1) The observer in the figure is positioned so that the far edge of the bottom of the empty glass is just visible. When the glass is filled with water (n=1.33), the center of the bottom of the glass is just visible to the observer. Find the height, H, of the glass, given that its width is W=6.2cm.

We need to use right triangles here. Snell’s Law says

\[ n_1 \sin(\theta_1) = n_2 \sin(\theta_2) \]

\[ \sin(\theta_1) = \frac{W}{\sqrt{H^2 + W^2}} \]

\[ \sin(\theta_2) = \frac{2}{\sqrt{H^2 + (W/2)^2}} \]

Plugging in n_1=1 and n_2=1.33, and W=6.2cm, we do some algebra and get

\[ H = 3.6\text{cm} \]

2) A glass paperweight with an index of refraction n rests on a desk, as shown. An incident ray of light enters the horizontal top surface of the paperweight at an angle \( \theta = 77^\circ \) to the vertical. Find the minimum value of n so that there is total internal reflection on the left side, as shown.

Snell’s Law applied to the top and the side give:

\[ (1) \sin(77^\circ) = (n) \sin(\theta_2) \]

\[ (n) \sin(90 - \theta_2) = (1) \sin(90^\circ) \]

Using the trig identity \( \sin(90-\theta) = \cos(\theta) \) gives us:

\[ \sin(77^\circ) = (n) \sin(\theta_2) \]

\[ (n)\cos(\theta_2) = 1 \]

Some algebra (and trig) yields our answer: \( n = 1.4 \)

3) An air wedge is formed by placing a human hair between two glass plates on one end, and allowing them to touch on the other end. When this wedge is illuminated with red light (\( \lambda = 771\text{nm} \)), it is observed to have 179 dark fringes. How thick is the hair?

The 2 rays that are interfering have a relative phase shift, so they are already out of phase. Thus for dark fringes we use the formula \( 2t = m\lambda \). Set \( m = 179 \) and solve for \( t \):

\[ t = \frac{(179)(771 \cdot 10^{-9}\text{m})}{2} = 6.9 \cdot 10^{-5}\text{m} \]

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4) The diffraction pattern shown in the figure is produced by passing He-Ne laser light ($\lambda=632.8\text{nm}$) through a single slit and viewing the pattern on a screen $1.5\text{m}$ behind the slit.

a) What is the width of the slit?

b) If monochromatic yellow light of wavelength $591\text{nm}$ is used with this slit instead, will the distance in the figure be greater or less than $15.2\text{cm}$?

\[ W = (1.5\text{m}) \left( \frac{591 \cdot 10^{-9}\text{m}}{0.076\text{m}} \right) = 2.4 \cdot 10^{-5}\text{m} \]

part (b) Longer wavelength = wider fringes.

5) Experiments show that the ground spider *Drassodes cupreus* uses one of its several pairs of eyes as a polarization detector. In fact, the two eyes in this pair have polarization directions that are at right angles to one another. Suppose linearly polarized light with an intensity of $825\text{ W/m}^2$ shines from the sky onto the spider, and that the intensity transmitted by one of the polarizing eyes is $212\text{ W/m}^2$.

a) For this eye, what is the angle between the polarization direction of the eye and the polarization direction of the incident light?

b) What is the intensity transmitted by the other polarizing eye?

Use $I = I_0 \cdot \cos^2(\theta)$

For part a) we are given $I$ and $I_0$: $212\text{ W/m}^2 = 825\text{ W/m}^2 \cdot \cos^2(\theta) \rightarrow \theta = 60^\circ$

For part b) we know the angle is $90^\circ$ from the first eye, so we use $\theta=30^\circ$:

$I = 825\text{ W/m}^2 \cdot \cos^2(30^\circ) = 619\text{ W/m}^2$

6) The asteroid Ida is orbited by its own small “moon” called Dactyl. If the separation between these two asteroids is $2.5\text{km}$, what is the maximum distance at which the Hubble Space Telescope (aperture diameter $2.4\text{m}$) can still resolve them with $550\text{nm}$ light?

Use Rayleigh’s criterion to find the $\theta_{\text{min}}$.

\[ \theta_{\text{min}} = 1.22 \frac{\lambda}{D} = 1.22 \frac{550 \cdot 10^{-9}\text{m}}{2.4\text{m}} = 2.8 \cdot 10^{-7}\text{rad} \]

From the triangle in the picture we get:

\[ \tan(\theta) = \frac{Y}{L} \Rightarrow L = \frac{2500\text{m}}{\tan(2.8 \cdot 10^{-7}\text{rad})} = 8.9 \cdot 10^9\text{m} \]