Chapter 34: Problems 14, 19, 31, 52, 68, 76, 86

14P
(a) From Eq. 34-1
\[ \frac{\partial^2 E}{\partial t^2} - c^2 \frac{\partial^2 E}{\partial x^2} = \frac{1}{E_m} \left[ E_m \sin(kx - wt) \right] = -\omega^2 E_m \sin(kx - wt) \]

and
\[ c^2 \frac{\partial^2 E}{\partial x^2} - \frac{\partial^2 E}{\partial t^2} = c^2 \frac{\partial^2 E}{\partial x^2} \left[ E_m \sin(kx - wt) \right] = -k^2 c^2 \sin(kx - wt) = -\omega^2 E_m \sin(kx - wt) \]

So:
\[ \frac{\partial^2 E}{\partial t^2} = c^2 \frac{\partial^2 E}{\partial x^2} \]
is satisfied. Analogously, you can show that Eq. 34-2 satisfies:
\[ \frac{\partial^2 B}{\partial t^2} = c^2 \frac{\partial^2 B}{\partial x^2} \]

(b) from \( E = E_m f(kx \pm \omega t) \)
\[ \frac{\partial^2 E}{\partial t^2} = E_m \frac{\partial^2 f(kx \pm wt)}{\partial t^2} \left|_{u=\pm \omega t} \right. = w^2 E_m \frac{d^2 f}{du^2} \]
and
\[ c^2 \frac{\partial^2 E}{\partial x^2} = c^2 E_m \frac{\partial^2 f(kx \pm \omega t)}{\partial x^2} \left|_{u=\pm \omega t} \right. = c^2 E_m k^2 \frac{d^2 f}{du^2} \]

Since \( \omega = ck \) the R.H.S. of the tow equations above are equal, so
\[ \frac{\partial^2 E}{\partial t^2} = c^2 \frac{\partial^2 E}{\partial x^2} \]

change E to B and repeat the derivation above to show that \( B = B_m f(kx \pm \omega t) \) satisfies
\[ \frac{\partial^2 B}{\partial t^2} = c^2 \frac{\partial^2 B}{\partial x^2} \]

19E.
The fraction is
\[ \frac{\pi R^2}{4 \pi d^2_{es}} = \frac{1}{4} \left( \frac{6.37 \times 10^6 m}{1.5 \times 10^{11} m} \right)^2 = 4.51 \times 10^{-10} \]
31P
(a) The average rate of energy flow per unit area, or intensity, is related to the electric field amplitude \(E_m\) by

\[ I = \frac{E_m^2}{2\mu_0 c}, \]

so

\[ E_m = \sqrt{2\mu_0 c I} = 8.7 \times 10^{-2} V/m \]

(b) The amplitude of the magnetic field is given by

\[ B_m = \frac{E_m}{c} = 2.9 \times 10^{-10} T \]

© at a distance \(r\) from the transmitter the intensity is \(I = \frac{P}{4\pi r^2}\), where \(P\) is the power of the transmitter. Thus

\[ P = 4\pi r^2 I = 1.3 \times 10^4 W \]

52E.
After passing through the first polarizer the initial intensity \(I_0\) reduces by a factor of 1/2. After passing through the second one it is further reduced by a factor of

\[ \cos^2(\pi - \theta_1 - \theta_2) = \cos^2(\theta_1 + \theta_2). \]

Finally after passing through the third one it is again reduced by a factor of

\[ \cos^2(\pi - \theta_2 - \theta_3) = \cos^2(\theta_2 + \theta_3). \]

So

\[ \frac{I}{I_0} = \frac{1}{2} \cos^2(\theta_1 + \theta_2) \cos^2(\theta_2 + \theta_3) = 4.5 \times 10^{-2} \%
\]

68P
(a)-(c) Use the law of refraction to determine the paths of various light rays. The index of refraction for fused quartz can be found in Fig. 34-19. The paths traversed by rays representing these lights are shown below. Here \(\phi \approx 61^\circ\) for red light, \(62^\circ\) for yellow-green light and \(63^\circ\) for blue light.

76E
(a) NO refraction occurs at the surface ab, so the angle of incidence at surface ac is \(90^\circ - \phi\). For total internal reflection at the second surface, \(n_g \sin(90^\circ - \phi)\) must be greater than \(n_a\). Here \(n_g\) is the index of refraction for the glass and \(n_a\) is the index of refraction for air. Since \(\sin(90^\circ - \phi) = \cos(\phi)\), you want the largest value of \(\phi\) for which

\[ n_g \cos(\phi) \geq n_a. \]

Recall that \(\cos(\phi)\) decrease as \(\phi\) increase from zero. When \(\phi\) has the largest value for which for which total internal reflection occurs, then

\[ n_g \cos(\phi) = n_a \]

or :
\[ \phi = \cos^{-1}\left( \frac{n_a}{n_g} \right) = 48.9^\circ \]

The index of refraction for air was taken to be unity.

(b) Replace the air with water. If \( n_w(=1.33) \) is the index of refraction for water, then the largest value of \( \phi \) for which total internal reflection occurs is

\[ \phi = \cos^{-1}\left( \frac{n_w}{n_g} \right) = 29.0^\circ \]

86E.

The angle of incidence \( \theta_b \) for which reflected light is fully polarized is given by Brewster’s law, Eq. 34-48 of the text. If \( n_1 \) is the index of refraction for the second medium, then

\[ \theta_b = \tan^{-1}(n_2/n_1) = 49.0^\circ \]