ELECTROMAGNETIC WAVES

PHYSICS - VOL 1

UNIT - 5

NAME :

STANDARD : 12 SECTION :

SCHOOL :

EXAM NO :

உடையார்முன் இல்லார்போல் ஏக்கற்றுங் கற்றார்
கடையரே கல்லா தவர்

செல்வர் முன் வறியவர் நிற்பது போல் (கற்றவர்முன்) ஏங்கித் தாழ்ந்து நின்றும்
கல்விக் கற்றவரே உயர்ந்தவர். கல்லாதவர் இழிந்தவர்.

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PART - II 2 MARK OUESTIONS & ANSWERS

1. Define 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
- That is when ever the change in electric field takes place, displacement current is produced.

2. Define electro magnetic waves.

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

3. Give the modified form of Ampere's circuital law.

- If I_C and I_D are the conduction and displacement current, then the modified Ampere's circuital law is givent by,

$$\oint \vec{B}.\vec{dl} = \mu_o (I_C + I_D)$$

$$(or) \quad \oint \vec{B}.\vec{dl} = \mu_o I_C + \mu_o \varepsilon_o \frac{d}{dt} \int \vec{E}.\vec{dA}$$

- This is also known as Ampere - Maxwell's law.

4. Write a note on Gauss's law in magnetism.

- Maxwell's second equation is called as Gauss' s law for magnetism. It states that the surface integral of magnetic field over a closed surface is zero.

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

- It implies that the magnetic lines of force form a continuous closed path. It means that no isolated magnetic monopole exists.

5. Write a note on Ampere -Maxwell law.

- It is modified Ampere's circuital law This law relates the magnetic field around any closed path toe the conduction current and displacement current through that path.
- Mathematically,

$$\oint \vec{B}.\vec{dl} = \mu_o (I_C + I_D)$$

$$(or) \quad \oint \vec{B}.\vec{dl} = \mu_o I_C + \mu_o \varepsilon_o \frac{d}{dt} \int \vec{E}.\vec{dA}$$

Here, $\vec{B} \rightarrow$ magnetic field

- It implies that both conduction and displacement current produces magnetic field

6. Define electromagnetic spectrum.

- The orderly distribution of electromagnetic waves in terms of wavelength or frequency is called electromagnetic spectrum.

7. Define dispersion.

- When white light is made to pass through the prism, it is split in to its seven xonstituent colours. This phenomenon is known as dispersion of light.
- The patern of colours obtanined on the screen after dispersion is called spectrum.

8. Define emission spectra.

- The spectrum obtained from a self luminous source of light is called emission spectrum.
- Each sourch has its own characteristic emission spectrum.

9. Define absorbtion spectra.

- When light is allowed to pass through an absorbing substance, then the spectrum obtained is known as absorbtion spectrum.
- It is the characteristic of absorbing substance.

10. Define Fraunhofer lines.

- When the spectrum obtained from the Sun is examined, it consists of large number of dark lines (line absorbtion spectrum).
- These dark lines in the solar spectrum are known as Fraunhofer lines.

11. What are the uses of Fraunhofer lines?

- The absorption spectra for various materials are compared with the Fraunhofer lines in the solar spectrum, which helps to identifying elements present in the Sun's atmosphere.

12. Why electro magnetic waves are non mechanical?

- Electromagnetic waves do not require any medium for propagation. So electromagnetic wave is a non-mechanical wave.

PART - III 3 MARK OUESTIONS & ANSWERS

1. Discuss briefly the experiment conducted by Hertz to produce and detect electromagnetic spectrum.

Hertz experiment :

- The theoritical prediction of existence of electromagnetic wave by Maxwell was experimentally confirmed by Henrich Hertz.
- His experimental set up 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 which produce very high emf.
- Due to this high voltage, the air between the electrodes gets ionized and spark is produced.
- A receiver (ring electrode) kept at a distance also gets spark which implies that the energy is transmitted from electrode to the receiver as a wave known as electromagnetic waves.
- 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 ($3\ X\ 10^8\ m\ s^{-1}$).

2. Write a note on Radio waves.

Radio waves :

- It is produced by oscillators in electric circuits.
- Wavelength range : $1\ X\ 10^{-4}\ m - 1\ X\ 10^4\ m$
- Frequency range : $3\ X\ 10^9\ Hz - 3\ X\ 10^4\ Hz$
- They obey reflection and diffraction
- It is used in,
  - (i) radio and television communication systems
  - (ii) cellular phones to transmit voice communication in the ultra high frequency band

3. Write a note on infra microwaves.

Microwaves :

- It is produced by electromagnetic oscillators in electrical circuits
- Wavelength range: $1\ X\ 10^{-3}\ m - 3\ X\ 10^{-4}\ m$
- Frequency range : $3\ X\ 10^{11}\ Hz - 1\ X\ 10^9\ Hz$
- They obey reflection and polarization

- ♣ It is used in,
  - (i) radar system for aircraft navigation,
  - (ii) speed of the vehicle,
  - (iii) microwave oven for cooking
  - (iv) very long distance wireless communication through satellites

4. Write a note on infra red rays.

Infra red rays :

- ♣ It is produced from hot bodies and also when the molecules undergo rotational and vibrational transitions.
- ♣ Wavelength range : $8\ X\ 10^{-7}\ m - 5\ X\ 10^{-3}\ m$
- ♣ Frequency range : $4\ X\ 10^{14}\ Hz - 6\ X\ 10^{10}\ Hz$
- ♣ It provides electrical energy to satellites by means of solar cells
- ♣ It is used in,
  - (i) producing dehydrated fruits
  - (ii) green housed to keep the plants warm,
  - (iii) heat therapy for muscular pain or sprain
  - (iv) TV remote as a signal carrier, to look through haze fof or mist
  - (v) night vision or infrared photography

5. Write a note visible light.

Visible light :

- ♣ It is produced by incandescent bodies and also it is radiated by excited atoms in gases.
- ♣ Wavelength range : $4\ X\ 10^{-7}\ m - 7\ X\ 10^{-7}\ m$
- ♣ Frequency range : $7\ X\ 10^{14}\ Hz - 4\ X\ 10^{14}\ Hz$
- ♣ It obeys the laws of reflection, refraction, interference, diffraction, polarization, photo -electric effect and photographic action.
- ♣ It can be used to,
  - (i) study the structure of molecules
  - (ii) arrangement of electrons in eternal shells of atoms and
  - (iii) sensation of our eyes

6. Write a note on ultra violet rays.

Ultra violet rays :

- ♣ It is produced by Sun, arc and ionized gases.
- ♣ Wavelength range : $6\ X\ 10^{-10}\ m - 4\ X\ 10^{-7}\ m$
- ♣ Frequency range : $5\ X\ 10^{17}\ Hz - 7\ X\ 10^{14}\ Hz$
- ♣ It has less penetrating power
- ♣ It can be absorbed by atmospheric ozone and harmful to human body.
- ♣ It is used to,
  - (i) destroy bacteria
  - (ii) sterilizing the surgical instruments,
  - (iii) burglar alarm
  - (iv) detect the invisible writing, finger prints and
  - (v) study of molecular structure

7. Write a note on X - rays.

X - rays :

- ♣ It is produced when there is a sudden deceleration of high speed electrons at high atomic number target.
- ♣ Also by electronic transitions among the innermost orbits of atoms.
- ♣ Wavelength range : $1\ X\ 10^{-13}\ m - 1\ X\ 10^{-8}\ m$
- ♣ Frequency range : $3\ X\ 10^{21}\ Hz - 1\ X\ 10^{16}\ Hz$
- ♣ It has more penetrating power than UV - rays.
- ♣ It is used in,
  - (i) studying structures of inner atomic electron shell and crystal structures.
  - (ii) detecting fracture, diseased organs, formation of bones and stones, observing the progress of healing bones
  - (iii) detect faults, cracks, flaws and holes in a finished metal product

8. Write a note on gamma rays.

Gamma rays :

- ♣ It is produced by transitionsof atomic nuclei and decay of certain elementary particles.
- ♣ Wavelength range : $1\ X\ 10^{-14}\ m - 1\ X\ 10^{-10}\ m$
- ♣ Frequency range : $3\ X\ 10^{22}\ Hz - 3\ X\ 10^{18}\ Hz$
- ♣ They produce chemical reactions on photographic plates, fluorescence, ionization, diffraction.
- ♣ Its penetrating power is higher than X-rays and UV rays.
- ♣ It has no charge but harmful to human body.
- ♣ It is used in,
  - (i) providing information about the structure of atomic nuclei
  - (ii) radio therapy for the treatment of cancer and tumour
  - (iii) food industry to kill pathogenic micro organism

PART - IV 5 MARK QUESTIONS & ANSWERS

1. Write down Maxwell equations in integral form.

Maxwel equations - Integral form :

- ♣ Electrodynamics can be summarized into four basic equations, known as Maxwell's equations.
- ♣ Maxwell's equations completely explain the behaviour of charges, currents and properties of electric and magnetic fields.
- ♣ This equation ensures the existence of electromagnetic waves.

Equtions - 1 :

- ♣ It is nothing but Gauss's law
- ♣ It relates the net electric flu to net electric charge enclosed in a surface.
- ♣ Mathematically, Gauss law is expressed as,

$$\oint \vec{E} \cdot \overrightarrow{dA} = \frac{Q_{closed}}{\varepsilon_o} \qquad ---- (1)$$

- ♣ Here, $\vec{E} \rightarrow$ electric field
  $Q_{closed} \rightarrow$ charge enclosed
- ♣ This equation is true for both discreate or continuous distribution of charges
- ♣ It also indicates that the electric field lines start from positive change and terminate at negative charge.
- ♣ The electric field lines do not form a continuous closed path (i.e.) isolated positive or negative charges can exist.

Equation - 2 :

- ♣ It has no name. But this law os similar to Gauss law in electrostatics. Hence this law can be called as Gauss's law in magnetism.
- ♣ According to this law, the surface integral of magnetic field over a closed surface is zero.
- ♣ Mathematically, this law can be expressed as,

$$\oint \vec{B} \cdot \overrightarrow{dA} = 0 \qquad ---- (2)$$

Here, $\vec{B} \rightarrow$ magnetic field

- ♣ This equation implies that the magnetic field lines form a continuous closed path. (i.e.) no isolated magnetic monopole exists

Equation - 3 :

- This is Faraday's laws of electromagnetic induction.
- This law relates electric field with the changing magnetic flux.
- 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.
- Mathematically it is expressed as,

$$\oint \vec{E} \cdot \vec{dl} = -\frac{d\Phi_B}{dt} \qquad ---- (3)$$

Here, $\vec{E} \rightarrow$ electric field

Equation - 4 :

- It is modified Ampere's circuital law and also called as **Ampere - Maxwell's law**.
- This law relates the magnetic field around any closed path toe the conduction current and displacement current through that path.
- Mathematically,

$$\oint \vec{B}.\vec{dl} = \mu_o (I_C + I_D)$$

$$(or) \qquad \oint \vec{B}.\vec{dl} = \mu_o I_C + \mu_o \varepsilon_o \frac{d}{dt}\int \vec{E}.\vec{dA}$$

Here, $\vec{B} \rightarrow$ magnetic field

- It implies that both conduction and displacement current produces magnetic field

2. Explain the modification of Ampere's circuital law.

Maxwell's corrections to Ampere's circuital law :

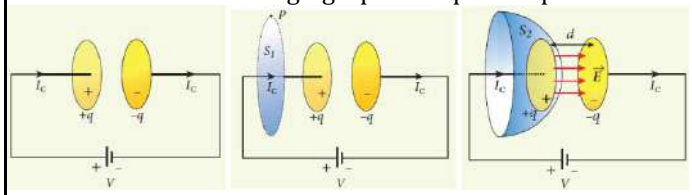
- According to Faraday's law of electromagnetic induction, the change in magnetic field produces an electric field. Mathematically

$$\oint \vec{E}.\vec{dl} = -\frac{\partial}{\partial t}\Phi_B = -\frac{\partial}{\partial t}\oint \vec{B}.\vec{dA}$$

- It implies that the electric field $\vec{E}$ is induced along a closed loop by the changing magnetic flux Φ_B in the region encircled by the loop.
- The converse of this statement, that is change in electric flux produces magnetic field is explained by Maxwell.

$$\oint \vec{B}.\vec{dl} = -\frac{\partial}{\partial t}\Phi_E = -\frac{\partial}{\partial t}\oint \vec{E}.\vec{dA}$$

- This is known as Maxwell's law of induction.
- To understand how the changing electric field produces magnetic field, let us consider the situation of charging a parallel plate capacitor.



- The electric current passing through the wire is the conduction current 'I_C'
- This current generates magnetic field around the wire connected across the capacitor.
- To calculate the magnetic field at a point 'P' near the wire, let us consider an amperian loop which encloses the surface S_1. Thus from Ampere circuital law,

$$\oint_{S_1} \vec{B}.\vec{dl} = \mu_o I_C \qquad ---- (1)$$

- Suppose the same loop is enclosed by balloon shaped surface S_2, then the boundaries of two surfaces are same but shape of the enclosing surfaces are different.
- Ampere's law does not depend on shape of the enclosing surface and hence the integrals will give the same answer.
- But there is no current in between the plates of the capacitor, the magnetic field on the surface is zero. So the magnetic field at 'P' is zero. Hence

$$\oint_{S_2} \vec{B}.\vec{dl} = 0 \qquad ---- (2)$$

- Here there is an inconsistency between equation (1) and (2). Maxwell resolved this inconsistency as follows.
- Due to external source, the capacitor gets charged up because of current flowing through the capacitor. This produces an increasing electric field between the capacitor plates.
- This time varying electric field (or flux) existing between the plates of the capacitor also produces a current known as displacement current.
- From Gauss 's law,

$$\Phi_E = \oint \vec{E}.\vec{dA} = E\,A = \frac{q}{\varepsilon_o}$$

- The change in electric flux is,

$$\frac{d\Phi_B}{dt} = \frac{1}{\varepsilon_o}\frac{dq}{dt} = \frac{1}{\varepsilon_o} I_d$$

$$\therefore \qquad \boldsymbol{I_d = \varepsilon_o \frac{d\Phi_B}{dt}}$$

Where, $\frac{dq}{dt} = I_d \rightarrow$ Displacement current

- The displacement current can be defined as the current which comes in to play in the region in which the electric field and the electric flux are changing with time.
- So Maxwell modified Ampere's law as

$$\oint \vec{B}.\vec{dl} = \mu_o I = \mu_o (I_C + I_d) \qquad ---(3)$$

- Where, $I = I_C + I_d \rightarrow$ total current

3. Explain the properties of electromagnetic waves.

Properties of electromagnetic waves :

- Electromagnetic waves are produced by any accelerated charge.
- They do not require any medium for propagation. So electromagnetic waves are non-mechanical wave.
- They are transverse in nature, (i.e) the oscillating electric field vector, oscillation magnetic field vector and direction of propagation are mutually perpendicular to each other.
- They travel with speed of light in vacuum or free space and it is given by,

$$\boldsymbol{c = \frac{1}{\sqrt{\varepsilon_o \mu_0}} = 3\,X\,10^8\ m\ s^{-1}}$$

- In a medium with permittivity 'ε' and permeability 'μ', the speed of electromagnetic wave is less than speed in free space or vacuum. (i.e.) $\boldsymbol{v < c}$

Hence, refractive index of the medium is,

$$\boldsymbol{\mu = \frac{c}{v} = \sqrt{\varepsilon_r \mu_r}}$$

- They are not deflected by electric or magnetic field.
- They show interference, diffraction and polarization.
- Like other waves, electromagnetic waves also carry energy, linear momentum and angular momentum.

4. Explain in detail the emission spectra.

Emission spectra :

- ♣ The lighe from self luminous source gives emission spectrum.
- ♣ Each source has its own characteristic emission spectrum.
- ♣ The emission spectrum can be divided in to three types ;

(i) **Continuous emission spectra** :

- ♣ Incandescent solids, liquids gives continuous spectra.
- ♣ It consists of wavelengths containing all the visible colours ranging from violet to red.

(e.g.) Spectrum obtained from carbon arc, incandescent filament lamp, etc

(ii) **Line emission spectra** :

- ♣ Light from excited atoms gives line spectrum. They are also known as discontinuous spectra.
- ♣ The line spectr are sharp lines of definite wavelengths or frequencies.
- ♣ It is different for different elements

(e.g.) spectra of atomic hydrogen, helium, etc

(iii) **Band emission spectra** :

- ♣ The light from excited molecules gives band spectrum.
- ♣ It consists of several number of very closely spaced spectral lines which overlapped together forming specific coloured bands.
- ♣ This spectrum has a sharp edge at one end and fades out at the other end.
- ♣ Band spectrum is the characteristic of the molecule.

(e.g.) spectra of hydrogen gas, ammonia gas in the discharge tube, etc

5. Explain in detail the absorption spectra.

Absorption spectra :

- ♣ When light is allowed to pass through an absorbing substance, then the spectrum obtained is known as absorption spectrum.
- ♣ It is characteristic of the absorbing substance.
- ♣ Absorption spectrum 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.
- ♣ For instance, when we pass white light through a blue glass plate, it absorbs every thing except blue. This is an example for continuous absorption spectrum.

(ii) Line absorption spectrum :

- ♣ When light from incandescent lamp is passed through cold gas, the spectrum obtained through the dispersion due to the prism is line absorption spectrum.
- ♣ For example, when light from carbon arc is made to pass through sodium vapour, a continuous spectrum of carbon arc with two dark lines in the yellow rigion 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 is known as band absorption spectra.
- ♣ It is also obtained when white light is passed through diluted solution of blood or chlorophyll or through certain solutions of organic and inorganic compounds.