Physics 111 Homework Solutions Week #7 - Friday

Tuesday, February 18, 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:

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

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

$$\theta_2 = 18.8^o$$

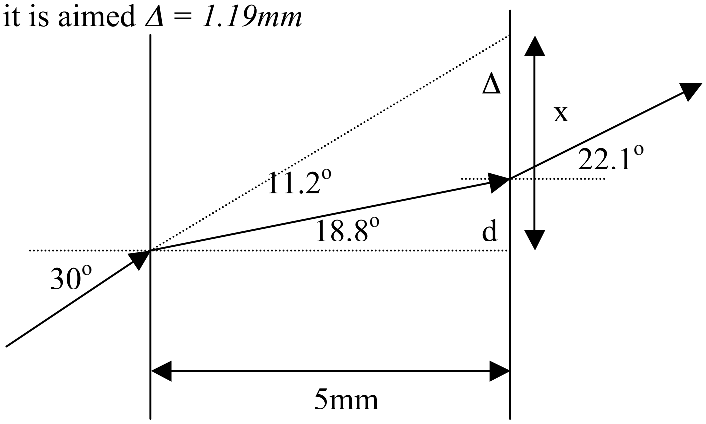
b. As the ray passes through the glass it will eventually strike the interface between the glass and the water at *18.8°*. For water the index of refraction is *1.33* and the angle of refraction in the water is given as:

$n_2 \sin\theta_2 = n_3 \sin\theta_3$

$1.55\sin(18.8) = 1.33\sin\theta_3$

$\theta_3 = 22.1^o$

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 $\Delta = 1.19mm$

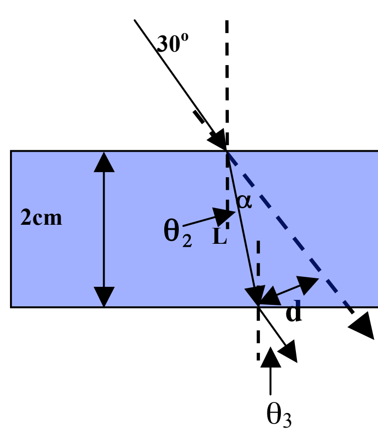


20.7. Using the diagram below we have at the upper surface, using Snell's law $n_{air} \sin 30 = n_2 \sin\theta_2 = 1.5\sin\theta_2 \rightarrow \theta_2 = \sin^{-1}(0.333) = 19.5^o$. At the lower surface we have the ray striking at 19.5o with respect to the normal and from this we can determine the exit 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 $v = \frac{c}{n} = \frac{3\times 10^8 \frac{m}{s}}{1.5} = 2\times 10^8 \frac{m}{s}$ and this corresponds to a wavelength in the medium of $\lambda_{air} = \frac{v}{f} = \frac{2\times 10^8 \frac{m}{s}}{88.3\times 10^6 s^{-1}} = 2.3m$. In the air we have the wavelength given as $\lambda_{air} = \frac{c}{f} = \frac{3\times 10^8 \frac{m}{s}}{88.3\times 10^6 s^{-1}} = 3.4m$. Using the results from problem #7, we have the time for the light to cover a distance *L* in the material as $v = \frac{L}{t} \rightarrow t = \frac{L}{v} = \frac{0.021m}{2\times 10^8 \frac{m}{s}} = 1.07\times 10^{-10} s = 0.107ns$

Wednesday, February 19, 2014
Chapter 19
Questions

- None

Multiple-Choice

- None

Problems

20.15 We find the critical angle from

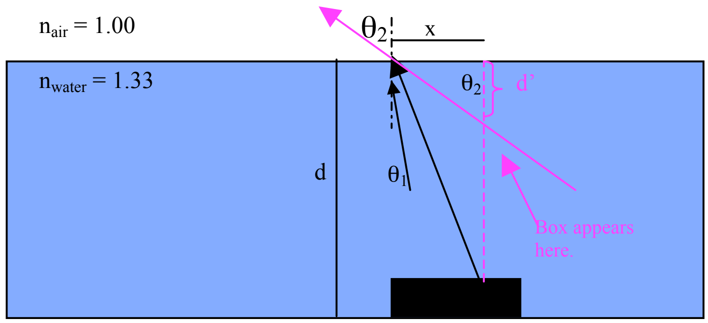
$n_1 \sin\theta_1 = n_2 \sin\theta_2 \rightarrow n_1 \sin\theta_c = n_2 \sin 90 \rightarrow \sin\theta_c = \frac{1.00}{1.33} \rightarrow \theta_c = 48.8^o$. The radius of the ring of light is given from $r = d\tan\theta_c = 8' \tan 48.8 = 9.1'$

20.16 We use Snell's Law with $n_{water} \sin\theta_1 = n_{air} \sin\theta_2 \rightarrow 1.33\sin\theta_1 = \sin\theta_2$. Defining *x* as the distance from the normal to the surface to where the ray originates, we can express θ_1 in terms of *d* and *x* and θ_2 in terms of *x* and *d'* as follows: $\tan\theta_1 = \frac{x}{d}$ and $\tan\theta_2 = \frac{x}{d'}$. Since the angles involved are small, we can use the small angle approximation to get $\sin\theta_1 \approx \tan\theta_1 = \frac{x}{d} \rightarrow x = d\sin\theta_1$ and

$\sin\theta_2 \approx \tan\theta_2 = \frac{x}{d'} \rightarrow x = d'\sin\theta_2$. Therefore,

$x = d\sin\theta_1 = d'\sin\theta_2 = d'\frac{n_{water}}{n_{air}}\sin\theta_1$. Thus the apparent depth is given as

$d' = \frac{n_{air}}{n_{water}} d$. A ray diagram is shown below.



20.17 From the diagram below we apply Snell's Law at the upper surface where we want the ray to strike at the critical angle. We have therefore

$n_{pipe} \sin\theta_c = n_{air} \sin 90 = 1.0 \sin 90 \rightarrow \theta_c = \sin^{-1}\left(\frac{1.00}{1.30}\right) = 50.3^o$. From the geometry we see that the angle of refraction of light off of the front surface of the pipe, α is $\alpha = 90^o - \theta_c = 90^o - 50.3^o = 39.7^o$. Therefore θ can be found by applying Snell's Law on the front surface and we have

$n_{air} \sin\theta = n_{pipe} \sin\alpha \rightarrow \theta = \sin^{-1}\left(\frac{n_{pipe} \sin\alpha}{n_{air}}\right) = \left(\frac{1.30 \sin 39.7}{1.00}\right) = 54.2^o$.