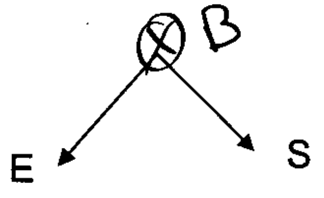
1) Short Answer (Show Your Work!)

a) In which direction is the magnetic field pointing? (2 pts)

$\vec{E} \times \vec{B} = \vec{S}$

down by Right hand Rule



b) When light enters a transparent media where the index of refraction is different, the [✓ (Wavelength)](Frequency) does change. (circle one) (2 pts)

this can since velocity does

this doesn't change

c) Estimate the force on the Earth due to the light emitted by the sun. The average intensity of solar energy at the earth is around 1250 W/m², and the radius of the earth is 6371 Km. (4 pts) Why isn't the earth blown off course by this force (try to be semi-quantitative to back up you assertions)? (2 pts)

$F_{\text{on earth}} = \text{Pressure} \cdot \text{Area}$

$\text{Pressure} = \frac{S_{av}}{c} = \frac{I}{c}$

$F = \frac{1250 \left(\frac{Nm}{s}\right)}{m^2} \frac{\pi (6371{,}000m)^2}{3.0 \times 10^8 \, m/s}$

$= 5.31 \times 10^8 N$

Force~ $5.3 \times 10^8 N$

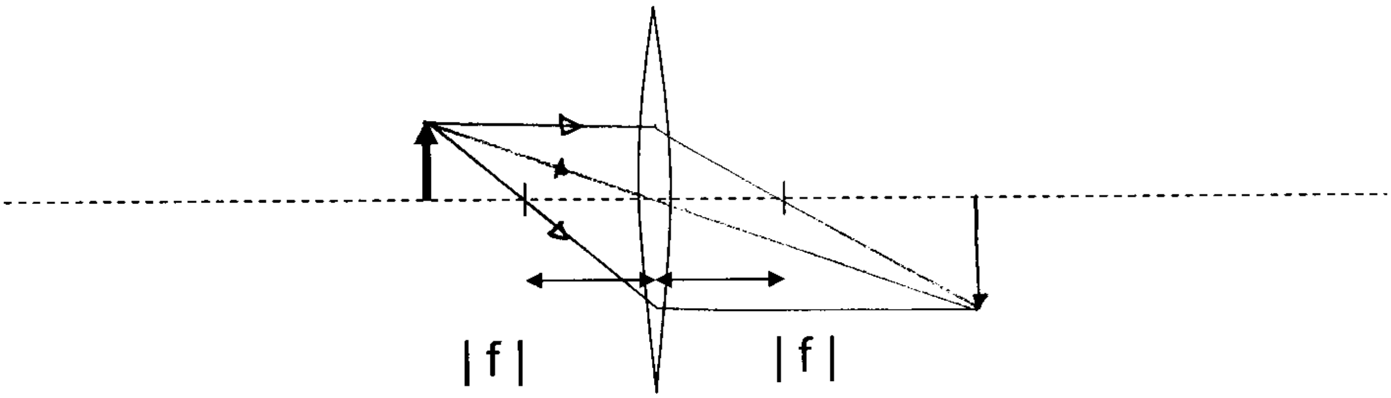
$F_{\text{on earth due to sun}}$? estimate $M_{earth} \sim 1000 \frac{kg}{m^3} \frac{4}{3}\pi (6371{,}000m)^3$ ~ an 10^{24} kg (underestimate!)

$F = mr\omega^2 \sim (10^{24} kg)(1.5 \times 10^{11} m)\left(\frac{2\pi}{\pi \times 10^7 s}\right)^2$

$= 6.5 \times 10^{21} N$ light is a small perterbation

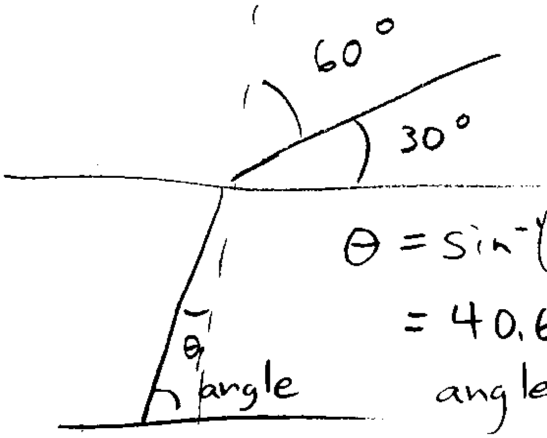
1) Short Answer cont'd (Show Your Work!)

d) Find the image for the object and lens shown below using graphical methods (ray tracing) (4 pts.)



e) A fish jumping out of the water notices that the sun is at an angle of 30 degrees relative to the horizon (or horizontal direction). As the fish plunges back into the water, it calculates the angle the sun should make relative to the horizontal direction under water. The fish opens its eyes and sees it is correct. What is the value of the angle the fish calculated? (n=1.33 for water) (4 pts)

Angle = 49.37°



$\theta = \sin^{-1}\left(\frac{\sin 60°}{1.33}\right)$

$= 40.63°$

$\text{angle} = 90 - \theta = 49.37°$

2) EM waves and Polarization (show your work, make a brief explanation)

An electro-magnetic wave is described by the following equation:

$$\vec{E}(x,t) = E_0 \sin(\frac{1.25e7}{m}\underset{\text{moves along } x}{x} - \frac{3.75e15}{s}t)\hat{k} \leftarrow \text{direction of } E \text{ field}$$

In what direction is this wave traveling ($\hat{i}, \hat{j}, or\ \hat{k}$)? (2 pts)

direction = $\hat{i}$

In order to absorb this wave completely with a polarizer, in which direction should the Transmission axis of the polarizer be oriented ($\hat{i}, \hat{j}, or\ \hat{k}$)? (2 pts)

needs to be ⊥ to $\hat{k}$ & direction

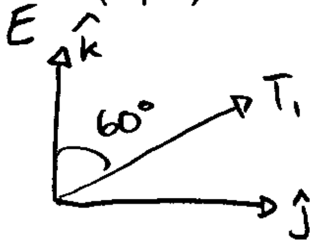
direction of travel $\hat{i}$

leaves $\hat{j}$

direction = $\hat{j}$

To reduce the Electric Field by a factor of 2 with a sheet of polarizing material, in which direction should the transmission axis of a single polarizer be placed? (More than one answer will work, you need supply only one answer)

(4 pts)



need $\cos\theta = \frac{1}{2}$

θ = angle between E & Transmission axis

$\theta = \cos^{-1}\frac{1}{2} = 60°$

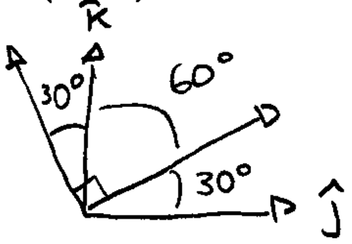
direction = (0) i

$\sin\theta \Rightarrow$ (0.866) j

$\cos\theta \Rightarrow$ ($\frac{1}{2}$) k

To reduce the Electric Field to zero, in which direction should I place the transmission axis of a second polarizer, placed after the first polarizer? (More than one answer will work, you need supply only one answer)

(4 pts) need ⊥ to 1st polarizer



Can re use work

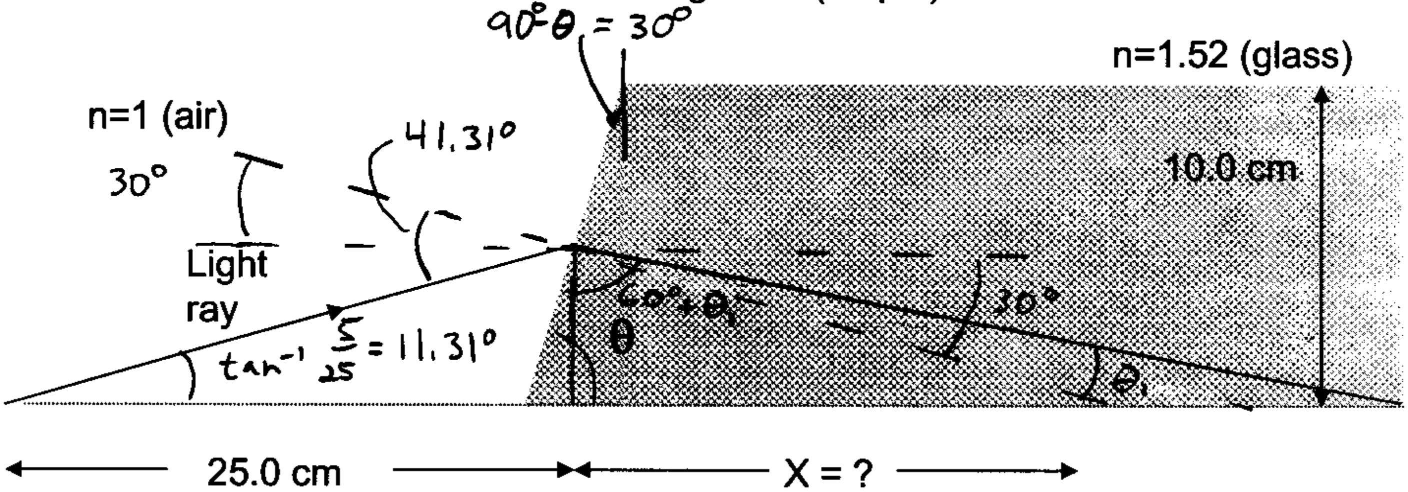
direction = (0) i

($-\frac{1}{2}$) j

(0.866) k

3) Index of Refraction (Show your work!)

A ray of light strikes a piece of glass at a point 5.00 cm above the dotted line as shown in the figure below. At what point x does the refracted ray cross the horizontal dashed line if Theta is 60 degrees? (10 pts)



$x = 5.0\text{cm} \tan(60° + \theta_1)$

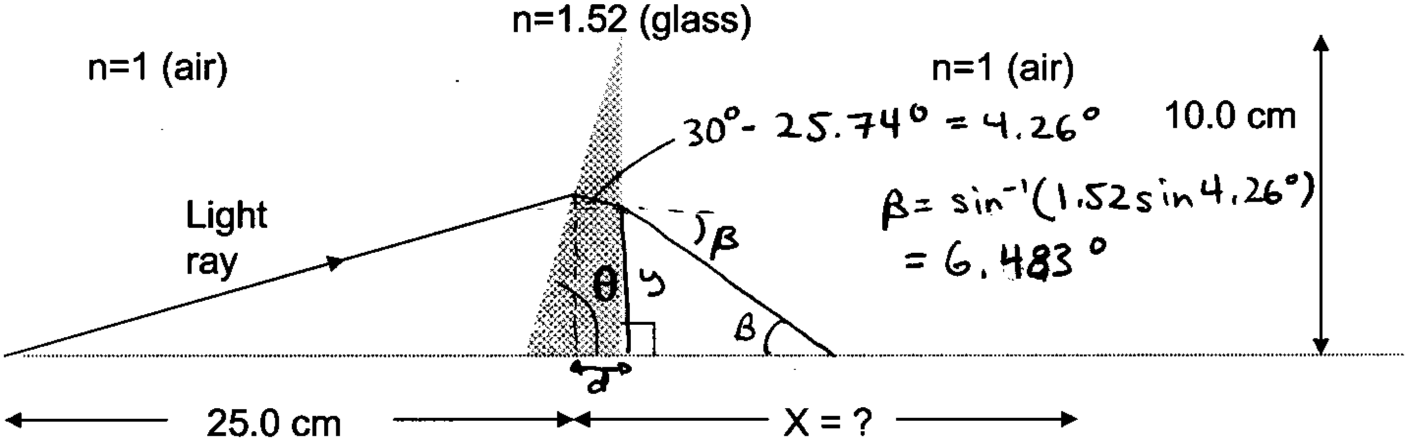
$\theta_1 = \sin^{-1}\left(\frac{\sin 41.31}{1.52}\right) = 25.74°$

$x = 5.0\text{cm} \tan(85.74°)$

$= 67.12\text{cm}$

X= 67.12cm

If a square portion of the glass block is removed, where does X move? (6 pts)



$d = \frac{10\text{cm}}{\tan 60°} - \frac{5\text{cm}}{\tan 60°} = 2.89\text{cm}$

$y = 5.0\text{cm} - 2.89\text{cm} \tan 4.26°$

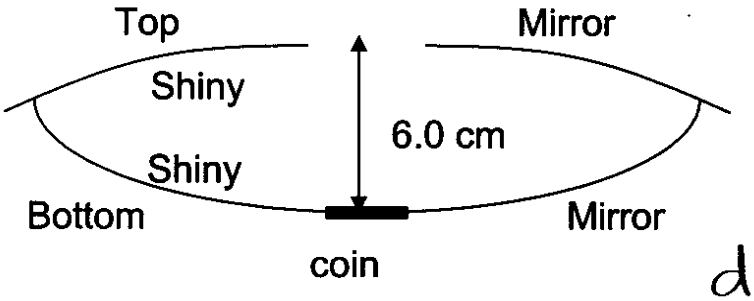
$= 4.78\text{cm}$

$x = d + \frac{y}{\tan\beta} = 2.89\text{cm} + \frac{4.78\text{cm}}{\tan 6.483°} = 44.95\text{cm}$

X= 45 cm

4) Lenses, Mirrors, Magic (Show your work!)

A popular optical illusion uses 2 concave spherical mirrors separated by 6.0 cm as shown. The top mirror, which has a hole in the center, has a radius of curvature of 16 cm. The bottom mirror has a radius of curvature of 10.0 cm. If a coin is placed on the surface of the bottom mirror, where is an image formed from these 2 mirrors with respect to the lower mirror? (10 pts) What is the overall magnification (4 pts), and is this image real or virtual (2 pts)? Hint: Do this in 2 steps, using the mirror with the hole in the first step. The hole is just there to let you see what happens, it won't affect the performance of the mirror for the purposes of this problem.



Location = 6.0cm above bottom mirror

Overall M = −0.8

do 2 steps

$p_1 = 6.0\text{cm}$

top mirror $\quad \frac{1}{p_1} + \frac{1}{i_1} = \frac{1}{f_1} \qquad f_1 = \frac{16.0\text{cm}}{2} = 8.0\text{cm}$

24cm above top mirror $\Longrightarrow i_1 = \frac{(6.0\text{cm})(8.0\text{cm})}{6.0\text{cm} - 8.0\text{cm}} = -24.0\text{cm}$

object for bottom mirror $\Longrightarrow m_{①} = -\frac{(-24.0\text{cm})}{6.0\text{cm}} = +4.0$

$$p_2 = 24.0\text{cm} + 6.0\text{cm} = 30.0\text{cm}$$

$$f_2 = \frac{10.0\text{cm}}{2} = 5.0\text{cm}$$

$$i_2 = \frac{30.0\text{cm}\,(5.0\text{cm})}{30.0\text{cm} - 5.0\text{cm}} = 6.0\text{cm}$$

$$m_{②} = -\frac{6.0\text{cm}}{30.0\text{cm}} = -\frac{1}{5}$$

$$m_{tot} = -\tfrac{1}{5}(4.0) = -0.8$$

real image, about at the height of the top mirror