Revision Notes

Class- 12 Physics

Chapter 8 – Electromagnetic waves

8.1 Introduction

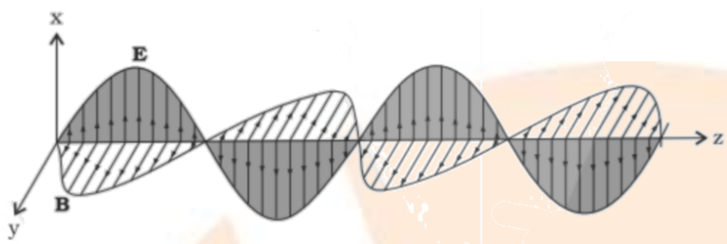
- Let us discuss electromagnetic waves, their properties and characteristics, and also their practical uses in our everyday life.
- One of the most important applications of electromagnetic waves is in the field of communication.
- Some of the important applications of electromagnetic waves are as follows:

1. We are able to see everything surrounding us because of electromagnetic waves.
2. These waves help in aircraft navigation and help the pilot for smooth take-off and landing of aero-planes. They also help to evaluate the speed of aero-planes.
3. In the medical field, these waves have very important applications. For instance, in laser eye surgery and in x-rays.
4. Radio and television broadcasting signals are transmitted with the help of electromagnetic waves.
5. Electromagnetic waves help in determining the speed of passing vehicles.
6. They are utilized in electronic appliances like T.V. remotes, remote cars, LED TV, microwave ovens, etc.
7. Voice transmission in mobile phones is made possible because of electromagnetic waves.

What are Electromagnetic Waves?

- Electromagnetic (EM) waves are the waves which are in relation to both electricity and magnetism.
- These waves are basically coupled time varying electric and magnetic fields which propagate in space.
- As these are waves associated with electricity and magnetism, they definitely would propagate in space.
- When electric and magnetic fields combine together and vary with time, they both give rise to electromagnetic waves.
- Electromagnetic equations are derived from Maxwell's equations.
- Maxwell concluded that these EM waves have so many special properties which can be utilized for many practical purposes.

- Time varying electric field + Time varying magnetic field = Electromagnetic waves.



The given diagram above demonstrates a linearly polarized electromagnetic wave propagating in the z-direction with oscillating electric field E in the x-direction and oscillating magnetic field B in the y-direction.

Maxwell's Experiments

- Maxwell claimed that time varying electric fields can generate magnetic fields.
- On the other hand, Faraday-Lenz law claims that a time varying magnetic field generates an electric field.
- According to Faraday-Lenz law, an EMF is induced in a circuit whenever the amount of magnetic flux linked with that circuit changes.
- As a result, electric current gets generated in the circuit which has an electric field associated with it.
  Now, when Maxwell came across this, he claimed that the vice-versa must also be true, i.e., a time varying electric field must also be able to generate a magnetic field.

Ampere's Circuital Law

- According to Ampere's circuital law, the line integral of magnetic field over the length element is equal to μ_0 times the total current passing through the surface. Mathematically, $\int dl = \mu_0 l$
- However, Maxwell found some inconsistencies in Ampere's circuital law.
- Hence, Ampere's circuital law was found to be correct only for some cases but not always.
- Maxwell observed various scenarios to conclude this. For instance, he took a capacitor and tried to determine the magnetic field at a specific point in a piece of this capacitor.

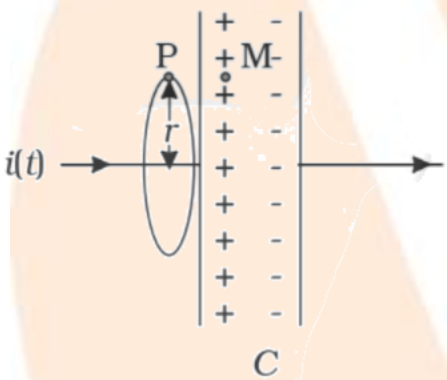
- Point P as shown in the coming figures is where he determined the value of B, assuming some current I, flowing through the circuit.
- He considered 3 different loops as shown in the following figures.
- If Ampere's circuital law was correct, it must be applicable for all these 3 setups.

Case 1: Maxwell considered a surface of radius r and the circumference of the surface, dl. According to Ampere's circuital law;

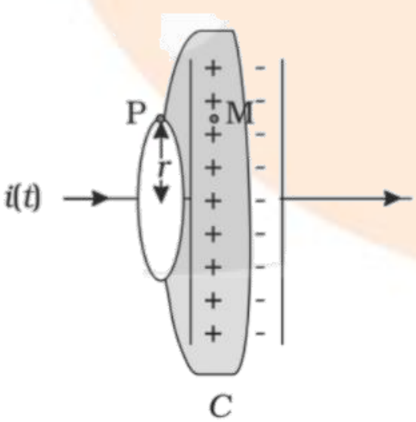
$$\int B.dl = \mu_0 l$$

$$\Rightarrow B(2\pi r) = \mu_0 l$$

$$\Rightarrow B = \frac{\mu_0 l}{2\pi r}$$



Case 2: Maxwell considered a surface, like a box with its lid open and applied the Ampere's circuital law;

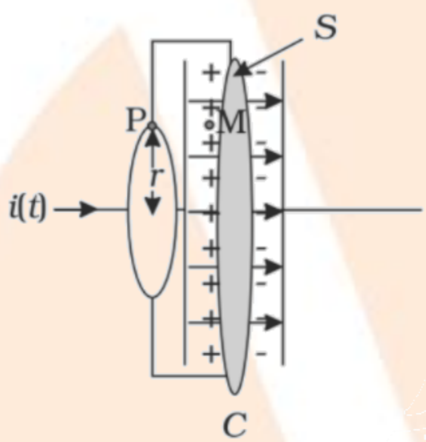


$$\int B.dl = \mu_0 l$$

Here, as there is no current flowing inside the capacitor, current, I turned out to be zero.

$$\Rightarrow \int B.dl = 0$$

Case 3: Maxwell considered the surface between 2 plates of a capacitor as shown. In this case also $I = 0$ and hence, $B = 0$.



- Clearly, at the same point but with different Amperial surfaces, Maxwell found that the values of magnetic fields are not the same, thus proving his claims on inconsistencies in the law.
- Maxwell pointed out that there were some gaps in the Ampere's circuital law. He rectified them and made Ampere's circuital law consistent in all the scenarios.

Maxwell's correction to Ampere's law

- Ampere's law states that the line integral of resultant magnetic field along a closed plane curve is equal to μ_0 times the total current crossing the area bounded by the closed curve, provided the electric field inside the loop remains constant.
- This law was applicable only for steady currents.
- Maxwell found the shortcomings in Ampere's law and modified this law by involving time-varying electric fields.
- For Ampere's circuital law to be correct, Maxwell assumed that there has to be some current existing between the plates of the capacitor.
- Outside the capacitor, current was due to the flow of electrons.
- There was no conduction of charges between the plates of the capacitor.

- According to Maxwell, between the plates of the capacitor, there should be an electric field which is directed from the positive plate to the negative plate.
- Magnitude of the electric field, $E = (V/d)$

  Where,

  $V =$ potential difference between the plates

  $d =$ distance between the plates

  $\Rightarrow E = (Q/Cd)$

  Where,

  $Q =$ charge on the plates of the capacitor,

  $C =$ Capacitance of the capacitor

  $\Rightarrow E = (Q/ \ (A\varepsilon_0 d/d))$

  $\Rightarrow E = Q/(A\varepsilon_0)$

  Where,

  $A =$ area of the capacitor.
- Direction of the electric field would be perpendicular to the selected surface (the plate of the capacitor).
- Now, as $E = 0$ outside the plates and $E = (Q/(A\varepsilon_0))$ between the plates, there might be some electric field between the plates because of which some current is present between the plates of the capacitor.
- Electric flux through the surface $= \Phi_E = (EA) = (QA)/(A\varepsilon_0) = (Q/ \ \varepsilon_0)$
- Assuming Q as charge on the capacitor and when it changes with time, current would get generated for sure.
- Therefore, current $I_d = (dQ/dt)$

  Where,

  $I_d =$ displacement current
- Now, differentiating $\Phi_E = (Q/ \ \varepsilon_0)$ with respect to time on both sides,

  $(d\Phi_E/dt) = (1/ \ \varepsilon_0)(dQ/dt)$

  Where,

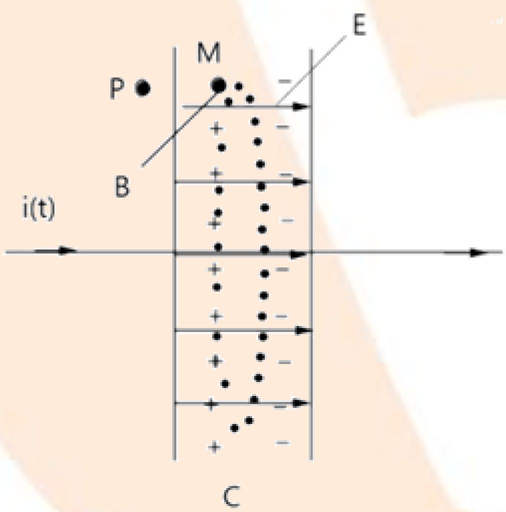
  $(dQ/dt) =$ current

  Therefore,

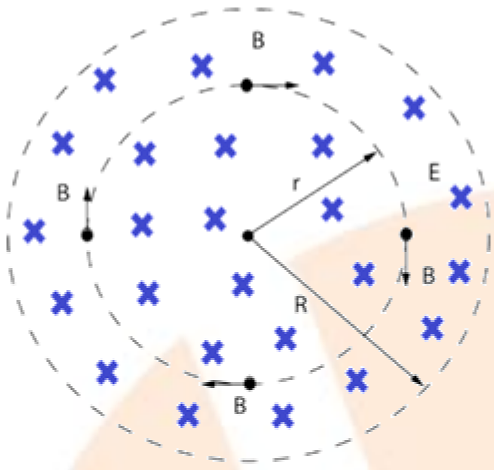
  $(dQ/dt) = \varepsilon_0 (d \ \Phi_E/dt)$

  Clearly, current gets generated because of change of electric flux with time.
- Electric flux arose because of the presence of electric field in the plates of the capacitor.

- $I_d = (dQ/dt)$ = displacement current
  Therefore, change in electric field gave rise to displacement current.
- Current won't be 0 but would be I_d.
- There is some current between the plates of the capacitor and there is some current at the surface.
- At certain points, there is no displacement current; there is only conduction current and vice-versa.
- Maxwell corrected the Ampere's circuital law by including displacement current.
- He said that apart from the current which existed outside the capacitor, there was also a current known as displacement current which existed between the plates of the capacitor.
- And this displacement current exists due to the change in the electric field between the plates of the capacitor.
- **Conclusion**: Magnetic fields are produced both by conduction currents and by time varying fields.



(a)



(b)

- Figure (a) represent the electric and magnetic fields E and B between the capacitor plates at the point M while figure (b) represents a cross-sectional view of figure (a).

Ampere-Maxwell Law

- Since Maxwell was able to correct the shortcomings of the Ampere's circuital law, the law came to be known as Ampere-Maxwell law from then onwards.
- Current which arises due to the flow of charges is known as conduction current. It is denoted by I_c.
- Current which arises due to change in electric field is known as displacement current. It is denoted by I_d.
- Thus, total current is given by $I = I_c + I_d$.
- Ampere-Maxwell law stated that

$$\int dl = \mu_0 (I_c + I_d)$$

$$\Rightarrow \int dl = \mu_0 I_c + \mu_0 \varepsilon_0 (d\Phi_E / dt)$$

- The above expression is known as modified Maxwell's law or Ampere-Maxwell law.

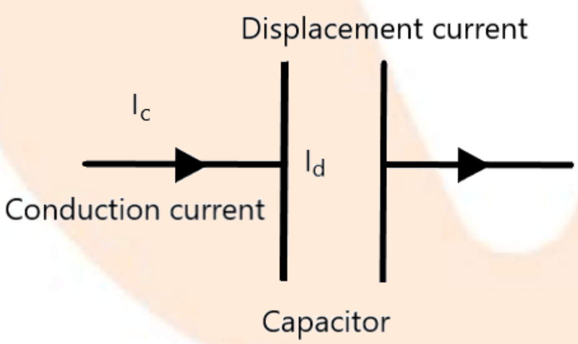
8.2 Displacement Current

- Consider a capacitor and that outside the plates of this capacitor, there is conduction current I_c.
- In the region between the plates i.e., inside the capacitor, let there be a displacement current, I_d.

- Physical behavior of displacement current is the same as that of induction current.
- Now, the difference between conduction current and displacement current is as given in the table below:

Conduction Current	**Displacement Current**
It arises due to the fixed charges.	It arises due to the change in electric field.

- For static electric fields, $I_d = 0$ whereas for time varying electric fields, $I_d \neq 0$.
- There can be some scenarios where there would only be conduction current and in some other cases where there would only be displacement current.
- However, outside the capacitor, there is only conduction current and no displacement current.
- Also, inside the capacitor there is only displacement current and no conduction current.
- But there can be some scenarios where both conduction as well as displacement current are present i.e., when $I = I_c + I_d$.
- Now, applying modified Ampere-Maxwell law to evaluate the magnetic field at the same point of the capacitor considering various Amperial loops, the result would be the same in all the cases.



Ampere – Maxwell law: Consequences

- **Case 1:** Magnetic field is given by

$$\int dl = \mu_0 I_c$$

$$\Rightarrow \int dl = \mu_0 I_c / 2\pi r$$

- **Case 2:** Magnetic field is given by

$$\int dl = \mu_0 I_d$$
$$\Rightarrow \int dl = \mu_0 I_d / 2\pi r$$

- **Conclusions:**

1. The value of B is the same in both cases.
2. Total current must be the same.
3. Time varying electric field generates magnetic field provided by Ampere-Maxwell law.
4. Considering the first step, there is an electric field between the plates and this electric field is varying with time.
5. As a result, there is displacement current and this displacement current gives rise to the magnetic field.
6. Time varying magnetic field generates an electric field provided by Faraday-Lenz law.
7. Clearly, when there is electric field changing with time, it generates magnetic field and when there is magnetic field changing with time, it generates electric field.

- Electromagnetic waves are based on the above conclusion.

Maxwell's Equations

- Maxwell's equations describe how an electric field can generate a magnetic field and vice-versa. These equations describe the relationship and behavior of electric and magnetic fields.
- Maxwell gave a set of four equations which are known as Maxwell's equations. They are:

1. $\oint E.dA = Q / \varepsilon_0$ (Gauss's Law for electricity)
2. $\oint B.dA = 0$ (Gauss's Law for magnetism)
3. $\oint E.dl = \frac{-d\phi_B}{dt}$ (Faraday's Law)
4. $\oint B.dl = \mu_0 i_c + \mu_0 \varepsilon_0 \frac{d\phi_E}{dt}$ (Ampere-Maxwell Law)

- According to Maxwell equations;

a) A flow of electric current will generate a magnetic field and if the current varies with time, magnetic field will also give rise to an electric field.
b) The first equation (1) describes the surface integral of an electric field.
c) The second equation (2) describes the surface integral of the magnetic field.

d) The third equation (3) describes the line integral of the electric field.

e) The fourth equation (4) describes the line integral of the magnetic field.

- Maxwell was the first to conclude that the speed of propagation of EM waves is the same as the speed of light. Experimentally, it was found that

  $$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

  Where,

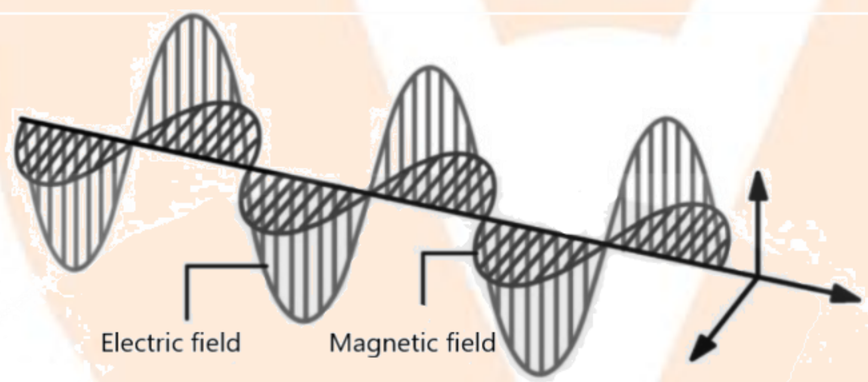
  μ_0 is the permeability;

  ε_0 is the permittivity;

  c is the velocity of light.

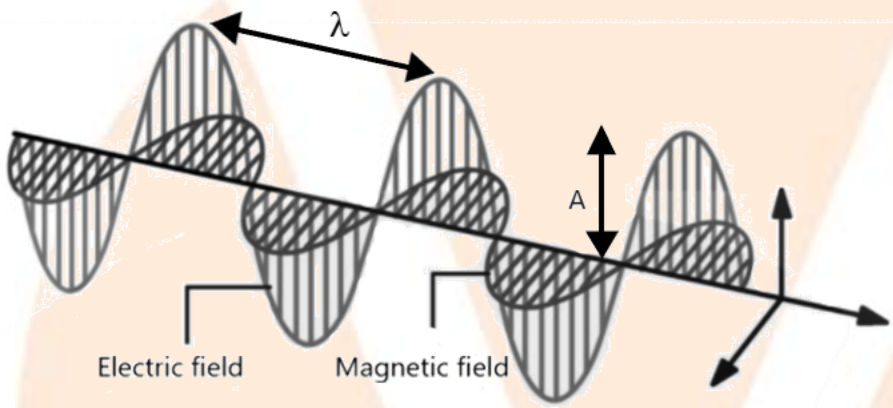
- Maxwell's equations show that the electricity, magnetism and ray optics are all inter-related to each other.

8.3 Electromagnetic Waves



- Electromagnetic waves refer to the coupled time varying electric and magnetic fields that propagate in space.
- Electric field is varying with time, and it will give rise to magnetic field; This magnetic field is varying with time and it further gives rise to electric field and the process continues so on.
- These time varying electric and magnetic fields, coupled with each other when propagating together in space give rise to electromagnetic waves.
- In the figure given above, the red line represents the electric field and it varies in the form of a sine wave whereas the blue line represents the magnetic field.

- The magnetic field is also a sine wave but in a perpendicular direction to the electric field.
- Both these fields give rise to electromagnetic fields.
- When the electric field is along the x-axis and the magnetic field along the y-axis, the wave would propagate in the z-axis.
- Electric and magnetic fields are perpendicular to each other as well as to the direction of wave propagation.



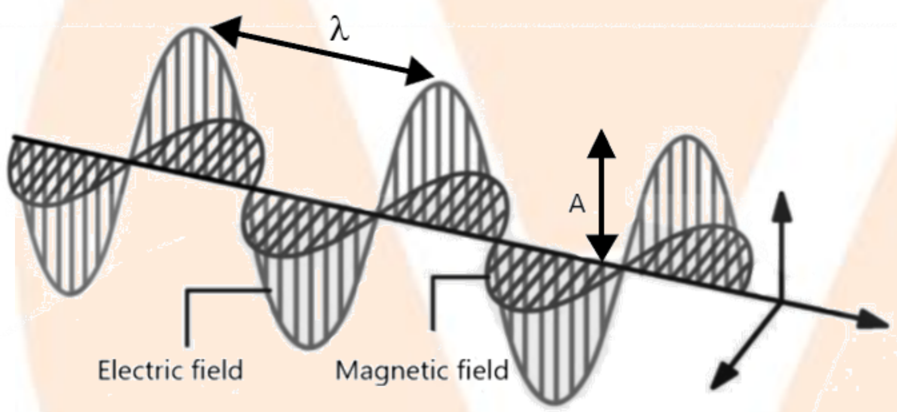
8.3.1 Sources of Electromagnetic Waves (EM)

- Electromagnetic waves are generated when electrically charged particles oscillate (accelerating charges).
- The vibration of the electric field associated with the accelerating charge generates a vibrating magnetic field.
- Both these vibrating electric and magnetic fields give rise to EM waves.
- When the charge is at rest, the electric field associated with the charge would also be static. Hence, there would be no generation of EM waves as the electric field does not vary with time.
- When the charge is moving with uniform velocity, the acceleration is zero. The change in electric field with time is also constant and as a result, again there would be no electromagnetic waves generated.
- This shows that only accelerated charges can generate EM waves.
- For example, consider an oscillating charge particle. It has an oscillating electric field which gives rise to an oscillating magnetic field.
- This oscillating magnetic field further gives rise to an oscillating electric field and so on, this process continues.

- The regeneration of electric and magnetic fields is the same as propagation of the wave.
- Such a wave where all these phenomena are known as an electromagnetic wave.
- It is also to be noted that the frequency of an EM wave is always equal to the frequency of the oscillating particle which generates it.

8.3.2 Nature of EM waves

- EM waves are transverse waves.
- Transverse waves are those in which direction of disturbance or displacement in the medium is perpendicular to that of the propagation of wave.
- In such a wave, the particles of the medium move in a direction perpendicular to the direction of propagation of the wave.



- Suppose the EM wave propagates along the x-axis, then, electric and magnetic fields are perpendicular to the wave propagation.
- This means that when wave propagation $\rightarrow$ x-axis; electric field $\rightarrow$ y-axis and magnetic field $\rightarrow$ z-axis.
- Clearly, EM waves are transverse waves in nature.
- Now, electric field of an EM wave is given by,

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

  Where,

  E_y = the electric field along the y-axis and x is the direction of propagation of wave.
- Wave number is given by,

  $k = (2\pi / \omega t)$

- Magnetic field of EM wave given by,

$B_z = B_0 \sin(kx - \omega t)$

Where,

$B_z =$ the electric field along the z-axis and x is the direction of propagation of wave.

8.3.3 Energy of EM wave

- When EM waves propagate, they carry energy. Because of this property, they have so many practical uses in our everyday life.
- Energy in EM wave is partly carried by electric field and partly by magnetic field.
- Mathematically,

Total energy stored per unit volume in EM wave, $E_T =$ Energy stored per unit volume by electric field + Energy stored per unit volume stored in magnetic field.

$$\Rightarrow E_T = \left(\frac{1}{2}\right)(E^2\varepsilon_0) + \left(\frac{1}{2}\right)(B^2\mu_0)$$

- Experimentally, it has been found that

Speed of the EM wave $=$ Speed of the light

$$\Rightarrow c = \frac{E}{B}$$

$$\Rightarrow B = (E/c)$$

$$\Rightarrow E_T = \left(\frac{1}{2}\right)(E^2\varepsilon_0) + \left(\frac{1}{2}\right)(E^2/c^2\mu_0)$$

- Now, from Maxwell's equations;

$$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$$

$$\Rightarrow E_T = \left(\frac{1}{2}\right)(E^2\varepsilon_0) + \left(\frac{1}{2}\right)\left(\frac{E^2\mu_0\varepsilon_0}{\mu_0}\right)$$

$$\Rightarrow E_T = \left(\frac{1}{2}\right)(E^2\varepsilon_0) + \left(\frac{1}{2}\right)(E^2\mu_0\varepsilon_0)$$

$$\Rightarrow E_T = E^2\varepsilon_0$$

This expression gives the amount of energy carried per unit volume by an EM wave.

8.3.4 Properties of EM waves

- Velocity of EM waves in free space or vacuum is a fundamental constant. Experimentally, it was found that the velocity of EM wave is the same as speed of light $(c = 3\times10^8 m/s)$.
- c is a fundamental constant given by,
  $$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$
- No material medium is necessary for EM waves. However, they can propagate within a medium as well.
- EM waves need time varying electric and magnetic fields to propagate.
- When there is medium present, then velocity is given by,
  $$v = \frac{1}{\sqrt{\mu\varepsilon}}$$
  Where,
  $\mu =$ permeability of the medium;
  $\varepsilon =$ permittivity of the medium.
  For example, consider the case of spectacles; When light falls on the glass of a spectacles, light rays pass through this glass. i.e., Light waves propagate through a glass medium.
- EM waves carry energy and momentum.
- Total energy stored per unit volume in EM wave is given by,
  $E_T = E^2\varepsilon_0$ (Partly carried by electric field and partly by magnetic field).
- As EM waves carry energy and momentum, it becomes an important property for its practical purposes.
- EM waves are used for communication purposes, voice communication in mobile phones and telecommunication used in radio.
- EM waves exert pressure. As they carry energy and momentum, they exert pressure. The pressure exerted by EM waves is termed radiation pressure.
  For example;
  The sunlight which we get from the sun is in the form of visible light rays. These light rays are also a part of EM waves. If we keep our palm in the sun, after some time, our palm becomes warm and starts sweating. This happens because the sunlight is getting transferred in the form of EM waves and these EM waves carry energy.
  Suppose total energy transferred to the hand $= E$;
  Momentum $= \left(E/c\right)$

Now, as c is extremely high, the momentum turns out to be very small. As momentum is very less, pressure experienced is also very less. This is the reason due to which the pressure exerted by the sun is not experienced by our palms.

8.4 Electromagnetic Spectrum

- Electromagnetic spectrum is the classification of EM waves with respect to their frequency or wavelength.
- Different categories of EM waves in decreasing order of their wavelength are as follows:
  a) Radio waves: $>0.1\text{m}$
  b) Microwaves: $0.1\text{ m}-1\text{mm}$
  c) Infra-Red: $1\text{mm}-700\text{ nm}$
  d) Visible light: $700\text{nm}-400\text{ nm}$
  e) Ultraviolet: $400\text{nm}-1\text{nm}$
  f) X-rays: $1\text{nm}-10^{-3}\text{nm}$
  g) Gamma rays: $<10^{-3}\text{nm}$
- These seven waves together constitute the electromagnetic spectrum.

Tip

- To remember the order of wavelength of each wave, we can just write the initial letter of all the waves and they seem to be in decreasing order of wavelength.
- R (Maximum wavelength), M, I, V, U, X and G (Minimum wavelength).
- This can be remembered like this: Red Man In Violet Uniform X Gun.

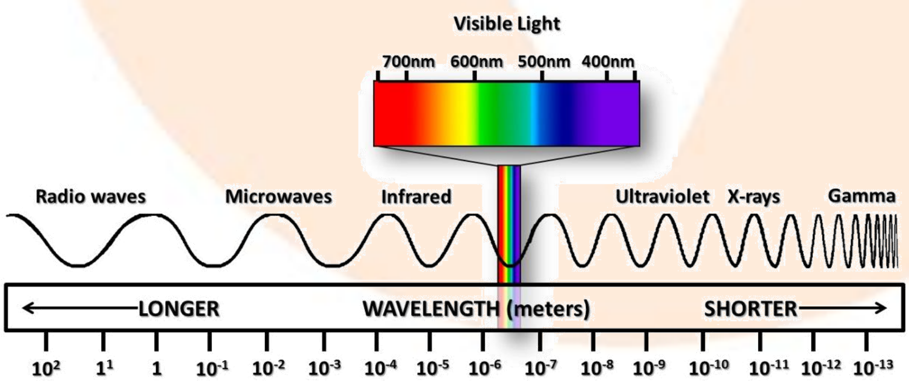
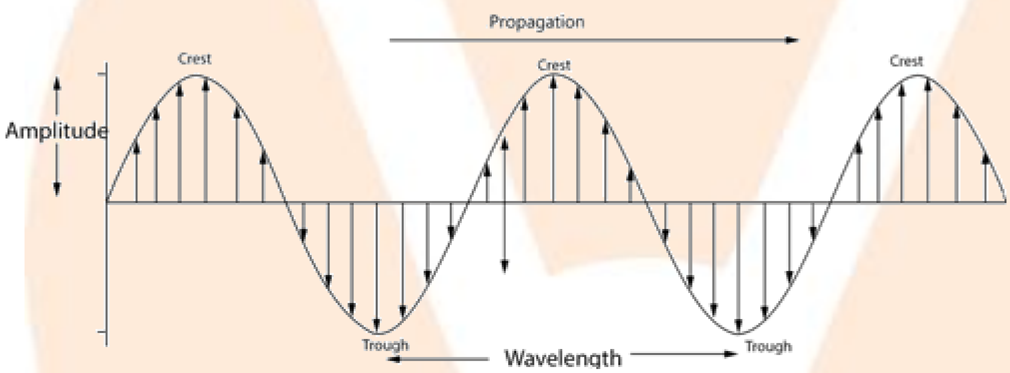


Image source: [Electromagnetic Spectrum (thinglink.com)]

- The electromagnetic spectrum has common names for various parts of it. These various regions do not have sharply defined boundaries.

Electromagnetic energy of each wave in Electromagnetic Spectrum

- Electromagnetic energy of electromagnetic waves can be described by frequency, wavelength or energy.
- Frequency - Both micro and radio waves are described in terms of frequencies.
- Frequency is the number of crests that pass a given point within one second.
- Consider a wave which has three crests which pass a point in one second. Therefore, its frequency $= 3\text{Hz}$. Its SI unit is hertz (Hz).
- Wavelength - Infrared and visible waves are generally described in terms of wavelength.
- Wavelength is the distance between consecutive crests or troughs.
- Wavelength can vary from a small value to a large value. Its S.I. unit is meter(m).



- Energy - X-rays and Gamma rays are described in terms of energies.
- An EM wave can be described in terms of energy. i.e., in units of eV.
- eV is the amount of kinetic energy needed to move one electron through a potential of one volt.
- Moving along the EM spectrum; energy increases as the wavelength decreases.
- Relation between wavelength and frequency is given by.

  $c = \nu\lambda$

  Where,

  $\lambda =$ wavelength;

  $\nu =$ frequency;

  $\Rightarrow \lambda = (c/\nu)$

  $\Rightarrow E = h\nu = (hc/\lambda)$

  $\Rightarrow E \propto \nu$ and $E \propto (1/\lambda)$

- Thus, EM spectrum in terms of decreasing order of wavelength $\rightarrow$ R, M, I, V, U, X and G
- Also, the spectrum in terms of increasing order of frequency $\rightarrow$ G, X, U, V, I, M, and R

8.4.1 Radio Waves

- Radio waves are produced by the accelerated motion of charges in conducting wires.
- Important application of radio waves:
  i. Radio and television communication systems.
  ii. Mobile phones for voice communication.
- In electromagnetic spectrum, the wavelength (λ) of radio waves is $> 0.1\text{m}$.
- Radio waves are further classified into different bands as follows:
  i. AM band (Amplitude Modulated) - $530\text{ kHz to }1710\text{ kHz}$ (lowest frequency band). They are similar to FM channels.
  ii. Short wave band - up to 54MHz
  iii. TV wave band - $54\text{MHz to }890\text{MHz}$
  iv. FM band (Frequency Modulated) - $88\text{MHz to }108\text{MHz}$
  v. UHF band - Ultra high frequency (used for voice communication over cell phones)

8.4.2 Micro Waves

- Micro waves are short wavelength radio waves.
- They are produced by special vacuum tubes (klystrons/magnetrons/Gunn diodes).
- They are used in microwave ovens and radar systems in aircraft navigation.

- **RADAR Technology**
  RADAR - Radio detection and ranging.
  Different applications of RADAR:

a) Air traffic control: To manage air traffic. The pilot should know if any other aero plane is present nearby or not. The pilot should also know the climatic conditions during take-off and landing.
Radar plays a very important role in aircraft navigation.
b) Speed detection: The instruments which are used to detect the speed of the vehicles which move on the roads utilize radar technology.
c) Military purposes: It helps to detect enemies and weapons.
d) Satellite tracking: In order to track satellites, radar technology is utilized.

Why do radio waves use micro waves?

- As they use short wavelength waves which are the same as micro waves.
- They are invisible to humans. If we are able to see the waves which get transmitted, it would be very irritating.
- Even the smallest presence of microwaves is easy to detect.

Working of Radar Set

It consists of:

1. Transmitter: It transmits the microwaves.
2. Receiver: It receives the echo produced by the microwaves when they strike any object. When the receiver receives the reflected ray, then it is possible to track the presence of other objects in the vicinity.

Microwave ovens

Microwaves are very useful because:

- They have smaller wavelengths.
- They get absorbed by water, fats and sugar.

Working of microwave oven

- In order to heat anything uniformly, microwave ovens are utilized.
- Any food material would have water, sugar and fats in it.
- When we heat any food material inside the microwave, the microwaves penetrate inside the food.
- Thus, the microwaves get absorbed by the water and the fat molecules.
- The molecules of the food material would start moving randomly with some frequency.
- This is the same as providing some wave to the food material with the same frequency with which the molecules start vibrating.
- This shows that the frequency of microwaves matches with the frequency of the molecules.
- As all the molecules are set in random motion, temperature increases and the food material gets heated uniformly throughout.
- Object can be heated in two ways:

a) Conduction of heat: It happens when anything is heated over a gas burner.

b) Exciting the molecules: This technique is used in microwave ovens.

8.4.3 Infrared waves

- Known as heat waves as they are produced by hot bodies.

- Their wavelength is lesser than both radio and micro waves.
- They readily get absorbed by water.

- **Applications:** Infrared lamps/Infrared detector/LED in remote switches of electronic devices/Greenhouse effect.
  For example:
  a) Fire gives out both visible light waves and infrared waves. The light rays are visible to us but the infrared waves cannot be seen by us.
  b) Humans also generate some infrared waves.
- There are some special glasses which have infrared detectors to view infrared waves.
- Infrared lamps are used to heat food materials and sometimes washrooms.
- When we switch on the TV with the help of a remote, there is an LED both on TV and on remote. The signal gets transferred from remote to TV via infrared waves.
- Greenhouse Effect: Greenhouse effect is an atmospheric heating phenomenon that allows incoming solar radiation to pass through; but blocks the heat radiated back from the Earth's surface.
- Consider that the sun gives radiation in the form of visible light to the earth.
- When the visible light reaches the earth's surface, all the objects on the earth become hot.
- The visible light carries energy from sun and that energy gets transferred to all the objects present on the earth.
- As a result of heat transfer, all the objects get heated up.
- These hot objects transmit infrared waves.
- The earth will re-radiate the infrared waves.
- When these infrared waves try to go out of the atmosphere, they get trapped by greenhouse gases like CO_2, CH_4 and water vapor.
- As a result, heat gets trapped inside the earth, which results in an increase in temperature.
- The greenhouse effect makes earth warm because of which the temperature of the earth is suitable for the survival of life on earth.
- However, global warming is due to an increase in temperature of the environment, due to pollution.

8.4.4 Visible or Light rays

- Light waves are the most common form of EM wave.
- Their wavelength range is $4\times10^{14}\text{Hz}-7\times10^{14}$
- We are able to see everything because of light rays.

- The radiation which we get from the sun is in the form of visible light.
- Most of the insects have compound eyes due to which they see not only the visible light but also the ultraviolet rays.
- Snakes can even see the infrared rays.

8.4.5 Ultraviolet rays (UV rays)

- It covers wavelengths ranging from about $4\times10^{-7}\text{m}\left(400\text{nm}\right)$ down to $6\times10^{-10}\text{m}\left(0.6\text{nm}\right)$.
- The UV rays are produced by special lamps and very hot bodies like the sun.
- UV rays have harmful effects on humans.
- UV lamps are used to kill germs in water purifiers.
- For example, when UV rays fall on the skin of humans then it leads to the production of a pigment called melamine which causes tanning of the skin.
- In order to protect from UV rays, glasses are used as the rays get absorbed by these glasses.
- UV rays help in LASER assisted eye surgery. As UV rays have very short wavelength, they can be focused into a narrow beam of light.
- The ozone layer which is present outside the atmosphere protects us from the harmful UV rays.
- Ozone has a property of reflecting the harmful UV rays. But due to the use of CFC (chlorofluorocarbon), the ozone layer is depleting. So, when ozone layer gets depleted, humans would get exposed to harmful UV rays coming from the sun.

8.4.6 X-Rays

- X-Rays are produced by bombarding a metal target by high energy electrons.
- It is a very important diagnostic tool.
- X-Rays have lesser wavelengths when compared to all other waves.
- Because of this, X-Rays can easily penetrate inside the skin (low density material). It either gets reflected or absorbed by the high-density material (like bone).
- In any X-Ray, bones look darker while skin looks lighter.
- It is also used for cancer treatment. In cancer there is unwanted growth of the cells. In order to treat cancer, the abnormal growth of cells should be stopped. X-Rays have the ability to damage the living tissue. This is how it helps in the treatment of cancer.

8.4.7 Gamma Rays

- Gamma rays are produced during nuclear reactions and are also emitted by radioactive nuclei.
- These rays are also utilized in the treatment of the cancer as they have very small wavelengths. Clearly, they help to kill the growth of unwanted living cells which grow when the body is suffering from cancer.