Useful Equations

\[ u = \frac{1}{2} \varepsilon_0 E^2 + \frac{1}{2\mu_0} B^2 \]
Energy of an EM wave

\[ \overline{S} = \frac{1}{\mu_0} \overline{E} \times \overline{B} \]
Poynting Vector, Energy flow per unit time per unit area.

\[ I = \langle S \rangle = \frac{1}{2\mu_0} E_{\text{max}} B_{\text{max}} \]
Intensity. Power per unit area. Harmonic plane wave.

\[ KE = \frac{1}{2} mv^2 = \frac{1}{2} pv \]
Kinetic energy using momentum, p.

\[ KE_{\text{light}} = pc \]
Energy of light

\[ \text{pressure} = \frac{F}{A} = \frac{1}{A} \frac{\Delta p}{\Delta t} = \frac{S}{c} = \frac{EB}{\mu_0 c} \]
Radiation pressure

Related Problems

1) The microwaves in a certain microwave oven have a wavelength of 12.2 cm. (Book 32.35)
(a) How wide must this oven be so that it will contain five antinodal planes of the electric field along its width in the standing wave pattern?
\[ L = 2.5 \lambda = 30.5 \text{ cm} \]

(b) What is the frequency of these microwaves?
\[ f = \frac{c}{\lambda} = 2.46(10^9) \text{ Hz} \]

(c) Suppose a manufacturing error occurred and the oven was made 6.0 cm longer than specified in part (a). In this case, what would have to be the frequency of the microwaves for there still to be five antinodal planes of the electric field along the width of the oven?
\[ f = \frac{c}{\lambda} = \frac{c}{36.6} = 2.05(10^9) \text{ Hz} \]
2) A sinusoidal electromagnetic wave from a radio station passes perpendicularly through an open window that has area of 0.600 m². At the window, the electric field of the wave has an rms value $2.20 \times 10^{-2}$ V/m. How much energy does this wave carry through the window during a 30 s commercial? (Book 32.18)

$$W = Ate \left( \frac{1}{2} E^2 \varepsilon_0 \right) = 2.31 \times 10^{-5} \text{ J}$$

Remember, half of the energy in an EM wave is in the E field, the rest is in the B field. Thus, multiply E field energy by 2.

3) An intense light source radiates uniformly in all directions. At a distance of 5.3 m from the source the radiation pressure on a perfectly absorbing surface is $7.5 \times 10^{-6}$ Pa. What is the average power output of the source? (Book 32.25)

$$P = IA = c(\text{pressure})(4\pi d^2) = 7.9 \times 10^5 \text{ W}$$

4) We can reasonably model a 90-W incandescent light bulb as a sphere 6.1 cm in diameter. Typically, only about 5% of the energy goes to visible light; the rest goes largely to non-visible infrared radiation. (Book 32.15)

(a) What is the visible light intensity at the surface of the bulb?

$$I = \frac{0.05P}{A} = \frac{0.05P}{4\pi \left( \frac{d}{2} \right)^2} = 380 \text{ W/m}^2$$

(b) What is the amplitude of the electric field at this surface, for a sinusoidal wave with this intensity?

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

$$\frac{I}{c} = u$$

$$\rightarrow E = \sqrt{\frac{2I}{\varepsilon_0 c}} = 540 \text{ V/m}$$

(c) What is the amplitude of the magnetic field at this surface, for a sinusoidal wave with this intensity?

$$B = \frac{E}{c} = 1.8 \mu T$$