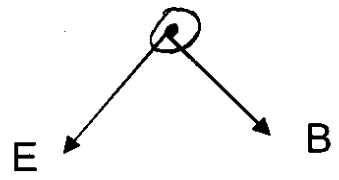
1) Short Answer (20 points)(Show Your Work!)

a) In which direction is the electromagnetic wave traveling?

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

out of page



b) An electromagnetic wave traveling through some material is described by the equation: $\vec{E}(x,t) = E_0 \sin(\frac{6.24e6}{m}x - \frac{1.23e15}{s}t)\hat{k}$ What is n (index of refraction) for this material?

$\frac{2\pi}{\lambda} = k$ $\omega = 2\pi f$

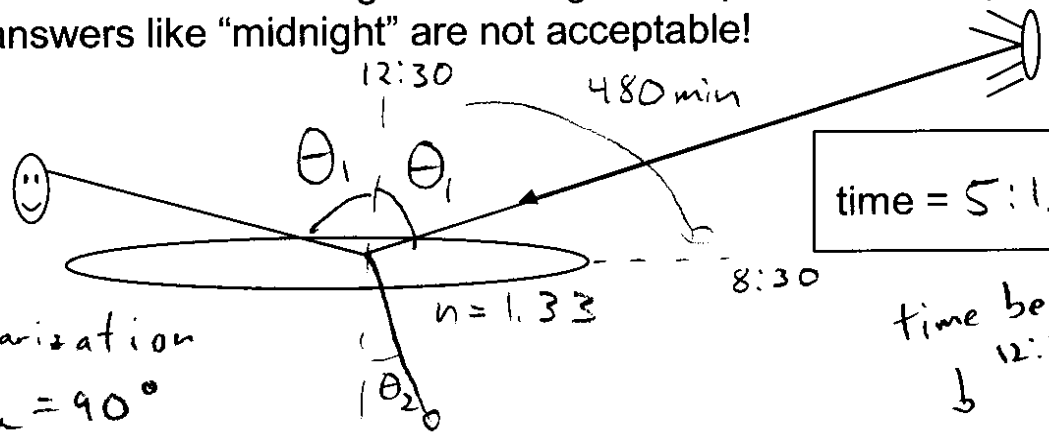
Velocity $= \lambda f$

$= f/k = \frac{1.23 \times 10^{15}/s}{6.24 \times 10^{6}/m} = 1.97 \times 10^{8}$ m/s

$n = c/v = \frac{3.0}{1.97} = 1.52$

n = 1.52

c) If at 12:30 pm the sun is overhead, and at 8:30 pm the sun is at the horizon, what time between 2:00 pm and 7:30 pm do you expect your polarizing sunglasses to be most effective if you are trying to cut the glare from a still pond? I.e. at what time is the light reflecting off the pond maximally polarized? Note that answers like "midnight" are not acceptable!



time = 5:13 pm

get max polarization when $\theta_1 + \theta_2 = 90°$

or $\theta_1 = \tan^{-1}\left(\frac{1.33}{1}\right)$

$= 53.06°$

time between 12:30 & 8:30

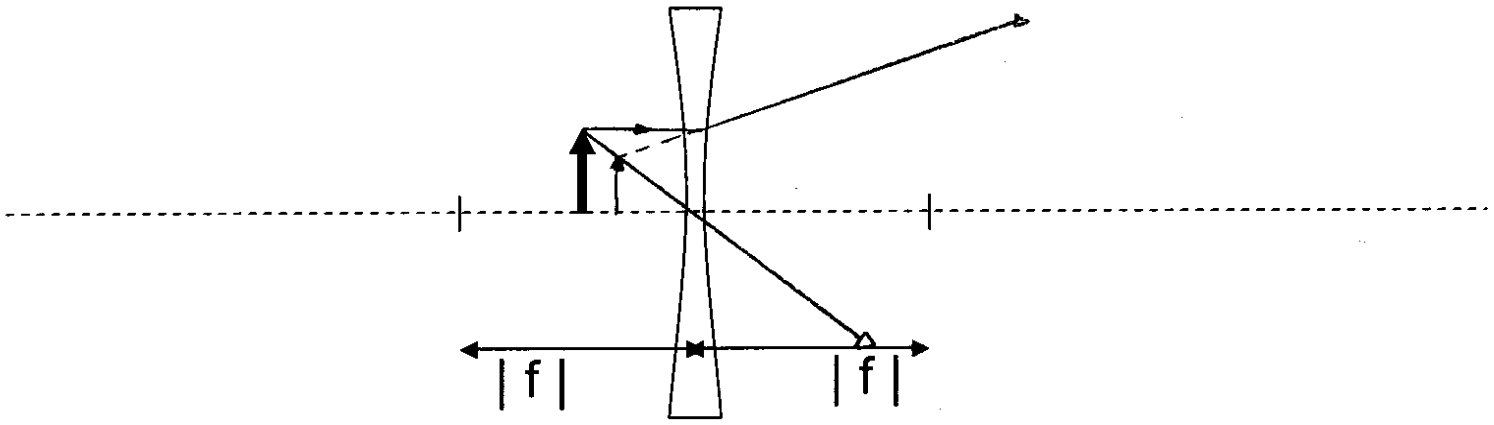
time since 12:30 pm $= 480 \text{ min}\left(\frac{53.06°}{90°}\right)$

$= 283 \text{ min} = 4 \text{ hours } 43 \text{ min}$

5:13 pm

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

d) Find the image for the object and lens shown below using graphical methods (ray tracing) (Try it yourself, no webassign for this one)



e) Estimate the maximum electric field coming from a 100W light bulb at a distance of 1.0 m from the light bulb.

Just like homework

average intensity $= S_{av} = E_{max} B_{max} / 2\mu_0$

$= E_{max}^2 / 2c\mu_0$

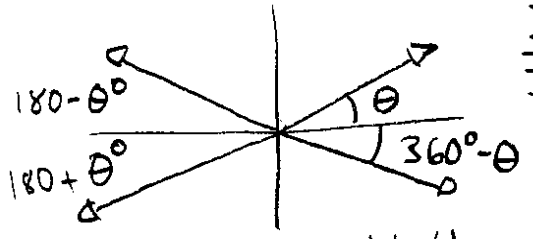
$$E_{max} = \sqrt{\frac{100\,W}{4\pi (1m)^2}(2)\,3.0\times10^8 \frac{m}{s}\left(4\pi\times10^{-7}\,\frac{(\frac{N}{mA})m}{A}\right)}$$

$= 77.46\ N/C$

$E_{max} = 77.46\ N/C$

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

Polarized light is incident on a polarizer. At what angles between 0 and 360 degrees can the transmission axis of the polarizer be placed relative to the electric field of the polarized light so that only 1/3 of the intensity of the original light is transmitted?



$\frac{I}{I_0} = \cos^2\theta$

$\theta = \cos^{-1}\frac{1}{\sqrt{3}}$

$= 54.73°$

all these have $\cos\theta$ the same

List the angles below:

54.73°

125.27°

234.73°

305.27°

If the first polarizer *is left in place*, and a second polarizer is placed after the first one, how many different angles between 0 and 360 degrees can this second polarizer be placed so that the final light transmitted has 1/9 of the intensity of the original light?

same deal, $\frac{1}{3}$ again

# of angles = 4

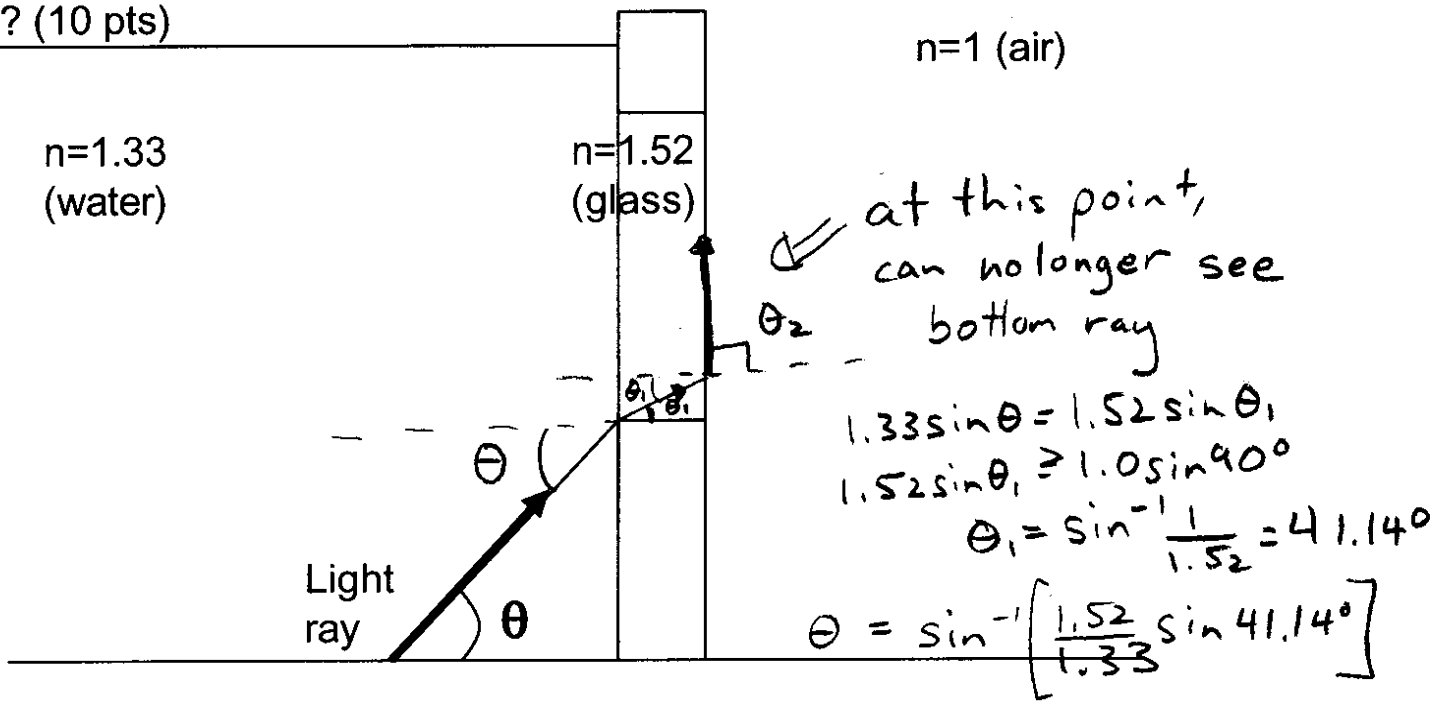
If the first polarizer *is left in place*, and a second polarizer is placed after the first one, how many different angles between 0 and 360 degrees can this second polarizer be placed so that no light is transmitted?

need 90° or $90° + 180° = 270°$

# of angles = 2

3) Index of Refraction (Show your work!)

An aquarium is being constructed with a viewing port. At what angle must the sides of the tank be constructed so that a ray of light traveling along the side (as shown below) makes it all the way through the viewing port to the outside (air)? (10 pts)



$1.33\sin\theta = 1.52\sin\theta_1$

$1.52\sin\theta_1 \geq 1.0\sin 90^\circ$

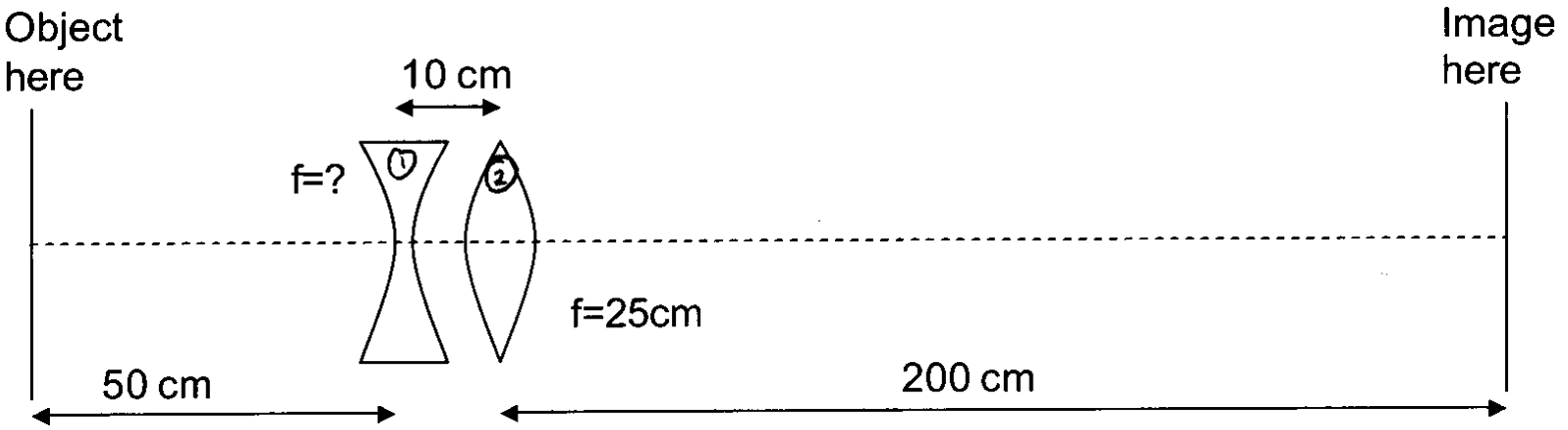
$\theta_1 = \sin^{-1}\frac{1}{1.52} = 41.14^\circ$

$\theta = \sin^{-1}\left[\frac{1.52}{1.33}\sin 41.14^\circ\right]$

$\theta = 48.75^\circ$

4) Lenses (Show your work!)

An overhead projector is being made with a diverging and a converging lens as shown in the figure below. If the focal length of the converging lens is 25 cm, what must the focal length of the diverging lens be to make this design work? What is the overall magnification of the system?



$p_1 = 50\text{cm}$

$i_2 = 200\text{cm}$

Know $p_2 = 10\text{cm} - i_1$

$$\frac{1}{i_1} + \frac{1}{p_1} = \frac{1}{f_1}$$

$$\frac{1}{i_2} + \frac{1}{p_2} = \frac{1}{f_2}$$

$$\frac{1}{i_2} + \frac{1}{i_1 - 10\text{cm}} = \frac{1}{f_2}$$

Diverging lens f = −29.54 cm

Overall M = −2.6

$$10\text{cm} - i_1 = \frac{i_2 f_2}{i_2 - f_2} = \frac{(200\text{cm})(25\text{cm})}{200\text{cm} - 25\text{cm}}$$

$$= 28.57\text{ cm}$$

$$i_1 = -18.57\text{cm}$$

$$f_1 = \frac{i_1 p_1}{i_1 + p_1} = \frac{-18.57\text{cm}(50\text{cm})}{-18.57\text{cm} + 50\text{cm}} = -29.54_{\text{cm}}$$

$$m = m_1 \cdot m_2 = \left(-\frac{i_1}{p_1}\right)\left(-\frac{i_2}{p_2}\right) = -\left(\frac{-18.57}{50\text{cm}}\right)\left(\frac{200}{28.57}\right)$$

$$= -2.6$$