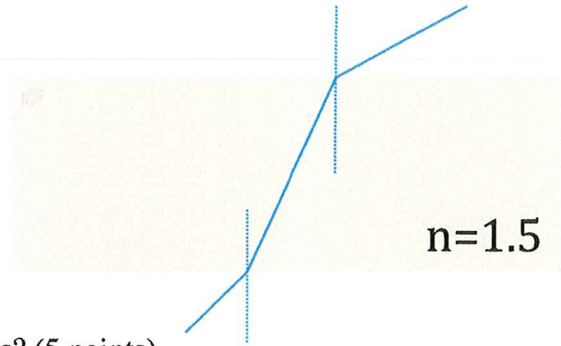
Name: Key

1) This problem concerns visible light with wavelength of 480 nm in air and a flat, rectangular shaped piece of glass with (n=1.5). Note: The rays in the drawing are shown only to define the problem – the angles are NOT drawn correctly.



a. What is the frequency the light in air? (5 points)

$$f = \frac{c}{\lambda} = \frac{3\times10^{8}}{480\times10^{-9}} = 6.25\times10^{14}\ Hz$$

b. What is the wavelength of the light inside the glass? (5 points)

$$\lambda_n = \frac{\lambda}{n} = \frac{480}{1.5} = 320\ nm$$

c. What is the frequency of the light after entering the glass? (5 points)

Same as outside! $F = 6.25\times10^{14}\ Hz$

d. If the light is incident on the glass (from air) at an angle of 30 degrees (relative to the surface normal), what is the angle of the transmitted beam relative to the surface normal? (5 points)

$$n_1 \sin 30 = n_2 \sin \theta_t$$

$$\sin\theta_t = \frac{1}{1.5}\cdot\frac{1}{2} \qquad \theta_t = 19.5^\circ$$

e. When exiting the glass block (light travelling from glass to air), what minimum angle of incidence would result in the light being totally reflected and remaining within the block? (5 points)

$$1.5 \sin\theta_c = 1 \sin(90)$$

$$\sin\theta_c = \frac{2}{3}$$

$$\theta_c = 41.8^\circ$$

f. Assuming the glass block surfaces are parallel, is it possible to shine a laser beam on the glass block (from the air) that will enter the block and then be totally internally reflected when it reaches the other side of the block? If not, why not? If so, what should be the angle of incidence when the beam is entering the glass from the air? (5 points)

No! Even if $\theta_i = 90^\circ \Rightarrow \theta_t = ?$ $\quad \sin\theta_t = \frac{1}{1.5} = \frac{2}{3}$

$$\theta_t = 41.8^\circ$$

$\Rightarrow$ to get θ_t large enough to match the critical angle on other side would require angle of incidence $\geq 90^\circ$

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2) You want to make a thin film out of a material with index of refraction n =1.25.

a. If you want to design the film such that it does NOT reflect 500 nm light, what is the minimum thickness of the film that will accomplish that? (assume the film is in air) (5 points) $\frac{\lambda}{2}$ phase change w/ reflection from front surface but not back surface

$\Rightarrow 2t = \lambda_n$ or $t = \frac{\lambda}{2n} = \frac{500\,nm}{2.5} = 200\,nm$

b. If you immerse the film from part (a) in water (n=1.3), will it reflect 500 nm light? Why or why not? (5 points) No! This only changes which surface gets $\lambda/2$ phase shift.

c. If you want to design the film such that it DOES reflect 500 nm light in air, what is the minimum thickness of the film that will accomplish that (assume the film is in air)? (5 points)

require $2t = \frac{\lambda_n}{2} \Rightarrow t = \frac{\lambda}{4n} = 100\,nm$

d. You now choose a harder problem: You want to design a film that will NOT reflect 500 nm light and WILL reflect 400 nm light. What is the minimum thickness of the film, in air, that will work? (10 points) [If you can't find this thickness, find three values for the thickness of the film that will reflect 400 nm light for partial credit.]

$2t = (m + \tfrac{1}{2})\lambda_n$

500 nm light

m	$m\lambda/2n$
1	200 nm
2	400 nm
3	600 nm
4	800 nm
5	1000 nm
⋮	⋮

400 nm light

m	$(m+\frac{1}{2})\frac{\lambda}{2n}$
0	$\frac{\lambda}{4n} = \frac{400\,nm}{5} = 80\,nm$
1	$\frac{3\lambda}{4n} = 240\,nm$
2	$\frac{5\lambda}{4n} = 400\,nm$

$t = 400\,nm$ works!

Name: Key

3) A converging lens has a focal length of 50 cm.

a. How far to the left of the lens should you place an object if you want its image to be real and twice the size of the object? (5 points)

$$m = -\frac{q}{p} = -2 \Rightarrow q = 2p$$

$$\frac{1}{p} + \frac{1}{2p} = \frac{1}{50\text{ cm}}$$

$$\frac{3}{2p} = \frac{1}{50\text{ cm}} \Rightarrow p = 75\text{ cm}$$

b. How far from the lens is the image in part (a)? (3 points)

$$q = 2p = 150\text{ cm}$$

c. Is the image in part (a): i) upright or ii) inverted? (circle one) (3 points)

d. If you place a concave mirror with focal length 30 cm, 160 cm to the right of the lens, find the location of the image formed by the mirror. Provide the distance of the image from the mirror and whether it is on the left or right side of the mirror. (5 points)

$$p = 10\text{ cm}$$

$$\frac{1}{10\text{ cm}} + \frac{1}{q} = \frac{1}{30\text{ cm}}$$

$$\frac{1}{q} = \frac{1}{30\text{ cm}} - \frac{3}{30\text{ cm}} = -\frac{2}{30\text{ cm}}$$

$q = -15\text{ cm}$ (this is to the right of the mirror)

e. Is the image formed by the mirror real or virtual? (3 points) $q < 0$

f. Is the image formed by the mirror upright or inverted compared with the original object? (3 points) mirror does not invert. $\Rightarrow$ still inverted from lens.

g. Will a person standing between the lens and mirror and facing towards the mirror be able to see the image formed by the mirror? Why or why not? (3 points)

yes - the light will reach your eye (from mirror)

Name: Key

4)

a. You set up a double slit interferometer with 632 nm laser light. If the two slits are separated by a distance of 0.1 mm and the observing screen is 2 meters from the slits, how far from the central maximum is the next bright peak in the interference pattern on the screen? (5 points)

$d \sin\theta = \lambda$

$\frac{y}{L} d = \lambda$

$y = L \cdot \frac{\lambda}{d} = 2m \cdot \frac{632 \times 10^{-9} m}{10^{-4} m} = 1264 \times 10^{-5} m$

$= 12.64 \text{ mm}$

b. Describe how you could create polarized light using an unpolarized light source, such as a flashlight, and a piece of flat glass (n=1.5). Specify appropriate angles as necessary. (5 points)

reflect the light off the glass at the polarizing angle. $\tan\theta_p = \frac{1.5}{1} \Rightarrow \theta_p = 56.3^\circ$

c. A "near sighted" person can focus on objects up to a certain distance away from their eye, the "far point", but is not able to focus on things that are farther away than the far point. For objects that are beyond the far point, the image formed by their eye is: (5 points)

i) in front of the retina

ii) behind their retina

[Hint: If you do not remember the answer, you should be able to figure it out from knowing that they are able to focus on some objects and then considering what happens to the image position as the object moves farther away.]

d. Which type of lens does the "near-sighted" person require to correct their distance vision: (circle one) (5 points)

i) converging lens

ii) diverging lens