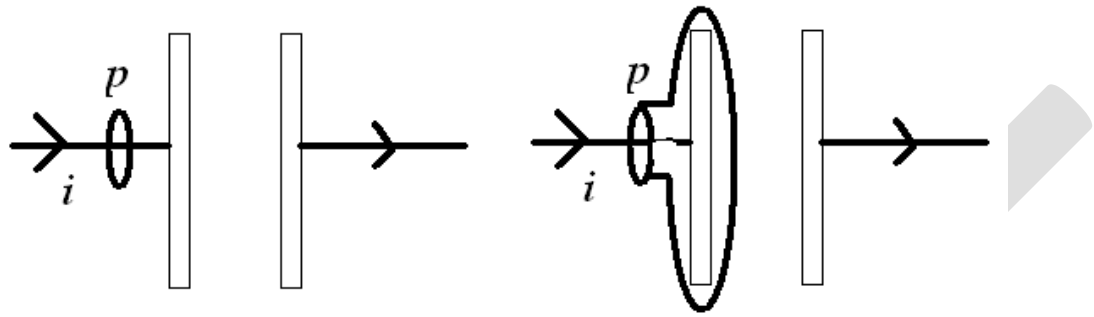
8. ELECTROMAGNETIC WAVES

Questions with answers

I. 1. Discuss the inconsistency in Ampere's circuital law. How did Maxwell modify this law?

Ans: According to Ampere's circuital law, $\oint \vec{\mathbf{B}} \cdot \vec{\mathbf{dl}} = \boldsymbol{\mu_0 i}$

To understand the inconsistency of this law, let us consider the process of charging of a capacitor. Let $\mathbf{S_1}$ and $\mathbf{S_2}$ be the two surfaces bounded by the same perimeter and let P be a point on them



When we apply Ampere's law to $\mathbf{S_1}$, we have $\oint \vec{\mathbf{B}} \cdot \vec{\mathbf{dl}} = \boldsymbol{\mu_0} i$

$$B\,(2\pi r) = \boldsymbol{\mu_0} i \ldots\ldots\ldots\ldots (1)$$

When we apply $\mathbf{S_2}$, we have $\oint \vec{\mathbf{B}} \cdot \vec{\mathbf{dl}} = 0$ ……(2)

Calculated one way ,there is a magnetic field at P ; calculated another way there is no magnetic field at P.It follows that Ampere's law is not consistent when the circuit includes a capacitor

2. what modification was made by Maxwell in ampere's circuital law?

Ans:In order to remove inconsistency, Maxwell suggested the existence of an additional current called displacement current. It is due to time-varying electric field

It is given by $\mathbf{i_d} = \boldsymbol{\varepsilon_0} \left[\frac{\mathbf{d}\emptyset_{\mathbf{E}}}{\mathbf{dt}}\right.$

Therefore Ampere's circuital is restated as $\oint \vec{B}\cdot\overrightarrow{dl}=\mu_0[i_c+i_d]$

Where i_c→conduction current and $i_d=\varepsilon_0[\frac{d\emptyset_E}{dt}]$→displacement current

$\oint \vec{B}\cdot\overrightarrow{dl}=\mu_0[i_c+\varepsilon_0\frac{d\emptyset_E}{dt}]$,this is known as Ampere-Maxwell law

3. Explain clearly how Maxwell was led to predict the existence of electromagnetic waves

Ans:On the basis of Faraday's law of electro magnetic induction and modified Ampere's law, Maxwell ,theoretically predicted the existence of electromagnetic wave

The magnetic field changing with time , gives rise to electric field[$\oint \vec{E}\cdot\overrightarrow{dl}=-\frac{d\emptyset_B}{dt}$] and an electric field changing with time gives rise to magnetic field

[$\oint \vec{B}\cdot\overrightarrow{dl}=\mu_0 i_c+\mu_0\varepsilon_o\frac{d\emptyset_E}{dt}$], it means laws of electricity and magnetism are symmetrical.The consequence of this symmetry is the existence of electromagnetic wave. According to Maxwell an accelerating charge produces electromagnetic waves. An electric charge oscillating harmonically with frequency ν,produces electromagnetic waves of same frequency ν .

4. Represent electric and magnetic fields of an electromagnetic wave mathematically by suitable wave equations. Express c in terms of μ_0 and ε_0 .

Ans: Mathematically, for a wave of angular frequency ω wavelength λ propagating along z-direction we can write E_x and B_y as follows

$E_x=E_0\sin(kz-\omega t)$ and $B_y=B_0\sin(kz-\omega t)$, where ω is the angular frequency and $k=\frac{2\pi}{\lambda}$ is the magnitude of the propagation vector and ω=c k

The amplitudes of the electric and magnetic fields are related as $B_0=\frac{E_0}{C}$

where $c=\frac{1}{\sqrt{\mu_0\varepsilon_0}}$ speed of light in vacuum

5. Write any four properties of electromagnetic waves.

Ans: * They are transverse in nature.

* They are produced by accelerated charges.

* In an electromagnetic wave, Electric and magnetic fields oscillate sinusoidally in space and time The oscillating $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ are perpendicular to each other, and to the direction of propagation.

* The oscillations of $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ are in same phase.

* All electromagnetic waves travel in vacuum with the same speed c=$\frac{\mathbf{1}}{\sqrt{\mu_0 \varepsilon_0}}$

c=3x$\mathbf{10^8}$ m$\mathbf{s^{-1}}$

* They transport energy and momentum as they travel through space

* When these waves strike the surface, a pressure is exerted on the surface

* They show the properties of reflection, refraction, interference, diffraction and polarization .

* Electric field is responsible for optical effects of em waves.

6 Name the main parts of the electromagnetic spectrum giving their wavelength range or frequency range

Ans: Types of em waves	Wavelength range	frequency range
* $\boldsymbol{\gamma}$-ray,	$< \mathbf{10^{-3}}$m	$\mathbf{10^{18}}$to$\mathbf{10^{22}}$Hz
* X-rays	$\mathbf{10^{-3}}$nm to 1 nm	$\mathbf{10^{16}}$ to $\mathbf{10^{19}}$Hz
*UV-rays	1nm to 400 nm	$\mathbf{10^{16}}$to$\mathbf{10^{17}}$Hz
* visible rays	400 nm to 700 nm	4× $\mathbf{10^{14}}$to 7× $\mathbf{10^{14}}$Hz
* IR-rays	700 nm to 1mm	$\mathbf{10^{11}}$to $\mathbf{5 \times 10^{14}}$Hz
*Microwaves	1 mm to 0.1m	$\mathbf{10^{9}}$to$\mathbf{10^{12}}$Hz
*Radio waves	0.1m to 3o km	$\mathbf{10^{4}}$ **to** $\mathbf{10^{8}}$Hz

7.In a plane electromagnetic wave ,the electric field oscillates sinusoidally at a frequency of 2.0x10^{10}Hz and amplitude 48 Vm^{-1}.(a)what is the wave length of the wave(b)what is the amplitude of the oscillating magnetic field(c)Show that the average energy density of the Electric field equals the average energy density of the magnetic field

$\boldsymbol{\lambda}$=c/v=3x10^8/2.0x10^{10}=1.5x10^{-2}m

$B_0=E_0/c=48/3x10^8=16x10^{-8}T$

$\frac{u_E}{u_m}=\frac{\frac{\varepsilon_0}{2}E^2}{\frac{B^2}{2\mu_0}}=\varepsilon_0\mu_0\left(\frac{E}{B}\right)^2=\frac{1}{c^2}xc^2=1$

Therefore $u_E=u_m$

II. 1. Distinguish between conduction current and displacement current.

Ans: conduction current	displacement current
*The electric current carried by conductors due to flow of charges is called conduction current.	*The electric current due to changing electric field is called displacement current.
* $i_c=\frac{V}{R}$	* $i_d=\varepsilon\frac{d\emptyset_E}{dt}$

2. What is displacement current? write the expression for displacement current

Ans:The electric current due to changing electric field is called displacement current

$i_d=\varepsilon_0\frac{d\emptyset_E}{dt}$ where ε_0 is called absolute permittivity of vacuum

3. State Ampere-Maxwell law. Write its mathematical form

Ans: **"**The total current passing through any surface of which the closed loop is the Perimeter" is the sum of the conduction current and the displacement current.

$$\oint \vec{B}.\vec{dl}=\mu_0 i_c+\mu_0\varepsilon_0\frac{d\emptyset_E}{dt}$$

4. Briefly explain, how does an accelerating charge act as a source of an electromagnetic wave?

Ans: Consider a charge oscillating with some frequency. This is an example of accelerating charge. This charge produces an oscillating electric field in space.

This field, in turn, produces an oscillating magnetic field in the neighbor hood.

The process continues because the oscillating electric and magnetic fields regenerate each other. Hence an electromagnetic wave originates from the accelerating cha

5. Write down the expression for the velocity of electromagnetic wave in
a) vacuum and b)material medium

Ans: *In vacuum, $c=\frac{1}{\sqrt{\mu_0\varepsilon_0}}$ where $\boldsymbol{\mu_0}$ absolute permeability and $\boldsymbol{\varepsilon_0}$ absolute permittivity of vacuum

*In material medium, $v=\frac{1}{\sqrt{\mu\varepsilon}}$

Where $\boldsymbol{\varepsilon}$ is called permittivity and $\boldsymbol{\mu}$ is called magnetic permeability of material medium.

6. What are the contributions of Hertz to electromagnetic wave theory?

Ans:* Hertz confirms the existence of electromagnetic waves

* He produced stationary electromagnetic waves

* Using $\boldsymbol{v=v\lambda}$,he found that the em-waves travelled with the same speed as the speed of light

7. The amplitude of the magnetic field part of a electromagnetic wave in vacuum is 510nT. What is the amplitude of the electric field part of the wave?

Ans: $\mathbf{B_0}=\frac{\mathbf{E_0}}{\mathbf{c}}=\frac{510\times10^{-9}}{3\times10^{8}}=170\times \mathbf{10^{-17}}$T

8. Give any two uses of microwaves.

Ans:Microwaves are used in aircraft navigation, (speed guns to time fast balls, tennis serves, and automobiles). Microwaves are also used in microwave ovens

9. Give any two uses of IR-waves

Ans:IR-waves from the sun keep the earth warm and hence help to sustain life on the earth

IR-rays photographs are used for weather forecasting. (They are used in detectors, remote switches)

10. Mention any two uses of UV waves

Ans: Highly focused UV-rays are used in eye surgery(LASIK-Laser Assisted in situ ketatomileusis)

UV-lamps are used to kill germs in water purifiers.

III 1. What is the source of an electromagnetic wave?

Ans:An accelerated charged particle is the source of e.m.waves

2Who proposed electromagnetic wave theory?

Ans:James clerk Maxwell proposed electromagnetic wave theory

3 what is displacement current?

Ans:The electric current due to changing electric field is called displacement current

4. Is displacement current a source of magnetic field?

Ans:Yes,it is a source of magnetic field.

5 write an expression for the dis placement current.

Ans: $i_d=\boldsymbol{\varepsilon_0}\frac{\mathbf{d\emptyset_E}}{\mathbf{dt}}$

Where,$\boldsymbol{\epsilon}_0$ is called absolute permittivity of air

6 Give the mathematical form of Ampere-Maxwell law.

Ans: $\oint \vec{\mathbf{B}}.\overrightarrow{\mathbf{dl}} = \boldsymbol{\mu_0 i_d} + \boldsymbol{\varepsilon_0\mu_0}\frac{\mathbf{d\emptyset_E}}{\mathbf{dt}}$

7. what are electromagnetic waves?

Ans:Waves radiated by accelerated charges and consist of time varying, transverse electric and magnetic fields are called electromagnetic waves

8. Name the scientist who first predicted the existence of e.m waves

Ans:Hertz

****