Physics 111 Homework Solutions Collected on Wednesday 10/22

Friday, October 17, 2014

Chapter 19

Questions

19.4 The intensity is the total amount of energy per unit time that flows across an area A. The Poynting vector gives the direction of the energy flow per unit time per unit area.

19.10 The polarizer must be oriented with its transmission axis horizontal.

19.11 Starting with unpolarized light of intensity S_o and passing this light through a polarizer with its transmission axis oriented say vertically, transmits ½ of the initial intensity. This light is polarized vertically, say and when this light passes strikes the 2nd polarizer with its transmission axis at a 45° to the vertical, the intensity that emerges is $S_{out} = S_{in}\cos^2\theta = \frac{S_0}{2}\cos^2 45 = \frac{S_0}{4}$

Multiple-Choice

19.7 B
19.8 B
19.9 C
19.10 C
19.14 D
19.15 B

Problems

19.6 A vertically polarized beam of light is passed through a Polaroid with its transmission axis at 30° with respect to the vertical has $I_T = I_o\cos^2 30 = 0.75I_o = 75\%I_o$ transmitted. This transmitted beam is incident on a Polaroid whose transmission axis is aligned with the vertical. The transmitted intensity is given by the equation above with $I_T = 0.75I_o\cos^2 30 = 0.563I_o = 56.3\%I_o$.

19.7 Here we have unpolarized light passing through a Polaroid and this results in half of the light's intensity transmitted with and now the light is polarized with its axis along that of the Polaroid. Passing through the second Polaroid we have $I_T = 0.5I_o\cos^2 60 = 0.125I_o = 12.5\%I_o$. So the fraction of the initial unpolarized light passing the second Polaroid 12.5%.

19.8 For unpolarized light incident on the 1st polarizer, the intensity that emerges is ½ I_0. This light is incident on a 2nd polarizer oriented at 30°, so the intensity that emerges from the 2nd polarizer is $I_2 = \frac{1}{2} I_0 \cos^2(30) = 0.375 I_0$. This light is incident on a 3rd polarizer oriented also at 30°, so the intensity of the light that emerges is $I_3 = 0.375 I_0 \cos^2(30) = 0.281 I_0 = 28.1\% I_0$. It is found that the intensity after the 3rd polarizer is *0.2 W/m²*, so the initial intensity of the beam is $I_3 = 0.281 I_0 \rightarrow 0.2 \frac{W}{m^2} = 0.281 I_o \rightarrow I_o = 0.71 \frac{W}{m^2}$.

19.11 The intensity is defined as the power radiated per unit area. Thus the intensity *4m* away in any direction from the light source is $\bar{I} = \frac{P}{A} = \frac{60W}{4\pi(4m)^2} = 0.298 \frac{W}{m^2}$. The detector only occupies a small fraction of the total surface area of the sphere centered on the light source and further the detector is only 75% efficient. Thus the power at the detector is

$$P_D = 0.75 \times \bar{I} A_D = 0.75 \times 0.298 \frac{W}{m^2} \left(10cm^2 \times \frac{1m^2}{(100cm)^2} \right) = 2.2 \times 10^{-4} W$$

19.12 A 50,000 Watt radio station

a. The wavelength is given by $\lambda = \frac{c}{f} = \frac{3 \times 10^8 \frac{m}{s}}{106.5 \times 10^6 s^{-1}} = 2.8m$.

b. The intensity is defined as the power radiated per unit area. Thus the intensity *100m* away in any direction from the light source passing through the sphere centered on the radio source is $\bar{I} = \frac{P}{A} = \frac{50 \times 10^3 W}{4\pi(100m)^2} = 0.398 \frac{W}{m^2}$. Passing through the detector area given at *100m* is $\bar{I} = \frac{P}{A} \rightarrow P = \bar{I}A = 0.398 \frac{W}{m^2} \times 1.0m^2 = 0.398W$.

c. The maximum electric field depends on the intensity through $I = \frac{1}{2} c \varepsilon_o E_{\max}^2 \rightarrow 0.398 \frac{W}{m^2} = \frac{1}{2} \times 3 \times 10^8 \frac{m}{s} \times 8.85 \times 10^{-12} \frac{C^2}{Nm^2} E_{\max}^2 \rightarrow E_{\max} = 17.3 \frac{N}{C}$

d. The electric potential difference induced over the length of the wire is $E = \frac{\Delta V}{\Delta x} \rightarrow \Delta V = E_{\max} L = 17.3 \frac{V}{m} \times 1m = 17.3V$

19.16 The laser pointer is rated at $3mW$ which is *3x10⁻³ J/s* and this energy (per second) is spread over the area of the beam spot. The area of the beam spot is $A = \pi r^2 = \pi (1 \times 10^{-3} m)^2 = 3.14 \times 10^{-6} m^2$. Thus the radiation pressure is

$$P = \frac{Power}{A \times c} = \frac{3 \times 10^{-3} \frac{J}{s}}{3.14 \times 10^{-6} m^2 \times 3 \times 10^8 \frac{m}{s}} = 3.18 \times 10^{-6} \frac{N}{m^2}$$

Monday, October 20, 2014
Chapter 20
Questions
20.2 The speed is inversely proportional to the index of refraction. Therefore the material with the highest index of refraction will have the lowest speed. We have from lowest speed to greatest speed: diamond, crown glass, water, air.

20.7 From figure 20.10 we see that as the wave fronts enter a higher refractive index material their speeds slow down and the wave fronts bunch of, just like the soldiers marching through the stream slow down and bunch up. This is consistent with equation 20.5, which is Snell's law. Noting that n is the ratio of the speed of light in vacuum to its speed in the material, the index of refraction scales with 1/n and also with 1/λ as well since v = fλ in each medium and as the ray crosses a boundary its frequency does not change, only its wavelength.

20.10 At each air/glass interface, 4% of the light is reflected. On the first pane at the upper air/glass interface, 96% of the light is transmitted into the glass. At the lower glass/air interface 4% of the incident light is reflected and thus 92% is transmitted into the air pocket between the panes. At the upper air/glass interface for the second pane, 4% is reflected and 88% transmitted, and at the lower glass/air interface 4% reflected and 84% transmitted into room. Thus the total amount of reflected light is approximately 16%.

Multiple-Choice
20.6 D
20.7 C
20.8 B
20.10 D
20.11 B
20.17 C
20.18 C

Problems
20.6 A narrow pencil of light striking a fish tank

a. Assuming that the index of refraction is *1.55*, the angle of refraction is given for the light ray going from air into glass as:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

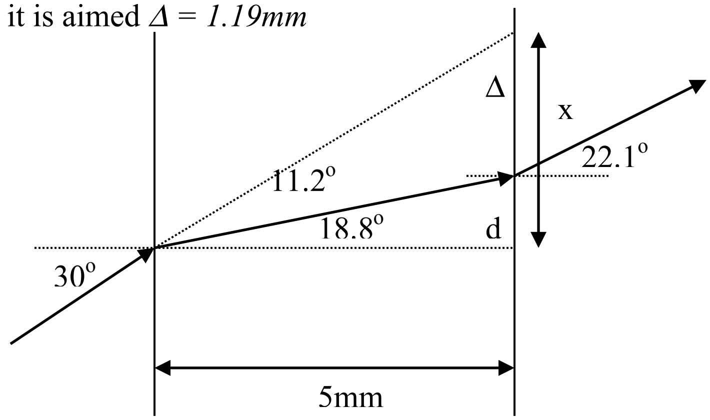
$$\sin(30) = 1.55 \sin\theta_2$$

$$\theta_2 = 18.8^o$$

b. As the ray passes through the glass it will eventually strike the interface between the glass and the water at *18.8°*. For water the index of refraction is *1.33* and the angle of refraction in the water is given as:

$$n_2 \sin\theta_2 = n_3 \sin\theta_3$$
$$1.55\sin(18.8) = 1.33\sin\theta_3$$
$$\theta_3 = 22.1^o$$

c. From the drawing we can see that $x = 5mm\tan 30 = 2.88mm$ and $d = 5mm\tan 18.8 = 1.70mm$ so that the difference between where the beam strikes and where it is aimed *Δ = 1.19mm*

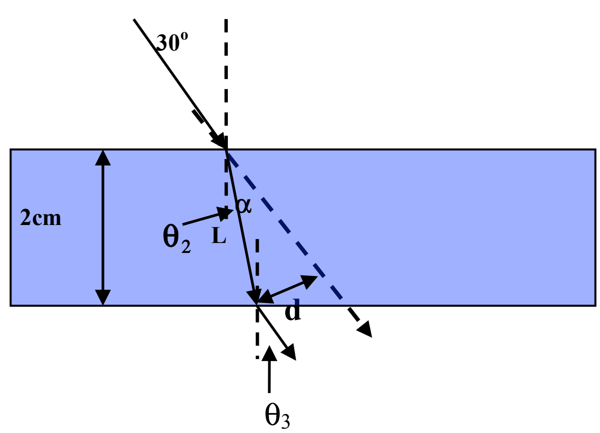


20.7. Using the diagram below we have at the upper surface, using Snell's law $n_{air}\sin 30 = n_2 \sin\theta_2 = 1.5\sin\theta_2 \rightarrow \theta_2 = \sin^{-1}(0.333) = 19.5^o$. At the lower surface we have the ray striking at 19.5o with respect to the normal and from this we can determine the exit angle, q3. Applying Snell's law we have $n_2 \sin 19.5 = 1.5\sin 19.5 = n_{air}\sin\theta_3 \rightarrow \theta_3 = \sin^{-1}(0.500) = 30^o$ and the ray leaves parallel to itself. However the ray is displaced by an amount *d* from its incident direction. To determine the displacement of the beam we first realize that $30^o = \theta_2 + \alpha$, so that $\alpha = 30^o - 19.5^o = 10.5^o$. Therefore from the geometry we have

$$\sin\alpha = \frac{d}{L} \rightarrow d = L\sin\alpha = \frac{0.02m}{\cos(19.5)}\sin(10.5) = 0.00389m = 0.39cm = 3.9mm.$$

Where again from the geometry the path the light takes is

$$\cos\theta_2 = \cos 19.5 = \frac{2cm}{L} \rightarrow L = \frac{0.02m}{\cos 19.5} = 0.021m.$$



20.8. In the medium we have the speed of light given by $v = \frac{c}{n} = \frac{3\times10^8 \frac{m}{s}}{1.5} = 2\times10^8 \frac{m}{s}$ and this corresponds to a wavelength in the medium of $\lambda_{air} = \frac{v}{f} = \frac{2\times10^8 \frac{m}{s}}{88.3\times10^6 s^{-1}} = 2.3m$. In the air we have the wavelength given as $\lambda_{air} = \frac{c}{f} = \frac{3\times10^8 \frac{m}{s}}{88.3\times10^6 s^{-1}} = 3.4m$. Using the results from problem #7, we have the time for the light to cover a distance L in the material as

$$v = \frac{L}{t} \rightarrow t = \frac{L}{v} = \frac{0.021m}{2\times10^8 \frac{m}{s}} = 1.07\times10^{-10} s = 0.107ns$$