1) Some short questions:

(*a*) Find the speed of light in water ($n = 1.33$).

$$v = c/n = 3\times10^8 \text{ m/s} / 1.33$$

Answer: 2.256×10^8 m/s

(*b*) Visible light has wavelengths that range from 400nm at the blue end of the spectrum to 700nm at the red end.

(*c*) Find the wavelength of the radio waves for an FM station that broadcasts at a frequency of 98 MHz.

$$\lambda f = c$$

$$\lambda = c/f = 3\times10^8 \text{ m/s} / 98\times10^6/\text{s}$$

Answer: 3.06 m

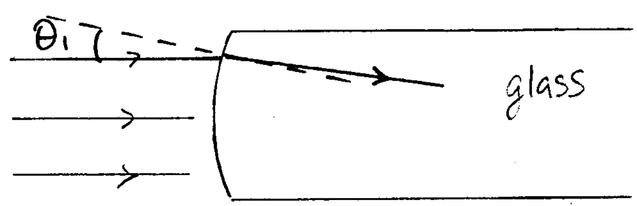
(*d*) The end of a glass rod is curved as shown in the drawings below. Circle the correct answers.

Light rays that are initially parallel are moving from left to right in air. When the rays enter the glass they will:

$\theta_2 < \theta_1$

A) converge to a point

B) diverge

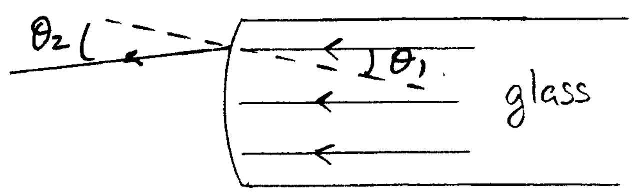


Light rays that are initially parallel are moving from right to left in the glass. When the rays come out into air they will:

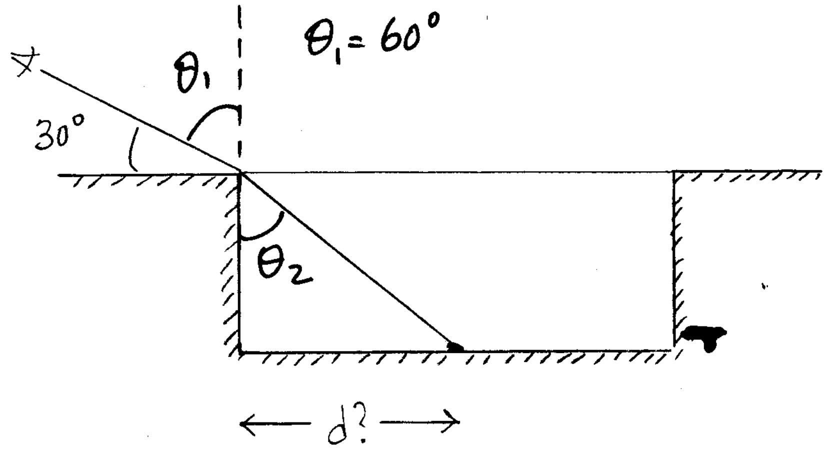
A) converge to a point

B) diverge

$\theta_2 > \theta_1$



2) A swimming pool is filled with water ($n = 1.33$) to a depth of 6 feet. By looking across the edge of the pool along a line of sight that is 30° downward from horizontal, you can just see a coin sitting on the bottom of the pool. How far is the coin from the edge of the pool?



Draw the normal

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

$1.0 \sin 60° = 1.33 \sin\theta_2$

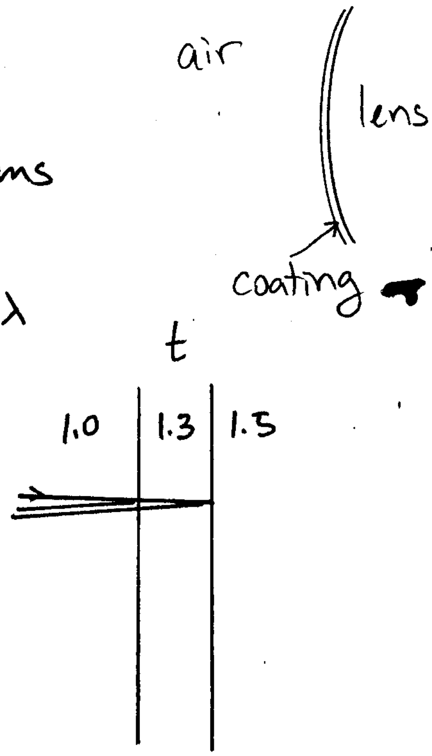
$\theta_2 = 40.63$

$d = 6' \times \tan 40.63$

$d = 5.15'$

$\boxed{5.15'}$

3) A lens with index of refraction $n = 1.5$ is coated with a thin film of a transparent material having $n = 1.3$. The goal is to minimize reflection of light at a wavelength of 550 nm. What is the smallest film thickness for which this is accomplished?



We want to minimize reflection which means destructive interference. Under normal conditions this requires δ = path diff = $(m+\frac{1}{2})\lambda$

Note that both rays invert on reflection so the normal condition still holds.

Here $\delta = 2t$ $\Rightarrow$ we have

$$2t = (m+\tfrac{1}{2})\lambda$$

t minimum when $2t = \frac{1}{2}\lambda$

$$t = \frac{\lambda}{4} = \frac{1}{4}\frac{\lambda_{vac}}{1.3} = \frac{550\,\text{nm}}{4 \times 1.3}$$

$\boxed{105.8\text{ nm}}$

4) Light of wavelength 600 nm is incident on a diffraction grating that has 4000 lines per cm. Two screens are set up as shown in the drawing below. Mark the position of <u>every</u> bright dot that will appear on either screen. Calculate the locations carefully and make sure that your drawing is clear and unambiguous. The drawing is to scale and distances along the screens are shown in centimeters. Show your work in the space below the drawing.

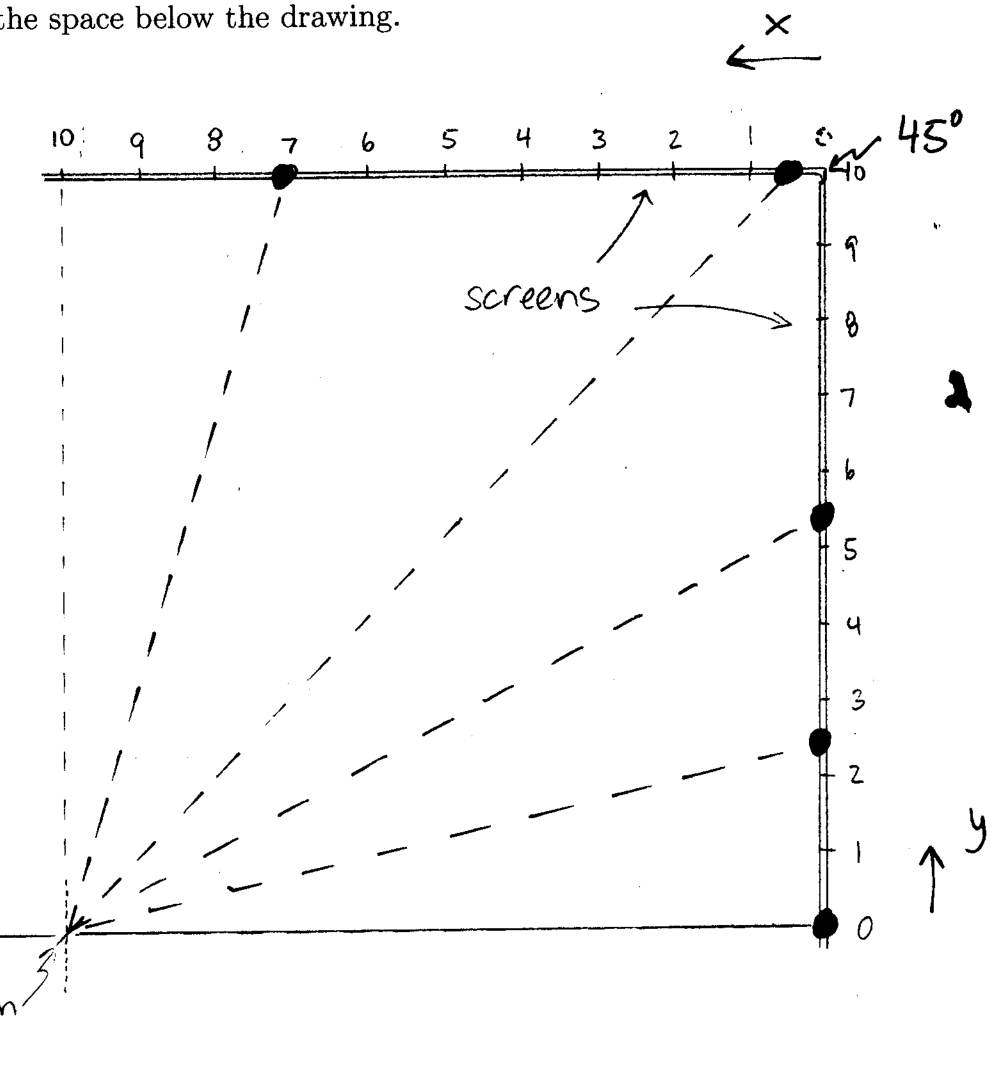
We get spots where

$d \sin\theta = m\lambda$

$d = \dfrac{1\,\text{cm}}{4000} = 2500\,\text{nm}$

$\sin\theta = m\dfrac{\lambda}{d} = m\dfrac{600}{2500}$

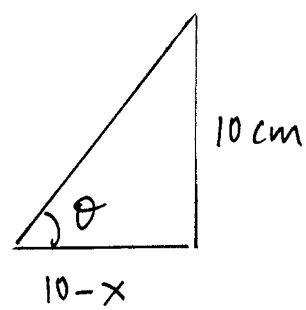
$\sin\theta = 0.24\,m$



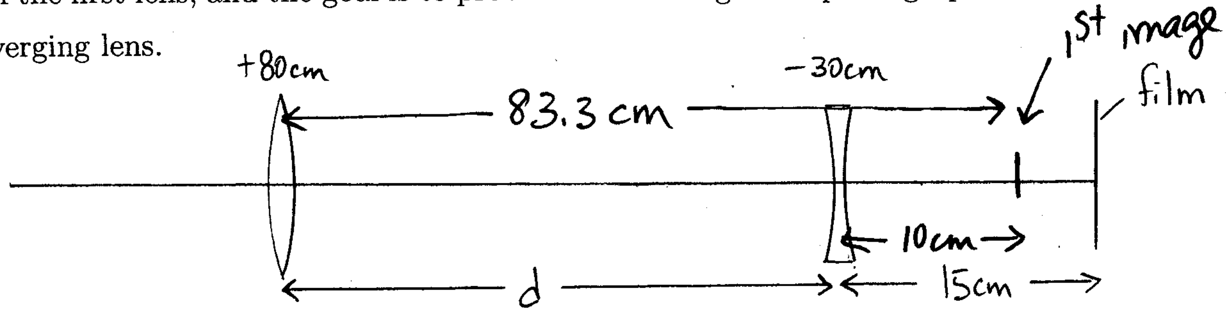
m	$\sin\theta$	θ	$\tan\theta$	$y = 10\,\text{cm} \times \tan\theta$
0	0	0	0	0
1	.24	13.9°	.247	2.47
2	.48	28.7°	.547	5.47
3	.72	46.05	1.037	X = 0.36
4	.96	73.74	3.429	X = 7.08
5		—		

Note: for $\tan\theta > 1$ we have

$\tan\theta = \dfrac{10}{10-x}$



5) A two lens system consists of a converging lens with a focal length of 80 cm and a diverging lens with a focal length of -30 cm separated by some distance d. An object is located 20 meters in front of the first lens, and the goal is to produce a real image on a photographic film 15 cm behind the diverging lens.



(a) For what value of d will the final image be in focus?

1) Find the 1st image $p_1 = 2000$ cm $\Rightarrow$ $\frac{1}{q_1} = \frac{1}{f} - \frac{1}{p_1}$

$$\frac{1}{q_1} = \frac{1}{80\text{cm}} - \frac{1}{2000\text{cm}} \qquad q_1 = 83.3 \text{ cm}$$

2) We need the final image at $q_2 = +15$ cm. $f_2 = -30$ cm

so the object for the second lens must be at

$$\frac{1}{p_2} = \frac{1}{f_2} - \frac{1}{q_2} = \frac{1}{-30} - \frac{1}{15} \Rightarrow p_2 = -10 \text{ cm}$$

The first image must be 10 cm behind the 2nd lens.

So $d = 73.3$ cm

$\boxed{73.3 \text{ cm}}$

(b) If the object is 12 cm high, how large will the final image be?

$$M_1 = -\frac{q_1}{p_1} = -\frac{83.3}{2000} \qquad M_2 = -\frac{q_2}{p_2} = -\frac{15}{-10}$$

$$M = M_1 \cdot M_2 = -\frac{83.3}{2000} \cdot \frac{15}{10} = -0.062$$

$$h_i = M h_o$$

$\boxed{0.75 \text{ cm}}$

(c) Determine whether the final image is upright or inverted.

M negative so

$\boxed{\text{inverted}}$