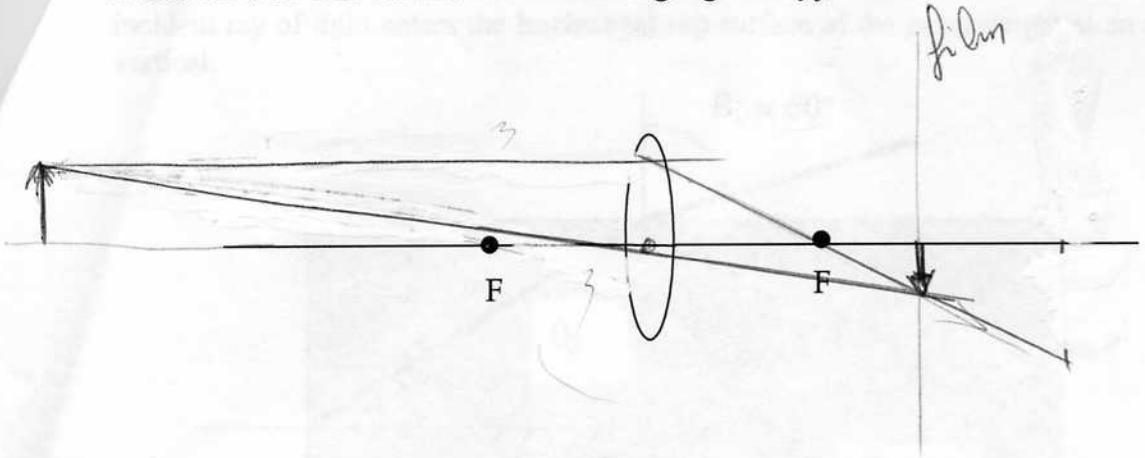
Problem #1. (25 points)

A lens for a 35-mm camera has a focal length given by $f = 45$ mm.



(8 pt) a) How close to the film should the lens be placed to form a sharp image of an object that is 5.0 m away?

(4) $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ $\quad \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$

$\frac{1}{d_i} = \frac{1}{45\times10^{-3}\,m} + \frac{1}{5\,m} = 22.0222\ m^{-1} \Longrightarrow$ (2) algebra $\quad d_i = 4.541\times10^{-2}\,m$

$= 45.41\ mm$ (2)

(8 pt) b) What is the magnification of the image on the film.

$m = -\frac{d_i}{d_o} = -\frac{4.541\times10^{-2}\,m}{5\,m} = -0.908\times10^{-2}$

$= -0.908\,\%$

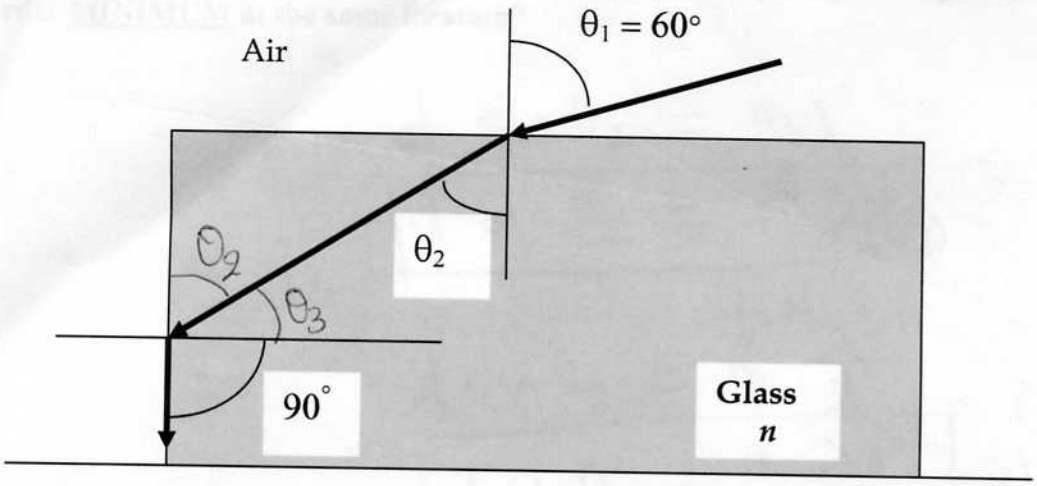
(4) (2)

-0.0091 (2)

(9 pt) c) In the above space, use a ray diagram to show the location of the object and its image.

Problem #2. (25 points)

A glass paperweight with an index of refraction n rests on a desk, as shown in the figure below. An incident ray of light enters the **horizontal top** surface of the paperweight at an angle $\theta_1 = 60°$ to the vertical.



(a) (20 points) Find the value of n for which we have a **total internal reflection** on the **vertical** surface of the paperweight **(Useful equations:** $\sin(90° - \theta) = \cos\theta$

$\tan\theta = \frac{\sin\theta}{\cos\theta}$ **).**

(1). $n_1 \sin\theta_1 = n \sin\theta_2$ or $\sin\theta_1 = n \sin\theta_2$

(2). $n_2 \sin\theta_3 = n_1 \sin 90°$ or $n_2 \sin\theta_3 = 1$

However: $\theta_3 = 90° - \theta_2$ (4) $\sin\theta_3 = \sin(90° - \theta_2) = \cos\theta_2$

$\Rightarrow$ $\sin\theta_1 = n \sin\theta_2$ (3) $\Rightarrow$ $\tan\theta_2 = \sin\theta_1 = \sin 60° = 0.866$

$1 = n \cos\theta_2$ (3) $\theta_2 = 40.89°$

$\Rightarrow n = \frac{1}{\cos\theta_2} = \frac{1}{0.7559} = 1.32$ (2)

(b) (5 points) If the angle of incidence is decreased, is the value of the index of n increased or decreased? Explain in detail for full credit.

If θ_1 is decreased, then θ_2 will decrease and $\tan\theta_2$ will decrease. Hence $\cos\theta_2$ will increase and hence n will decrease (since in denominator)

Problem 3. (25 points)

In a **double-slit** experiment it is found that blue light of wavelength 460 nm gives a **second-order MAXIMUM** at a certain location on the screen. What wavelength of light would have a **second-order MINIMUM at the same location**?

$$d \sin\theta_2 = m\lambda$$

$$\boxed{d \sin\theta_2 = 2\lambda_1} \quad (1) \quad (8)$$

$$d \sin\theta_2 = m \frac{\lambda}{2} \quad (m \text{ odd}) \quad (8)$$

$$\boxed{d \sin\theta_2 = 3\frac{\lambda_2}{2}} \quad (2)$$

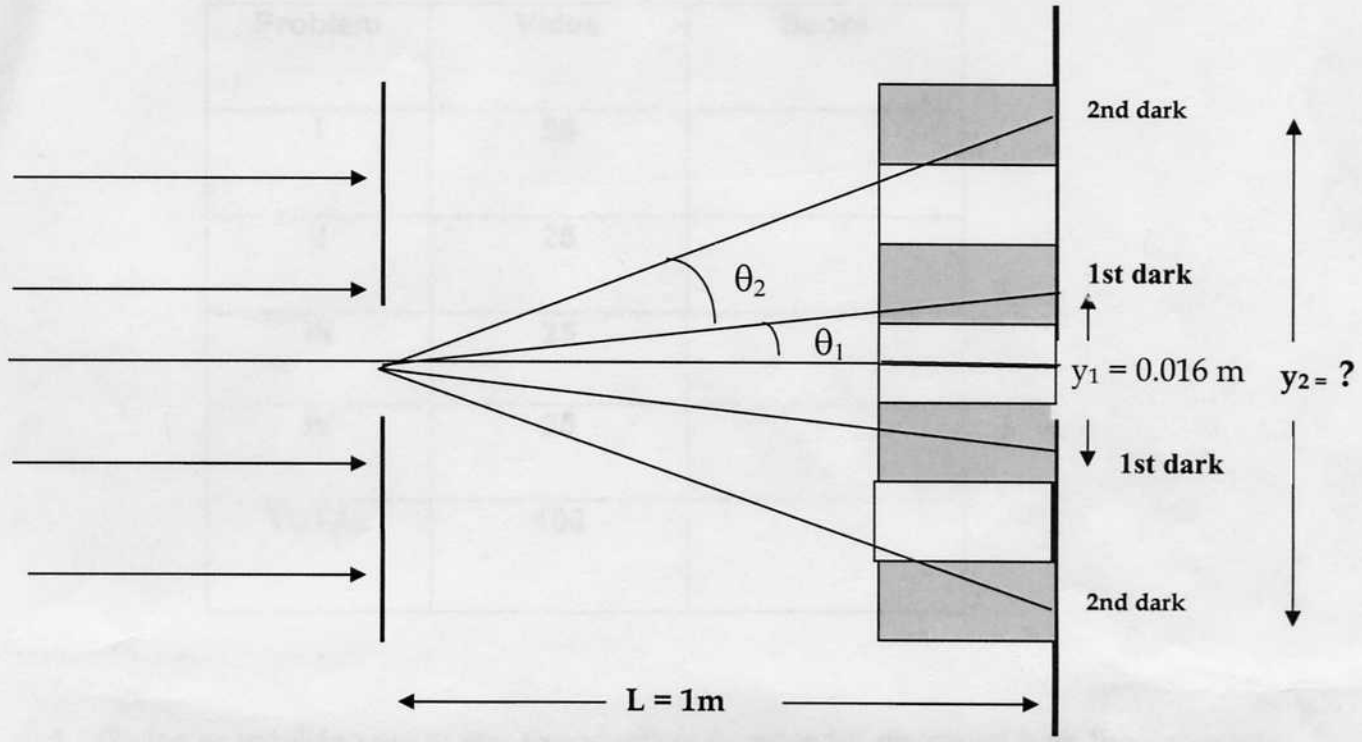
Dividing (1) by (2) we get: (6)

$$1 = \frac{2\lambda_1}{\frac{3}{2}\lambda_2} \quad \text{or} \quad \frac{3}{2}\lambda_2 = 2\lambda_1$$

$$\Rightarrow \lambda_2 = \frac{4\lambda_1}{3} = \frac{4(460\,\text{nm})}{3} = 613.3\,\text{nm} \quad (2)$$

Problem 4 (25 points)

A screen is placed 1.0 m behind a **single** slit. The central maximum in the resulting diffraction pattern on the screen is 0.016 m wide – that is, the two **first-order minima** are separated by 0.016m, as shown below. What is the distance between the two **second-order minima**?



(3) $\tan\theta_1 = \frac{y_1/2}{L} = \frac{8\times10^{-3}\,m}{1\,m} = 8\times10^{-3}$

$\theta_1 = 0.458^\circ$ (2)

$\sin\theta = m\lambda$ (5)

$\sin\theta_1 = 1\lambda$ (1)

$\sin\theta_2 = 2\lambda$ (5)

(3) $y_2 = 2L\tan\theta_2$

$= 2(1m)(1.6\times10^{-2}m)$

$= 0.032m$

$= 3.2cm$ (2)

Dividing: (3) $\frac{\sin\theta_1}{\sin\theta_2} = \frac{1}{2}$ or $\sin\theta_2 = 2\sin\theta_1$

$\sin\theta_2 = 2\sin(0.458^\circ) = 1.599\times10^{-2}$

$\theta_2 = 0.916^\circ$ (2)