Useful Equations

\[ v = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} = c = 3 \times 10^8 \text{ m/s} \]  
Speed of light

\[ \overrightarrow{E} = E_{\text{max}} \cos(kt - \omega t) \hat{j} \]
\[ \overrightarrow{B} = B_{\text{max}} \cos(kt - \omega t) \hat{k} \]
Harmonic EM wave propagating in x-direction. E and B are ALWAYS in phase

\[ k = \frac{2\pi}{\lambda}, \quad \omega = 2\pi f, \quad c = \lambda f \]

\[ \overrightarrow{E} \times \overrightarrow{B} \]
Propagation direction

\[ E = cB \]
Magnitude relationship between E and B fields

\[ v = \frac{1}{\sqrt{\varepsilon \mu}} = \frac{c}{\sqrt{k \kappa_m}} = \frac{c}{n} \]
EM wave speed in non-vacuum medium. n is the refraction index

Diagram:

Related Problems

1) A sinusoidal electromagnetic wave having a magnetic field of amplitude 1.25 μT and a wavelength of 432 nm is traveling in the +x direction through empty space. (Book 32.5)
(a) What is the frequency of this wave?

\[ f = \frac{c}{\lambda} = \frac{6.94 \times 10^{14}}{432 \times 10^{-9}} \text{ Hz} \]

(b) What is the amplitude of the associated electric field?
\[ E = cB = 375 \text{ V/m} \]

(c) Write equations for electric and magnetic fields as a function of \( x \) and \( t \)

\[ B_{\text{max}} = 1.25 \text{ \mu T} \]

\[ E_{\text{max}} = 375 \text{ V/m} \]

\[ \omega = 2\pi f = 5.91 \times 10^{15} \text{ rad/s} \]

\[ \lambda = 432 \times 10^{-9} \text{ m} \]

\[ \vec{E} = E_{\text{max}} \cos \left( \frac{2\pi}{\lambda} x - \omega t \right) \hat{j} \]

\[ \vec{B} = B_{\text{max}} \cos \left( \frac{2\pi}{\lambda} x - \omega t \right) \hat{k} \]

2) The electric field of a sinusoidal electromagnetic wave obeys the equation:

\[ E = -(375\text{V/m}) \sin[(5.97 \times 10^{15}\text{rad/s})t + (1.99 \times 10^{7}\text{rad/m})x]. \]  
(Book 32.8)

(a) What is the amplitude of the electric field of this wave?

\[ E_{\text{max}} = 375 \text{ V/m} \]

(b) What is the amplitude of the magnetic field of this wave?

\[ B_{\text{max}} = 1.25 \text{ \mu T} \]

(c) What is the frequency of the wave?

\[ f = \frac{\omega}{2\pi} = 9.50 \times 10^{14} \text{ Hz} \]

(d) What is the wavelength of the wave?

\[ \lambda = \frac{2\pi}{k} = 316 \text{ nm} \]

(e) What is the period of the wave?

\[ T = \frac{1}{f} = 1.05 \times 10^{-15} \text{ s} \]

(f) Is this light visible to humans?

No, humans can see within the wavelength range of 390 to 750 nm.

(g) What is the speed of the wave?

\[ v = \lambda f = 3 \times 10^8 \text{ m/s} \]

3) An electromagnetic wave with frequency 64.0 Hz travels in an insulating magnetic material that has dielectric constant 3.64 and relative permeability 5.18 at this frequency. The electric field has amplitude 7.20(10^{-3}) \text{ V/m}.  (Book 32.14)

(a) What is the speed of propagation of the wave?

\[ v = \frac{c}{\sqrt{\kappa \mu_m}} = 9.91 \times 10^7 \text{ m/s} \]

(b) What is the wavelength of the wave?

\[ \lambda = \frac{v}{f} = 1.06 \times 10^6 \text{ m} \]

(c) What is the amplitude of the magnetic field?

\[ B = \frac{E}{c} = \frac{E}{\lambda f} = 1.04 \times 10^{-6} \text{ T} \]