$E_y = E_0 \sin (kz - \omega t)$

$B_y = B_0 \sin (kz - \omega t)$

E_0, B_0 - Amplitude of oscillating electric and magnetic field,

k - wave number

ω - angular frequency of the wave

$\hat{k}$ - propagation vector (denotes the direction of propagation of electromagnetic wave)

In free space or in vacuum,

speed of light **c** = E_0 / B_0

Energy of electromagnetic waves comes from the energy of the oscillating charge.

7.What is emission spectra? Give their types

<u>Emission spectra</u>

- ❖ When the **spectrum of self luminous source** is taken, we get emission spectrum.
- ❖ Each source has its **own characteristic emission spectrum**.
- ❖ It has **three** types

<u>(i) Continuous emission spectra (or continuous spectra)</u>

- ❖ If the light from incandescent lamp (filament bulb) is allowed to pass through prism (simplest spectroscope), it splits into seven colours.
- ❖ Thus, it consists of wavelengths containing all the visible colours ranging from violet to red.

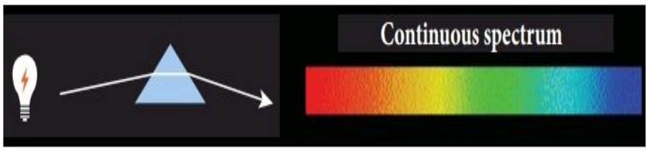


Figure 5.13 continuous emission spectra

<u>Examples:</u>

- ❖ Spectrum obtained from carbon arc, incandescent solids
- ❖ liquids gives continuous spectra.

<u>(ii) Line emission spectrum (or line spectrum)</u>

- ❖ Suppose light from **hot gas** is allowed to pass through prism, **line spectrum** is observed.
- ❖ Line spectra are also known **as discontinuous spectra.**
- ❖ The line spectra **are sharp lines of definite wavelengths or frequencies.**
- ❖ Such spectra arise due to excited atoms of elements.
- ❖ These lines are the characteristics of the element which means it **is different for different elements**.
- ❖ **For diagram refer book**

<u>Examples</u>

spectra of atomic hydrogen, helium, etc.

(iii) Band emission spectrum (or band spectrum)

- Band spectrum consists of several number of very closely spaced spectral lines which overlapped together forming specific bands which are **separated by dark spaces**, known as band spectra.
- This spectrum has a **sharp edge at one end** and **fades out at the other end**. Such spectra arise when the molecules are excited.
- Band spectrum is the characteristic of the molecule hence, the **structure of the molecules can be studied using their band spectra**.

Examples,

Spectra of hydrogen gas, ammonia gas in the discharge tube etc.

8.What is absorption spectra ?Give their types

Absorption spectra

- When **light** is allowed to **pass** through a medium or an **absorbing substance** then the **spectrum** obtained is known as **absorption spectrum.**
- It is the **characteristic of absorbing substance**.
- It is classified into **three types:**

(i) Continuous absorption spectrum

- When the **light** is passed through a **medium**, it is **dispersed by the prism**, we get continuous absorption spectrum.
- **Example**
- When we pass white light through a blue glass plate, it absorbs everything except blue.

(ii) Line absorption spectrum

- When **light from the incandescent** lamp is passed through **cold gas** (medium), the **spectrum obtained** through the dispersion due to prism **is line absorption spectrum**.

- **For diagram refer book**

Example

- Similarly, if the light from the carbon arc is made to pass through sodium vapour, a continuous spectrum of carbon arc with two dark lines in the yellow region of sodium vapour is obtained.

(iii) Band absorption spectrum

- When the **white light** is passed through the **iodine vapour**, **dark bands on continuous bright background** is obtained.
- This type of band is also obtained when white light is passed through diluted solution of blood or chlorophyll or through certain solutions of organic and inorganic compounds.

Book inside long answers

1.What are the properties and uses of Infrared radiation and Ultraviolet radiation

Infrared radiation

Properties

- It is produced from **hot bodies** (also known as heat waves) and also when the molecules **undergo rotational and vibrational transitions**.

- **Wavelength** range is **8 × 10^{-7} m to 5 × 10^{-3} m**
- **Frequency range** are **4 × 10^{14} Hz to 6 × 10^{10} Hz.**

Uses

- It provides electrical energy to satellites by means of solar cells.
- It is used to produce dehydrated fruits, in green houses to keep the plants warm, heat therapy for muscular pain or sprain, TV remote as a signal carrier
- To look through haze fog or mist and used in night vision or infrared photography.

Ultraviolet radiation

Properties

- It is produced by **Sun, arc and ionized gases. Wavelength** range is **6 × 10^{-10} m to 4 × 10^{-7} m**
- **Frequency** range are **5 × 10^{17} Hz to 7 × 10^{14} Hz.** It has less penetrating power.
- It can be absorbed by atmospheric ozone and harmful to human body.

Uses

- It is used to destroy bacteria, sterilizing the surgical instruments, burglar alarm, detect the invisible writing, finger prints and also in the study of molecular structure.