OZTURK

Robert Ozturk

Name

805137230

UID

✓

1.	2.	3.	Total
24	23	35	82

good

Physics 1CH Midterm #1

April 30, 2019

On all problems, you need to show your work to get full credit.

Below are a set of numerical constants. If you have any questions, please raise your hand to ask for help.

Acceleration of gravity (Earth)	g	10.0 m/s^2
Boltzmann constant	k	1.38×10^{-23} J/K
Electron charge	e	1.60×10^{-19} C
Electron mass	m_e	9.11×10^{-31} kg
		0.511 MeV/c^2
Electron-volt	eV	1.60×10^{-19} J
Permeability of free space	μ_o	$4\pi \times 10^{-7}$ N/A^2
Permittivity of free space	ε_o	8.85×10^{-12} C^2/N-m^2
Planck constant	h	6.63×10^{-34} J-s
Proton mass	m_p	1.67×10^{-27} kg
		938 MeV/c^2
Speed of light in vacuum	c	3.00×10^{8} m/s
Speed of sound in air (20° C)	v_s	340 m/s
Temperature conversion		0° C = 273 K

Index of refraction: Air $n \sim 1.0$

Water $n = 1.33$

Problem 1: Short Answer (40 points total):

a) True or False? *Chromatic aberration can occur in simple lenses, but not in ordinary mirrors.* Explain your answer – i.e. if true, you need to explain why chromatic aberration occurs in one but not the other; if false, you need to explain why it is false.

True, Chromatic abberation is a result of refraction. Specifically, that different frequencies of light have different indices of refraction within a material. Ie. $n(\nu)$. This causes different frequencies of light (diff. colors) to refract more or less, which creates chromatic abbration. Refraction is not involved when dealing with ordinary mirrors, so chromatic abberation does not occur.

8

By definition, refraction does not occur in reflection. What you wanted to say is that reflection is independent of n.

b) A plane electromagnetic wave with angular frequency $\omega = 3.9 \times 10^{15}$ rad/s is traveling through a transparent medium with index of refraction $n = 1.2$. What is the shortest distance between two points along the wave that are separated by a phase difference of 45°?

$\phi = Kx - \omega t$ $\quad v = \frac{c}{n}$ so $v = 2.5 \times 10^8$ m/s ✓

$V = \frac{\omega}{K}$ so $K = \frac{\omega}{V} = \frac{3.9 \times 10^{15}}{2.5 \times 10^8} = 1.56 \times 10^7 \text{ m}^{-1}$ ✓

6

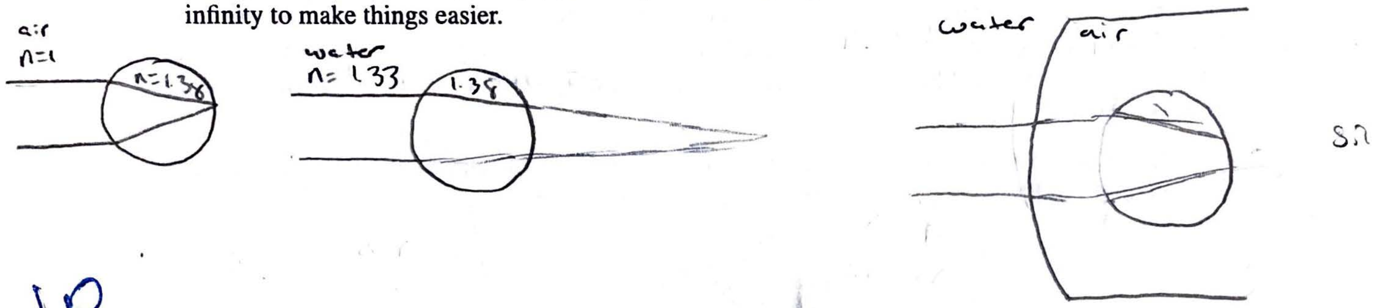
$t = 0 \rightarrow \Delta\phi = Kx_1 - Kx_2 = K\Delta x = 45$ $\quad \Delta x = \frac{45}{K} = \boxed{2.88 \times 10^{-6} \text{ m}}$

→ It's 45° relative to 360° (one cycle)

→ There is a 2π Between K, λ

Problem 1 (continued):

c) The index of refraction of the human cornea is about 1.38. If you can see clearly in air, why can't you see clearly underwater? Why do goggles help? Drawing a picture will help and you can consider an object at infinity to make things easier.



10

Since the index of refraction of water is close to that of the cornea, there will be very little refraction ($n_1\sin\theta_1=n_2\sin\theta_2$). Thus, the light rays coming in from ∞ will converge far past the retina, leading to a blurry image. Goggles help because they create a pocket of air where light can be refracted as if one were out of the water. If the goggles are close it work well

d) True or [✓ False]? *When sunlight reflects off the top surface of a swimming pool, the reflected wave incurs a phase shift of π/2 radians.* Explain your answer.

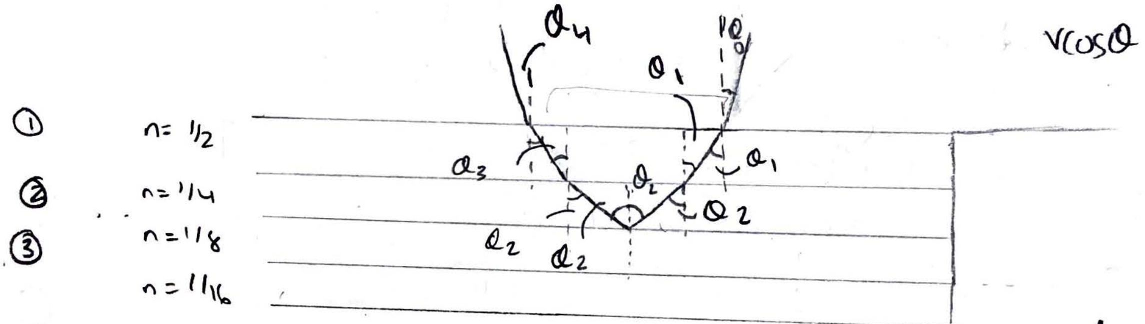
0

The phase shift depends on the) Does not angle of incidence. It is 2θ, since the shift is $\theta_i+\theta_r$ & the law of reflection states that $\theta_i=\theta_r$.

Problem 2: Mystery Lake (25 Points Total):

Deep in the Amazon rainforest is a lake containing a mysterious transparent liquid. The local villagers know that the top 1 m layer has an index of refraction n=1/2, the next 1 m layer has an index of refraction n=1/4, then n=1/8, then n=1/16, and so forth. The lake is very deep, and the index of refraction approaches zero near the bottom. Standing on a ledge above the lake, you take a laser pointer from your pocket and direct it into the lake. Assume that the laser beam hits the planar surface of the lake at an incident angle (measured with respect to the normal) of θ_0, where $0° < \theta_0 < 90°$.

a) What happens to the laser beam for $\theta_0 = 10°$? Support your answer with a calculation that determines the path of the beam in the lake. Illustrate the path of the beam with a figure.



light is alway going into medium w/ half its n value.

① $\sin(10°) = \frac{1}{2}\sin(\theta_1)$ $\theta_1 = 20.3°$

② $\frac{1}{2}\sin(20.3) = \frac{1}{4}\sin(\theta_2)$ $\theta_2 = 43.9°$

$\cancel{n}\sin(\theta_c) = \frac{\cancel{n}}{2}$

③ $\frac{1}{4}\sin(43.9°) = \frac{1}{8}\sin(\theta_3)$ $\theta_3 = ???$

$\theta_c = \sin^{-1}(\frac{1}{2})$

→ Total internal reflection.

Since $\theta_2 > \theta_c$

$\boxed{\theta_c = 30°}$ is critical angle

goes back up. → same θ from law of reflection

$\frac{1}{4}\sin(43.9°) = \frac{1}{2}\sin(\theta_3)$ $[\theta_3 = 20.3°]$

the out of the liquid:

$\frac{1}{2}\sin(20.3°) = 1\sin(\theta_4)$ $[\theta_4 = 10°]$

So, the laser beam comes back out of the liquid at the same angle to the normal as when it entered.

Problem 2 (continued)

b) Now discuss what happens to the laser beam for all values of θ_0. Support your answer with a calculation and discuss the path of the beam for various ranges of θ_0.

The path down:

$n\sin(\theta_c) = \frac{n}{2}$ $\theta_c = 30°$

whenever the angle of incidence exceeds 30°, the beam will come back up mirroring how it went down.

for θ_0 $\theta_1 = \sin^{-1}(2\sin(\theta_0)))$

$\theta_2 = \sin^{-1}(2\sin(\theta_1)) = \sin^{-1}(2\cancel{\sin}(\sin^{-1}(2\sin\theta_0)))$

$= \sin^{-1}(4\sin(\theta_0)))$

So $\theta_n = \sin^{-1}(2n\sin(\theta_0))$

when $\theta_n > 30°$, the beam returns up.

Problem 3: Objects and Images (35 points total)

On an optical bench is a lens with a focal length, $f_1 = +10\,\text{cm}$, and a mirror of unknown type (convex, concave, or planar) and unknown focal length. An upright object, O_1, is located 15 cm to the left of the lens. The mirror is located 50 cm to the right of the lens. The image formed by the mirror, I_2, is inverted and is the same size when compared to the original object O_1.

a) Determine the position of the image formed by the lens, I_1. Is it real/virtual, upright/inverted, and what is its magnification?

$$\frac{1}{15cm} + \frac{1}{I_1} = \frac{1}{10cm} \qquad I_1 = \boxed{30cm}$$ to the right of the lens

$$M = \frac{-i}{o} = \frac{-30}{15} = -2$$

↓

So image is real, inverted, & twice the size

b) Given what you know about the second image, determine the parameters of the mirror: is it convex, concave, or planar, and what is its radius of curvature, R? Determine the position of the image formed by the mirror, I_2. Is it real/virtual?

we know $O_2 = 20cm$ $\quad M = \frac{1}{2} = \frac{-I_2}{O} = \frac{-I_2}{20cm} = \frac{1}{2}$

So $\underline{I_2 = -10\,cm}$

$$\frac{1}{20} + \frac{1}{-10} = \frac{1}{f}$$

$f = -20cm < 0$ so convex

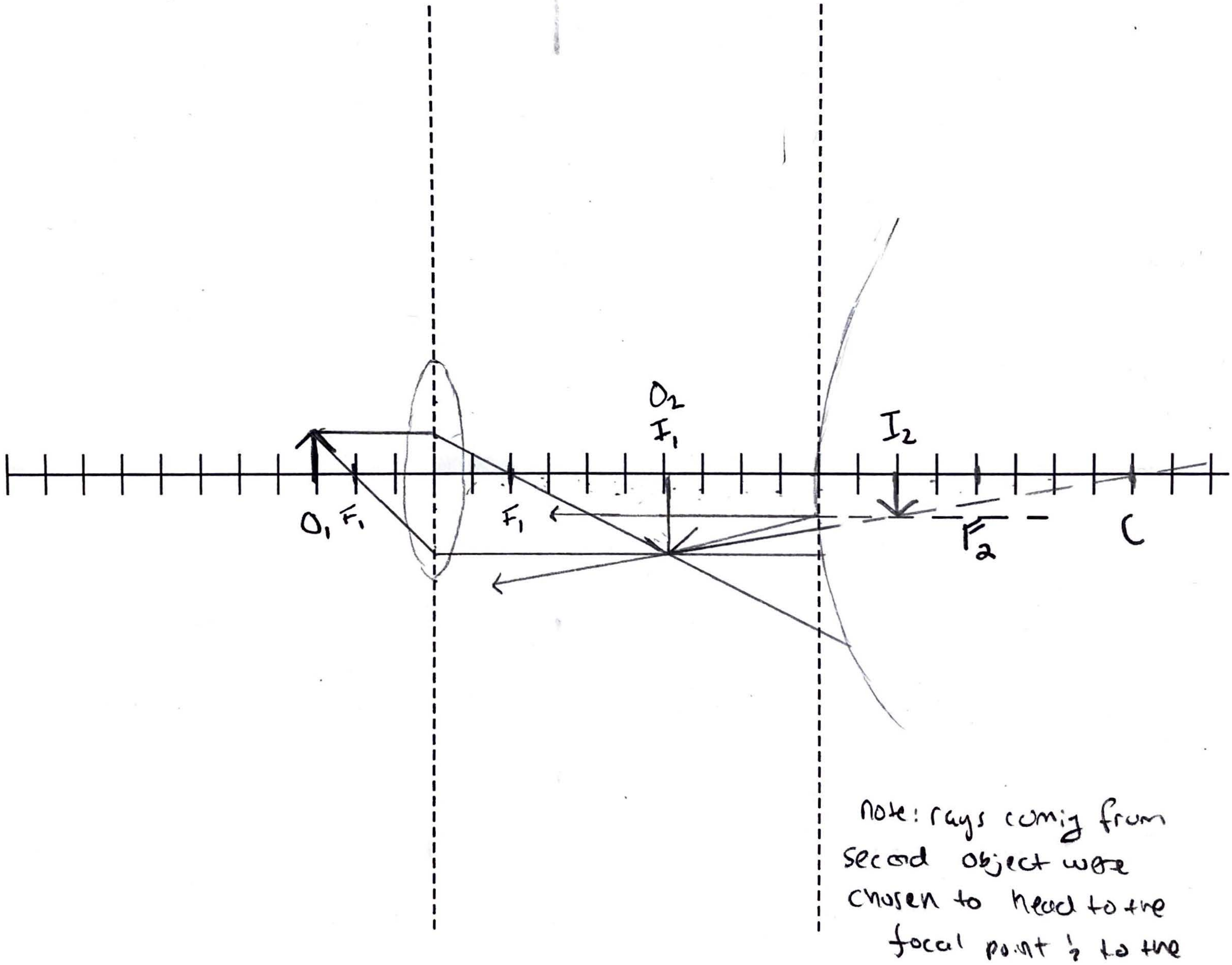
$f = -R/2$ so $R = 40cm$

So the mirror is convex with a radius of curvature of $R = 40cm$

The image is 10 cm to the right of the mirror & Virtual.

Problem 3 (continued)

c) On the horizontal axis below, draw the lens and the mirror. Then, provide a to-scale ray-trace for at least two rays from the initial object to the first image and then at least two rays from the second object to the second image. Indicate the positions of O_1, I_1, O_2, I_2, F_1, F_2, and C, where F_1 identifies the focal points of the lens, F_2 identifies the focal point of the mirror, and C identifies the center of the mirror. (You do not have to ray-trace back through the lens to form a third image).



note: rays coming from second object were chosen to head to the focal point & to the center of the mirror.