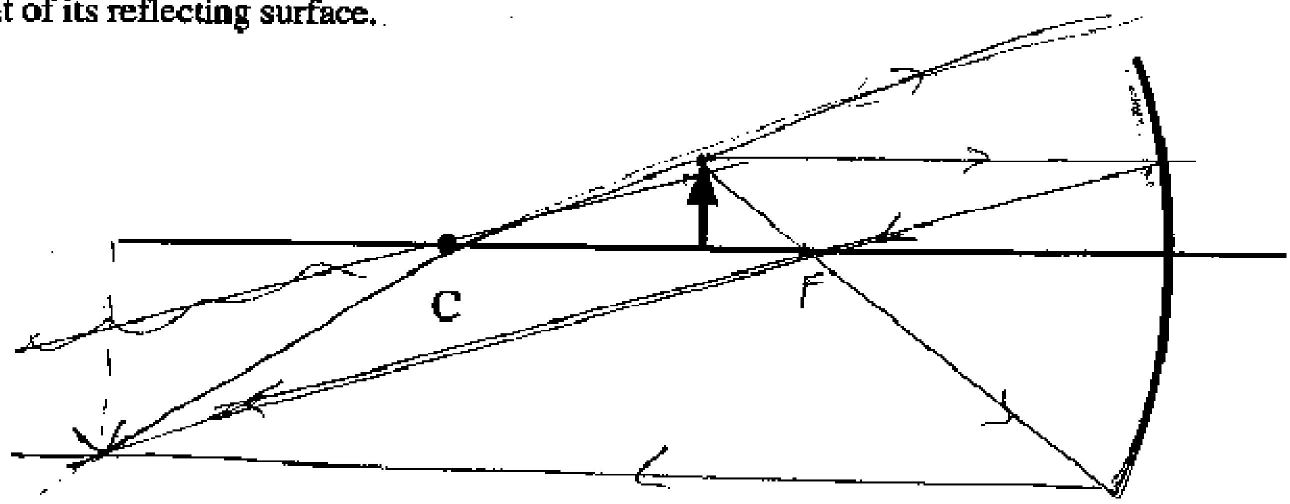
1. A spherical mirror is shown below. Its center of curvature is 50 cm. An object is placed 30 cm in front of its reflecting surface.



A) How far from the mirror surface is the focal point of the mirror?
Draw this in the figure above. (You do not need to be exact in placing this in the figure above since you do not have a ruler handy) (5)

B) Sketch in the drawing above the rays needed to determine where the reflected image is located. (12)

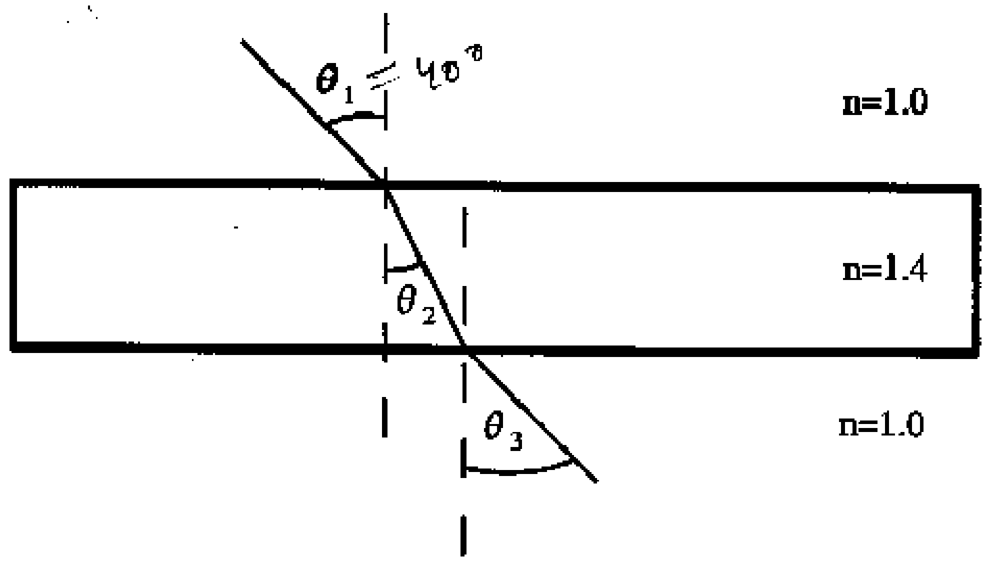
C) Is the image inverted or upright, real or imaginary, and larger or smaller than the object? (you may use your approximate sketch to determine this) (8)

(a) $f = \frac{R}{2} = \frac{50\text{cm}}{2} = 25\text{ cm}$ +2 3

(b) 3 rays → +4 each

(c) Image ⇒ real → +3
inverted → +3
larger → +2

2. A ray of light traveling through air hits a material with an index of refraction of 1.4 at an angle $\theta_1 = 40^\circ$.



A) What is the refracted angle of the ray inside the material (θ_2) ? (5)

B) What is the angle the beam makes with respect to the normal once it leaves the material and enters the air again (θ_3) ? (5)

C) If the wavelength of light in air is given to be 600 nm, is the wavelength different in the material and if so, what is it? (7)

D) If the ray is totally reflected back into the material at the interface between the point where it leaves the material and enters the air again, what is the initial incident angle (θ_1) ? (8)

(a) $\theta_2 = \sin^{-1}\left(\frac{n_1 \sin\theta_1}{n_2}\right)$ +3

$= \sin^{-1}\left(\frac{1}{1.4} \sin 40^\circ\right)$

$\theta_2 = 27.3^\circ$ +2

(b) $\theta_3 = \theta_1 = 40^\circ$ +5

(c) $n = \frac{c}{v} = \frac{\lambda_{vacuum} f}{\lambda_{material} f}$ +3

+2

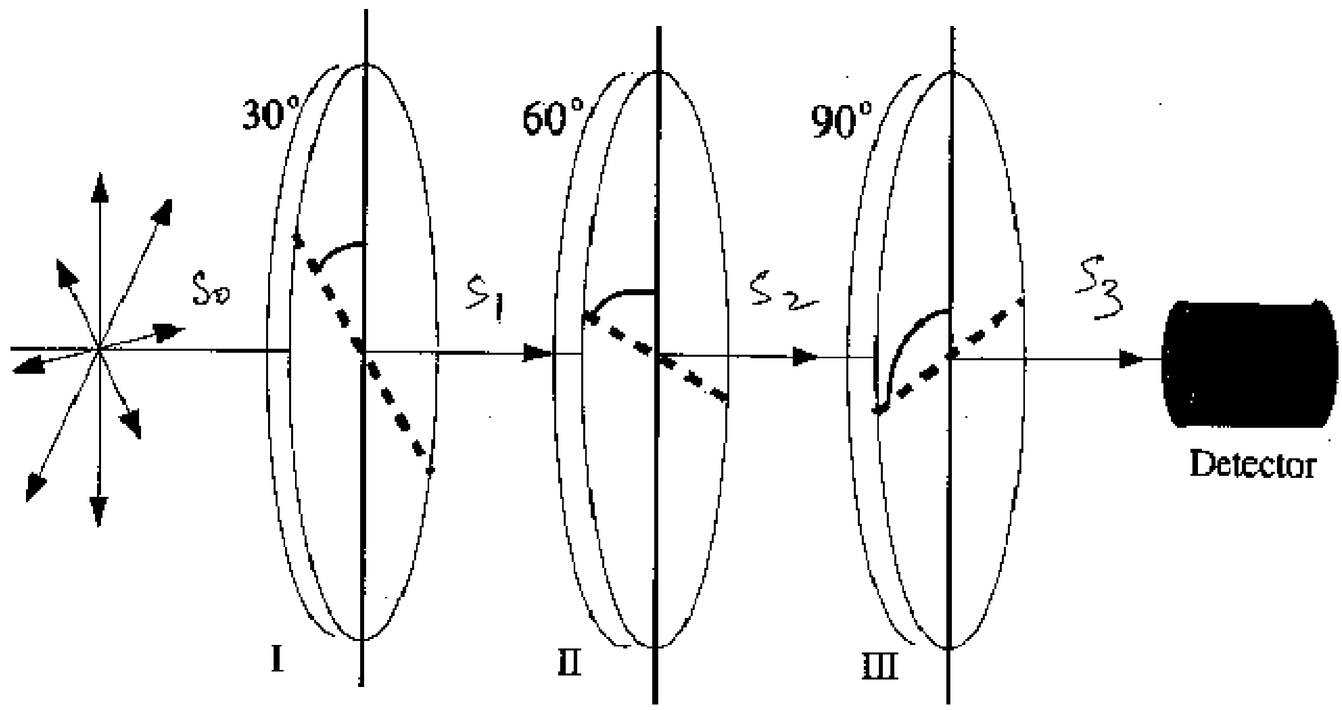
$\Rightarrow \lambda_{material} = \frac{\lambda_{vacuum}}{n} = 428.6$ +5 +2

(D) → +8

$n_1 = \frac{c}{v_1}$ $n_2 = \frac{c}{v_2}$; $\frac{n_1}{n_2} = \frac{v_2}{v_1} = \frac{\lambda_2 f}{\lambda_1 f}$

$\frac{c}{v_1} = n_1$ $\frac{c}{v_2} = n_2$ $\frac{n_1}{n_2} = \frac{v_2}{v_1}$ $n_1 v_1 = n_2 v_2$

3. Three linear polarizing filters are place in the path of an unpolarized light beam whose intensity is 750 W/m². The first one has a polarization aligned 30° from the vertical, the second one has a polarization which is rotated 60° from the vertical and the third one has a polarization rotated 90° from the first filter.



A) Does light make it through all three filters? If so, what is the direction of its polarization at the detector? (5)

B) What is the intensity of light on the right side of the third filter? (20)

(a) Yes, +1 90° w.r.t vertical +4

(b) +5 $S_1 = \frac{1}{2} S_0 = 375 \text{ W/m}^2$

+2 $S_2 = S_1 \cos^2(30^\circ)$ +5

$= 281.25 \frac{W}{m^2}$

+2 $S_3 = S_2 \cos^2(30^\circ)$ +5

$= 210.9 \frac{W}{m^2}$

4. You are in your car and approaching a traffic light. You are driving so fast that the red light appears green. Use 620 nm as the wavelength of the red light and 540 nm as the wavelength of the green light.

A) What is the frequency of the red and the green light? (5)

B) How fast are you approaching the traffic light? (15)

C) According to what was stated in lecture, can you really use the simple equation for the Doppler effect to describe the color shift induced by your speed calculated in part B) ? Explain. (5)

(a) $f_R = \frac{c}{\lambda_R} = \frac{3\times10^8}{620\times10^{-9}} = 0.48\times10^{15}$ Hz (+1) (+2)

$f_g = \frac{c}{\lambda_G} = \frac{3\times10^8}{540\times10^{-9}} = 0.56\times10^{15}$ Hz (+2)

(b) $f_o = f_s\left(1 \pm \frac{v_{rel}}{c}\right)$ +6

$\frac{c}{\lambda_o} = \frac{c}{\lambda_s}\left(1 \pm \frac{v_{rel}}{c}\right)$ +3

$\frac{f_o - f_s}{f_s} = \frac{v_{rel}}{c}$

→ approaching

$\Rightarrow \lambda_s = \lambda_o\left(1 + \frac{v_{rel}}{c}\right)$

Wrong eq. -10 everything else correct

$\Rightarrow \left(\frac{\lambda_s}{\lambda_o} - 1\right)c = v_{rel}$ +4

+2 pts. - correct frequencies

0.44×10^8 m/s $= v_{rel}$

+2

(c) (+1) No → for relativistic speeds we need to modify the eqn. (+4)