Ch 33: Electromagnetic Waves

•11 A plane electromagnetic wave traveling in the positive direction of an *x* axis in vacuum has components $E_x = E_y = 0$ and $E_z = (2.0 \text{ V/m}) \cos[(\pi \times 10^{15} \text{ s}^{-1})(t - x/c)]$. (a) What is the amplitude of the magnetic field component? (b) Parallel to which axis does the magnetic field oscillate? (c) When the electric field component is in the positive direction of the *z* axis at a certain point *P*, what is the direction of the magnetic field component there?

11 (a) $B_m = E_m/c = \frac{2}{3\times10^{8}} = 6.67\times10^{-9}$ Tesla

(b) $\vec{E}\times\vec{B} = \hat{i}$, B along y axis

(c) $\hat{k}\times(-\hat{j}) = \hat{i}$

(negative y axis).

••**13** Sunlight just outside Earth's atmosphere has an intensity of 1.40 kW/m^2. Calculate (a) E_m and (b) B_m for sunlight there, assuming it to be a plane wave.

13 (a) $I = \frac{1}{2\mu_0 c} E_m^2 \Rightarrow E_m = \sqrt{2 I \mu_0 c}$

$E_m = \sqrt{2 * 1.4\times10^3 \times 4\pi\times10^{-7} \times 3\times10^8}$

$E_m = 1.03\times10^3$ V/m

(b) $B_m = \frac{E_m}{c} = \frac{1.03\times10^3}{3\times10^8} = 3.4\times10^{-6}$ Tesla

••41 A beam of polarized light is sent into a system of two polarizing sheets. Relative to the polarization direction of that incident light, the polarizing directions of the sheets are at angles θ for the first sheet and 90° for the second sheet. If 0.10 of the incident intensity is transmitted by the two sheets, what is θ?

(41)

$I_1 = I_0 \cos^2\theta$

$I_2 = I_1 \cos^2(90-\theta)$

$I_2 = I_1 \sin^2\theta = 0.1\, I_0$

$\cancel{I_0} \cos^2\theta \sin^2\theta = 0.1\, \cancel{I_0}$

$\sqrt{\cos^2\theta \sin^2\theta = 0.1}$

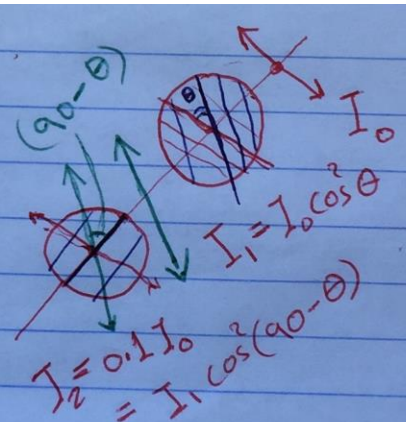
$\cos\theta \sin\theta = \sqrt{0.1}$

$\frac{1}{2}\sin(2\theta) = \sqrt{0.1} \Rightarrow \sin(2\theta) = 0.632455$

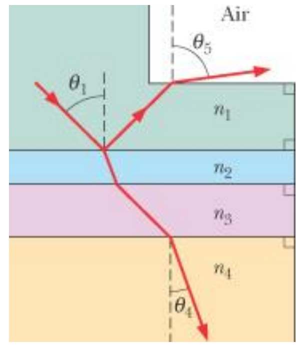
$2\theta = 39.2$

$\Rightarrow \boxed{\theta = 19.6^\circ}$

$\boxed{\text{or } \theta = 70.4^\circ}$



••51 In Fig. 33-51, light is incident at angle $\theta_1 = 40.1°$ on a boundary between two transparent materials. Some of the light travels down through the next three layers of transparent materials, while some of it reflects upward and then escapes into the air. If $n_1 = 1.30$, $n_2 = 1.40$, $n_3 = 1.32$, and $n_4 = 1.45$, what is the value of (a) θ_5 in the air and (b) θ_4 in the bottom material?



51) $n_1 \sin \theta_1 = n_4 \sin \theta_4$

$1.3 \sin(40.1°) = 1.45 \sin \theta_4$

$\Rightarrow \boxed{\theta_4 = 35.3°}$

•58 The index of refraction of benzene is 1.8. What is the critical angle for a light ray traveling in benzene toward a flat layer of air above the benzene?

58 $\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) = \sin^{-1}\left(\frac{1}{1.8}\right)$

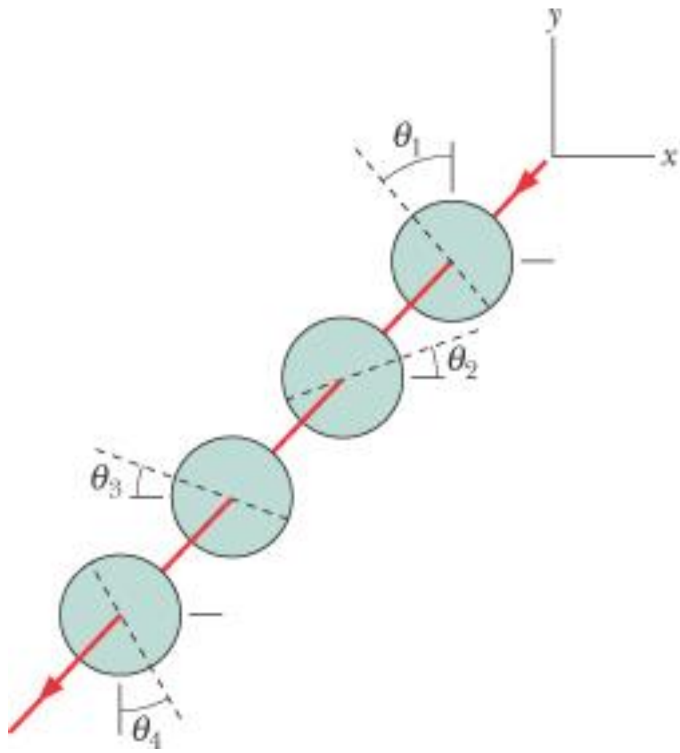
$\theta_c = 33.7^\circ$

•69 Light that is traveling in water (with an index of refraction of 1.33) is incident on a plate of glass (with index of refraction 1.53). At what angle of incidence does the reflected light end up fully polarized?

69 $\theta_B = \tan^{-1}\left(\frac{n_2}{n_1}\right) = \tan^{-1}\left(\frac{1.53}{1.33}\right)$

$\boxed{\theta_B = 49^\circ}$

76 In Fig. 33-66, unpolarized light with an intensity of 25 W/m^2 is sent into a system of four polarizing sheets with polarizing directions at angles $\theta_1 = 40°$, $\theta_2 = 20°$, $\theta_3 = 20°$, and $\theta_4 = 30°$. What is the intensity of the light that emerges from the system?

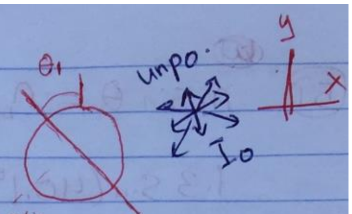


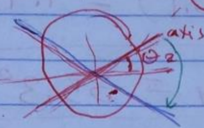
(76) $I_0 = 25\ W/m^2$

$\theta_1 = 40^\circ,\ \theta_2 = 20^\circ$

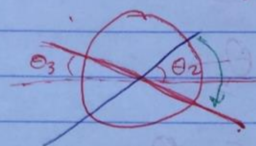
$\theta_3 = 20^\circ,\ \theta_4 = 30^\circ$

$I_{final} = ?$

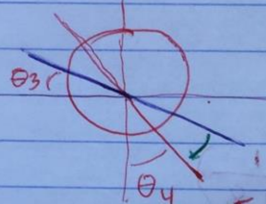




$I_1 = \frac{1}{2} I_0$



$I_2 = I_1 \cos^2(\theta_2 + 90 - \theta_1)$



$I_3 = I_2 \cos^2(\theta_2 + \theta_3)$

$I_4 = I_3 \cos^2[90 - (\theta_3 + \theta_4)]$

$I_4 = I_3 \cos^2(90^\circ - 20^\circ - 30^\circ) = I_3 \cos^2(40^\circ)$

$I_4 = I_2 \cos^2(20^\circ + 20^\circ) \cos^2(40^\circ)$

$= I_2 \cos^2(40) \cos^2(40)$

$= I_1 \cos^2(20^\circ + 90^\circ - 40^\circ) \cos^2(40) \cos^2(40)$

$= I_1 \cos^2(70) \cos^2(40) \cos^2(40)$

$= \frac{1}{2} I_0 \cos^2(70) \cos^2(40) \cos^2(40)$

$= 0.5035\ W/m^2$