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Q1. Give the ratio of velocities of light rays of wavelength 4,000 Å in vacuum.

Q2. The current in a circuit containing a capacitor is 0.15 A. What is the displacement current and where does it exist?

Q3. What are the directions of the electric and magnetic field vectors relative to the direction of propagation of electromagnetic waves.

Q4. Express the velocity of propagation of an electromagnetic wave in terms of the peak values of the electric and magnetic fields.

Q5. Which physical quantity if any has the same value for waves belonging to the different parts of the electromagnetic spectrum?

Q6. Is displacement current, like conduction current, a source of magnetic field?

Q7. Name the scientist, who first
(a) predicted the existence of electromagnetic waves.
(b) experimentally demonstrated the existence of electromagnetic waves.

Q8. The charging current for a capacitor is 0.25 A. What is the displacement current across its plates?

Q9. What is Maxwell's displacement current?

Q10. The magnetic field in a plane electromagnetic wave is given by

$$B_y = 2 \times 10^{-7} \sin [0.5 \times 10^3 x + 1.5 \times 10^{11} t]$$

What is the wavelength and frequency of the wave?

Q11. State the principle of production of e.m. waves. What is the value of velocity of these wave?

Q12. When an ideal capacitor is charged by a d.c. battery, no current flows continuously. How does one explain this, based on the concept of displacement current.

Q13. A parallel plate capacitor has plates of area 0.32 m^2, which are separated by a distance of 5 mm. The capacitor is raised to a potential of 1, 200 V. Estimate the average value of to a potential of 1, 200V. Estimate the average value of displacement current, when it is discharged for 1 μs.

Q14. The medium wave (MW) band corresponds to wavelength range 200 m to 625 m. If a radio can tune to any station in this band, what is the corresponding frequency band?

Q15. Calculate displacement current between the square plates of side 1.0 cm of a capacitor of electric field between the plates is changing at the rate of 30×10^6 V/m s.

Q16. A parallel plate capacitor (as shown in figure) made of circular plates each of radius $R = 6.0$ cm has a capacitance $C = 100$ pF. The capacitor is connected to a 230 V a.c. supply with a (angular) frequency of 300 rad s^{-1}.

(a) What is the rms value of the conduction current?

(b) Is the conduction current equal to the displacement current?

(c) Determine the amplitude of B at a point 3.0 cm from the axis between the plates.

Q17. Draw a labelled diagram of Hertz's experiment.

Explain how electromagnetic radiations are produced using this set-up.

Q18. A plane electromagnetic wave propagating in the X-direction has a wavelength of 6 mm. The electric field is in the Y-direction and its maximum magnitude is 33 Vm^{-1}. Write suitable equations for the electric magnetic field as a function of x and t.

Q19. A parallel plate capacitor is made of two circular plates each of radius 12 cm and separated by some distance. A constant charging current of 0.15 A is used to charge it.

(a) Using modified Ampere's circuital law, calculate magnetic field between the plates at a point (i) 15 cm from the axis, (ii) 6.5 cm from the axis and (iii) on the axis.

(b) At what distance from the axis is the magnetic field due to the displacement current maximum? Obtain the maximum value of the field.

Q20. Green light of mercury has a wavelength 4.0×10^{-5} cm. (a) What is the frequency in MHz and period in μs in vacuum? (b) What is the wavelength in glass, if refractive index of glass is 1.5? Given, $c = 3 \times 10^{8}$ m s^{-1}.

Q21. A parallel plate capacitor with plate area A and plate separation d, is charged by a constant current I. Consider a plane surface of area $A/2$ parallel to the plates and situated symmetrically between the plates. Determine the displacement current through this area.

Q22. What is displacement current ? Why was this concept introduced?

Q23. The electric field of a plane electromagnetic wave in vacuum is represented by

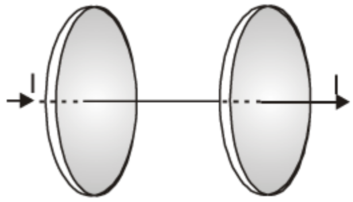
$$E_x = 0, \quad E_y = 0.5 \cos [2\pi \times 10^8 (t - x/c)] \quad \text{and} \quad E_z = 0.$$

(a) What is the direction of propagation of electromagnetic waves?

(b) Determine the wavelength of the wave.

Q24. Suppose a parallel plate capacitor of plate area A is being charged. Show that the displacement current across the capacitor between the plates and parallel to it is equal to the conduction current in the connecting wires.

Q25. Figure shows a capacitor made of two circular plates, each of radius $R = 12$ cm, separated by $d = 5.0$ mm. The capacitor is being charged by an external source (not shown in figure). The charging current I is constant and equal to 0.15 A.



(a) Calculate the capacitance the rate of charge of potential difference between the plates.

(b) Obtain the displacement current across the plates.

(c) Is the Kirchhoff's rule valid at each plate of the capacitor?

Q26. A parallel plate capacitor with plate area A and plate separation d, is charged by a constant current I. Consider a plane surface of area $2A$ parallel to the plates and situated symmetrically between the plates. Determine the displacement current through this area.

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S1. It is equal to 1.

S2. As conventional current is equal is to displacement current. It is also 0.15 A. It exists across the capacitor plates.

S3. The electric field and magnetic field vectors ate right angle to each other and to the direction of wave propagation.

S4. The amplitudes (peak values) of electric and magnetic fields in free space are related to the speed of electromagnetic waves in free space as

$$c = \frac{E_0}{B_0} \qquad \begin{cases} \text{where } E_0 : \text{is electric field in free space} \\ \quad\quad\quad B_0 : \text{is magnetic field in free space} \end{cases}$$

S5. It is frequency.

S6. Yes, the displacement current is also a source of magnetic field like the conduction current.

S7. (a) J. C. Maxwell (b) H. Hertz

S8. The displacement current is always equal to conduction current and therefore it is also equal to 0.25 A.

S9. The displacement current is produced, when in an electric circuit (say across the plates of a charged capacitor), the electric field changes with time. Mathematically,

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

S10. Given, $B_y = 2 \times 10^{-7} \sin [0.5 \times 10^3 x + 1.5 \times 10^{11} t]$ ...(i)

The y-component of the magnetic field is given by

$$B_y = B_0 \sin 2\pi\left(\frac{x}{\lambda} + \frac{t}{T}\right) \quad \text{...(ii)}$$

Compare the Eq. (i) w.r.t. Eq (ii)

$$\frac{2\pi}{\lambda} = 0.5 \times 10^3$$

or

$$\lambda = \frac{2\pi}{0.5 \times 10^3} = 1.257 \times 10^{-2} m$$

Also, $$\frac{2\pi}{T} = 1.5 \times 10^{11}$$

or $$\nu = \frac{1}{T} = \frac{1.5 \times 10^{11}}{2\pi} = \mathbf{2.387 \times 10^{10} Hz}$$

S11. The accelerated charge produces electric and magnetic fields, which vary both in space and time. These varying electric and magnetic fields give rise to electro-magnetic waves.

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \times 10^8 \text{ ms}^{-1}$$

S12. A capacitor offers infinite resistance to d.c. Therefore, no current flows, when it is connected to a d.c. battery. On the other hand, a capacitor offers a finite resistance to a.c. Therefore, the current flows through it, when an a.c. source is connected to it.

S13. Here, $V = 1,200$ V; A = 0.32 m^2 ; d = 5 mm = 5×10^{-3} m

and $t = 1\ \mu\text{s} = 10^{-6}$ s

Now, $$\phi_E = E \times A = \frac{V}{d} \times A = \frac{1{,}200}{5 \times 10^{-3}} \times 0.32$$
$$= 7.68 \times 10^4 \text{ N m}^2 \text{ C}^{-1}$$

The average displacement current is given by

$$I_D = \varepsilon_0 \frac{\phi_E}{t} = 8.854 \times 10^{-12} \times \frac{7.68 \times 10^4}{10^{-6}} = 0.68\text{A}$$

S14. Let λ_1 and λ_2 be the frequencies corresponding to wavelengths 200 m to 625 m respectively. Then,

$$\nu_1 = \frac{c}{\lambda_1} = \frac{3 \times 10^8}{200} = 1.5 \times 10^6 \text{ Hz} = \mathbf{1{,}500\ kHz}$$

and $$\nu_2 = \frac{c}{\lambda_2} = \frac{3 \times 10^8}{625} = 4.8 \times 10^5 \text{ Hz} = \mathbf{480\ kHz}$$

Therefore, frequency band corresponding to the given wavelength band is **480 kHz to 1,500 kHz**.

S15. Given $\varepsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2\text{N}^{-1}\ \text{m}^{-2}$

$A = 10^{-4}$ m^2

$$\frac{dE}{dt} = 3 \times 10^6 \text{ V/m s}$$

We know displacement current. $I_D = \varepsilon_0 A \dfrac{dE}{dt}$

$$I_D = (8.85 \times 10^{-12}) \times (10^{-4}) \times (3 \times 10^{6})$$
$$= 2.7 \times 10^{-9}\text{ A}$$

S16. Radius of each circular plate, $R = 6.0\text{ cm} = 0.06\text{ m}$

Capacitance of a parallel plate capacitor, $C = 100\text{ pF} = 100 \times 10^{-12}\text{ F}$

Supply voltage, $V = 230\text{ V}$

Angular frequency, $\omega = 300\text{ rad s}^{-1}$

(a) R.m.s. value of conduction current, $I = \dfrac{V}{X_C}$

Where, X_C = Capacitive reactance $= \dfrac{1}{\omega C}$

$\therefore$ $I = V \times \omega C$

$$= 230 \times 300 \times 100 \times 10^{-12}$$
$$= 6.9 \times 10^{-6}\text{ A}$$
$$= 6.9\ \mu\text{A}$$

Hence, the r.m.s. value of conduction current is 6.9 μA.

(b) Yes, conduction current is equal to displacement current.

(c) Magnetic field is given as:

$$B = \frac{\mu_0 r}{2\pi R^2} I_0$$

Where, μ_0 = Free space permeability

$= 4\pi \times 10^{-7}\text{ N A}^{-2}$

I_0 = Maximum value of current $= \sqrt{2}\,I$

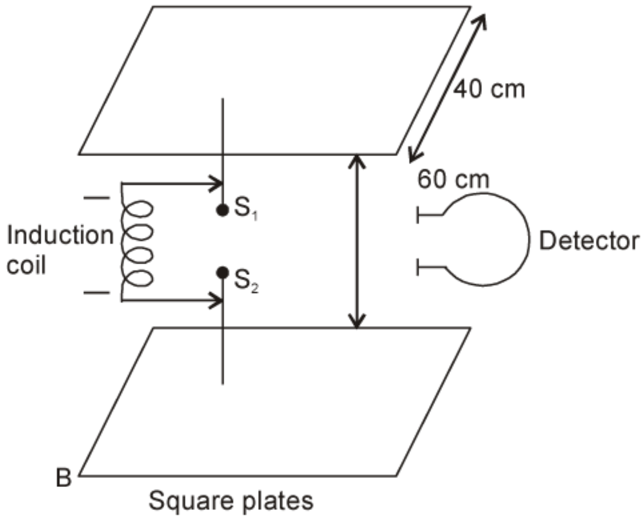
r = Distance between the plates from the axis

$= 3.0\text{ cm} = 0.03\text{ m}$

$\therefore$
$$B = \frac{4\pi \times 10^{-7} \times 0.03 \times \sqrt{2} \times 6.9 \times 10^{-6}}{2\pi \times (0.06)^2}$$
$$= 1.63 \times 10^{-11}\text{ T}$$

Hence, the magnetic field at that point is 1.63×10^{-11} T.

S17. In Hertz's experiment, transmitter is a capacitor made up of two brass plates. To each plate a highly polished brass knob is attached with the help of thick copper wires. A source of high voltage (induction coil) is connected with copper wires. Induction coil charges the capacitor. Due to high voltage air in the gap between S_1 and S_2 gets ionised. Thus, capacitor gets discharged through the gap. This way capacitor is in a process of charging and discharging again and again. This produces damped e.m. waves of frequency.



$$f = \frac{1}{2\pi\sqrt{LC}}$$

Oscillating magnetic field of e.m. waves induces an electric field in the ring of detector thus producing a spark across the air-gap in the ring.

S18. Given $\lambda = 6 \text{ mm} = 6 \times 10^{-3} \text{ m}$ and $E_0 = 33 \text{V m}^{-1}$

$$E_y = E_0 \sin \omega(t - x/c) \quad \text{... (i)}$$

and $$B_z = B_0 \sin \omega(t - x/c) \quad \text{... (ii)}$$

Now, $$\omega = 2\pi\nu = \frac{2\pi c}{\lambda} = \frac{2\pi \times 3 \times 10^8}{6 \times 10^{-13}} = \pi \times 10^{11} \text{rad s}^{-1}$$

and $$B_0 = \frac{E_0}{c} = \frac{33}{3 \times 10^8} = 1.1 \times 10^{-7} \text{T}$$

put the values in Eq. (i) and (ii) we get

$$\boldsymbol{E_y = 33 \sin \pi \times 10^{11} (t - x/c)}$$

and $$\boldsymbol{B_z = 1.1 \times 10^{-7} \sin \pi \times 10^{11} (t - x/c)}$$

Note: The, wavelength of light in glass can also be determined by using the relation $\lambda' = \lambda/\mu$.

S19. (a) Given, $I_D = 0.15 \text{ A}$; $R = 12 \text{ cm} = 12 \times 10^{-2} \text{m}$

(i) Here, $r = 15 \text{ cm} = 15 \times 10^{-2} \text{ m}$

when $r > R$, the magnetic field is given by

$$B = \frac{\mu_0}{4\pi} \cdot \frac{2I}{r} \quad \text{(1)}$$

$\therefore$ $$B = \frac{10^{-7} \times 2 \times 0.15}{15 \times 10^{-2}} = \mathbf{2 \times 10^{-7}\ T}$$

(ii) Here, $r = 6.5$ cm $= 6.5 \times 10^{-2}$ m

when $r < R$, the magnetic field is given by

$$B = \frac{\mu_0}{2\pi} \cdot \frac{r}{R^2} I = \frac{\mu_0}{4\pi} \cdot \frac{2r}{R^2} I \qquad \text{——————} \qquad (2)$$

$\therefore$ $$B = \frac{10^{-7} \times 2 \times (6.5 \times 10^{-2}) \times 0.15}{(12 \times 10^{-2})^2} = \mathbf{1.354 \times 10^{-7}\ T}$$

(iii) Here, $r = 0$

In the equation (ii), setting $r = 0$, we get

$$B = 0$$

(b) From the equations (i) and (ii), it follows that the magnetic field due to the displacement current is maximum,

when $r = R$. It is given by

$$B = \frac{\mu_0}{2\pi} \cdot \frac{I}{R} = \frac{\mu_0}{4\pi} \cdot \frac{2I}{R}$$

$\therefore$ $$B = \frac{10^{-7} \times 2 \times 0.15}{12 \times 10^{-2}} = \mathbf{2.5 \times 10^{-7}\ T}$$

S20. Here, wavelength, $\lambda = 4.0 \times 10^{-5}$ cm $= 4.0 \times 10^{-7}$ m

velocity of light, $c = 3 \times 10^{8}$ m s^{-1}

(a) If ν is the frequency, then

$$\nu = \frac{c}{\lambda} = \frac{3 \times 10^8}{4.0 \times 10^{-7}} = 7.5 \times 10^{14}\ \text{Hz} = 7.5 \times 10^{8}\ \text{MHz}$$

Time period, $$T = \frac{1}{\nu} = \frac{1}{7.5 \times 10^{14}} = 1.42 \times 10^{-15}\ \text{s} = \mathbf{1.42 \times 10^{-9}\ \mu s}$$

(b) Now, refractive index,

$$\mu = \frac{\text{velocity of light in vacuum}}{\text{velocity of light in glass}} = \frac{c}{v}$$

Therefore, velocity of light in glass,

$$v = \frac{c}{\mu} = \frac{3 \times 10^8}{1.5} = 2 \times 10^8 \ m\,s^{-1}$$

The wavelength of light in glass,

$$\lambda' = \frac{v}{\nu} = \frac{2 \times 10^8}{7.50 \times 10^{14}} = \mathbf{3.67 \times 10^{-7}\ m}.$$

Note: The, wavelength of light in glass can also be determined by using the relation, $\lambda' = \lambda/\mu$

S21. Let charge on capacitor plates at any instant to be Q. Then electric field between the capacitor plates will be

$$E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A}$$

Electric flux through the area $A/2$ will be

$$\phi_E = E \cdot \frac{A}{2} = \frac{Q}{\varepsilon_0 A} \cdot \frac{A}{2} = \frac{Q}{2\varepsilon_0}$$

$\therefore$ The displacement current

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

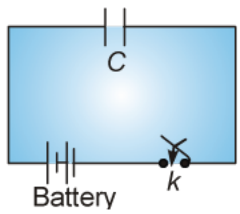
$$= \varepsilon_0 \cdot \frac{d}{dt}\left(\frac{Q}{2\varepsilon_0}\right)$$

$$= \varepsilon_0 \cdot \frac{1}{2\varepsilon_0} \cdot \frac{dQ}{dt} = \frac{1}{2}\frac{dQ}{dt}$$

$$= \frac{I}{2} \qquad \left(\because \frac{dQ}{dt} = I\right)$$

S22. Displacement current is the current which comes into existence in a region, wherever the electric field, and hence the electric flux changes with time.

Let us consider a capacitor C connected to a battery through at key K, as shown in figure. When the key is closed, transient current flows through the circuit till the capacitor is fully charged. now, current can only flow if it has a continuous path from positive to negative terminal of the battery.



A conduction current can flow only in the portion having connecting wire. No conduction current can flow in the space between capacitor plates having some dielectric.

To make the current continuous Maxwell suggested that a current flows across the plates of the capacitor. This current exists as long as a time varying electric field exists in this region. This current is called *displacement current.*

If A the area of plates and Q the charge on the plates at any instant of time, then electric field between the plates is

$$E = \frac{Q}{\varepsilon_0 A}$$

$$\therefore \qquad \frac{dE}{dt} = \frac{1}{\varepsilon_0 A}\frac{dQ}{dt}$$

or $$\frac{dE}{dt} = \frac{1}{\varepsilon_0 A} I \qquad \left(\because \frac{dQ}{dt} = I\right)$$

$\therefore$ Displacement current, $I_d = \varepsilon_0 A \dfrac{dE}{dt}$

S23. (a) Since the argument of cosine in the equation

$$E_y = 0.5 \cos [2\pi \times 10^8 (t - x/c)] \qquad \text{... (i)}$$

is of the type w($t - x/c$), the electromagnetic waves are propagating along the positive direction of X-axis.

(b) Comparing the equation (i) with the equation in the standard form *i.e.*

$$E_y = E_0 \cos \omega (t - x/c) \qquad \text{...(ii)}$$

we have,

Compare Eq. (i) w.r.t. Eq (ii) we get

$$\omega = 2\pi \times 10^8 \quad \text{or} \quad 2\pi\nu = 2\pi \times 10^8$$

or $$\nu = 10^8 \text{ s}^{-1}$$

Now, $$\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{10^8} = \mathbf{3\ m}.$$

S24. During the process of charging of the capacitor, if Q is the charge on the plates at any instant, the electric field between the plates is given by

$$E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A}$$

where σ is the surface charge density and A the area of the plates.

Therefore, electric flux through the plates is

$$\phi_E = EA = \frac{Q}{\varepsilon_0 A} \times A = \frac{Q}{\varepsilon_0}$$

$\therefore$ Displacement current $I_d = \varepsilon_0 \frac{d\phi_E}{dt}$ is given by

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

But d is the rate of flow of charge through the connecting wire *i.e.* it is conduction current I_c. Therefore

$$I_d = I_c$$

S25. (a)

$$C = \frac{\varepsilon_0 A}{d}$$

Here, $A = \pi(0.12)^2$, $d = 5.0$ mm $= 5.0 \times 10^{-3}$ m

$$\therefore \quad C = \frac{8.85 \times 10^{-12} \times \pi \times (0.12)^2}{5.0 \times 10^{-3}} \text{F}$$

$$= 80 \times 10^{-12} \text{ F} = 80 \text{ pF}$$

$$Q = VC$$

$$\therefore \quad \frac{dV}{dt} = \frac{1}{C}\frac{dQ}{dt} = \frac{I}{C} = \frac{0.15}{80 \times 10^{-12}} = 1.9 \times 10^9 \text{ V/s}$$

(b)

$$I_d = C\frac{dV}{dt} = I \text{ (charging current)} = 0.15 \text{ A}$$

(c) Yes, Kirchhoff's first rule is valid at each plate of the capacitor.

S26. Let charge on capacitor plates at any instant to be Q. Then electric field between the capacitor plates will be

$$E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A}$$

Electric flux through the area $2A$ will be

$$\phi_E = E \,.\, 2A = \frac{Q}{\varepsilon_0 A} \,.\, 2A = \frac{2Q}{\varepsilon_0}$$

$\therefore$ The displacement current

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

$$= \varepsilon_0 \cdot \frac{d}{dt}\left(\frac{2Q}{\varepsilon_0}\right)$$

$$= \varepsilon_0 \cdot \frac{2}{\varepsilon_0} \cdot \frac{dQ}{dt}$$

$$= 2I \qquad \left(\because \frac{dQ}{dt} = I\right)$$

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Q1. Write down Maxwell's equation for steady electric field.

Q2. What is the frequency of electromagnetic waves produced by oscillating charge of frequency ν?

Q3. The amplitude of the magnetic field part of a harmonic electromagnetic wave in vacuum is $B_0 = 510\ nT$. What is the amplitude of the electric field part of the wave?

Q4. A charged particle oscillates about its mean equilibrium position with a frequency of 10^9 Hz. What is the frequency of the electromagnetic waves produced by the oscillator?

Q5. What are electromagnetic waves?

Q6. Why are electromagnetic waves called so?

Q7. Write an expression for speed of electromagnetic waves in free space.

Q8. A plane electromagnetic wave travels in vacuum along Z-direction. What can you say about the direction of electric and magnetic field vectors?

Q9. Write two properties of electromagnetic waves.

Q10. What are the directions of electric and magnetic field vectors relative to each other and relative to the direction of propagation of electromagnetic waves?

Q11. The speed of an electromagnetic wave in a material medium is given be $v = \frac{1}{\sqrt{\mu\varepsilon}}$, μ being the permeability of the medium and ε its permittivity. how does its frequency change?

Q12. What is the frequency of electromagnetic waves produced by oscillating charge of frequency ν?

Q13. Name the electromagnetic radiation which can be produced by a klystron or a magnetron valve.

Q14. What is common between different types of e.m. radiations?

Q15. What oscillates in an electromagnetic wave of frequency 10 MHz and at what frequency?

Q16. An electric charge is oscillating with a frequency of 3×10^{10} Hz. Calculate the wavelength of the E.M. waves emitted by the oscillating electric charge in vacuum.

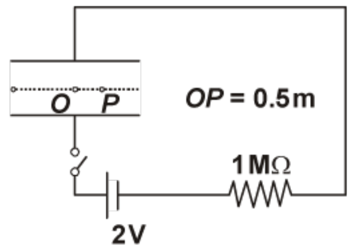
Q17. The charge on a parallel plate capacitor varies as $q = q_0 \cos 2\pi vt$. The plates are very large and close together (area = A, separation = d). Neglecting the edge effects, find the displacement current through the capacitor?

Q18. A variable frequency a.c. cource is connected to a capacitor. How will the displacement current change with decrease in frequency?

Q19. A plane electromagnetic wave travels in vacuum along z-direction. What can you say about the directions of its electric and magnetic field vectors? If the frequency of the wave is 30 MHz, what is its wavelength?

Q20. A radio can tune in to any station in the 7.5 MHz to 12 MHz band. What is the corresponding wavelength band?

Q21. A parallel plate capacitor with circular plates of radius 1 m has a capacitance of 1 nF. At $t = 0$, it is connected for charging in series with a resistor $R = 1\ M\Omega$ across a 2V battery (see figure). Calculate the magnetic field at a point P, halfway between the centre and the periphery of the plates, after $t = 10^{-3}$ s. (The charge on the capacitor at time t is $q(t) = CV[1 - \exp(-t/\tau)]$, where the time constant τ is equal to CR.)



Q22. The magnetic field amplitude of an electromagnetic wave is $B_0 = 1.6 \times 10^{-7}$ T. If its frequency is 30 MHz, determine the values of E_0, ω, k and λ.

Q23. Find the wavelength of electromagnetic waves of frequency 5×10^{19} Hz in free space. Given its applications.

Q24. What is the wave length of a television station, which transmits vision on 500 MHz? Given $c = 3 \times 10^8\ ms^{-1}$.

Q25. State any four properties of electromagnetic waves.

Q26. A plane electromagnetic wave travels in vacuum along the Y-direction. Write the (a) ratio of the magnitudes and (b) the directions of its electric and magnetic field vectors.

Q27. Draw a sketch of a plane electromagnetic wave propagating along the X-direction. Depict clearly the directions of electric and magnetic fields varying sinusoidally with x.

Q28. Light with an energy flux of 18 W/cm^2 falls on a nonreflecting surface at normal incidence. If the surface has an area of 20 cm^2, find the average force exerted on the surface during a 30 minute time span.

Q29. Find the wavelength of electromagnetic waves of frequencies 4×10^{17} Hz in free space. Given its two applications.

Q30. The electric field in a plane electromagnetic wave is given by

$$E_y = 72 \sin[1.5 \times 10^3 x + 5 \times 10^{11} t] \text{ (in V m}^{-1}\text{)}$$

What are the amplitudes of the electric and magnetic fields associated with the wave?

Q31. In a plane e.m. wave, the magnetic field oscillates sinusoidally with a frequency of 3×10^{10} Hz and amplitude 128×10^{-9} T.

(a) What is the wavelength of the wave?

(b) What is the amplitude of the oscillating electric field?

Q32. A Plane electromagnetic wave of frequency 25 MHz travels in free space along the x-direction. At a particular point in space and time the electric vector is $\vec{E} = 6.3\ \hat{j}$ V/m. Calculate $\vec{B}$ at this point.

Q33. In an electromagnetic wave propagating along the x-direction, the magnetic field oscillates at a frequency of 3×10^{10} Hz and has an amplitude of 10^{-7} Tesla, acting along the y-direction.

(a) What is the wavelength of the wave?

(b) Write the expression representing the corresponding electric field.

Q34. How does a charge *q* oscillating at certain frequency produce electromagnetic waves? Sketch a schematic diagram depicting electric and magnetic field for an electromagnetic wave propagating along the z-direction.

Q35. Show that average value of radiant flux density '*S*' over a single period '*T*' is given by

$$S = \frac{1}{2c\mu_0} E_0^2$$

Q36. Suppose that the electric field amplitude of an electromagnetic wave is E_0 = 120 N/C and that its frequency is ν = 50.0 MHz. (a) Determine, B_0, ω, *k*, and λ. (b) Find expressions for *E* and *B*.

Q37. In a plane electromagnetic wave, the electric field oscillates sinusoidally at a frequency of 2.0×10^{10} Hz and amplitude 48 V m^{-1}.

(a) What is the wavelength of the wave?

(b) What is the amplitude of the oscillating magnetic field?

(c) Show that the average energy density of the *E* field equals the average energy density of the *B* field. [$c = 3 \times 10^8$ m s^{-1}.]

Q38. Suppose that the electric field part of an electromagnetic wave in vacuum is

$$E = \{(3.1 \text{ N/C}) \cos [(1.8 \text{ rad/m})\, y + (5.4 \times 10^6 \text{ rad/s})\, t]\}\, \hat{i}\,.$$

(a) What is the direction of propagation?

(b) What is the wavelength λ?

(c) What is the frequency ν?

(d) What is the amplitude of the magnetic field part of the wave?

(e) Write an expression for the magnetic field part of the wave.

Q39. Calculate the electric and magnetic fields produced by the radiation coming from a 100 W bulb at a distance of 3 m. Assume that the efficiency of the bulb is 2.5% and it is a point source.

Q40. Show that only an accelerated charge can produce an electromagnetic wave.

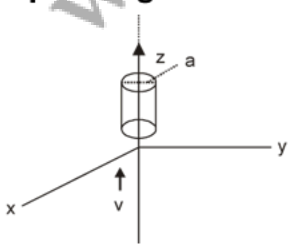
Q41. In a plane e.m. wave, oscillates with frequency 2.0×10^{10} Hz and the electric field of amplitude 48 V m^{-1}.

(a) What is the wavelength of a wave?

(b) What is the amplitude of the oscillating magnetic field?

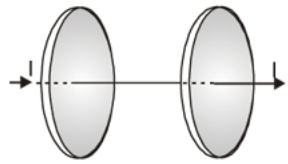
(c) Show that the average energy density of the *B* field. [$c = 3 \times 10^8$ ms^{-1}].

Q42. An infinitely long thin wire carrying a uniform linear static charge density λ is placed along the z-axis (in figure). The wire is set into motion along its length with a uniform velocity v-υk_z. C calculate the pointing vector $S = \frac{1}{\mu_0}(E \times B)$.



Q43. Green light of mercury has a wavelength 4.5×10^{-5} cm. (a) What is the frequency in MHz and period in μs in vacuum? (b) What is the wavelength in glass, if refractive index of glass is 1.5 ? Given, $c = 3 \times 10^8$ m s^{-1}.

Q44. Figure, shows a capacitor made of two circular plates, each of radius $R = 12$ cm, separated by $d = 10$ mm. The capacitor is being charged by an external source (not shown in figure). The charging current I is constant and equal to 0.2 A.



(a) Calculate the capacitance the rate of charge of potential difference between the plates.

(b) Obtain the displacement current across the plates.

(c) Is the Kirchhoff's rule valid at each plate of the capacitor?

Q45. Discuss Maxwell's modification of Ampere's law.

Q46. Suppose a parallel plate capacitor of plate area $4A$ is being charged. Show that the displacement current across the capacitor between the plates and parallel to it is equal to the conduction current in the connecting wires.

Q47. A electromagnetic wave has a wavelength 5.0×10^{-5} cm. (a) What is he frequency in MHz and period in μs in vacuum? (b) What is the wavelength in glass, if refractive index of glass is 1.5? Given, $c = 3 \times 10^8$ m s^{-1}.

Q48. Electromagnetic waves of frequency 5×10^{14} Hz are passed through a liquid. The wavelength of the waves in liquid is measured to be 4.5×10^{-7} m. Calculate

(a) the wavelength of e.m. waves in vacuum,

(b) velocity of e.m. waves in the liquid and

(c) refractive index of the liquid.

Given, velocity of e.m. waves in vacuum = 3×10^8 m s^{-1}.

Date: 21/10/2021

S1. Maxwell's equation for steady electric field are

(a) $\oint \vec{E}.\vec{dS} = \frac{q}{\varepsilon_0}$ (b) $\oint \vec{E}.\vec{dl} = 0$

S2. The modified Ampere's circuital law states that

$$\oint \vec{B}.\vec{dl} = \mu_0(I_C + I_D) = \mu_0\left(I_C + \varepsilon_0 \frac{d\phi_E}{dt}\right)$$

Here, the letters have their usual meanings.

S3. Amplitude of magnetic field of an electromagnetic wave in a vacuum,

$$B_0 = 510\, nT = 510 \times 10^{-9}\, \text{T}$$

Speed of light in a vacuum, $c = 3 \times 10^8$ m/s

Amplitude of electric field of the electromagnetic wave is given by the relation,

$$E = cB_0 = 3 \times 10^8 \times 510 \times 10^{-9} = 153 \text{ N/C}$$

Therefore, the electric field part of the wave is 153 N/C.

S4. The frequency of an electromagnetic wave produced by the oscillator is the same as that of a charged particle oscillating about its mean position *i.e.*, 10^9 Hz.

S5. The transverse time varying electric and magnetic fields propagating in space in a direction perpendicular to the directions of both the electric and magnetic fields are said to constitute electromagnetic waves.

S6. It is because, electric and magnetic fields constitute the electromagnetic waves.

S7. The speed of electromagnetic waves in free space is given by

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

where

μ_0 : is magnetic permibility in free space

ε_0 : is electric permibility in free space

S8. The electromagnetic wave travels in the direction given by $\vec{E} \times \vec{B}$. Therefore, the electric field ($\vec{E}$) and magnetic field ($\vec{B}$) vectors are directed along *X*- and *Y*-axis.

S9. (a) Electromagnetic waves propagate in the form a varying electric and magnetic fields, such that the two fields are perpendicular to each other and also to the direction of propagation of the wave. In other words, electromagnetic waves are transverse in nature.

(b) Electromagnetic waves are produced by accelerated charges.

S10. Mutually perpendicular.

S11. It will remain same.

S12. The frequency of electromagnetic waves produced by oscillating charge of frequency ν is also ν.

S13. Microwave.

S14. (a) All e.m. waves have transverse nature.

(b) All e.m. waves travel with the same speed, i.e., 3×10^8 ms^{-1} in vacuum.

S15. Electric and magneitc fields and with frequency 10 MHz.

S16.

$$\text{Wavelength} = \frac{c}{\nu} = \frac{3 \times 10^8}{3 \times 10^{10}} = 0.01\,\text{m}.$$

S17.

$$I_C = I_D = \frac{dq}{dt} = -2\pi q_0 \nu \sin 2\pi\nu t.$$

S18. On decreasing the frequency, reactance $X_C = \frac{1}{\omega C}$ will increase which will lead to decrease in conduction current. In this case $I_D = I_C$; hence displacement current will decrease.

S19. The electromagnetic wave travels in a vacuum along the z-direction. The electric field (E) and the magnetic field (H) are in the x-y plane. They are mutually perpendicular.

Frequency of the wave, $\nu = 30$ MHz $= 30 \times 10^6$ s^{-1}

Speed of light in a vacuum, $c = 3 \times 10^8$ m/s

Wavelength of a wave is given as:

$$\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{30 \times 10^6} = 10\,\text{m}.$$

S20. A radio can tune to minimum frequency, $\nu_1 = 7.5$ MHz $= 7.5 \times 10^6$ Hz

Maximum frequency, $\nu_2 = 12$ MHz $= 12 \times 10^6$ Hz

Speed of light, $c = 3 \times 10^8$ m/s

Corresponding wavelength for ν_1 can be calculated as:

$$\lambda_1 = \frac{c}{\nu_1} = \frac{3 \times 10^8}{7.5 \times 10^6} = 40\,\text{m}.$$

Corresponding wavelength for ν_2 can be calculated as:

$$\lambda_2 = \frac{c}{\nu_2} = \frac{3 \times 10^8}{12 \times 10^6} = 25\,\text{m}.$$

Thus, the wavelength band of the radio is 40 m to 25 m.

S21. The time constant of the CR circuit is $\tau = CR = 10^{-3}$ s. Then, we have

$$q(t) = CV[1 - \exp(-t/\tau)]$$
$$= 2 \times 10^{-9}[1 - \exp(-t/10^{-3})]$$

The electric field in between the plates at time t is

$$E = \frac{q(t)}{\varepsilon_0 A} = \frac{q}{\pi\varepsilon_0}; \quad A = \pi(1)^2 \text{ m}^2 = \text{area of the plates.}$$

Consider now a circular loop of radius $(1/2)$ m parallel to the plates passing through P. The magnetic field $\boldsymbol{B}$ at all points on the loop is along the loop and of the same value.

The flux Φ_E through this loop is

$$\Phi_E = E \times \text{area of the loop}$$
$$= E \times \pi \times \left(\frac{1}{2}\right)^2 = \frac{\pi E}{4} = \frac{q}{4\varepsilon_0}$$

The displacement current

$$i_d = \varepsilon_0 \frac{d\Phi_E}{dt} = \frac{1}{4}\frac{dq}{dt} = 0.5 \times 10^{-6} \exp(-1)$$

at $t = 10^{-3}$ s. Now, applying Ampere-Maxwell law to the loop, we get

$$B \times 2\pi \times \left(\frac{1}{2}\right) = \mu_0(i_c + i_d) = \mu_0(0 + i_d)$$
$$= 0.5 \times 10^{-6} \mu_0 \exp(-1)$$

or, $$B = 0.74 \times 10^{-13} \text{ T.}$$

S22.

$$E_0 = cB_0 = 3 \times 10^8 \times 1.6 \times 10^{-7} = 48 \text{ V m}^{-1},$$
$$\omega = 2\pi\nu = 2\pi \times 30 \times 10^6 = \mathbf{1.885 \times 10^8 \text{ rad s}^{-1}},$$

$$k = \frac{\omega}{c} = \frac{1.885 \times 10^8}{3 \times 10^8} = \mathbf{0.628 \text{ rad m}^{-1}}$$

and $$\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{30 \times 10^6} = \mathbf{10 \text{ m}}$$

S23. Given, $$\nu = 5 \times 10^{19} \text{ Hz}; c = 3 \times 10^8 \text{ m s}^{-1}$$

$$\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{5 \times 10^{19}} = 6 \times 10^{-12} \text{ m}$$

It follows that $\lambda = 6 \times 10^{-12}$ m corresponds to γ-rays.

For applications of γ-rays:

(a) γ-rays are used in radiotherapy. In hospitals, γ-rays are used to treat cancer and tumours.

(b) In food industry, soft γ-rays are used to kill microorganisms. It helps to preserve the foodstuffs for a prolonged time.

(c) γ-rays are used to produce nuclear reactions.

S24. Here, ν = 500 MHz = 500×10^6 Hz ; c = 3×10^8 m s^{-1}

Now, $$\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{500 \times 10^6} = 0.8 \text{ m}$$

S25. The e.m. spectrum consists of a number of distinct parts. But the radiation from all the parts possess the following common properties:

(a) They are transverse in nature.

(b) They do not require any material medium for propagation.

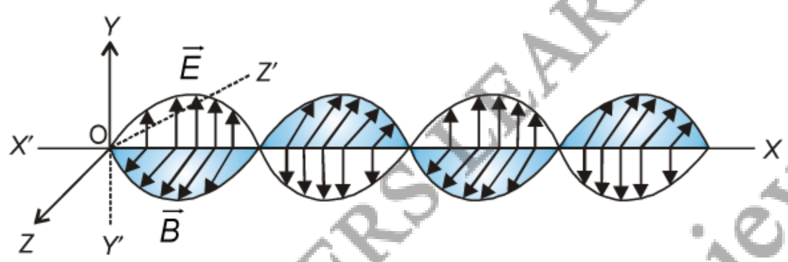
(c) They travel with the same speed of 3×10^8 m s^{-1} in the vacuum.

(d) They consist of mutually transverse varying electric and magnetic fields.

S26. (a) $\frac{E}{B} = c$, the speed of electromagnetic waves.

(b) In an electromagnetic wave propagating along Y-direction, the electric and magnetic field vectors vary sinusoldally along X-direction and Z-direction respectively.

S27.



S28. The total energy falling on the surface is

$$U = (18 \text{ W/cm}^2) \times (20 \text{ cm}^2) \times (30 \times 60)$$
$$= 6.48 \times 10^5 \text{ J} \qquad [\text{Time} = 30 \times 60 \text{ s, Area} = 20 \text{ cm}^2]$$

Therefore, the total momentum delivered (for complete absorption) is

$$p = \frac{U}{c} = \frac{6.48 \times 10^5 \text{ J}}{3 \times 10^8 \text{ m/s}} = 2.16 \times 10^{-3} \text{ kg m/s}$$

The average force exerted on the surface is

$$F = \frac{p}{t} = \frac{2.16 \times 10^{-3}}{0.18 \times 10^4} = 1.2 \times 10^{-6} \text{ N}$$

S29. Given, $\nu = 4 \times 10^{17}$ Hz; $c = 3 \times 10^8$ m s^{-1}

$$\lambda = \frac{3 \times 10^8}{4 \times 10^{17}} = 7.5 \times 10^{-10} \text{ m}$$

This wave length are show X-ray

(a) They are not deviated by electric and magnetic fields.

(b) They effect the photographic plate very intensely.

S30. Given $E_Y = 72 \sin [1.5 \times 10^3 x + 5 \times 10^{11} t]$ ...(i)

we know $E_Y = E_O \sin\left(\frac{x}{\lambda} + \frac{t}{T}\right)$ ...(ii)

compare the eq (i) *w.r.t.* (ii) we get

$$E_0 = 72 \text{ V m}^{-1}$$

Also, $B_0 = \frac{E_0}{c} = \frac{72}{3 \times 10^8} = \mathbf{2.4 \times 10^{-7} \ T}$

S31.

$$\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{3 \times 10^{10}} = \mathbf{10^{-2} \ m}$$

$$E_0 = c\,B_0 = 3 \times 10^8 \times 128 \times 10^{-9} = 38.4 \text{ V m}^{-1}$$

S32. Given $E = 6.3\hat{j}\ V/m$

$C = 2 \times 10^8 \text{ ms}^{-1}$

We have relation, $B = \frac{E}{C}$

$$B = \frac{6.3}{3 \times 10^8} = 2.1 \times 10^{-8} T$$

We have $\vec{E} = 6.3\hat{j}\ V/m$ i.e., it has direction along *y*-axis. wave is propagating along *x*-axis. As electromagnetic wave is propagating along *x*-axis. As electromagnetic wave is transverse in nature, it should be along *z*-axis.

Thus $\vec{B} = 2.1 \times 10^{-8}\ \hat{k}\ T$

S33. Formula for wavelength is

$$\lambda = \frac{c}{\nu}$$

(a) $\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{3 \times 10^{10}} = 10^{-2}\ m$

$\therefore$ $\lambda = 10^{-2}$ m

(b) $c = \frac{E_0}{B_0}$

or $E_0 = cB_0$

$= (3 \times 10^8) \times 10^{-7} = 30\ Vm^{-1}$

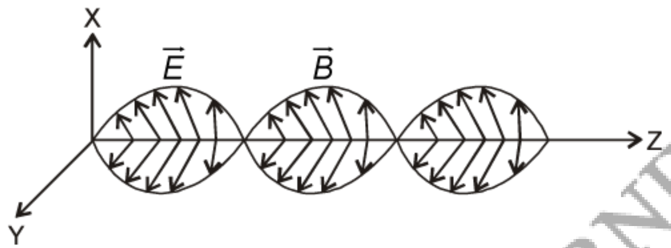
$$E_z = E_0 \sin 2\pi \left[\nu t + \frac{1}{\lambda} x \right] \quad \dots (i)$$

put the values in Eq. (i) we get

$$E_z = 30 \sin 2\pi\, [3 \times 10^{10} t + 100x]\ Vm^{-1} \quad \dots (ii)$$

S34. As the charge q moves accelerating, the electric and magnetic fields produced will change with space and time. E and B varying with time produce the other field B and E varying with time produce the other field B and E respectively and sustain the E.M. Pattern. This is from the interpretation of Maxwell supported by

$$\int \vec{E}.\vec{dl} = \frac{d\phi_B}{dt} \text{ and } \oint \vec{B}.\vec{dl} = \mu_0 I + \mu_0 I_d$$



S35. Given radiant flux density, $S = \frac{1}{2c\mu_0} E_0^2$

Average radiant flux density is S_{av} is given by

$$S_{av} = c^2 \varepsilon_0 \left| E_0 \times B_0 \right| \frac{1}{T} \int_0^T \cos^2 (kx - \omega t) dt \text{ as}$$

$$S = c^2 \varepsilon_0 (E \times B)$$

$$= c^2 \varepsilon_0 E_0 B_0 \frac{1}{T} \times \frac{T}{2}$$

$$= c^2 \varepsilon_0 E_0 B_0 \left(\frac{E_0}{B_0} \right) \times \frac{1}{2} \qquad \left(\text{as } c = \frac{E_0}{B_0} \right)$$

$$= \frac{1}{2} \varepsilon_0 E_0^2 c$$

$$= \frac{E_0^2}{2\mu_0 c} \text{ as } \left(c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} \right)$$

S36. Electric field amplitude, $E_0 = 120$ N/C

Frequency of source, $\nu = 50.0 \text{ MHz} = 50 \times 10^6$ Hz

Speed of light, $c = 3 \times 10^8$ m/s

(a) Magnitude of magnetic field strength is given as:

$$B_0 = \frac{E_0}{c} = \frac{120}{3 \times 10^8} = 4 \times 10^{-7} = 400\ nT$$

Angular frequency of source is given as:

$$\omega = 2\pi\nu$$
$$= 2\pi \times 50 \times 10^6$$
$$= 3.14 \times 10^8 \text{ rad/s}$$

Propagation constant is given as:

$$k = \frac{\omega}{c} = \frac{3.14 \times 10^8}{3 \times 10^8} = 1.05 \text{ rad/m}$$

Wavelength of wave is given as:

$$B_0 = \frac{c}{\nu} = \frac{3 \times 10^8}{50 \times 10^8} = 6.0 \text{ m}$$

(b) Suppose the wave is propagating in the positive *x*-direction. Then, the electric field vector will be in the positive *y*-direction and the magnetic field vector will be in the positive *z*-direction. This is because all three vectors are mutually perpendicular.

Equation of electric field vector is given as:

$$\vec{E} = E_0 \sin (kx - \omega t)\ \hat{j}$$
$$= 120 \sin [1.05 x - 3.14 \times 10^8 t]\ \hat{j}$$

And, magnetic field vector is given as:

$$\vec{B} = B_0 \sin (kx - \omega t)\ \hat{k}$$
$$\vec{B} = (4 \times 10^{-7}) \sin [1.05 x - 3.14 \times 10^8 t]\ \hat{k}\ .$$

S37. Frequency of the electromagnetic wave,

$\nu = 2.0 \times 10^{10}$ Hz

Electric field amplitude, $E_0 = 48 \text{ V m}^{-1}$

Speed of light, $c = 3 \times 10^8$ m/s

(a) Wavelength of a wave is given as:

$$\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{2 \times 10^{10}} = 0.015 \text{ m.}$$

(b) Magnetic field strength is given as:

$$B_0 = \frac{E_0}{c} = \frac{48}{3 \times 10^8} = 1.6 \times 10^{-7}\,\text{T}$$

(c) Energy density of the electric field is given as:

$$U_E = \frac{1}{2}\varepsilon_0 E^2$$

And, energy density of the magnetic field is given as:

$$U_R = \frac{1}{2\mu_0} B^2$$

Where, ε_0 = Permittivity of free space

μ_0 = Permeability of free space

We have the relation connecting E and B as:

$$E = cB \quad \text{... (i)}$$

Where, $$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} \quad \text{... (ii)}$$

Putting Eq. (ii) in Eq. (i), we get

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

Squaring both sides, we get

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

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

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

$\Rightarrow$ $$U_E = U_B.$$

S38. (a) From the given electric field vector, it can be inferred that the electric field is directed along the negative x-direction. Hence, the direction of motion is along the negative y-direction *i.e.*, $-\hat{j}$.

(b) It is given that,

$$\vec{E} = 3.1\,\text{N/C} \cos[(1.8\,\text{rad/m})\,y + (5.4 \times 10^8\,\text{rad/s})\,t]\,\hat{i} \quad \text{... (i)}$$

The general equation for the electric field vector in the positive x-direction can be written as:

$$\vec{E} = E_0 \sin(kx - \omega t)\,\hat{i} \quad \text{... (ii)}$$

On comparing Eqs. (i) and (ii), we get

Electric field amplitude, $E_0 = 3.1$ N/C

Angular frequency, $\nu = 5.4 \times 10^8$ rad/s

Wave number, $k = 1.8$ rad/m

Wavelength, $\lambda = \frac{2\pi}{1.8} = 3.490$ m

(c) Frequency of wave is given as:

$$\nu = \frac{\omega}{2\pi} = \frac{5.4 \times 10^8}{2\pi} = 8.6 \ \ 10^7 \text{ Hz}$$

(d) Magnetic field strength is given as:

$$B_0 = \frac{E_0}{c}$$

Where, c = Speed of light = 3×10^8 m/s

$\therefore$ $B_0 = \frac{3.1}{3 \times 10^8} = 1.03 \times 10^{-7}$ T

(e) On observing the given vector field, it can be observed that the magnetic field vector is directed along the positive z-direction. Hence, the general equation for the magnetic field vector is written as:

$$\vec{B} = B_0 \cos(kx - \omega t)\,\hat{k}$$

$$= \{(1.03 \times 10^{-7} \text{ T}) \cos [(1.8 \text{ rad/m})\, y + (5.4 \times 10^6 \text{ rad/s})\, t]\}\,\hat{k}\,.$$

S39. The bulb, as a point source, radiates light in all directions uniformly. At a distance of 3 m, the surface area of the surrounding sphere is

$$A = 4\pi r^2 = 4\pi (3)^2 = 113 \text{ m}^2$$

The intensity at this distance is

$$I = \frac{\text{Power}}{\text{Area}} = \frac{100 \text{ W} \times 2.5\%}{113 \text{ m}^2} = 0.022 \text{ W/m}^2$$

Half of this intensity is provided by the electric field and half by the magnetic field.

$$\frac{1}{2} I = \frac{1}{2}(\varepsilon_0 E^2_{\text{r.m.s}} C)$$

$$= \frac{1}{2}(0.022 \text{ W/m}^2)$$

$$E_{\text{r.m.s.}} = \sqrt{\frac{0.022}{(8.85\times10^{-12})(3\times10^{8})}}\ \text{V/m} = 2.9\ \text{V/m}$$

The value of E found above is the root mean square value of the electric field. Since the electric field in a light beam is sinusoidal, the peak electric field, E_0 is

$$E_0 = \sqrt{2}\,E_{\text{r.m.s.}} = \sqrt{2}\times 2.9\ \text{V/m} = 4.07\ \text{V/m}$$

Now, let us calculate the strength of the magnetic field. It is

$$B_{\text{r.m.s.}} = \frac{E_{\text{r.m.s}}}{c} = \frac{2.9\ \text{Vm}^{-1}}{3\times10^{8}\ \text{ms}^{-1}} = 9.6\times10^{-9}\,\text{T}$$

Again, since the field in the light beam is sinusoidal, the peak magnetic field is

$$B_0 = \sqrt{2}\,B_{\text{r.m.s.}} = 1.4\times10^{-8}\,\text{T}.$$

S40. A stationary charge produces only an electric field around it. when a charge moves with a constant velocity it produces a constant magnetic field in addition to the electric field. As the charge is accelerated, both electric and magnetic fields change with time and space. one become the source of the other, thus giving electromagnetic waves.

S41. Given $\nu = 2.0 \times 10^{10}$ Hz; $E_0 = 48$ Vm^{-1} and c = 3×10^{8} ms^{-1}

(a) $$\lambda = \frac{c}{\nu} = \frac{3\times10^{8}}{2.0\times10^{10}} = 1.5 \times 10^{-2}\ \text{m}$$

(b) $$B_0 = \frac{E_0}{c} = \frac{48}{3\times10^{8}} = 1.6 \times 10^{-7}\ \text{T}$$

(c) $$u_E = \frac{1}{2}\varepsilon_0 E^2 = \frac{1}{2}(8.854\times10^{-12})\times(48)^2$$
$$= 1.02\times10^{-8}$$

$$u_B = \frac{1}{2\mu_0}B^2 = \frac{1}{2}\frac{(1.6\times10^{-7})^2}{4\pi\times10^{-7}} = 1.02\times10^{-8}$$

$$u_E = u_B$$

S42. $$E = \frac{\lambda \hat{e}_s}{2\pi\varepsilon_0 a}\hat{j}$$

$$B = \frac{\mu_1 i}{2\pi a} i = \frac{\mu_0 \lambda \nu}{2\pi a}$$

$$S = \frac{1}{\mu_0}(E\times B)$$

$$= \frac{1}{\mu_0}\left(\frac{\lambda\,\hat{j}_s}{2\pi\varepsilon_0 a}\hat{j}\times\frac{\mu_0\lambda\nu}{2\pi a}\hat{i}\right) = \frac{-\lambda^2\nu}{4\pi^2\varepsilon_0 a^2}\hat{k}$$

S43. Here, wavelength, $\lambda = 4.5 \times 10^{-5}$ cm $= 4.5 \times 10^{-7}$ m

velocity of light, $c = 3 \times 10^{8}$ m s^{-1}

(a) If ν is the frequency, then

$$\nu = \frac{c}{\lambda} = \frac{3 \times 10^8}{4.5 \times 10^{-7}} = 6.67 \times 10^{14} \text{ Hz}$$

$$= 6.67 \times 10^{8} \text{ MHz}$$

Time period, $$T = \frac{1}{\nu} = \frac{1}{6.67 \times 10^{14}}$$

$$= 1.15 \times 10^{-15} \text{ s} = 1.5 \times 10^{-9}\ \mu\text{s}$$

(b) Now, refractive index,

$$\mu = \frac{\text{velocity of light in vacuum}}{\text{velocity of light in glass}} = \frac{c}{v}$$

Therefore, velocity of light in glass,

$$v = \frac{c}{\mu} = \frac{3 \times 10^8}{1.5} = 2 \times 10^8 \text{ ms}^{-1}$$

The wavelength of light in glass,

$$\lambda' = \frac{v}{\nu} = \frac{2 \times 10^8}{5.45 \times 10^{14}}$$

$$\mathbf{= 3.67 \times 10^{-7}\ m}$$

Note: The, wavelength of light in glass can also be determined by using the relation $\lambda' = \lambda/\mu$

S44. (a) $$C = \frac{\varepsilon_0 A}{d}$$

Here, $A = \pi(0.12)^2$, $d = 10$ mm $= 10 \times 10^{-3}$ m

$$\therefore \quad C = \frac{8.85 \times 10^{-12} \times \pi \times (0.12)^2}{10 \times 10^{-3}} \text{F}$$

$$= 4.0 \times 10^{-11} \text{ F} = 0.4 \text{ pF}$$

$$Q = VC$$

$$\therefore \quad \frac{dV}{dt} = \frac{1}{C}\frac{dQ}{dt} = \frac{I}{C} = \frac{0.2}{4.0 \times 10^{-12}} = 5 \times 10^{10} \text{ V/s}$$

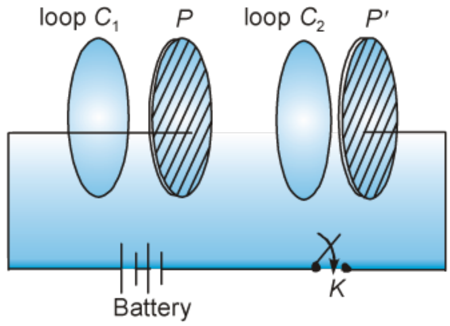
(b) $$I_d = C\frac{dV}{dt} = I \text{ (charging current)}$$

$$= 0.2 \text{ A.}$$

(c) Yes, Kirchhoff's first rule is valid at each plate of the capacitor.

S45. According to Ampere's circuit law, the line integral of the magnetic field B along a closed loop C is proportional to the current enclosed by the loop, *i.e.*

$$\oint_C \vec{B} \cdot \vec{dl} = \mu_0 I$$



As shown in figure, let us consider the charging of a capacitor when it is connected to a battery. Consider two loops C_1 and C_2 as shown in figure. Ampere's circuital law for loop C_1 is given by

$$\oint_{C_1} \vec{B} \cdot \vec{dl} = \mu_0 I \qquad \text{... (i)}$$

where I is the conduction current enclosed by loop C_1, and passing through the wire during the charging process.

Ampere's circuit law for loop C_2 is given by

$$\oint_{C_2} \vec{B} \cdot \vec{dl} = 0 \qquad \text{... (ii)}$$

Since no conduction current is enclosed by loop C_2 as it is inside the plates of capacitor. Eqs. (i) and (ii) contradict each other because if we consider the loops to be infinitesimally closed to each other (just on the opposite sides of the plates of the capacitor) then we must have

$$\oint_{C_1} \vec{B} \cdot \vec{dl} = d \oint_{C_2} \vec{B} \cdot \vec{dl}$$

Therefore, Maxwell felt the need of modifying Ampere's law. by arguing that a changing magnetic field induces an electric field (Faraday's law), hence a changing electric field must induce a magnetic field, Maxwell introduced the concept of *displacement current* which rise due to a changing electric field in between the plates of the capacitor. He Modified Ampere's circuital law as

$$\oint \vec{B} \cdot \vec{dl} = \mu_0 \left[I + \varepsilon_0 \frac{d\phi_E}{dt} \right] = \mu_0 (I + I_d)$$

where ϕ_E is the electric flux and I_d the displacement current. Thus,

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

Thus, together with conduction current, the displacement current satisfies the property of continuity.

S46. During the process of charging of the capacitor, if Q is the charge on the plates at any instant, the electric field between the plates is given by

$$E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{\varepsilon_0 A}$$

where σ is the surface charge density and A the area of the plates.

Therefore, electric flux through the plates is

$$\phi_E = EA = \frac{Q}{\varepsilon_0 A} \times 4A = \frac{4Q}{\varepsilon_0}$$

$\therefore$ Displacement current $I_d = \varepsilon_0 \frac{d\phi_E}{dt}$ is given by

$$I_d = \frac{d}{dt}\left(\frac{4Q}{\varepsilon_0}\right) = 4\frac{dQ}{dt}$$

But d is the rate of flow of charge through the connecting wire *i.e.* it is conduction current I_c. Therefore

$$I_d = 4I_c$$

S47. Here, wavelength, $\lambda = 5.0 \times 10^{-5}$ cm $= 5.0 \times 10^{-7}$ m

velocity of light, $c = 3 \times 10^8$ m s^{-1}

(a) If ν is the frequency, then

$$\nu = \frac{c}{\lambda} = \frac{3 \times 10^8}{5.0 \times 10^{-7}} = 6.0 \times 10^{14} \text{ Hz} = 6.0 \times 10^8 \text{ MHz}$$

Time period, $T = \frac{1}{\nu} = \frac{1}{6.0 \times 10^{14}} = 1.67 \times 10^{-15}$ s $=$ $\mathbf{1.67 \times 10^{-9}}$ **μs**

(b) Now, refractive index,

$$\mu = \frac{\text{velocity of light in vacuum}}{\text{velocity of light in glass}} = \frac{c}{v}$$

Therefore, velocity of light in glass,

$$v = \frac{c}{\mu} = \frac{3 \times 10^8}{1.5} = 2 \times 10^8 \ m\, s^{-1}$$

The wavelength of light in glass,

$$\lambda' = \frac{\lambda}{\mu} = \frac{5.0 \times 10^{-7}}{1.5} = \mathbf{3.3 \times 10^{-7} \ m}$$

Note: The, wavelength of light in glass can also be determined by using the relation, $\lambda' = \lambda/\mu$

S48. Given

$$\nu = 5 \times 10^{14} \text{Hz}$$

$$\lambda = 4.5 \times 10^{-7} \text{ m}$$

$$c = 3 \times 10^{8} \text{ ms}^{-1}$$

(a) $\lambda_{vacuum} = \frac{c}{\nu} = \frac{3 \times 10^8}{5 \times 10^{14}} = \mathbf{6 \times 10^{-7}\,m}$

(b) $\nu = \nu\, \lambda_{liquid} = 5 \times 10^{14} \times 4.5 \times 10^{-7}$

$= 2.25 \times 10^{8} \text{ m s}^{-1}$

(c) $\mu = \frac{c}{\nu} = \frac{3 \times 10^8}{2.25 \times 10^8} = \mathbf{1.33}$

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Q1. What is electromagnetic spectrum?

Q2. The wavelength of electromagnetic radiation is doubled. What will happen to the energy of the photon?

Q3. Name the physical quantity, which remains same for microwaves of wavelength 1 mm and UV radiations of 1,600 Å in vacuum.

Q4. Give the ratio of velocities of light rays of wavelengths 4,000 Å and 8,000 Å in vacuum.

Q5. Some scientists have predicted that a global nuclear war on the Earth would be followed by a severe 'nuclear winter' with a devastating effect on life on Earth. What might be the basis of this prediction?

Q6. If the Earth did not have an atmosphere, would its average surface temperature be higher or lower than what it is now?

Q7. The small ozone layer on top of the stratosphere is crucial for human survival. Why?

Q8. Optical and radio telescopes are built on the ground but X-ray astronomy is possible only from satellites orbiting the Earth. Why?

Q9. It is necessary to use satellites for long distance TV transmission. Why?

Q10. Long distance radio broadcasts use short-wave bands. Why?

Q11. Which of the following belong to the electromagnetic spectrum:
α-rays, β-rays, γ-rays, cathode rays, X-ray, ultra-violet rays, microwaves, ultrasonic waves, radio-waves, infra-red rays? Arrange them in order of increasing frequency.

Q12. Name any six electromagnetic waves in increasing order of their frequencies.

Q13. Which of the following has shortest wave-length? *X*-rays, microwaves and ultra-violet rays.

Q14. Rewrite the following radiations in a descending order of wavelength values: Infra-red rays, radio-waves, γ-rays, microwaves.

Q15. Write the following radiations in an ascending order in respect of their frequencies: *X*-rays, microwaves, ultra-violet rays and radio-waves.

Q16. Arrange the given electromagnetic radiations in the descending order of their frequencies: Infra-red, *X*-rays, ultra-violet and gamma rays.

Q17. Arrange the following electromagnetic radiations in the ascending order of their frequencies: (a) Microwaves, (b) Radio-waves, (c) *X*-rays, (d) Gamma rays.

Q18. Which of the following has shortest frequency – Microwaves, X-rays, Ultraviolet rays?

Q19. Which of the following has shortest wavelength – Radio waves, red light, Ultraviolet rays?

Q20. Which of the following has shortest frequency? *X*-rays, microwaves and ultra-violet rays.

Q21. Write the following radiations in a descending order of frequencies : red light, *X*-rays, microwaves, radio-waves.

Q22. Arrange the following radiation in the descending order of wavelength: *X*-ray, infra-red ray red light, yellow light, radio waves.

Q23. Name the part of electromagnetic spectrum, whose wavelength lies in the range of 10^{-10} m. Give its one use.

Q24. Write the frequency limit of visible range of electromagnetic spectrum kHz.

Q25. What are microwaves?

Q26. Name the electromagnetic radiation to which waves of wavelength in the range of 10^{-2} m belong. Give one use of this part of electromagnetic spectrum.

Q27. Write two applications of microwaves.

Q28. Which part of the electromagnetic spectrum is used in operating a RADAR?

Q29. Microwaves are used in RADER. Why?

Q30. Name the part of electromagnetic spectrum of wavelength 10^{-2} m and mention its one application.

Q31. State two applications of infra-red radiations.

Q32. Name the electromagnetic radiation used for viewing objects through haze and fog.

Q33. What is the ratio of speed of infra-red rays and ultra-violet rays in vacuum?

Q34. State two applications of ultra-violet radiations.

Q35. How does the frequency of a beam of ultra-violet light change, when it goes from air into glass?

Q36. Name the electromagnetic waves that have frequencies greater than those of ultra-violet light but less than those of gamma rays.

Q37. Name one method each for the (a) production and (b) detection of *X*-rays.

Q38. Write two properties of gamma (γ) rays.

Q39. What is the ratio of speed of gamma rays and radio-waves in vacuum?

Q40. Radio-waves and gamma rays both are transverse in nature and electromagnetic in character and have the same speed in vacuum. In what respects are they different.

Q41. Which part of electromagnetic spectrum has largest penetrating power?

Q42. Name the electromagnetic waves, which (a) maintain the Earth's warmth and (b) are used in aircraft navigation.

Q43. How are infra-red waves produced? What is the range of their wavelength?

Q44. How are radio-waves produced?

Q45. How are *X*-rays produced?

Q46. How are microwaves produced?

Q47. Write two uses of microwaves.

Q48. Write two uses of infra-red rays.

Q49. Write two uses of X-rays.

Q50. Which part of electromagnetic spectrum has largest penetrating power?

Q51. Which part of electromagnetic spectrum is absorbed from sunlight by ozone layer?

Q52. Name the part of electromagnetic spectrum whose wavelength lies in the range of 10^{-10} m. Give its one use.

Q53. Which part of electromagnetic spectrum is used in radar systems?

Q54. Name the electromagnetic radiation to which waves of wavelength in the range of 10^{-2} m belong. Give one use of this part of EM spectrum.

Q55. Name the electromagnetic radiation used to destroy cancer cells and write its frequency range.

Q56. Arrange the following in descending order of wavelength:
***X*-ray, Radio-wave, Blue light, Infra-red light.**

Q57. Name the EM waves used for studying crystal structure of solids. What is its frequency range?

Q58. Name the electromagnetic radiations which are produced when high energy electrons are bombarded on a metal target.

Q59. Why is shortwave band used for long distance radio broadcast?

Q60. Why does microwave oven heats up a food item containing water molecules most efficiently?

Q61. Why is the orientation of the portable radio with respect to broadcasting station important?

Q62. What physical quantity is the same for X-rays of wavelength 10^{-10} m, red light of wavelength 6800 Å and radio-waves of wavelength 500 m?

Q63. What is the approximate wavelength of *X*-rays?

Q64. About 5% of the power of a 100 W light bulb is converted to visible radiation. What is the average intensity of visible radiation (a) at a distance of 1 m from the bulb? (b) at a distance of 10 m? Assume that the radiation is emitted isotropically and neglect reflection.

Q65. Use the formula $\lambda_m T = 0.29$ cm K to obtain the characteristic temperature ranges for different parts of the electromagnetic spectrum. What do the numbers that you obtain tell you?

Q66. Name the part of the electromagnetic spectrum, which is suitable for
(a) radar system used in aircraft navigation.
(b) treatment of cancer tumors.

Q67. Identify the part of the electromagnetic spectrum, which is
(a) suitable for radar system used in aircraft navigation.
(b) adjacent to the low frequency end of the electromagnetic spectrum.
(c) produced in nuclear reaction.
(d) Produced by bombarding a metal target by high speed electrons.

Q68. What are microwaves? Write their two uses.

Q69. How are infrared waves produced? why are these referred to as 'heat waves? Write their one important use?

Q70. Give one use of each of the following:
(a) infra-red rays (b) gama rays (c) microwaves and (d) ultraviolet radiations.

Q71. Identify the following electromagnetic radiations as per the wavelengths given below. Write on application of each.
(a) 10^{-3} nm (b) 10^{-3} (c) 1 m

Q72. Identify the type of electromagnetic waves, whose method of production is associated with (a) a klystron valve, (b) vibration of atoms and molecules and (c) decay of atomic nuclei. Also give the approximate range of wavelengths of each of these waves.

Q73. Find the wavelength of electromagnetic waves of frequency 6×10^{12} Hz in free space. Given its two applications.

Q74. How are infrared waves produced? Why are these referred to as 'heat waves'? Write their one important use.

Q75. The magnetic field in a plane electromagnetic wave is given by

$$B_y = 2 \times 10^{-7} \sin(0.5 \times 10^3 x + 1.5 \times 10^{11} t) T.$$

Q76. Given below are some famous numbers associated with electromagnetic radiations in different contexts in physics. State the part of the electromagnetic spectrum to which each belongs.
(a) 21 cm (wavelength emitted by atomic hydrogen in interstellar space).
(b) 1057 MHz (frequency of radiation arising from two close energy levels in hydrogen; known as Lamb shift).
(c) 2.7 K [temperature associated with the isotropic radiation filling all space-thought to be a relic of the 'big-bang' origin of the universe].
(d) 5890 Å – 5896 Å [double lines of sodium]
(e) 14.4 keV [energy of a particular transition in ^{57}Fe nucleus associated with a famous high resolution spectroscopic method (Mössbauer spectroscopy)].

Q77. The terminology of different parts of the electromagnetic spectrum is given in the text. Use the formula $E = h\nu$ (for energy of a quantum of radiation: photon) and obtain the photon energy in units of eV for different parts of the electromagnetic spectrum. In what way are the different scales of photon energies that you obtain related to the sources of electromagnetic radiation?

Q78. Identify the following electromagnetic radiations as per the frequencies given below. write one application of each.
(a) 10^{20} Hz (b) 10^{9} Hz (c) 10^{11} Hz

Q79. Identify the following electromagnetic. radiations as per the wavelengths given below. Write one application of each.

(a) 1 mm (b) 10^{-12} m (c) 10^{-8} nm

Q80. Name the following constituent radiation as of electromagnetic spectrum which

(a) Produce intense heating effect.

(b) is absorbed by the ozone layer in the atmosphere.

(c) is used for studying crystal structure.

Q81. Write the order of frequency range and one use of each of the following electromagnetic radiations.

(a) Microwaves (b) Ultra-violet rays (c) Gamma rays.

Q82. Given reasons for the following :

(a) Long distance radio broadcasts use short wave bands.

(b) The small ozone layer on top of the stratosphere is crucial for human survival.

(c) Satellites are used for long distance TV transmission

Q83. Name the radiations of electromagnetic spectrum which are used in

(a) warfare to look through fog.

(b) radar and geostationary satellites.

(c) studying the structure and properties of atoms and molecules.

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S1. The orderly distribution of electromagnetic waves in the form of distinct groups having widely differing properties is called electromagnetic spectrum.

S2. The frequency and hence energy will become half, when the wavelength of the electromagnetic radiation is doubled, Hence energy get halfed.

S3. Speed.

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

where
μ_0 : is magnetic permibility in free space
ε_0 : is electric permibility in free space

S4. The velocity of light rays of different wavelengths in vacuum is same and hence the ratio of their velocities is 1.

S5. A global nuclear war on the surface of the Earth would have disastrous consequences. Post-nuclear war, the Earth will experience severe winter as the war will produce clouds of smoke that would cover maximum parts of the sky, thereby preventing solar light form reaching the atmosphere. Also, it will lead to the depletion of the ozone layer.

S6. In the absence of an atmosphere, there would be no greenhouse effect on the surface of the Earth. As a result, the temperature of the Earth would decrease rapidly, making it chilly and difficult for human survival.

S7. The small ozone layer on the top of the atmosphere is crucial for human survival because it absorbs harmful ultraviolet radiations present in sunlight and prevents it from reaching the Earth's surface.

S8. With reference to X-ray astronomy, X-rays are absorbed by the atmosphere. However, visible and radio waves can penetrate it. Hence, optical and radio telescopes are built on the ground, while X-ray astronomy is possible only with the help of satellites orbiting the Earth.

S9. It is necessary to use satellites for long distance TV transmissions because television signals are of high frequencies and high energies. Thus, these signals are not reflected by the ionosphere. Hence, satellites are helpful in reflecting TV signals. Also, they help in long distance TV transmissions.

S10. Long distance radio broadcasts use shortwave bands because only these bands can be refracted by the ionosphere.

S11. The following belong to electromagnetic spectrum and are arranged in order of their increasing frequency:

Radio-waves, microwaves, infra-red rays, ultra-violet rays, X-rays and γ-rays.

S12. Radio-waves, infra-red rays, visible light, ultra-violet rays, X-rays and γ-rays.

S13. *X*-rays.

S14. Radio waves, microwaves, infra-red rays and γ-rays.

S15. Radio-waves, microwaves, ultra-violet rays and X-rays.

S16. Gamma rays. X-rays, ultra-violet and infra-red.

S17. Radio-waves, microwaves, X-rays and gamma rays.

S18. Microwaves.

S19. Ultraviolet rays.

S20. Microwaves.

S21. X-rays, red light, microwaves, and radio-waves.

S22. Radio waves, infra-red ray, red light, yellow light, X-ray.

S23. X-rays.

They are used in hospitals to diagnose the diseases.

S24. The frequency range of visible spectrum is 4×10^{11} kHz to 7.7×10^{11} kHz.

The corresponding wavelength range of visible part of visible part of electromagnetic spectrum is 3,900 Å to 7,600 Å.

S25. The microwaves are radio-waves of comparatively smaller wavelength and are produced by oscillating electric circuits. They are part of electromagnetic spectrum.

S26. Microwaves. They are used in RADAR.

S27. (a) Microwaves are used in radar systems .

(b) Microwaves are used in long distance telephone communication systems.

S28. Microwaves.

S29. Microwaves are e.m. waves of very short wave-length. Such waves are used in RADAR due to the reason that they can travel in a particular direction in the form of a beam.

S30. Microwaves.

Such waves are used in RADAR.

S31. (a) Infra-red rays from the sun keep the earth warm and hence help to sustain life on earth.

(b) The coal deposits in the interior of earth are the result of conversion of forest wood into coal due to infra-red rays.

S32. Infra-red rays.

S33. It is 1.

S34. (a) Ultra-violet rays are electromagnetic waves and travel with the speed of 3×10^8 m s^{-1}.

(b) They can also obey the laws of reflection and refraction.

S35. There is no effect on the frequency of ultra-violet light.

S36. *X*-rays.

S37. (a) *X*-ray tube (b) Photographic plate.

S38. (a) γ-rays are electromagnetic waves and have velocity equal to that of light.

(b) γ-rays are highly penetrating. They can penetrate through several centimetres thick iron and lead blocks.

S39. It is 1.

S40. The radio-waves have atomic orgin, while the γ-rays are of nuclear origin. Further, owing to their very small wave length, γ-rays are highly penetrating in comparison to radio-waves.

S41. Gamma rays.

S42. (a) Infrared (b) Microwaves

S43. Infrared range are produced by hot bodies due to the vibrations of the atoms and molecules. Their wavelength ranges from 1 mm to 700 nm.

S44. By rapid acceleration and deceleration of electrons in conducting wires.

S45. By bombarding a metal target by high energy electrons.

S46. Microwaves are produced by specical vacuum tubes like klystrons, magnetrons and Gunn diodes.

S47. (a) In radar system for aircraft navigation (b) Microwaves ovens are used for cooking.

S48. (a) In electronic devices (b) Infrared lamps are used in physical therapy.

S49. (a) *X*-ray are used as a diagnostic tool in medicine

(b) In the treatment of certain forms of cancer.

S50. (a) γ-rays

S51. Ultraviolet rays

S52. Gamma rays

Use: In radiotherapy for the treatment of malignant tumours.

S53. Microwaves

S54. Micro-waves—Cooking food containing water.

S55. Gamma rays

Frequency range 3×10^{19} Hz to 5×10^{20} Hz

S56. Radiowaves > Infrared light > Blue light > X-rays.

S57. X-ray. Frequency range 10^{17} to 10^{20} Hz.

S58. X-rays.

S59. Short waves are used in long distance broadcast becuase they are relfected by the ionosphere back ot the surface of the earth. This way long distance can be reached.

S60. Frequency of the microwave matches the resonant frequency of water molecules.

S61. As electromagnetic wave are plane polarised, so the receiving antenna should be parallel to electric/magnetic part of the wave.

S62. The speed of light in vacuum is same for all. It is equal to 3×10^8 ms^{-1}.

S63. Wavelength of X-rays is approximately 1Å.

S64. Power rating of bulb, $P = 100$ W

It is given that about 5% of its power is converted into visible radiation.

Power of visible radiation,

$$P' = \frac{5}{100} \times 100 = 5\,\text{W}$$

Hence, the power of visible radiation is 5 W.

(a) Distance of a point from the bulb, $d = 1$ m

Hence, intensity of radiation at that point is given as:

$$I = \frac{\text{Power}}{\text{Area}} = \frac{P'}{4\pi d^2}$$

$$= \frac{5}{4\pi(1)^2} = 0.398\ \text{W/m}^2$$

(b) Distance of a point from the bulb, $d_1 = 10$ m

Hence, intensity of radiation at that point is given as:

$$I = \frac{P'}{4\pi(d_1)^2}$$

$$= \frac{5}{4\pi(10)^2} = 0.00398 \text{ W/m}^2.$$

S65. A body at a particular temperature produces a continous spectrum of wavelengths. In case of a black body, the wavelength corresponding to maximum intensity of radiation is given according to Planck's law. It can be given by the relation,

$$\lambda_m = \frac{0.29}{T} \text{ cm K}$$

Where, λ_m = maximum wavelength

T = temperature

Thus, the temperature for different wavelengths can be obtained as:

For $\lambda_m = 10^{-4}$ cm; $T = \frac{0.29}{6^{-4}} = 2900\ °K$

For $\lambda_m = 5 \times 1\ 0^{-5}$ cm; $T = \frac{0.29}{5 \times 6^{-5}} = 5800\ °K$

For $\lambda_m = 10^{-6}$ cm; and so on. $T = \frac{0.29}{6^{-6}} = 290000\ °K$

The numbers obtained tell us that temperature ranges are required for obtaining radiations in different parts of an electromagnetic spectrum. As the wavelength decreases, the corresponding temperature increases.

S66. (a) Microwaves (b) γ-rays

S67. (a) Microwaves (b) Rad

(c) γ- rays (d) X-rays

S68. Microwaves are electromagnetic in nature and their wavelength ranges from 10^{-3} m to about 1 m.

Uses: 1. Microwaves are used in radars.

2. They are used in the study of atomic and molecular structure.

S69. Infra-red rays are produced due to the de-excitation of atoms. They are also emitted by the hot bodies.

Since infra-red rays produce heat on falling on matter, these rays are referred to as 'heat waves'.

Infra-red rays are used in solar water heaters or cookers and to take photographs during the conditions of fog, smoke, etc.

S70. (a) Infra-red rays photographs are used for weather forecasting.

(b) Gamma rays are used in nuclear reactions.

(c) Microwaves are used in RADAR.

(d) Ultra-violet rays used for sterilizing surgical instruments.

S71. (a) **γ-rays:** These rays are used in radiotherapy. In hospitals, γ-rays are used to treat cancer and tumors.

(b) **Microwaves:** They are used RADAR

(c) **Infra-red rays:** They are used for viewing objects through haze and fog.

S72. (a) **Microwaves:** The wavelength range is 10^{-3} m to 1 m.

(b) **Infra-red rays:** The wavelength range is 8×10^{-9} m to 3×10^{-3} m.

(c) **Gama rays:** The wavelength range is 6×10^{-3} m to 10^{-11} m.

S73. Here, $\nu = 6 \times 10^{12}$ Hz; $c = 3 \times 10^{8}$ m s^{-1}

$$\therefore \quad \lambda = \frac{3 \times 10^8}{6 \times 10^{12}} = 7.5 \times 10^{-5} \text{ m}$$

It follows that $\lambda = 5 \times 10^{-5}$ m corresponds to infra-red rays.

Applications of X-ray: X-rays have been found to be of great use in variety of fields as listed below:

(a) **Surgery:** *X*-rays are used in surgery for the detection of fractures, diseased organs, foreign matter like bullets and formation of bones or stones in the human body and observing the progress of healing bones. They are also used to diagnose the diseases.

(b) **Radiotherapy:** Controlled *X*-ray exposures are used to cure untraceable skin diseases and malignant growths. Soft *X*-rays are used, if the affected parts are superficial, while hard X-rays are used for deep seated organs.

S74. (a) By vibration of atoms and molecules.

(b) Water molecules present in most materials readily absorb infrared waves. Thermal motion increases, they heat up and heat surroundings.

(c) In earth satellites electronic devices.

S75. Given

$$B_y = 2 \times 10^{-7} \sin (0.5 \times 10^3 x + 1.5 \times 10^{11} t) \quad \text{... (i)}$$

$$B_y = B_0 \sin \left[2\pi \left(\frac{x}{\lambda} + \frac{t}{T} \right) \right] \quad \text{... (ii)}$$

Compare the Eq. (i) w.r.t. Eq. (ii) we get

(a)
$$\lambda = \frac{2\pi}{0.5 \times 10^3} = 1.26 \text{ cm}$$

$$\frac{1}{T} = \nu = 1.5 \times 10^{11}$$

$$= 23.9 \text{ GHz}$$

(b) $$E_0 = B_0 C$$

$$= 2 \times 10^{-7} \times 3 \times 10^{8} = 60 \text{ V/M}$$

$$E_Z = 60 \sin (0.5 \times 10^{3} x + 1.5 \times 10^{11} t) \text{V/M}$$

S76. (a) Radio waves; it belongs to the short wavelength end of the electromagnetic spectrum.

(b) Radio waves; it belongs to the short wavelength end.

(c) Temperature, $T = 2.7$ K

λ_m is given by Planck's law as:

$$\lambda_m = \frac{0.29}{2.7} = 0.11 \text{ cm}$$

This wavelength corresponds to microwaves.

(d) This is the yellow light of the visible spectrum.

(e) Transition energy is given by the relation,

$$E = h\nu$$

Where,

h = Planck's constant

$= 6.6 \times 10^{-34}$ Js

ν = Frequency of radiation

Energy, $E = 14.4 \text{ K eV} = 14.4 \times 10^{3} \times 1.6 \times 10^{-19}$ J

$$\therefore \quad \nu = \frac{E}{h} = \frac{14.4 \times 10^{3} \times 1.6 \times 10^{-19}}{6.6 \times 10^{-34}} = 3.4 \times 10^{18} \text{ Hz}$$

This corresponds to X-rays.

S77. Energy of a photon is given as:

$$E = h\nu = \frac{hc}{\lambda}$$

Where, h = Planck's constant = 6.6×10^{-34} Js

c = Speed of light = 3×10^{8} m/s

λ = Wavelength of radiation

$$\therefore \quad E = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{\lambda} = \frac{19.8 \times 10^{-26}}{\lambda} \text{ J}$$

$$= \frac{19.8 \times 10^{-26}}{\lambda \times 1.6 \times 10^{-19}} = \frac{12.375 \times 10^{-7}}{\lambda} \text{ eV}$$

The given table lists the photon energies for different parts of an electromagnetic spectrum for different λ.

λ (*m*)	10^3	1	10^{-3}	10^{-6}	10^{-8}	10^{-10}	10^{-12}
E (eV)	12.375×10^{-10}	12.375×10^{-7}	12.375×10^{-4}	12.375×10^{-1}	12.375×10^{1}	12.375×10^{3}	12.375×10^{5}

The photon energies for the different parts of the spectrum of a source indicate the spacing of the relevant energy levels of the source.

S78. (a) **X-rays:** Are as a diagnostic tool in medicine.

(b) **Radio waves:** Are used in radio and television communication systme.

(c) **Microwaves:** Are in microwave ovens.

S79. (a) **Microwaves:** In aircraft navigation for the radar system.

(b) **Gamma rays:** Are used in medicine to destroy cancer cells

(c) **Ultraviolet rays:** Are used in LASIK eye surgery.

S80. (a) Infra-red waves

Use: For producing dehydrated fruits.

(b) Ultraviolet light

Use: These are used to destroy the bacteria and for sterilizing surgical instruments.

(c) Micro-waves

Use: Radar system in aircraft navigation uses micro-waves.

S81. (a) **Microwaves:** Order of frequency range 10^8 Hz to 10^{12} Hz.

Use: Microwaves are used for radar systems in aircraft navigation.

(b) **Ultraviolet rays:** Order of frequency range 10^{14} Hz to 10^{17} Hz.

Use: Ultraviolet rays are used to destroy the bacteria and for sterilizing the surgical instruments

(c) **Gamma rays:** Order of frequency range 10^{18} Hz to 10^{22} Hz.

Use: Gamma rays are used in the treatment of cancer and tumours.

S82. (a) As radio waves from short-waves bands get reflected from ionosphere, we use them for long distance communication.

(b) It absorbs large portion of ultraviolet radiations harmful for living organism on the earth. emitted by the sun.

(c) Television signals of the frequency range from 100 MHz to 200 MHz neither follows the ionosphere. Therefore satellites are used for long distance TV transmission.

S83. (a) Electromagnetic waves are produced by accelerated charges. An oscillating charge produces an oscillating magnetic field which in its own turn is a source of oscillating electric field. The oscillating electric and magnetic fields thus regenerate each other *i.e.*, they produce electromagnetic waves through the space.

(b) (i) **Microwaves:** In cooking and communication.

(ii) **Ultraviolet rays:** Photocells and in sterilizing the surgical equipment.

(iii) **Infrared rays:** Infrared photography and physical therapy.

(iv) **Gamma rays:** In cancer treatment and study of structure of atomic nucleus.