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PHYSICS
Q N A-E M WAVE

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PHYSICS - CBSE - XII

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Q N A-E M WAVES

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Helplines: +91-9939586130
+91-7739650505

2nd FLOOR, SATKOUDI COMPLEX
THANA CHOWK, RAMGARH
JHARKHAND-829122

E M WAVES

Electromagnetic Waves

History
In 1886 Heinrich Hertz became the first person to transmit and receive controlled radio.

Conduction current
The current due to flow of charge is often called conduction current,

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

Displacement current
If there exists an electric current as well as a changing electric field, if results magnetic field and causes displacement current,

$i_d = \varepsilon_0 \frac{-d\phi_E}{dt}$

Electromagnetic spectrum
- Radio waves : $\lambda > 10^8$nm
  Use : radio, TV signal
- Micro waves : $10^8 > \lambda > 10^5$nm
  Use : micro wave oven, radar
- Infrared : $10^5 > \lambda > 700$ nm
  Use : night vision
- Visible light : $700 > \lambda > 400$ nm
  Use : to observe world
- UV rays : $400 > \lambda > 10$nm
  Use : destroying bacteria
- X-rays : $10 > \lambda > 0.01$ nm
  Use : detect bone break
- γ rays : $0.01\text{nm} > \lambda$
  Use : to treat cancer

Maxwell's equations
Gauss's law (electricity)

$\oint \vec{E}.\vec{ds} = \frac{q_{in}}{\varepsilon_0}$

Gauss's law (magnetism)

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

Faraday's law

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

Ampere's law

$\oint \vec{B}.\vec{dl} = \mu_0 i + \mu_0\varepsilon_0 \frac{-d\phi_E}{dt}$

Energy density
- $U = \frac{1}{2}\varepsilon_0 E^2 + \frac{1}{2}\frac{B^2}{\mu_0}$ = Total energy per unit volume
- U_{av} over a long time
  $= \frac{1}{4}\varepsilon_0 E_0^2 + \frac{1}{4}\frac{B_0}{\mu_0}$
  $= \frac{1}{2}\varepsilon_0 E_0^2$ [as $c = \frac{E_0}{B_0}$ and $\mu_0\varepsilon_0 = \frac{1}{c^2}$]
  $= \frac{1}{2}\frac{B_0^2}{\mu_0}$

Characteristics of Electromagnetic waves
- Do not need any material medium for propagation
- Travel with speed of light (c) $= \frac{1}{\sqrt{\mu_0\varepsilon_0}}$
- Produced be accelerated charged particle
- Transverse in nature
- Oscillating electric & magnetic fields are in phase and their ratio is constant (c)$=E_0/B_0$

Definition
Combination of mutually perpendicular electric and magnetic fields is referred to as an electromagnetic wave

Trace the Mind Map
- First Level
- Second Level
- Third Level

E M WAVES

Syllabus

- *Basic idea of displacement current, Electromagnetic waves, their characteristics, their Transverse nature, qualitative ideas only.*
- *Electromagnetic spectrum (radio waves, microwaves, infrared, visible, ultraviolet, X-rays, gamma rays) including elementary facts about their uses.*

Trend Analysis

List of Concepts	2018		2019		2020	
	OD	D	OD	D	OD	D
Electromagnetic Waves and Maxwell's Equations		1 Q (1 M)	1 Q (1 M) 1 Q (2 M)	1 Q (1 M)	2 Q (3 M)	1 Q (1 M)
Electromagnetic Spectrum		2 Q (1 M)	1 Q(1 M)	1 Q (2 M)	1 Q (3 M)	1 Q (2 M)

TOPIC-1
Electromagnetic Waves and Maxwell's Equations

Revision Notes

Basic idea of displacement current:

- Displacement current is a quantity appearing in Maxwell's equations that is defined in terms of the rate of change of electric flux.
- Displacement current has the units of electric current and has associated magnetic field similar as actual currents.
- Displacement current plays an important role in the propagation of electromagnetic radiation, such as light and radio waves, through empty space.
- Displacement current is defined as:

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

$$\left(I_d = \varepsilon_0 A \frac{dE}{dt}\right)$$

where, $\phi_E = \int \vec{E}.\vec{dA}$ is the electric flux and ε_0 is the permittivity of free space.

- As per Ampere Maxwell law, line integral of magnetic field around any closed path is equal to $\mu_0 \times$ (sum of conduction current and displacement current through that path.)

i.e.,
$$\oint \vec{B}.\vec{dl} = \mu_0[I_c + I_d]$$

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

$$= \mu_0 I_C + \mu_0 \varepsilon_0 \frac{d}{dt}(E.A)$$

This proves that change in electric field E, is responsible for the induction of magnetic field.

Electromagnetic waves and their characteristics

- Waves that can travel through vacuum of outer space and do not need the presence of material medium for transporting energy from one location to another.
- EM waves are produced by accelerated charged particles.
- The electric and magnetic fields produced by accelerated charge change with time, which radiate electromagnetic waves.

Example:

- Electron jumping from its outer to inner orbits radiates EM waves.
- Electrical oscillations in LC circuit produce EM waves.
- Electric sparking generates EM waves.

Characteristics of EM waves:

- EM waves are propagated as electric and magnetic fields oscillating in mutually perpendicular directions.
- EM waves travel in vacuum along a straight line with the velocity 2.997924591×10^8 m/s which is often assumed as 3×10^8 m/s.
- EM waves are not affected by electric and magnetic fields.
- Relation between electric and magnetic field components is:

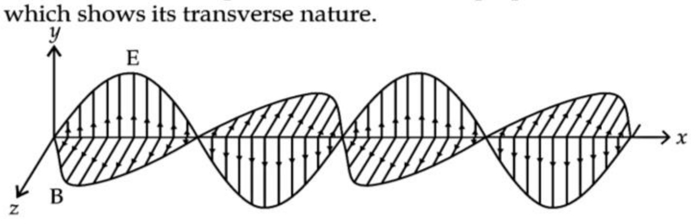
$$B_0 = E_0/c$$

where, $c \cong 3 \times 10^8$ m/s. and $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

The λ and f are related as $c = f\lambda$. where λ is the wavelength and f is the frequency.

Transverse nature of electromagnetic waves

- In electromagnetic wave, electric and magnetic field vectors are perpendicular to each other in the direction of propagation of wave which shows its transverse nature.



- A plane EM wave travelling in the x-direction is of the form:

$$E(x, t) = E_{max}\cos(kx - \omega t + \phi)$$
$$B(x, t) = B_{max}\cos(kx - \omega t + \phi)$$

where, E = electric field vector, B = magnetic field vector

- In this, wave propagates along z-axis, the electric and magnetic field propagation will be:

$$E = E_0 \sin(kz - \omega t)$$
$$B = B_0 \sin(kz - \omega t)$$

- **Gauss Law:** For electricity, electric flux of closed surface equals to the charge enclosed divided by permittivity.

$$\oint \vec{E}.\vec{dA} = \frac{Q}{\varepsilon_0}$$

For magnetism, total magnetic flux of the closed surface is zero

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

Know the Formulae

- Displacement current between the plates of a capacitor

$$I_D = \varepsilon_0 \frac{d(EA)}{dt} = \varepsilon_0 A \frac{dE}{dt}$$

$$I_D = \varepsilon_0 A \frac{d}{dt}\left(\frac{V}{d}\right) = \frac{\varepsilon_0 A}{d}\frac{dV}{dt} = C\frac{dV}{dt}$$

Here, E = Electric field between the plates of the capacitor, V = Potential difference, d = Separation between the plates, C = Capacitance of the capacitor, A = Area of plates.

- For the EM waves, the energy density is given by

$$U_E = \frac{1}{2}\varepsilon_0 E^2 \text{ (Due to electric field)}$$

$$U_B = \frac{1}{2}\frac{B^2}{\mu_0} \text{ (Due to magnetic field)}$$

- The energy transported by EM waves per unit area per second is called Poynting vector ($\vec{S}$).

  It is given by $\vec{S} = \vec{E} \times \frac{\vec{B}}{\mu_0}$.

  Since, $\vec{E} \perp \vec{B}$, hence $S = \frac{EB}{\mu_0}$.

- In EM waves, the total energy density of EM waves is

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

$$U = \varepsilon_0 E^2 = \frac{B^2}{\mu_0} \qquad \left[\text{As, } E = \frac{B}{\sqrt{\mu_0 \varepsilon_0}}\right]$$

- The variation in magnetic field causes electric field and vice versa.
- In the EM waves: $\vec{E} \perp \vec{B}$, both $\vec{E}$ and $\vec{B}$ are in the same phase.
- In the EM waves: $E = E_0 \sin(\omega t - kx)$, $B = B_0 \sin(\omega t - kx)$.
- The EM waves travel in the direction of $\vec{E} \times \vec{B}$ *i.e.*, EM waves propagate perpendicular to both $\vec{E}$ and $\vec{B}$.

Maxwell's Equations:

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

How is it done on the GREENBOARD?

AI Q. 1. How does a charge q oscillating at certain frequency produce electromagnetic waves ? Sketch a schematic diagram depicting electric and magnetic fields for an electromagnetic wave propagating along the Z-direction. U

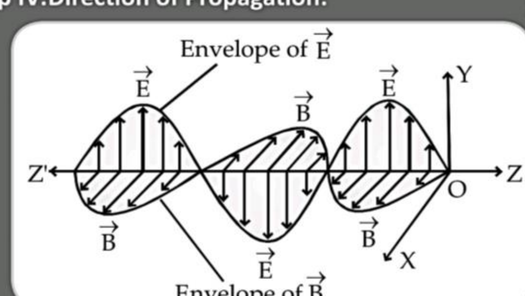
Solution:

Step I: When the charge accelerates, then there will be change in electric and magnetic fields with respect to space and time which generates electromagnetic waves. So we see that an accelerated charge will give electromagnetic waves.

Step II: In an oscillatory L-C circuit, a charge oscillates across the capacitor plates. This oscillating charge has a non-zero acceleration; hence it emits electromagnetic waves of frequency same as that of the oscillating charge.

Step III: The figure shows the graphical representation of an electromagnetic wave where the electric field vector $\vec{E}$ and the magnetic field vector $\vec{B}$ are vibrating along Y and X-directions respectively, and the wave is propagating along Z-direction. Both $\vec{E}$ and $\vec{B}$ vary with time and space and have the same frequency. [as $(E\hat{j} \times B\hat{k}) = -EB\hat{i}$]

Step IV: Direction of Propagation: 2



Mnemonics

Concept: Electromagnetic spectrum : Arrangement of em waves with increasing frequency (decreasing wavelength) :

Mnemonics: Russian magicians introduced and very unusual X-ray eye Game

Mnemonic: **R**ussian **m**agicians **i**ntroduced and **v**ery **u**nusual **X**-ray eye **g**ame.

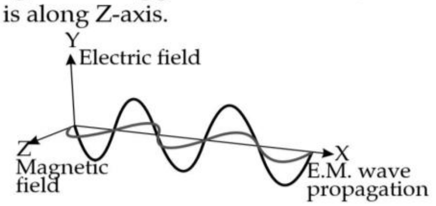
R	m	i	v	u	X	g
Radio Wave	Micro Wave	Infra red	Visible Light	Ultra violet	X-Rays	Gamma Rays

Very Short Answer Type Questions (1 mark each)

Q. 1. Depict the fields diagram of an electromagnetic wave propagating along positive X-axis with its electric field along Y-axis.

R **[CBSE DEL SET 1 2020]**

Ans. Electric field is in Y-axis. Electromagnetic wave propagation along positive X-axis. So, the magnetic field is along Z-axis.



1

AI **Q. 2. Prove that the average energy density of the oscillating electric field is equal to that of the oscillating magnetic field.**

R **[CBSE DEL SET 1 2019]**

Ans. Average energy density of the electric field

$$= \frac{1}{2}\varepsilon_0 E^2$$
$$= \frac{1}{2}\varepsilon_0 (cB)^2$$
$$= \frac{1}{2}\varepsilon_0 \frac{1}{\mu_0 \varepsilon_0} B^2$$
$$= \frac{1}{2}\frac{B^2}{\mu_0}$$ 1

= Average energy density of the magnetic field.

[**Note:** Award 1 mark for this part if the student just writes the expressions for the average energy density of the electric and magnetic fields].

[CBSE Marking Scheme, 2019]

Q. 3. How are electromagnetic waves produced by accelerating charges? R **[CBSE OD SET I 2019]**

Ans. Production of electromagnetic waves

Accelerated charge produces an oscillating electric field which produces an oscillating magnetic field, which is a source of oscillating electric field and so on. Thus electromagnetic waves are produced. **1**

[CBSE Marking Scheme, 2019]

Detailed Answer:

Production of EM waves:

Electromagnetic waves consist of both electric and magnetic fields travelling through empty space with the speed of light *c*. These waves oscillate in perpendicular planes with respect to each other and are in phase. An electromagnetic wave can be created by accelerating charges; moving charges back and forth, producing oscillating electric and magnetic fields. When the accelerating charged particle moves with acceleration, both magnetic and electric fields change continuously which lead to production of electromagnetic waves. **1**

Q. 4. What do you understand by the statement, ''Electromagnetic waves transport momentum'' ?

U **[CBSE 2018]**

Ans. Electromagnetic waves can set (and sustain) charges in motion. Hence, they are said to transport momentum.

(Also accept the following: Electromagnetic waves are known to exert 'radiation pressure'. This pressure is due to the force associated with rate of change of momentum. Hence, EM waves transport momentum). **1**

[CBSE Marking Scheme, 2018]

AI **Q. 5. How is the speed of EM-waves in vacuum determined by the electric and magnetic fields?**

R **[CBSE DEL SET 1 2017]**

Ans. Speed of EM waves is determined by the ratio of the peak values of electric and magnetic field vectors. **1**

[**Alternatively,** Give full credit, if student writes directly $c = \frac{E_0}{B_0}$]

[CBSE Marking Scheme, 2017]

Q. 6. Do electromagnetic waves carry energy and momentum ? R **[CBSE OD 1 2017]**

Ans. Yes. **[CBSE Marking Scheme, 2017] 1**

Detailed Answer:

EM waves carry energy and momentum without having mass and can exert pressure which is known as radiation pressure. These waves like other waves carry energy as they travel through empty space without which, it wouldn't be able to heat or generate photo current in photo cells. 1

Q. 7. Write the relation for the speed of electromagnetic waves in terms of the amplitudes of electric and magnetic fields. R **[CBSE OD SET 2 2017]**

Ans. Speed of electromagnetic wave, $c = \frac{E_0}{B_0}$. 1

[CBSE Marking Scheme, 2017]

Q. 8. In which directions do the electric and magnetic field vectors oscillate in an electromagnetic wave propagating along the *x*-axis? U **[CBSE OD SET 3 2017]**

Ans. $\vec{E}$ along y- axis and $\vec{B}$ along *z*-axis

(Alternatively: $\vec{E}$ along *z*-axis and $\vec{B}$ along *y*-axis) ½+½

[CBSE Marking Scheme, 2017]

Q. 9. The electric field of an electromagnetic wave in free space is given by

$$\vec{E} = 10\cos(10^7 t + kx)\hat{j}\,\text{V/m}$$

where *t* and *x* are in seconds and metres respectively. Find the wavelength. R **1**

Ans. As given

$$E = 10\cos(10^7 t + kx) \quad \ldots\text{(i)}$$

$$E = E_0\cos(\omega t + kx) \quad \ldots\text{(ii)}$$

Amplitude $E_0 = 10$ V/m and $\omega = 10^7$ rad/s

$$\because \quad c = \upsilon\lambda = \frac{\omega\lambda}{2\pi}$$

or $$\lambda = \frac{2\pi c}{\omega} = \frac{2\pi \times 3 \times 10^8}{10^7} = 188.4\,\text{m} \quad 1$$

The wave is propagating along *y* direction.

Q. 10. Which waves are known as transverse wave ? U

Ans. Waves for which the vibration of particles and propagation of wave are perpendicular to each other are known as transverse waves. 1

Q. 11. In which situation there exist a displacement current, but no conduction current ? U **[CBSE OD SET 3 2016]**

Ans. When there exists time varying electric field alone, there exists a displacement current but no displacement current.

Example: Between two plates of a capacitor when it is being charged. 1

Q. 12. Write the expression for speed of electromagnetic waves in a medium of electrical permittivity ε and magnetic permeability μ. R **[Foreign I, II, III 2017]**

Ans. Formula

$$c = \frac{1}{\sqrt{\mu\varepsilon}} \quad 1$$

Alternatively,

$$c = \frac{1}{\sqrt{\mu_0\mu_r\varepsilon_0\varepsilon_r}} \quad 1$$

[CBSE Marking Scheme, 2017]

Q. 13. A capacitor has been charged by a dc source. What are the magnitudes of conduction and displacement currents, when it is fully charged? U

Ans. Conduction and displacement currents are both zero. 1

Q. 14. What oscillates in electromagnetic waves? Are these waves transverse or longitudinal? U

Ans. **(i)** The electric and magnetic fields oscillate in mutually perpendicular directions in electromagnetic waves. ½

(ii) Electromagnetic waves are transverse in nature. ½

Q. 15. The relative electric permittivity of a medium is 9 and the relative permeability is close to unity. What is the speed of electromagnetic waves in the medium? A & E

Ans. $\because$ Electrical permittivity $\varepsilon = \varepsilon_r.\varepsilon_0 \Rightarrow \varepsilon = 9\varepsilon_0$

Magnetic permeability, $\mu = \mu_r.\mu_0 \Rightarrow \mu = 1.\mu_0$

$\therefore$ Speed of em wave in the medium, $v = \frac{1}{\sqrt{\mu\varepsilon}}$

$$v = \frac{1}{\sqrt{(9\varepsilon_0)(1.\mu_0)}} = \frac{c}{\sqrt{9}} = \frac{c}{3} \quad 1$$

$$\left(\because c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}\right)$$

Short Answer Type Questions-I

(2 marks each)

Q. 1. A capacitor made of two parallel plates, each of area 'A' and separation 'd' is charged by an external dc source. Show that during charging, the displacement current inside the capacitor is same as the current charging the capacitor. A **[O.D. I 2019]**

Ans. For writing expression for total current 1

For showing that displacement current is the same as the current charging the capacitor 1

$$i = i_c + i_d \quad 1$$

where, i_c is conduction current and i_d is displacement current.

Outside the capacitor, $i_d = 0$ so $i = i_c$ ½

Inside the capacitor, $i_c = 0$ so $i = i_d$ ½

[CBSE Marking Scheme, 2019]

Detailed Answer:

The charge on the plates is because of the conduction current flowing in the wires.

$$I_c = \frac{dq}{dt} \quad \ldots\text{(i)}$$

According to Maxwell's equation, displacement current between the plates is given by,

$$I_d = \varepsilon_0 \frac{d\phi_E}{dt} \quad \ldots\text{(ii)}$$

where, φ_E is the electric flux.

Now, using Gauss theorem,

$$\phi_E = \frac{q}{\varepsilon_0}$$

So, from equation (ii)

$$I_d = \varepsilon_0 \frac{d}{dt}\left(\frac{q}{\varepsilon_0}\right)$$

$$I_d = \frac{dq}{dt} \quad \ldots\text{(iii)}$$

Therefore, form equation (i) and (iii), both the displacement current and conduction currents are equal.

Q. 2. How does Ampere-Maxwell law explain the flow of current through a capacitor when it is being charged by a battery ? Write the expression for the displacement current in terms of the rate of change of electric flux. R & U **[CBSE DEL I 2017]**

Ans. Explanation of flow of current through capacitor 1

Expression for displacement current. 1

During charging, electric flux between the plates of capacitor keeps on changing; this results in the production of a displacement current between the plates.

$$I_d = \varepsilon_0 \frac{d\phi_E}{dt}\left(I_d = \varepsilon_0 A \frac{dE}{dt}\right)$$

[CBSE Marking Scheme, 2017]

Detailed Answer:

When a battery is attached to a capacitor, conduction current flow in wire outside capacitor. In the capacitor, the Electric flux, $\phi_E = EA$

Where, $E = \frac{Q}{\varepsilon_0 A}, Q = \varepsilon_0 EA$

$\therefore \quad I = \frac{dQ}{dt} = \varepsilon_0 \frac{d\phi_E}{dt}$

This maintains the current in the capacitor.

Amperes-Maxwell law states that displacement current comes into existence due to rate of change of electric flux *w.r.t.* time.

$\therefore$ Displacement current $I_d = \varepsilon_0 \frac{d\phi_E}{dt}$ 2

AI **Q. 3. How is electromagnetic wave produced ? Draw a sketch of a plane EM wave propagating along *X*-axis depicting the directions of the oscillating electric and magnetic fields.** U **[Delhi Comptt. I, II, III 2017]**

Ans. Production of EM waves. 1

Diagram depicting the oscillating electric and magnetic fields. 1

Electromagnetic waves are produced due to oscillating/accelerating charged particles. 1

1

[CBSE Marking Scheme, 2017]

Detailed Answer:

Production of EM wave: Electromagnetic waves consist of both electric and magnetic fields travelling through empty space with the speed of light *c*. These waves oscillate in perpendicular planes with respect to each other and are in phase. An electromagnetic wave can be created by accelerating charges; moving charges back and forth, producing oscillating electric and magnetic fields. When the accelerating charged particle moves with acceleration, both magnetic and electric fields change continuously which lead to production of electromagnetic waves. 2

Q. 4. For a plane electromagnetic wave, propagating along the *z*-axis, write the two (possible) pairs of expressions for its oscillating electric and magnetic fields. How are the peak values of these (oscillating) fields related to each other ? U **[Foreign 2016]**

Ans. For the EM wave, propagating along the *z*-axis, we have

$E = E_0 \sin(kz \mp \omega t)$ and

$B = B_0 \sin(kz \mp \omega t)$ ½

The two possible forms are:

$E_x = E_0 \sin(kz - \omega t)$ ½

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

And $E_y = E_0 \sin(kz + \omega t)$ ½

$B_x = B_0 \sin(kz + \omega t)$

We have, $E_0 = cB_0$ ½

[Do not deduct any mark if the student uses any of the two signs (– or +) in the two sets of expression.]

[CBSE Marking Scheme, 2016]

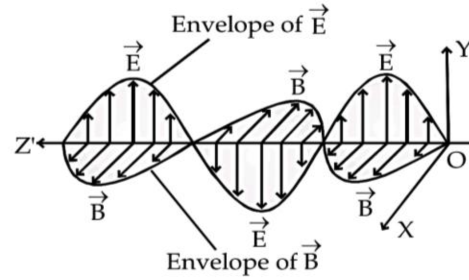
AI **Q. 5. How does a charge *q* oscillating at certain frequency produce electromagnetic waves ? Sketch a schematic diagram depicting electric and magnetic fields for an electromagnetic wave propagating along the *Z*-direction.** U

Ans. When the charge accelerates, then there will be change in electric and magnetic fields with respect to space and time which generates electromagnetic waves. So we see that an accelerated charge will give electromagnetic waves.

In an oscillatory *L-C* circuit, a charge oscillates across the capacitor plates. This oscillating charge has a non-zero acceleration; hence it emits electromagnetic waves of frequency same as that of the oscillating charge.

The figure shows the graphical representation of an electromagnetic wave where the electric field vector $\vec{E}$ and the magnetic field vector $\vec{B}$ are vibrating along Y and X-directions respectively, and the wave is propagating along Z-direction. Both $\vec{E}$ and $\vec{B}$ vary with time and space and have the same frequency. [as $(E\hat{j} \times B\hat{k}) = -EB\hat{i}$]

Direction of Propagation:



2

Short Answer Type Questions-II (3 marks each)

Q. 1. (a) We feel the warmth of the sunlight but not the pressure on our hands. Explain.

(b) Which out of wavelength, frequency and speed of an electromagnetic wave does not change on passing from one medium to another ?

(c) A thin ozone layer in the upper atmosphere is crucial for humans' survival on Earth, why ? R & U **[CBSE OD SET 2 2020]**

Ans. (a) The sun outputs about 1300 watts per square metre (W/m^2) in space near the Earth, which gets reduced to around 650 W/m^2 after through the atmosphere. So, the amount of heat is quite realisable.

The forces generated by solar radiation is generally too small to be noticed under everyday life. The radiation pressure of sunlight on Earth is equivalent to that exerted by about a thousandth of a gram on an area of 1 square metre . It is approximately 10 μN/m^2. Hence, it is negligible.

(b) Wavelength and velocity of electromagnetic wave change from one medium to another medium.

(c) Ozone layer absorbs biologically harmful ultraviolet radiation coming from the Sun. Hence, it is crucial for humans' survival on Earth. 3

Q. 2. (a) How are electromagnetic waves produced ? Depict an electromagnetic wave propagating in Z-direction with its magnetic field $\vec{B}$ oscillating along X-direction.

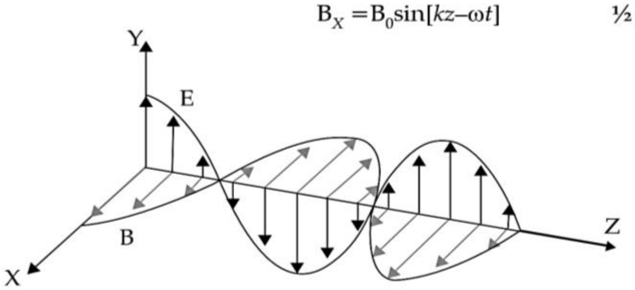
(b) Write two characteristics of electromagnetic waves. R **[CBSE OD SET 3 2020]**

Ans. (a) An electromagnetic wave can be created by accelerating charges or moving charges back and forth.

Electromagnetic wave propagating along the Z-axis:

The magnetic field $\vec{B}$ will be along X-axis.

$$B_X = B_0 \sin[kz - \omega t] \quad ½$$



The electric field $\vec{E}$ will be along Y-axis

$$E_Y = E_0 \sin[kz - \omega t] \quad ½$$

(b) Characteristic of electromagnetic waves:

(i) No medium is required for the electromagnetic wave to travel through. ½

(ii) An electromagnetic wave, although it carries no mass, does carry energy. It also has momentum and can exert pressure (known as radiation pressure). ½

(iii) The energy carried by an electromagnetic wave is proportional to the frequency of the wave. ½

Q. 3. How are em waves produced by oscillating charges?

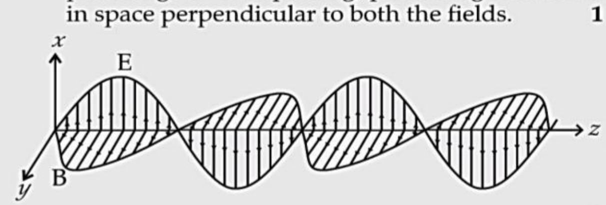
Draw a sketch of linearly polarized em waves propagating in the Z-direction. Indicate the directions of the oscillating electric and magnetic fields. R & U **[CBSE DEL SET 1 2016]**

Ans. Production of em waves 1

Drawing of sketch of linearly polarized em waves 1

Indication of directions of oscillating electric and magnetic fields ½ + ½

A charge oscillating with some frequency, produces an oscillating electric field in space, which in turn produces an oscillating magnetic field perpendicular to the electric field, this process goes on repeating, producing em waves in space perpendicular to both the fields. 1



1

Directions of $\vec{E}$ and $\vec{B}$ are perpendicular to each other and also perpendicular to direction of propagation of em waves. 1

[CBSE Marking Scheme, 2016]

Q. 4. (i) How are electromagnetic waves produced ? Explain.

(ii) A plane electromagnetic wave is travelling through a medium along the +ve z-direction.

Depict the electromagnetic wave showing the directions of the oscillating electric and magnetic fields. R&U **[Foreign I, II, III 2017]**

Ans. Try yourself, See Q. 3. of 3 Marks Questions. **3**

Q. 5. Write Maxwell's generalization of Ampere's Circuital Law. Show that in the process of charging a capacitor, the current produced within the plates of the capacitor is $i = \varepsilon_0 \frac{d\phi_\varepsilon}{dt}$

Where ϕ_ε is the electric flux produced during charging of the capacitor plates.

R **[CBSE DEL SET 1 2016]**

Ans. Maxwell's generalization of Ampere's Circuital law **1**

Showing that current produced, within the plates of a capacitor is $i = \varepsilon_o \frac{d\phi_E}{dt}$ **2**

Ampere's circuital law is given by as

$$\oint \vec{B}.\vec{dl} = \mu_o i_c$$

But for a circuit containing capacitor, during its charging / discharging the current within the plates of the capacitor varies, (producing displacement current i_d). Therefore, the above equation, as generalized by Maxwell, is given as

$$\oint \vec{B}.\vec{dl} = \mu_0 i_c + \mu_0 i_d \quad \mathbf{1}$$

During the process of charging of capacitor, electric flux (ϕ_E) between the plates of capacitor changes with time, which produces the current within the plates of capacitor. This current, being proportional to $\frac{d\phi_E}{dt}$, we have

$$i = \varepsilon_o \frac{d\phi_E}{dt} \quad \mathbf{2}$$

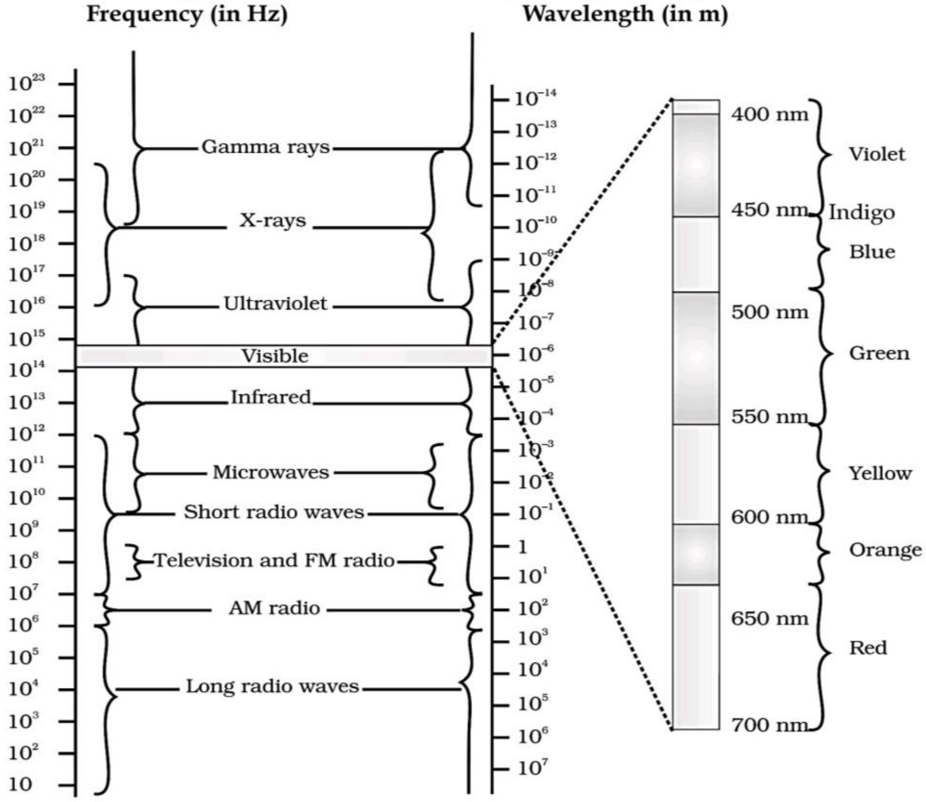
[CBSE Marking Scheme, 2016]

TOPIC-2
Electromagnetic Spectrum

Revision Notes

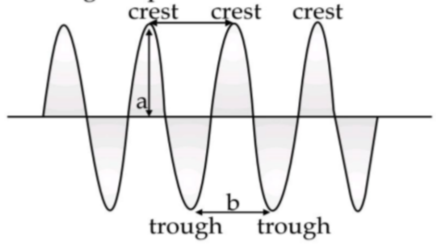
Electromagnetic spectrum

- Classification of EM-waves is based on their frequency or wavelength range.
- EM radiations are classified as per the frequency and wavelength of wave such as radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays and gamma rays.



General properties of electromagnetic waves (radio waves, microwaves, infrared, visible, ultraviolet, X-rays, gamma rays)

- Electromagnetic waves require no medium to travel or propagate.
- Varying electric and magnetic fields are the sources of electromagnetic waves.
- Electromagnetic waves are transverse waves which are characterized by their amplitude, wavelength, or distance between highest/lowest points.
- In electromagnetic waves, a crest is the highest point of the wave and though the lowest point of wave in a cycle.



a = Amplitude
b = wavelength

Electromagnetic spectrum is divided into following regions:

The electromagnetic spectrum is the distribution of electromagnetic radiation in terms of energy, frequency or wavelength. The electromagnetic radiation can be described as a stream of photons travelling in a wave like pattern, at the speed of light.

Type of radiation	Frequency range	Wavelength range
Gamma rays	$> 3 \times 10^{20}$	<1 fm
X-rays	$3 \times 10^{17} - 3 \times 10^{20}$	1 fm – 1 nm
Ultraviolet	$7.5 \times 10^{14} - 3 \times 10^{17}$	1 nm – 400 nm
Visible	$4 \times 10^{14} - 7.5 \times 10^{14}$	0.4 μm – 0.75 μm
Near-infrared	$10^{14} - 7.5 \times 10^{14}$	0.75 μm – 3.0 μm
Midwave infrared	$5 \times 10^{13} - 10^{14}$	3.0 μm – 6 μm
Long wave infrared	$2 \times 10^{3} - 5 \times 10^{13}$	6.0 μm – 15 μm
Extreme infrared	$3 \times 10^{13} - 2 \times 10^{13}$	15 μm – 15 μm
Micro and radio waves	$< 3 \times 10^{11}$	> 1 mm

Uses of Electromagnetic waves:

Band designation	Applications
Audible	Acoustics
Extremely Low Frequency (ELF) Radio	Electronics, Submarine Communications
Infra Low Frequency (ILF)	Not applicable
Very Low Frequency (VLF) Radio	Navigation, Weather
Low Frequency (LF) Radio	Navigation, Maritime Communications, Information and Weather Systems, Time Systems
Medium Frequency (MF) Radio	Navigation, AM Radio, Mobile Radio
High Frequency (HF) Radio	Citizens Band Radio, Mobile Radio, Maritime Radio
Very High Frequency (VHF) Radio	Amateur (Ham) Radio, VHF TV, FM Radio, Mobile Satellite, Mobile Radio, Fixed Radio
Ultra High Frequency (UHF) Radio	Microwave, Satellite, UHF TV, Paging, Cordless Telephone, Cellular and PCS Telephony, Wireless LAN (Wi-Fi)
Super High Frequency (SHF) Radio	Microwave, Satellite, Wireless LAN (Wi-Fi)
Extremely High Frequency (EHF) Radio	Microwave, Satellite, Radiolocation

Infrared Light (IR)	Wireless LAN Bridges, Wireless LANs, Fiber Optics Remote control
Visible Light	Photographic plate, photocells.
Ultraviolet (UV)	Photocells, kill bacteria and germs.
X-Rays	In medical, Geiger tubes, ionization chamber.
Gamma and Cosmic Rays	In medical (cancer cell killing)

Types of Electromagnetic waves, wavelength range, Production and Detection:

Type of radiation	Wavelength range	Production	Detection
Radio	$> 1.0 \times 10^{-1}$ m	Rapid acceleration and decelerations of electrons in aerials	Receiver's aerials
Microwave	0.1 m – 1.0×10^{-3} m	Klystron valve or magnetron valve	Point contact diodes
Infra-red	1.0×10^{-3} m – 700×10^{-9} m	Vibration of atoms and molecules	Thermopiles Bolometer, Infrared photographic film
Light	700×10^{-9} m – 400×10^{-9} m	Electrons in atoms emit light when they move from one energy level to a lower energy level	The eyes, Photocells Photographic film
Ultraviolet	400×10^{-9} m – 1.0×10^{-9} m	Inner shell electrons in atoms moving from one energy level to a lower level	Photocells Photographic film
X-rays	1.0×10^{-9} m – 1.0×10^{-12} m	*X*-ray tubes or inner shell electrons	Photographic film, Geiger tubes, Ionization chamber
Gamma rays	$<1.0 \times 10^{-12}$ m	Radioactive decay of the nucleus	Photographic film, Geiger tubes, Ionization chamber

Know the Terms

- **Electromagnetic waves:** The waves that are generated from changing of electric and magnetic fields.
- **Gamma rays:** Rays with smallest wavelengths and highest frequencies having high energy capable of travelling long distances through air and these are most penetrating.
- ***X*-rays:** These are the rays with long and small wavelengths having higher energy as compared to ultraviolet radiation.
- **Ultraviolet (UV) radiation:** It is a part of electromagnetic spectrum that lies between X-rays and visible light.
- **Visible light:** It is a visible spectrum which is part of electromagnetic spectrum which can be seen by human eyes.
- **Infrared (IR) radiation:** These are thermal radiations which is the part of electromagnetic spectrum that lie between visible light and microwaves.
- **Radio waves:** Waves with long wavelengths used in television, cell phone and radio communications.

Objective Type Questions

(1 mark each)

[A] Very Short Answer Type Questions

Q. 1. Which part of the electromagnetic spectrum is used in RADAR? Give its frequency range.
R [CBSE OD SET 1 2019]

Ans. To identify the part of the electromagnetic spectrum ½
For writing its frequency range ½
Microwaves
Frequency range is 10^{10} to 10^{12} Hz 1
[CBSE Marking Scheme, 2019]

Q. 2. Name the electromagnetic radiations used for (a) water purification and (b) eye surgery.
R [CBSE 2018]

Ans. (a) Ultra violet rays ½
(b) Ultra violet rays/Laser ½
[CBSE Marking Scheme, 2018]

Q. 3. Why are infra-red waves often called as heat waves? Explain. **R [CBSE 2018]**

Ans. Reason for calling IR rays as heat rays 1
Infrared rays are readily absorbed by the (water) molecules in most of the substances and hence increases their thermal motion.
(If the student just writes that "infrared ray produce heating effects", award ½ mark only) 1
[CBSE Marking Scheme, 2018]

Q. 4. Why are microwaves considered suitable for radar systems used in aircraft navigation ? R **[CBSE OD SET 1 2016]**

Ans. Due to their short wavelengths, (they are suitable for radar system used as aircraft navigation).
[CBSE Marking Scheme, 2016] 1

Q. 5. What is the wavelength of light waves if their frequency is 5.0X10^14 Hz? A

Ans. The relationship between wavelength and frequency is given by

$$\text{Wavelength} = \frac{\text{Speed of light}}{\text{Frequency}}$$

$$= \frac{3\times10^{8}\text{m / s}}{5\times10^{14}\text{Hz}}$$

$$= 0.6\times10^{-6}\text{m}$$

$$= 0.6\mu\text{m}.$$

Q. 6. What is the range of wavelength of electromagnetic radiations ? R

Ans. Generally the wavelength lie in the range of metres to nano-metres. 1

Q. 7. You are given a 2 μF parallel plate capacitor. How would you establish an instantaneous displacement current of 1 mA in the space between its plate ? A

Ans. The capacitance of capacitor $C = 2\,\mu\text{F}$,
Displacement current $I_d = 1\text{ mA}$
Charge in capacitor, $q = CV$

$$I_d\,dt = CdV \quad [\because q = it]$$

or $$I_d = C\frac{dV}{dt}$$

$$1\times10^{-3} = 2\times10^{-6}\times\frac{dV}{dt}$$

or $$\frac{dV}{dt} = \frac{1}{2}\times10^{3} = 500\text{ V/s}$$ 1

Hence, by applying a varying potential difference of 500 V/s, we would produce a displacement current of desired value.

Q. 8. How is the energy of an electromagnetic wave related to its wavelength? What is the value of the ratio of energy of wave to that of its frequency? U

Ans. The energy of an electromagnetic wave is related to its wavelength as $E = \frac{hc}{\lambda}$

The ratio of energy of wave to that of its frequency is known as the Planck's constant whose value is given by 6.63 x 10^{-34} Js.

[B] ASSERTION REASON TYPE QUESTIONS

For the following questions, two statements are given-one labelled as Assertion (A) and the other labelled as Reason (R), Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false and R is also false

Q. 1. Assertion(A): X-ray travels with the speed of light.
Reason(R): X-ray is an e.m. wave. 1

Ans. (a) 1
Explanation: Velocity of all electromagnetic wave is 3 × 10^8 m/s which is the velocity of light.
X ray is an electromagnetic wave. So, it travels with the velocity 3 x 10^8 m/s which is the velocity of light.
So, assertion and reason both are correct and reason properly explains the assertion.

Short Answer Type Questions (2 & 3 marks each)

Q. 1. Gamma rays and radio waves travel with the same velocity in free space. Distinguish between them in terms of origin and the main application. R **[CBSE DEL SET 1, 2020]**

Ans.

	Gamma rays	Radio waves
Origin	Nuclear decay	Lightning
	From hottest and most energetic objects in the universe, such as neutron stars, pulsars, supernova explosions, and regions around black holes	From broadcast radio towers, cell phones and radars.
Application	In radiotherapy, sterilisation and disinfection	In fixed and mobile radio communication, radar and other navigation systems, communications satellites, computer networks

Q. 2. Identify the part of electromagnetic spectrum used in (i) radar and (ii) eye surgery. Write their frequency range. R **[CBSE DEL SET 1, 2019]**

Ans. Identification ½ + ½
Frequency Range ½ + ½
Proof

Microwaves: Frequency range
($\sim 10^{10}$ to 10^{12} Hz) ½ + ½
Ultraviolet rays: Frequency range
($\sim 10^{15}$ to 10^{17} Hz) ½ + ½
[**Note:** Award $\left(\frac{1}{2}+\frac{1}{2}\right)$ marks for frequency ranges even if the student just writes the correct order of magnitude for them].

[CBSE Marking Scheme, 2019]

AI Q. 3. Identify the electromagnetic waves whose wavelengths vary as:
(a) 10^{-12} m < λ < 10^{-8} m
(b) 10^{-3} m < λ < 10^{-1} m
Write one use for each. R **[CBSE O.D. SET 1, 2017]**

Ans. (a) Identification ½+½
(b) Uses ½+½
(a) X-rays ½
Used for medical purposes.
(Also accept UV rays and gamma rays and any one use of the em wave named) ½
(b) Microwaves ½
Used in radar systems.
(Also accept short radio waves and any one use of the em wave named) ½

[CBSE Marking Scheme, 2017]

Detailed Answer:
(a) Wavelength 10^{-12} m < λ < 10^{-8} m shows the existence of X-rays
The radiation of X - rays takes place due to electron transitions among upper and lower energy levels of heavy elements that are excited by electron bombardment. X-rays are mainly used in medicine and dentistry which can be detected using photographic film. **1**
(b) Wavelength 10^{-3} m < λ < 10^{-1} m shows the existence of Microwaves.
Microwaves are produced by magnetron which are used in radar, telemetry and electron spin resonance studies and in microwave ovens. Microwaves are detected with crystal detectors or solid-state diodes. **1**

Q. 4. Identify the electromagnetic waves whose wavelengths lie in the range
(a) 10^{-11} m < λ < 10^{-14} m
(b) 10^{-4} m < λ < 10^{-6} m
Write one use of each. R **[CBSE OD SET 2, 2017]**

Ans. (a) Identification ½+½
(b) One use each ½+½
(a) X-rays/Gamma rays ½
One use of the name given ½
(b) Infrared/Visible/Microwave ½
One use of the name given ½
(**Note:** Award ½ mark for each correct use (relevant to the name chosen) even if the name chosen are incorrect.)

[CBSE Marking Scheme, 2017]

Detailed Answer:
(i) Wavelength range of 10^{-11} m < λ < 10^{-14} m shows the presence of both X-rays and Gamma rays as Gamma-rays has wavelength ranges from 10^{-14} m - 10^{-11} m while the X-rays wavelength ranges from 10^{-12} m - 10^{-8} m.
Uses:
(a) Gamma-radiations are used in medical treatment and for checking flaws in metal castings and for detection by photographic plates or radiation detectors.
(b) X-rays are used in medicine and dentistry, and may be detected using photographic film. **1**
(ii) Wavelength range of 10^{-4} m < λ < 10^{-6} m shows the presence of Infrared, Visible and Microwave.
Uses:
(a) Infrared radiation is useful for haze photography and is used by Earth resource satellites to detect healthy crops.
(b) Visible light affects photographic film, stimulates the retina in the eye and causes photosynthesis in plants.
(c) Microwaves are used in radar, telemetry and electron spin resonance studies and in microwave ovens. **1**

AI Q. 5. (i) How are microwaves produced ? Why is it necessary in microwave ovens to select the frequency of microwaves to match the resonant frequency of water molecules ?
(ii) Write two important uses of infrared waves. U

Ans. (i) Microwaves are produced by special vacuum tubes like the Klystron / Magnetron / Gunn diode. ½
The frequency of microwaves is selected to match the resonant frequency of water molecules, so that energy is transferred efficiently to the kinetic energy of the molecules. ½
(ii) (a) Associated with the greenhouse effect. ½
(b) In remote switches of household electrical appliances. ½

Q. 6. Name the electromagnetic waves with their frequency range, produced in
(a) some radioactive decay
(b) sparks during electric welding
(c) TV remote R **[CBSE OD SET 1, 2020]**

Ans. (a) Electromagnetic wave produced in some radioactive decay is γ-rays (frequency > 3×10^{17} Hz).
(b) Electromagnetic wave produced in arc welding are UV ($7.5 \times 10^{14} - 3 \times 10^{16}$ Hz), IR ($3 \times 10^{12} - 4.3 \times 10^{14}$ Hz) and visible ($4.3 \times 10^{14} - 7.5 \times 10^{14}$ Hz) rays.
(c) Electromagnetic wave produced in TV remote is IR rays.

Q. 7. Name the type of EM waves having a wavelength range of 0.1 m to 1 mm. How are these waves generated ? Write their two uses.
U **[O.D. comptt 2, 2017]**

Ans. Name of EM wave 1
Method of generation 1
Two uses ½+½
Microwaves 1
Produced by special vacuum tubes 1
Klyston, magnetron, gunn diodes
Uses:
(i) In Radar system for aircraft navigation
(ii) In ovens for heating/cooking ½+½
[CBSE Marking Scheme, 2017]

Detailed Answer:
(i) Microwaves: Wavelength 10^{-4} m - 10^{-1} m, frequency 10^{13} Hz - 10^{9} Hz 1
(ii) Generation:
Microwaves are produced by valves like magnetron or using a maser. They are detected with crystal detectors or solid-state diodes. 1
(iii) Uses:
(a) Used in radar ½
(b) Used in telemetry ½
OR
(a) Used in electron spin resonance studies ½
(b) Used in microwave ovens for heating food ½

Visual Case-based Questions (1×4=4 marks)

Attempt any 4 sub-parts from the given 5 Questions. Each question carries 1 mark.

1. Microwave oven: The spectrum of electromagnetic radiation contains a part known as microwaves. These waves have frequency and energy smaller than visible light and wavelength larger than it. What is the principle of a microwave oven and how does it work ? Our objective is to cook food or warm it up. All food items such as fruit, vegetables, meat, cereals, etc., contain water as a constituent. Now, what does it mean when we say that a certain object has become warmer? When the temperature of a body rises, the energy of the random motion of atoms and molecules increases and the molecules travel or vibrate or rotate with higher energies. The frequency of rotation of water molecules is about 2.45 gigahertz (GHz). If water receives microwaves of this frequency, its molecules absorb this radiation, which is equivalent to heating up water. These molecules share this energy with neighbouring food molecules, heating up the food. One should use porcelain vessels and non metal containers in a microwave oven because of the danger of getting a shock from accumulated electric charges. Metals may also melt from heating. The porcelain container remains unaffected and cool, because its large molecules vibrate and rotate with much smaller frequencies, and thus cannot absorb microwaves. Hence, they do not get eaten up. Thus, the basic principle of a microwave oven is to generate microwave radiation of appropriate frequency in the working space of the oven where we keep food. This way energy is not wasted in heating up the vessel. In the conventional heating method, the vessel on the burner gets heated first and then the food inside gets heated because of transfer of energy from the vessel. In the microwave oven, on the other hand, energy is directly delivered to water molecules which is shared by the entire food.

(i) As compared to visible light microwave has frequency and energy:
(a) more than visible light
(b) less than visible light
(c) equal to visible light
(d) Frequency is less but energy is more

Ans. (b) 1
Explanation: Microwaves have frequency and energy smaller than visible light and wavelength larger than it.

(ii) When the temperature of a body rises:
(a) the energy of the random motion of atoms and molecules increases.
(b) the energy of the random motion of atoms and molecules decreases.
(c) the energy of the random motion of atoms and molecules remains same.
(d) the random motion of atoms and molecules becomes streamlined.

Ans. (a) 1
Explanation: When the energy of the random motion of atoms and molecules of a substance increases and the molecules travel or vibrate or rotate with higher energies, the substance becomes hot.

(iii) The frequency of rotation of water molecules is about:
(a) 2.45 MHz **(b)** 2.45 kHz
(c) 2.45 GHz **(d)** 2.45 THz

Ans. (c) 1
Explanation: The frequency of rotation of water molecules is about 2.45 gigahertz.

(iv) Why should one use porcelain vessels and non-metal containers in a microwave oven ?
(a) Because it will get too much hot
(b) Because it may crack due to high frequency
(c) Because it will prevent the food items to become hot
(d) Because of the danger of getting a shock from accumulated electric charges.

Ans. (d) 1
Explanation: One should use porcelain vessels and non-metal containers in a microwave oven because of the danger of getting a shock from accumulated electric charges. Metals may also melt from heating.

The porcelain container remains unaffected and cool, because its large molecules vibrate and rotate with much smaller frequencies and thus cannot absorb microwaves. Hence, they do not get heated up.

(v) In the microwave oven,

(a) Energy is directly delivered to water molecules which is shared by the entire food

(b) The vessel gets heated first, and then the food grains inside

(c) The vessel gets heated first and then the water molecules collect heat from the body of the vessel

(d) Energy is directly delivered to the food grains.

Ans. (a) **1**

Explanation: In the conventional heating method, the vessel on the burner gets heated first and then the food inside gets heated because of transfer of energy from the vessel. In the microwave oven, on the other hand, energy is directly delivered to water molecules which is shared by the entire food.

2. LASER: Electromagnetic radiation is a natural phenomenon found in almost all areas of daily life, from radio waves to sunlight to x-rays. Laser radiation – like all light – is also a form of electromagnetic radiation. Electromagnetic radiation that has a wavelength between 380 nm and 780 nm is visible to the human eye and is commonly referred to as light. At wavelengths longer than 780 nm, optical radiation is termed infrared (IR) and is invisible to the eye. At wavelengths shorter than 380 nm, optical radiation is termed ultraviolet (UV) and is also invisible to the eye. The term "laser light" refers to a much broader range of the electromagnetic spectrum that just the visible spectrum, anything between 150 nm up to 11000 nm (*i.e.* from the UV up to the far IR). The term laser is an acronym which stands for "light amplification by stimulated emission of radiation".

Einstein explained the stimulated emission. In an atom, electron may move to higher energy level by absorbing a photon. When the electron comes back to the lower energy level it releases the same photon. This is called spontaneous emission. This may also so happen that the excited electron absorbs another photon , releases two photons and returns to the lower energy state. This is known as stimulated emission.

Laser emission is therefore a light emission whose energy is used, in lithotripsy, for targeting and ablating the stone inside human body organ.

Apart from medical usage, laser is used for optical disk drive, printer, barcode reader etc.

(i) What is the full form of LASER ?

(a) light amplified by stimulated emission of radiation

(b) light amplification by stimulated emission of radiation

(c) light amplification by simultaneous emission of radiation

(d) light amplified by synchronous emission of radiation

Ans. (b)

Explanation: The term laser is an acronym which stands for "light amplification by stimulated emission of radiation". **1**

(ii) The "stimulated emission" is the process of :

(a) release of a photon when electron comes back from higher to lower energy level

(b) release of two photons by absorbing one photon when electron comes back from higher to lower energy level

(c) absorption of a photon when electron moves from lower to higher energy level

(d) None of the above

Ans. (b)

Explanation: Einstein explained the stimulated emission. In an atom, electron may move to higher energy level by absorbing a photon. When the electron comes back to the lower energy level it releases the same photon. This is called spontaneous emission. This may also so happen that the excited electron absorbs another photon, releases two photons and returns to the lower energy state. This is known as stimulated emission. **1**

(iii) What is the range of amplitude of LASER?

(a) 150 nm – 400 nm

(b) 700 nm – 11000 nm

(c) Both the above

(d) None of the above

Ans. (c)

Explanation: The term "laser light" refers to a much broader range of the electromagnetic spectrum that just the visible spectrum, anything between 150 nm up to 11000 nm (*i.e.* from the UV up to the far IR). **1**

(iv) Lithotripsy is:

(a) An industrial application

(b) A medical application

(c) Laboratory application

(d) Process control application **1**

Ans. (b)

Explanation: Laser emission is therefore a light emission whose energy is used, in lithotripsy, for targeting and ablating the stone inside human body organ.

(v) LASER is used in:

(a) Optical disk drive

(b) Transmitting Satellite signal

(c) Radio communication

(d) Ionization **1**

Ans. (a)

Explanation: An optical disc drive (ODD) is a disc drive that uses laser light or electromagnetic waves within or near the visible light spectrum as part of the process of reading or writing data to or form optical discs.

❑❑

SELF ASSESSMENT PAPER-5

Time : 1 Hours **Maximum Marks : 25**

SECTION - A

1. (i) Name the phenomenon which shows the quantum nature of electromagnetic radiation.

(ii) What is the maximum number of spectral lines emitted by a hydrogen atom when it is in the third excited state ? **1**

(iii) Show, by giving a simple example, how EM waves carry energy and momentum? **1**

(iv) To which part of the electromagnetic spectrum does a wave of frequency 5×10^{19} Hz belong ? **1**

2. For question number 2 two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both A and R are true and R is the correct explanation of A

(b) Both A and R are true but R is NOT the correct explanation of A

(c) A is true but R is false

(d) A is false and R is also false

(i) Assertion (A) : X-ray travels with the speed of light.

Reason (R) : X-ray is an e.m. wave. **1**

(ii) Assertion (A) : Mass of moving photon varies inversely with the wavelength.

Reason (R) : Energy of particle = mass × (velocity of light)^2 **1**

3. Read the Passage given below and answer any 4 Questions.

Microwave oven : The spectrum of electromagnetic radiation contains a part known as microwaves. These waves have frequency and energy smaller than visible light and wavelength larger than it. What is the principle of a microwave oven and how does it work ? Our objective is to cook food or warm it up. All food items such as fruit, vegetables, meat, cereals, etc., contain water as a constituent. Now, what does it mean when we say that a certain object has become warmer? When the temperature of a body rises, the energy of the random motion of atoms and molecules increases and the molecules travel or vibrate or rotate with higher energies. The frequency of rotation of water molecules is about 2.45 gigahertz (GHz). If water receives microwaves of this frequency, its molecules absorb this radiation, which is equivalent to heating up water. These molecules share this energy with neighbouring food molecules, heating up the food. One should use porcelain vessels and not metal containers in a microwave oven because of the danger of getting a shock from accumulated electric charges. Metals may also melt from heating. The porcelain container remains unaffected and cool, because its large molecules vibrate and rotate with much smaller frequencies, and thus cannot absorb microwaves. Hence, they do not get eaten up. Thus, the basic principle of a microwave oven is to generate microwave radiation of appropriate frequency in the working space of the oven where we keep food. This way energy is not wasted in heating up the vessel. In the conventional heating method, the vessel on the burner gets heated first, and then the food inside gets heated because of transfer of energy from the vessel. In the microwave oven, on the other hand, energy is directly delivered to water molecules which is shared by the entire food. **4**

(i) As compared to visible light microwave has frequency and energy :

(a) More than visible light **(b)** Less than visible light

(c) Equal to visible light **(d)** Frequency is less but energy is more

(ii) When the temperature of a body rises :

(a) The energy of the random motion of atoms and molecules increases

(b) The energy of the random motion of atoms and molecules decreases

(c) The energy of the random motion of atoms and molecules remain same

(d) The random motion of atoms and molecules become streamlined

(iii) The frequency of rotation of water molecules is about :

(a) 2.45 MHz **(b)** 2.45 kHz

(c) 2.45 GHz **(d)** 2.45 THz

(iv) Why should one use porcelain vessels and non- metal containers in a microwave oven ?

(a) Because it will get too much hot

(b) Because it may crack due to high frequency

(c) Because it will prevent the food items to become hot
(d) Because of the danger of getting a shock from accumulated electric charges.

(v) In the microwave oven,
(a) Energy is directly delivered to water molecules which is shared by the entire food.
(b) The vessel gets heated first, and then the food grains inside.
(c) The vessel gets heated first, and then the water molecules the collect heat from the body of the vessel
(d) Energy is directly delivered to the food grains.

SECTION - B

4. Professor C.V. Raman surprised his students by suspending a tiny light ball freely in a transparent vacuum chamber by shining a laser beam on it. Which property of EM waves was he exhibiting? Give one more example of this property ? **2**

5. Identify the electromagnetic waves whose wavelengths vary as :
(i) 10^{-12} m $< \lambda <$ 10^{-8} m
(ii) 10^{-3} m $< \lambda <$ 10^{-1} m
Write one use for each. **2**

SECTION - C

6. Name the type of EM waves having a wavelength range of 0.1 m to 1 mm. How are these waves generated ? Write their two uses. **3**

7. (a) Identify the part of electromagnetic spectrum used in (i) radar and (ii) eye surgery. Write their frequency range.
(b) Prove that the average energy density of the oscillating electric field is equal to that of the oscillating magnetic field. **3**

SECTION - D

8. (i) Can we say that both electric and magnetic field vectors are parallel to each other and perpendicular to the direction of propagation of the wave ? Justify **2**
(ii) For a plane electromagnetic wave, propagating along the *z*-axis, write the two (possible) pairs of expressions for its oscillating electric and magnetic fields. How are the peak values of these (oscillating) fields related to each other ? **3**