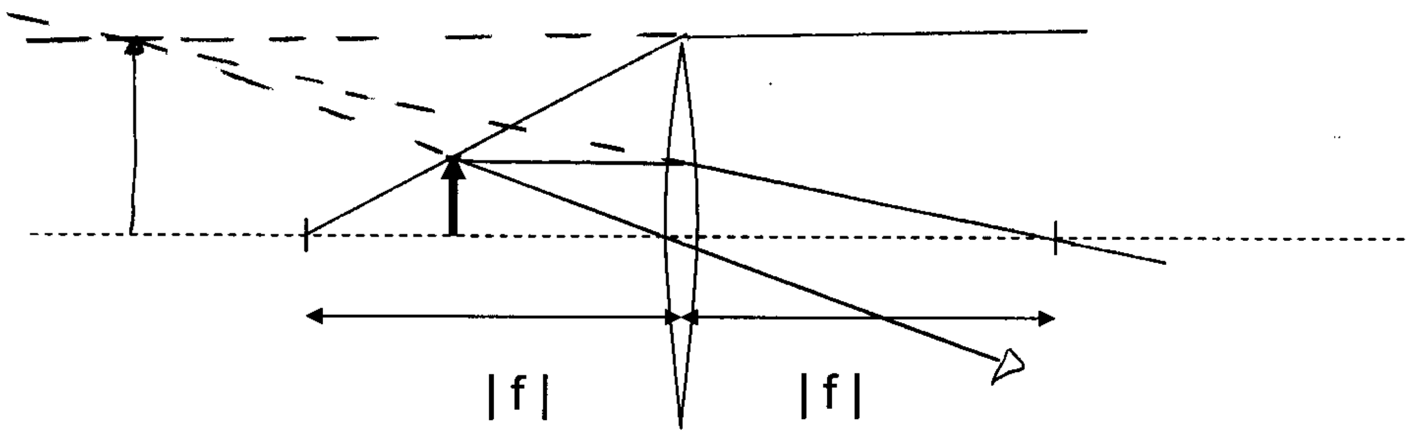
1) Short Answer (Show Your Work!)

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



b) When light enters a transparent media where the index of refraction is different, the (Wavelength) (Frequency) doesn't change. (circle one) (2 pts)

no light pile up

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

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 1200 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)

Pressure = S_{av}/c

Force = Pressure × Area (Assume light is absorbed)

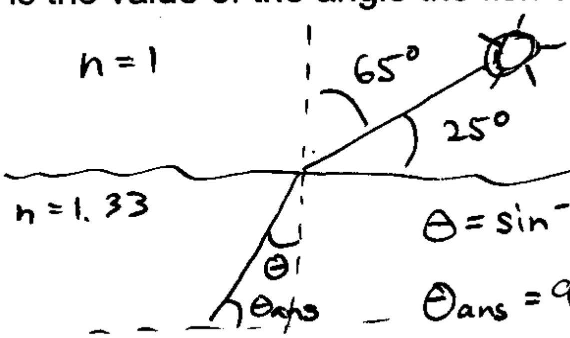
Force~ $5.1\times10^{8}N$

$= \left(1200 \frac{(\frac{Nm}{s})}{m^2}\right) \frac{(\pi (6{,}371{,}000m)^2)}{3.0\times10^{8}\, m/s} = 5.1\times10^{8}N$ small compared to

Assuming earth is water $M_{earth} > 1000\frac{kg}{m^3}\frac{4}{3}\pi(6.371\times10^{6}m)^3 = 10^{24}kg$

& force needed to keep earth in orbit is $mr\omega^2 = (10^{24}kg)(1.5\times10^{11}m)\left(\frac{2\pi}{\pi\times10^{7}s}\right)^2$
$= 6.5\times10^{21}N$ at minimum

d) A fish jumping out of the water notices that the sun is at an angle of 25 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)

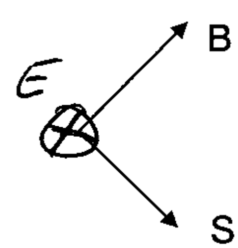


Angle = 47.04°

$\theta = \sin^{-1}\left(\frac{\sin 65°}{1.33}\right) = 42.96°$

$\theta_{ans} = 90° - 42.96° = 47.04°$

e) In which direction is the Electric field pointing? (2 pts)



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

into page by right hand rule

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

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

$$\vec{E}(y,t) = E_0 \sin(\frac{1.25e7}{m} y - \frac{3.75e15}{s} t)\hat{i}$$ ← goes up & down (y ← moves)

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

ex $90° = ky - \omega t$

$k\frac{dy}{dt} - \omega = 0 \quad \frac{dy}{dt} = \frac{\omega}{k}$

direction = $\hat{j}$

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)

E is in $\hat{i}$ direction

polarizer in $\hat{k}$ direction

$\perp$ to $\hat{j}$ & $\hat{i}$

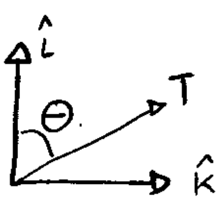
direction = $\hat{k}$

To reduce the Electric Field (intensity) 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 $\cos^2\theta = \frac{1}{2}$

θ = angle bet polarizer & E

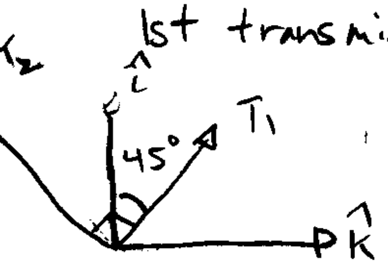
$\theta = \cos^{-1}\frac{1}{\sqrt{2}} = 45°$



direction = (	$\frac{1}{\sqrt{2}}$	) i
(	0	) j
(	$\frac{1}{\sqrt{2}}$	) 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)

Should be 90° wrt the 1st transmission axis

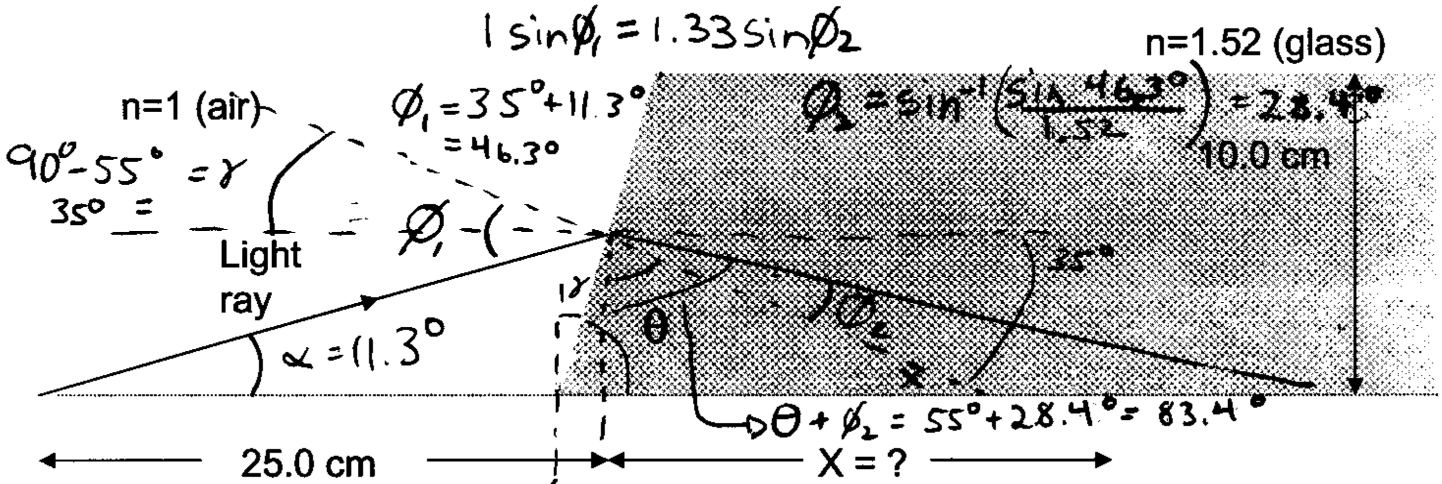


direction = (	$\frac{1}{\sqrt{2}}$	) i
(	0	) j
(	$-\frac{1}{\sqrt{2}}$	) k

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 55 degrees? (10 pts)

$1 \sin\phi_1 = 1.33 \sin\phi_2$



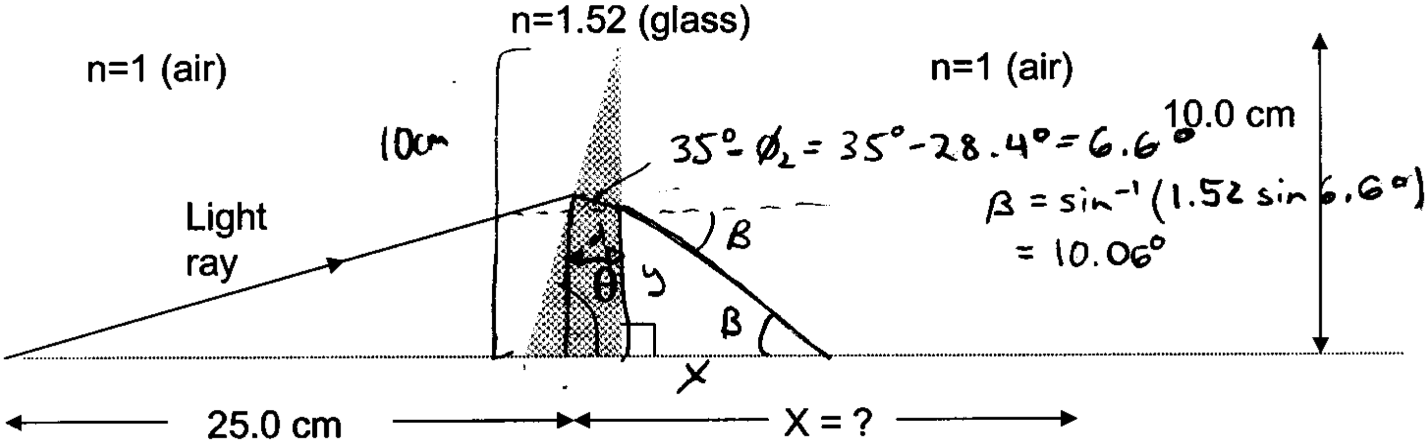
$\alpha = \tan^{-1}\frac{5}{25} = 11.3°$

$\frac{x}{5cm} = \tan(\theta + \phi_2)$

$x = 5.00cm \tan(83.4°)$
$= 43.22cm$

X= 43.22cm

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



$d = \frac{10cm}{\tan 55°} - \frac{5cm}{\tan 55°} = 3.5cm$

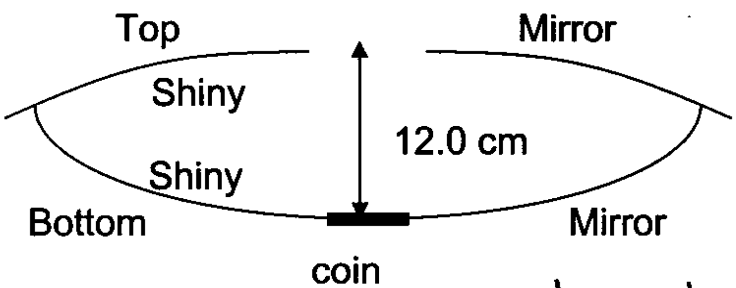
X= 29.4cm

$y = 5cm - 3.5cm \tan 6.6°$
$= 4.60cm$

$x = d + y/\tan\beta = 3.5cm + \frac{4.60cm}{\tan 10.06°} = 29.43cm$

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 32.0 cm. The bottom mirror has a radius of curvature of 20.0 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 = 12.0 cm from bottom
Overall M = −0.8

step 1

$$\frac{1}{p_1} + \frac{1}{i_1} = \frac{1}{f_1} \qquad f_1 = \frac{32.0\text{cm}}{2} = 16.0\text{cm}$$

$$p_1 = 12.0\text{cm}$$

$$i_1 = \frac{p_1 f_1}{p_1 - f_1} = \frac{(12.0\text{cm})(16.0\text{cm})}{12.0\text{cm} - 16.0\text{cm}}$$

$$= -48\text{cm} \qquad m_{①} = -(\frac{-48}{12}) = 4$$

places image 48cm behind the top mirror or 50cm from the bottom mirror

$$p_2 = 60\text{cm} \qquad f_2 = \frac{20\text{cm}}{2} = 10\text{cm}$$

$$i_2 = \frac{(60\text{cm})(10\text{cm})}{(60\text{cm} - 10\text{cm})} = 12.0\text{cm}$$

$$m_{②} = -\frac{12.0}{60} = -\frac{1}{5}$$

$$m_{tot} = 4\left(-\frac{1}{5}\right) = -0.8$$

real image, at about the height of the top mirror, of the same magnification