William Fehrnstrom

Name

[redacted]

ID

2C

Section

Physics 1C
Fall 2018
Sivaramakrishnan

Midterm Exam

Problem 1: 15

Problem 2: 20

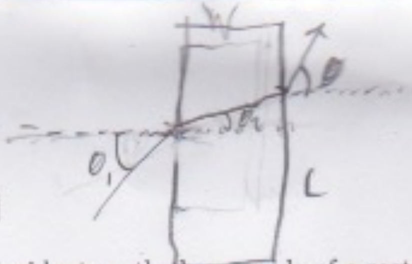
Problem 3: 24

Problem 4: 19

Total: 78 /100

To get credit for an answer you must show your work!

Problem 1: [25 points]



William Fehmstrom

Name

15 a) [15 pts] A light ray is incident on the longer side of a rectangular block of glass at angle θ from the normal. The block has index of refraction $n > 1$, width W, and length $L > W$. Find the path of the ray through the block and out the other side (draw your answer and compute all relevant angles). Is it possible to find a value of n and θ such that no light makes it all the way out the other side (i.e. it is reflected back)? Why or why not?

0 b)[5 pts] Suppose instead there is a small light bulb inside the block of glass. Draw a ray diagram to show where the apparent image would be, as viewed by the eye outside the block of glass.

0 c)[5 pts] Now exchange the location of the eye and bulb so the bulb is outside the block and the observer is inside. Draw a ray diagram to show where the apparent image would be.

a.) Using Snell's law

$\sin\theta_1 = n_{glass}\sin\theta_2$ $\quad \theta_2 = \arcsin\left(\frac{\sin\theta_1}{n_{glass}}\right)$ ✓ $\quad n_{glass}\sin\theta_2 = \sin\theta_3$

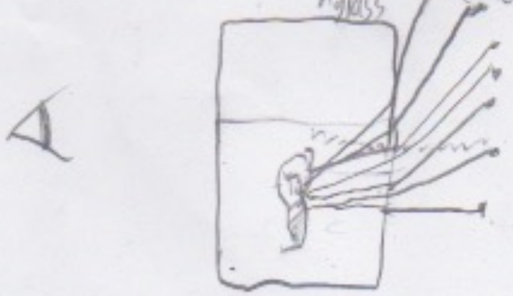
$\theta_1 = \arcsin(n_{glass}\sin\theta_2)$ $\quad$ so $\theta_1 = \theta_3 = \arcsin(n_{glass}\sin\theta_2)$ ✓

$n_{glass}\sin\theta_2 = \sin\theta_3$

$n_{glass} = \frac{1}{\sin\theta_2}$

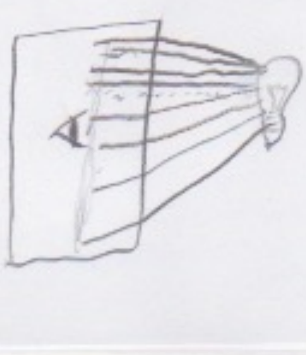
$n_{glass} = \frac{1}{\frac{\sin\theta_1}{n_{glass}}} \neq \frac{n_{glass}}{\sin\theta_1}$ unless $\sin\theta_1 = 1$ and $\theta = \frac{\pi}{2}$ so unless $\theta_1 = \frac{\pi}{2}$ (and it may be considered internal here), it is not possible ✓

b.)



image?

c.)



Q_0

Will Fehrnstrom

Problem 2: [25 points] Name

A circuit contains an inductor L, capacitor C, resistor R, and open switch in series. The capacitor initially carries change Q_0. The switch is closed. Applying Kirchhoff's loop rule, we have the relationship $Q/C + IR + L\frac{dI}{dt} = 0$ where Q is the charge on the capacitor.

12 a) [15 pts] Suppose the charge takes the form $Q(t) = Ae^{t/\tau}\cos(\omega t)$ for some values of τ, ω, A. If $R = 0$, find the value of ω, τ, A such that this is a valid solution to $Q/C + IR + L\frac{dI}{dt} = 0$ with $R = 0$.

3 b) [5 pts] The solution for ω with $R \neq 0$ is $\omega = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$. This solution is only valid for ω real, but at fixed L, ω becomes imaginary for large enough R or C. What do you expect to be the qualitative difference of $I(t)$ between the ω real and imaginary cases? How does this compare to the behavior in an LR circuit (or if you prefer, an RC circuit)?

5 c) [5 pts] What is I_{rms} in the case of $R = 0$?

a.) $Q(t) = Ae^{t/\tau}\cos\omega t$

$L\frac{d^2q}{dt^2} + \frac{dq}{dt}R + \frac{q}{C} = 0 \Rightarrow \frac{d^2q}{dt^2} + \frac{dq}{dt}\frac{R}{L} + \frac{q}{LC} = 0$

by the eqn for harmonic motion

$$\frac{-\frac{R}{L} \pm \sqrt{\frac{R^2}{L^2} - \frac{4}{LC}}}{2}$$

because $\frac{R^2}{L^2} - \frac{4}{LC} < 0$

we then have $\frac{\frac{4}{LC} - \frac{R^2}{L^2}}{2} > 0$

$\omega^2 = \frac{1}{LC} - \frac{R^2}{4L^2}$

$\Rightarrow \frac{1}{LC} - \frac{R^2}{4L^2}$

$\tau = -\frac{2L}{R}$ and since

$\omega = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$

the capacitor is initially charged, $A = Q_0$

$Q(0) = A\cos(0)$

$Q(0) = A$

$= Q_0$

if $R = 0$, $\omega = \sqrt{\frac{1}{LC}}$, $A = Q_0$, τ goes away so we only have harmonic oscillation

~~so~~ τ goes away if $R = 0$ because there is no damping

$\tau \neq 0$, $\tau \to \infty$

b.) Qualitatively if ω is ~~real~~ imaginary then this harmonic system will be overdamped and there will no oscillatory behavior and just current decay.
in the ~~imaginary~~ real case, we do have oscillatory behavior. In an LR circuit, the current does not oscillate, simply decays behaving like an overdamped case.

c.) $\omega = \sqrt{\frac{1}{LC}}$ for $R = 0$

So $I_{Rms} = \frac{\sqrt{\frac{1}{LC}}\,Q_0}{\sqrt{2}}$

and so we have

$Q(t) = Q_0\cos\left(\sqrt{\frac{1}{LC}}\,t\right)$

$I(t) = \frac{dq}{dt} = -\sqrt{\frac{1}{LC}}\,Q_0\sin\left(\sqrt{\frac{1}{LC}}\,t\right)$

Win Rehrasam

Name

Problem 3: [25 points] e.) on back

8 a) [8 pts] Consider an object with ~~some non~~-zero height (for example a rectangle or arrow) on the optical axis of a mirror. Draw four ray diagrams showing how to find the image for the cases of a concave or convex mirror, with the object inside or outside the focal point. State whether the image is inverted or not, and whether the image is real or virtual.

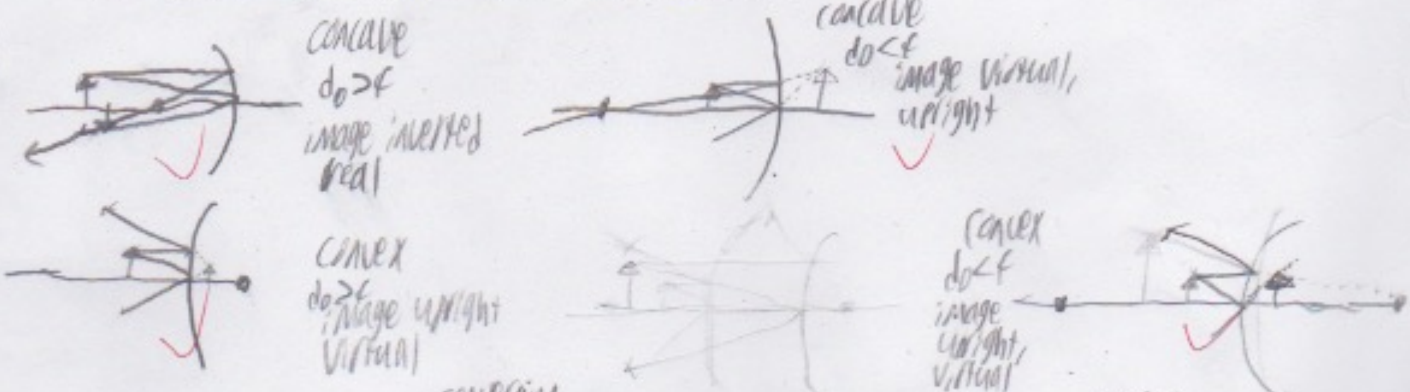
8 b) [8 pts] Do the same for a diverging and converging lens.

5 c) [5 pts] Using ray diagrams and/or the thin lens equation, briefly justify the statement that "solving the converging lens is equivalent to solving the converging mirror" and the same for a diverging lens/mirror.

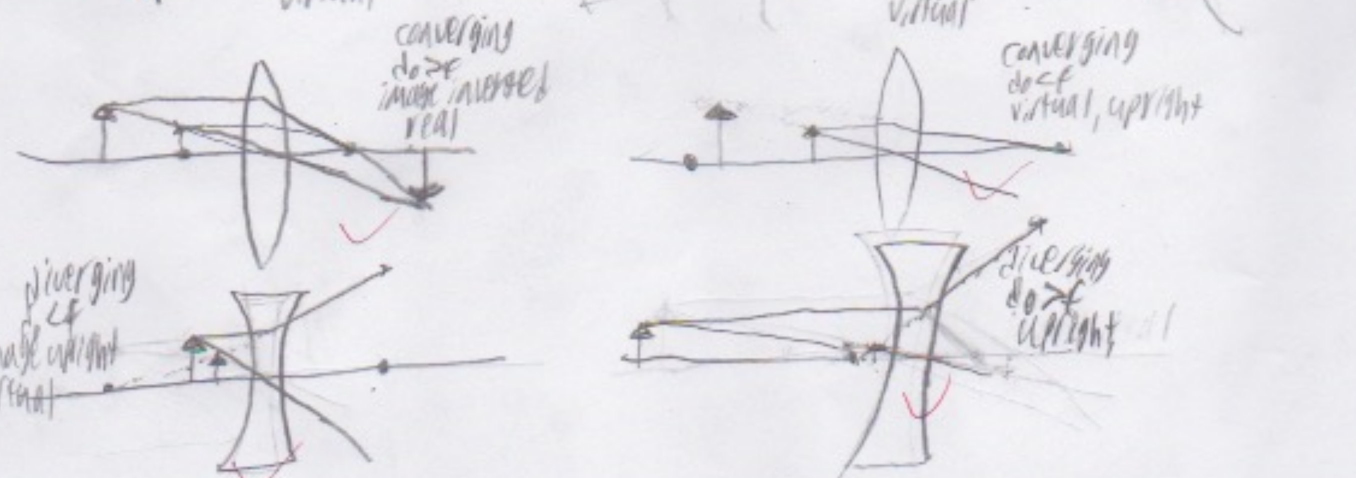
1 d) [2 pts] Where is the image located when the object is placed at the focal point of a converging lens with focal length f? What about for a diverging lens?

2 e) [2 pts] Where is the image located when the object is placed infinitely far from a converging lens with focal length f? What about for a diverging lens?

a.)



b.)



c.) Since mirrors are just like folded versions of lenses, solving a converging lens (unfolded) must give you the folded version (concave mirror) and this is what we see similarly diverging lens are an unfolded version of convex mirrors. we can see this because the thin lens equation applies universally to both mirrors and lens

d.) $\frac{1}{d_o} = \frac{1}{f}$ $\quad \frac{1}{f} + \frac{1}{d_i} = \frac{1}{f}$ $\quad \frac{1}{d_i} = 0$ converging lens, image distance $\to \infty$ $\quad \frac{1}{d_o} = -\frac{1}{f}$

diverging lens, $-\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \Rightarrow \frac{2}{f} = \frac{1}{d_i}$, $d_i = \frac{f}{2}$ $\quad d_i = -\frac{f}{2}$