QB365

Important Questions - Electromagnetic Waves

12th Standard CBSE

Physics Reg.No. :

Time : 01:00:00 Hrs

Total Marks : 50

Section-A

1) If $\vec{E}$ and $\vec{B}$ represent electric and magnetic field vectors of the electromagnetic wave the direction of propagation of electromagnetic wave is along **1**

(a) $\vec{E}$ (b) $\vec{B}$ (c) $\vec{B} \times \vec{E}$ (d) $\vec{E} \times \vec{B}$

2) The ratio of contributions made by the electric field and magnetic field components to the intensity of an EM wave is **1**

(a) $c : 1$ (b) $c^2 : 1$ (c) $1 : 1$ (d) $\sqrt{c} : 1$

3) Light with an energy flux of $20 \quad W/cm^2$ falls on a non-reflecting surface at normal incidence. If the surface has an area of $30cm^2$, the total momentum delivered (for complete absorption) during 30 minutes is: **1**

(a) $36 \times 10^{-5} \quad Kg \quad m/s$ (b) $36 \times 10^{-4} \quad Kg \quad m/s$ (c) $108 \times 10^4 \quad Kg \quad m/s$

(d) $1.08 \times 10^7 \quad Kg \quad m/s$

4) An EM wave radiates out waves from a dipole antenna, with E_0 as the amplitude of its electric field vector. The electric field E_0 which transports significant energy from the source falls off as: **1**

(a) $\frac{1}{r^3}$ (b) $\frac{1}{r^2}$ (c) $\frac{1}{r}$ (d) remains constant.

5) A plane electromagnetic wave propagating along $x$direction can have the following Paris of E and B: **1**

(a) $E_x . B_Y$ (b) $E_y . B_z$ (c) $B_x . E_y$ (d) $E_x . B_y$

6) Am electromagnetic wave travels in vacuum along z direction: $\vec{E} = (E_1\hat{i} + E_2\hat{j})cos(kz - wt)$. Choose the correct options from the following: **1**

(a) The associated magnetic field is given as $\vec{B} = \frac{1}{c}(E_1\hat{i}E_2\hat{j})cos(kz - wt)$

(b) The associated magnetic field is given as $\vec{B} = \frac{1}{c} \quad (E_1\hat{i} - E_2\hat{j}) \quad cos \quad (kz - wt)$

(c) The given electromagnetic field is circularly polarised .

(d) The given electromagnetic wave is plane polarised .

Section-B

7) Show that the radiation pressure exerted by an EM wave of intensity I on a surface kept in vacuum is I/c. **2**

8) A beam of light travelling along x-axis is described by the electric field **2**

$E_3 = (600Vm^{-1})sin\omega \quad (t - x/c)$

calculate the maximum electric and magnetic forces on a charge q=2e, moving along a y-axis with a speed of $3.0 \times 10^7 ms^{-1}$

where e=$1.6 \times 10^{-19}C$

9) Even though an electric field $\vec{E}$ exerts a force q$\vec{E}$ on a charged particle yet the electric field of an EM wave does not contribute to the radiation pressure (but transfers energy). Explain. **2**

10) The average energy flux of sunlight is $1.0 \quad kW \quad m^{-2}$. This energy of radiation is falling normally on the metal plate surface of area $10 \quad cm^2$ which completely absorbs the energy. how much force is exerted on the plate if it is exposed to sunlight for 10 minutes? **2**

11) In a plane electromagnetic wave, the electric field varies with time having an amplitude.$1 \quad Vm^{-1}$ The frequency of a wave is $0.5 \times 10^{15} Hz$ The wave is propagating along Z-axis. what is the average energy density of **2**

(i) electric field

(ii) magnetic field

(iii) total

(iv) what is the amplitude of magnetic field?

12) What happens to the intensity of light from a bulb if the distance from the bulb is doubled? As a laser beam travels across the length of a room, its intensity essentially remains constant. What geometrical characteristic of LASER beam is responsible for the constant intensity which is missing in the case of light from the bulb? **2**

Section-C

13) Monica's mother was heating food on a gas stove. Her friend Ruchi came and saw her mother heating food on the gas stove. Ruchi told Monica's mother, "Why don't you buy a microwave oven"? Monica's mother replied at once that she doesn't like to use microwave oven. Monica and Ruchi made it clear that microwave is not harmful for cooking food. This is an easy and safe process. Monica's mother got convinced and ordered for a microwave oven. Monica's mother then arranged a small party for her friends and told them the advantages of a microwave oven. **3**

14) Show that the energy density of em radiations is $\varepsilon_0 E^2$. Hence, find the intensity of radiations? **3**

15) 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. **3**

16) What value was displayed by Monica and her friend?

17) What value was displayed by Monica to her friends?

18) In a plane e.m. wave, the electric field oscillates sinusoidally at a frequency of 2.0×10^{10} Hz and amplitude $48 \quad Vm^{-1}$. **3**

(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 to the average energy density of the B field.

$[c = 3.0 \times 10^8 \quad ms^{-1}]$

Section-D

19) How would you establish an instantaneous displacement current of 2.0 A in the space between the two parallel plates of $1 \mu F$ capacitor? **5**

20) Calculate the peak values of electric and magnetic fields produced by the radiation coming from a 100 watt bulb at a distance of 3 m. Assume that the efficiency of the bulb is 2.5% and it is a point source? **5**

21) A parallel plate capacitor $C = 0.2\mu F$ connected across an a.c. source of angular frequency 400 rad s^{-1} . The value of conduction current is 2 mA. Find the rms value of the voltage from the source and the displacement current in the region between the two plates. **5**

22) There is a parallel plate capacitor of capacitance $2.0\mu F$. The voltage between the plates of parallel plate capacitor is changing at the rate of 6.0 V s^{-1} . What is the displacement current in the capacitor? **5**

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Section-A

1) (b) $36 \times 10^{-4} \quad Kg \quad m/s$ **1**

2) (a) $\vec{E}$ **1**

3) (c) $1:1$ **1**

4) (c) $\frac{1}{r}$ **1**

5) (a) The associated magnetic field is given as $\vec{B} = \frac{1}{c}(E_1 \hat{i} E_2 \hat{j}) cos(kz - wt)$ **1**

6) (b) $E_y.B_z$ **1**

Section-B

7) $1.92 \times 10^{-16} N; \quad 1.92 \times 10^{-17} N$ **2**

8) (i) $2.21 \times 10^{-12} \quad Jm^{-3}$ **2**

(ii) $2.21 \times 10^{-12} \quad Jm^{-3}$

(iii) $4.42 \times 10^{-12} \quad Jm^{-3}$

(iv) $3.3 \times 10^{-12} \quad Jm^{-3}$

9) $3.3 \times 10^{-9} N$ **2**

10) **2**

Pressure $P = \frac{force}{area} = \frac{F}{A} = \frac{1}{A}(\triangle p/\triangle t) \times \frac{c}{c}$

$\left[\because F = \frac{\triangle p}{\triangle t} = rate \quad of \quad change \quad of \quad momentum\right]$

$\therefore \quad P = \frac{1}{Ac\triangle t} \times c\triangle p = \frac{1}{Ac\triangle t} \times \triangle U \qquad ..(i)$

(where c $\triangle p$ = $\triangle U$= energy imparted by wave in time $\triangle t$

Intensity, $I = \frac{energy \quad imparted}{area \times time} = \frac{\triangle U}{A\triangle t} = Pc$

P = I/c

11) **2**

Intensity of light is reduced to one fourth because the light beam spreads as it approaches into a spherical region of area $4\pi r^2, i.e., I \infty 1/r^2$ But laser beam does not spread, hence its intensity remains constant. Laser beam is unidirectional, monochromatic and coherent light, whereas the light from a bulb does not posses the above properties.

12) **2**

Electric field of an electromagnetic wave is an oscillating field. Due to it, the electric force caused by electric field in e.m. wave on a charged particle is an oscillating one. This electric force averaged over an integral number of cycle is zero, since its direction changes every half cycle. Hence, electric field is not responsible for radiation pressure.

Section-C

13) (a) $\lambda = \frac{c}{v} = \frac{3\times10^8}{2.0\times10^{10}}$ **3**

$= 1.5 \times 10^{-2} m$

$E = 48 V m^{-1}$

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

(c) Energy density in E field,

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

Energy density in B field,

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

Using $E = cB$ and $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$,

We find $U_E = U_B$.

14) **3**

(a) At a distance of 1m, the surface area of the surrounding sphere $A = 4\pi r2 = 4 \times 3.14 \times 1^2$

$= \quad 12.56 \quad m^2$

$\therefore$ Intensity at this distance $I = \frac{Power}{Area} = \frac{100W\times5}{12.56}$ **(b)** At distance $10m A_1 = 4\pi r^2 = 4 \times 3.14 \times 100$

$= 0.39$ $\quad = 1256 m^2$

$I = 0.4 \quad W m^{-2}$ $\quad I_1 = \frac{Power}{Area} = \frac{100W\times5}{1256}$

$= 0.004 \quad W m^{-2}$

15) **3**

Since $\varepsilon_E = \frac{1}{2}\varepsilon_0 E^2$ and $\varepsilon_B = \frac{B^2}{2\mu_0}$ $\therefore$ Total energy density $u = u_E + u_B = \frac{1}{2}\varepsilon_0 E_2 + \frac{1}{2}\frac{B^2}{\mu_0}$ For a plane em wave, Band E are related as $B_v = \frac{E_V}{C}$ $\quad u = \frac{1}{2}\varepsilon_0 E_{v2} + \frac{1}{2\mu_0}\left(\frac{E_v}{c}\right)^2$

$= E^2{}_v \frac{(\mu_0 \varepsilon_{0c2}+1)}{2\mu_{0c2}} = E_v^2$ or $u = \frac{E_v^2(1+1)}{2\mu_0 \frac{1}{\mu_0\varepsilon_0}}$ $\left[\therefore c^2 = \frac{1}{\mu_0\varepsilon_0}\right]$ $= \varepsilon_0 E_v^2$ So

$I = \frac{Energy/Time}{Area}$ or $I = \frac{Energy \quad density/Time}{Area} \times volume$ Using eqn.(i), we get $I = \varepsilon_0 E_v^2$

$= Energy \quad density \times \frac{length}{Time}$

$= u \times c$

16) 17) Sharing knowledge **3**

18) Understanding

19) Creating awareness

Section-D

20) $C = 2.0\mu F = 2 \times 10^{-6} F,$ **5**

$\frac{dV}{dt} = 6 V s^{-1}$

Displacement current,

$I_D = \epsilon_0 A \frac{dE}{dt} = \epsilon_0 A \frac{d}{dt}\left(\frac{V}{d}\right)$

$= \frac{\epsilon_0 A}{d}\frac{dV}{dt} = C\frac{dV}{dt}$

$= \left(2 \times 10^{-6}\right) \times 6 = 12 \times 10^{-6} A$

$= 12\mu A$

21) Here, $C = 0.2\mu F = 0.2 \times 10^{-6} F$ **5**

$= 2 \times 10^{-7} F,$

$\omega = 400 \quad rad/s, \quad I_{rms} = 2mA = 2 \times 10^{-3} A$

$V_{rms} = I_{rms} \times X_C$

$= I_{rms} \times \frac{1}{\omega C} = \left(2 \times 10^{-3}\right) \times \frac{1}{400 \times \left(2 \times 10^{-7}\right)}$

= 25 V.

Displacement current = conduction current

= 2 mA

22) **5**

Here, $I_D = 2.0A, \quad C = 1\mu F = 10^{-6} F.$

We know, $I_D = \epsilon_0 \frac{d\phi_E}{dt} = \epsilon_0 \frac{d}{dt}(EA)$

$= \epsilon_0 A \frac{dE}{dt} = \epsilon_0 A \frac{d}{dt}\left(\frac{V}{d}\right) = \epsilon_0 \frac{A}{d} \frac{dV}{dt} = C \frac{dV}{dt}$

$\left(\because E = \frac{V}{d}\right)$ *and* $\left(C = \frac{\epsilon_0 A}{d}\right)$

or $\frac{dV}{dt} = \frac{I_D}{D} = \frac{2.0}{10^{-6}} = 2 \times 10^{-6} V s^{-1}$

Thus a displacement current of 2.0 A can be set up by changing the potential difference across the parallel plates of capacitor at the rate of 2 x 10^6 Vs^{-1} .

23) Useful Intensity, **5**

$I = \frac{power}{area} = \frac{100 \times (2.5/100)}{4\pi(3)^2} = \frac{2.5}{36\pi} W m^{-2}$

Half of this intensity (I) belongs to electric field and half of that to magnetic field. Therefore,

$\frac{I}{2} = \frac{1}{4}\varepsilon_0 E_0^2 c \quad or \quad E_0 = \sqrt{\frac{2I}{\varepsilon_0 c}}$

$= \sqrt{\frac{2 \times (2.5/36\pi)}{\left(\frac{1}{4\pi \times 9 \times 10^9}\right) \times (3 \times 10^8)}} = 4.08 V m^{-1}$

$B_0 = \frac{E_0}{c} = \frac{4.08}{3 \times 10^8} = 1.36 \times 10^{-8} T$