University Physics, PHYS 227/232 Quiz 6 Fri Apr 18, 2014

Your name and table number: ______________________

Please show your work, write neatly, write units, and $\boxed{\text{box}}$ your answers.

Reflection: $\theta_{\text{incident}} = \theta_{\text{reflected}}$ (measured relative to *normal* to surface)

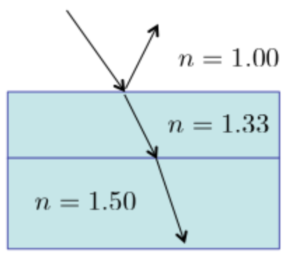
Index of refraction: $n \equiv \frac{c}{v}$ (where $c = 3.0 \times 10^8$ m/s is the speed of light in a vacuum)

Snell's Law for refraction: $n_1 \sin\theta_1 = n_2 \sin\theta_2$

Mirror equation: $1/s_{\text{object}} + 1/s_{\text{image}} = 1/f$ (where f is focal length of the mirror)

Mirror magnification: $M \equiv h_{\text{image}}/h_{\text{object}} = -s_{\text{image}}/s_{\text{object}}$

For a mirror with a circular arc: $s_{\text{center}} = 2f$



1. Consider the above diagram of water in a glass pan, where the top medium is air ($n = 1.00$), the middle medium is water ($n = 1.33$), and the bottom layer is glass ($n = 1.50$). A ray of light strikes the first surface (between the air and water) at an angle of $\theta = 30°$ from the normal.

   (a) (1 points) What is the angle of the ray that is reflected from the first surface as shown in the picture?
   Solution: The reflected angle is equal to the incident angle, so $\boxed{\theta_{\text{reflected}} = 30°}$.

   (b) (3 points) What are the angles from normal for the refracted light rays in the water and the glass?
   Solution: Using Snell's Law:

$$\begin{aligned} n_1 \sin\theta_1 &= n_2 \sin\theta_2 \\ \theta_{\text{water}} &= \sin^{-1}\left(\frac{(1.0)\sin(30°)}{(1.33)}\right) = \sin^{-1}(0.376) = \boxed{22.1° = \theta_{\text{water}}} \\ \theta_{\text{glass}} &= \sin^{-1}\left(\frac{(1.33)\sin(22.1°)}{(1.50)}\right) = \sin^{-1}(0.333) = \boxed{19.5° = \theta_{\text{water}}} \end{aligned}$$

2. An optic fiber is made of clear plastic with an index of refraction of n=1.60, surrounded by a coating with index of refraction of n=1.10.

   (a) (1 points) What is the speed of light v in the fiber, in m/s?
   Solution:

$$n = \frac{c}{v} \quad \Rightarrow \quad v = \frac{c}{n} = \frac{3.0 \times 10^8 \text{ m/s}}{1.60} = \boxed{1.88 \times 10^8 \text{ m/s} = v}$$

   (b) (2 points) For what minimum angle of incidence θ will the light remain within the plastic fiber?
   Solution: The critical angle is where the refracted beam makes an angle of 90° relative to normal, or bends far enough that the refraction does not exist and all you have is internal reflection. Then you can use Snell's Law to find

$$\begin{aligned} n_1 \sin\theta_c &= n_2 \sin\theta_2 = n_2 \sin(90°) = n_2 \\ \theta_c &= \sin^{-1}\left(\frac{n_2}{n_1}\right) = \sin^{-1}\left(\frac{1.10}{1.60}\right) = \sin^{-1}(0.6875) = \boxed{43.4° = \theta_c} \end{aligned}$$

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3. A candle is s_{object}=50.0 cm from the center (on axis) of a concave mirror. The mirror has a focal length of $f = 10.0$ cm.

   (a) (1 points) How far is its image from the center of the mirror?
   Solution: The mirror equation gives

$$\begin{aligned} \frac{1}{s_{\text{object}}} + \frac{1}{s_{\text{image}}} &= \frac{1}{f} \\ \frac{1}{s_{\text{image}}} &= \frac{1}{(10.0 \text{ cm})} - \frac{1}{(50.0 \text{ cm})} = \frac{4}{(50 \text{ cm})} \\ s_{\text{image}} &= \frac{50 \text{ cm}}{4} = \boxed{12.5 \text{ cm} = s_{\text{image}}} \end{aligned}$$

   (b) (2 points) How do the image and object sizes compare?
   Solution: The magnification is

$$\begin{aligned} M &= \frac{h_{\text{image}}}{h_{\text{object}}} = -\frac{s_{\text{image}}}{s_{\text{object}}} \\ \frac{h_{\text{image}}}{h_{\text{object}}} &= -\frac{(12.5 \text{ cm})}{(50.0 \text{ cm})} = -\frac{1}{4} \quad \Rightarrow \quad h_{\text{image}} = -\frac{h_{\text{object}}}{4} \end{aligned}$$

   So the $\boxed{\text{image is 1/4 the size of the object}}$ (and the negative sign indicates it's a real image).