2220 homework 2

1. PSE6 34.P.007. [317859] In SI units, the electric field in an electromagnetic wave is described by the following equation.

$$E_y = 118 \sin(1.20 \times 10^7 x - \omega t)$$

(a) Find the amplitude of the corresponding magnetic field oscillations.

0.393 μT

(b) Find the wavelength λ.

0.523 μm

(c) Find the frequency *f*.

5.7×10^14 Hz

(a) $E_0 = 118$ V/d $\quad B_z = B_0 \sin(1.20 \times 10^7 x - \omega t)$

$$B_0 = \frac{E_0}{c} = \frac{118}{3.0\times10^8} = 39.3 \times 10^{-8} = 3.93\times10^{-7}\ T$$

(b) $\frac{2\pi}{\lambda} = 1.20 \times 10^7$

$$\lambda = \frac{2\pi}{1.2} \times 10^{-7} = 5.23 \times 10^{-7}\ m$$

(c) $\lambda f = c$

$$f = \frac{c}{\lambda} = \frac{3.0\times10^8}{5.23\times10^{-7}} = 5.7\times10^{14}\ Hz$$

2. PSE6 34.P.014. [317992] A monochromatic light source emits 135 W of electromagnetic power uniformly in all directions.

(a) Calculate the average electric-field energy density 3.00 m from the source.

2 nJ/m^3

(b) Calculate the average magnetic-field energy density at the same distance from the source.

2 nJ/m^3

(c) Find the wave intensity at this location.

1.2 W/m^2

(a) $u = \varepsilon_0 E^2 \quad S = \varepsilon_0 E^2 c$

$$4\pi R^2 S = 135$$

So: $S = \frac{135}{4\pi R^2}$ So: $\varepsilon_0 E^2 = \frac{135}{4\pi R^2 c}$

So: $u = \varepsilon_0 E^2 = \frac{135}{4\pi R^2 c} = \frac{135}{4\times3.14\times9\times3.0\times10^8} = 0.4\times10^{-8} = 4\ nJ/m^3$

$u_E = \frac{u}{2} = 2\ nJ/m^3$

(b) $u_B = \frac{u}{2} = 2\ nJ/m^3$

(c) $S = cu = 3.0\times10^8 \times 0.4\times10^{-8} = 1.2\ W/m^2$

3. PSE6 34.P.024. [317923] A 20.0 mW laser has a beam diameter of 1.30 mm.

(a) What is the intensity of the light, assuming it is uniform across the circular beam?

15 kW/m^2

(b) What is the average energy density of the beam?

50 μJ/m^3

(a) $S = \frac{20.0\times10^{-3}}{\frac{1}{4}\pi\, 1.3^2\times10^{-6}} = \frac{80\times10^{3}}{3.14\times1.3^2} = 15\ \text{kW/m}^2$

(b) $U = \frac{S}{c} = \frac{15\times10^{3}}{3.0\times10^{8}} = 5\times10^{-5}\ \text{J/m}^3$.

$= 50\ \mu\text{J/m}^3$

4. PSE6 34.P.027. [317963] A radio wave transmits 27.0 W/m^2 of power per unit area. A flat surface of area A is perpendicular to the direction of propagation of the wave. Calculate the radiation pressure on it, assuming the surface is a perfect absorber.

90 nPa

$P = \frac{S}{c} = \frac{27.0}{3.0\times10^{8}} = 9\times10^{-8}\ \text{Pa}$

$= 90\ \text{nPa}$

5. PSE6 34.P.029. [318001] A 15.0 mW helium-neon laser (λ = 632.8 nm) emits a beam of circular cross-section with a diameter of 1.90 mm.

(a) Find the maximum electric field in the beam.
2 kN/C

(b) What total energy is contained in a 1.00 m length of the beam?
50 pJ

(c) Find the momentum carried by a 1.00 m length of the beam.
1.67×10^{-19} kg · m/s

(a) $u = \frac{1}{2}\varepsilon_0 E_0^2$ $\quad S = \frac{15.0\times10^{-3}}{\pi R^2}$.

So: $\frac{1}{2}\varepsilon_0 E_0^2 c = \frac{15.0\times10^{-3}}{\pi R^2}$

$E_0^2 = \frac{30\times10^{-3}}{2\varepsilon_0 c R^2} = \frac{9.0\times10^{9}\times 120\times10^{-3}}{3.0\times10^{8}\times 0.95^2\times10^{-6}} = \frac{3.6}{0.95^2}\times10^{6}$

So: $E_0 = 2$ KN/C

(b) $U = 15.0 \times \frac{1\times10^{-3}}{3.0\times10^{8}} = 5\times10^{-11} = 50$ PJ

(c) $p = \frac{U}{c} = \frac{50\ \text{PJ}\times10^{-12}}{3.0\times10^{8}} = 1.67\times10^{-19}$ kg·m/s.

6. PSE6 34.P.041. [317850] What are the wavelengths of electromagnetic wave in free space that have the following frequencies?

(a) 9.00×10^{19} Hz
3.3 pm

(b) 8.00×10^{9} Hz
3.75 cm

(a) $\lambda\nu = c$

$\lambda = \frac{c}{\nu} = \frac{3.0\times10^{8}}{9.0\times10^{19}} = 3.3$ pm.

(b) $\lambda = \frac{c}{\nu} = \frac{3.0\times10^{8}}{8\times10^{9}} = 3.75$ cm