Physics 375 - Homework 3

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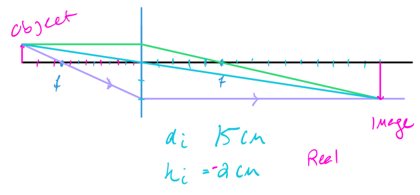
Problem 1

With what we are given in the problem, we can just set up a ratio. We know the relationship is linear between the index of refraction and the focal length, so I believe this would be an appropriate way to solve the problem.

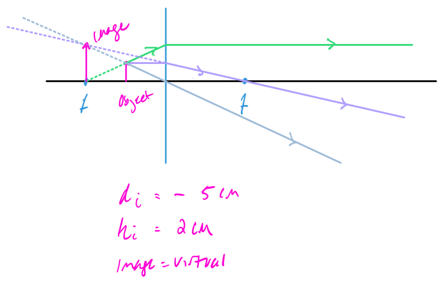
$$\begin{aligned}
\frac{n_{air}}{n_{liquid}} &= |\frac{f_{air}}{f_{liquid}}| \\
\frac{1.48}{n_{liquid}} &= |\frac{0.25m}{1.75m}| \\
1.48 &= |0.1428| * n_{liquid} \\
10.36 &= n_{liquid}
\end{aligned} \tag{1}$$

Problem 2

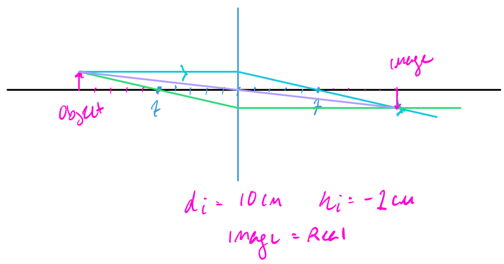
a)



b)



c)



Problem 3

Part A

First use thin lens equation. From there we can use magnification equation to determine height of object and whether it is inverted.

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

$$d_o = 30m;\ f = 0.14m$$

$$\begin{aligned} \frac{1}{30} + \frac{1}{d_i} &= \frac{1}{0.14} \\ \frac{1}{d_i} &= \frac{1}{0.14} - \frac{1}{30} \\ d_i &= 0.1406m \end{aligned} \tag{2}$$

This image will be inverted. This is reflected in the negative sign of the equation below.

$$
\begin{aligned}
m = \frac{h_i}{h_o} &= \frac{-d_i}{d_0} \\
d_o = 30m;\ d_i = 0.1406m;&\ h_0 = 1.85m \\
m = \frac{h_i}{1.85} &= \frac{-0.1406}{30} \\
h_i &= \frac{-0.1406}{30} * 1.85 \\
h_i &= -0.0087m
\end{aligned} \tag{3}
$$

Part B

First handle the convex lens in the front. This calculation is straight-forward and we will be able to take our formulas from above to get the answers.

From there, we will treat the concave lens as a one lens system and figure out the focal length we need in order for the image to converge in the same CCD plane (therefore be real).

Convex lens

$$
\begin{aligned}
\frac{1}{d_o} + \frac{1}{d_i} &= \frac{1}{f} \\
d_o = 29.92m;&\ f = 0.12m \\
\frac{1}{29.92} + \frac{1}{d_i} &= \frac{1}{0.12} \\
\frac{1}{d_i} &= \frac{1}{0.12} - \frac{1}{29.92} \\
d_i &= 0.12048m
\end{aligned} \tag{4}
$$

$$
\begin{aligned}
m = \frac{h_i}{h_o} &= \frac{-d_i}{d_0} \\
d_o = 30m;\ d_i = 0.1406m;&\ h_0 = 1.85m \\
m = \frac{h_i}{1.85} &= \frac{-0.12048}{29.92} \\
h_i &= \frac{-0.12048}{29.92} * 1.85 \\
h_i &= -0.0074m
\end{aligned} \tag{5}
$$

Now we have our numbers to input into our second lens

Concave lens

$$
\begin{aligned}
\frac{1}{-d_o} + \frac{1}{d_i} &= \frac{1}{f} \\
d_o = -0.08048m;&\ f = -0.14m
\end{aligned}
$$

We know that at $f = d_o$, the light will diverge and it will never be formed. We also know that $f_{convex} < f_{concave}$ or else the divergent lens will overpower the convex lens, therefore making the light diverge. From these constraints we can choose a d_i that makes sense for our problem.

$$\begin{aligned}\frac{1}{-0.08048} + \frac{1}{d_i} &= \frac{1}{-0.14} \\ \frac{1}{d_i} &= \frac{1}{-0.14} - \frac{1}{-0.08048} \\ d_i &= 0.1893m\end{aligned} \tag{6}$$

d_i is positive, so we know it is real.

$$\begin{aligned}m = \frac{h_i}{h_o} &= \frac{-d_i}{d_0} \\ d_o = -0.08048m;\ d_i &= 0.1893m;\ h_0 = -0.0074m \\ m = \frac{h_i}{-0.08048} &= \frac{-0.1893}{0.0074} \\ h_i &= \frac{-0.1893}{0.0074} * -0.08048 \\ h_i &= 2.05878m\end{aligned} \tag{7}$$

The image through the telephoto lens will still be inverted compared to the original object, but not inverted compared to the image formed by the convex lens.

$$\begin{aligned}h_{telephoto} &= 2.05878m \\ h_{\text{concave image}} &= -0.0074m\end{aligned} \tag{8}$$

The image through the telephoto lens is $\approx 278x$ larger than the image using just the concave lens

Problem 4

Uncertainty

To estimate uncertainty, I first took a few runs of the code to get a sense of the order to which my measurements where going to come out to. I ran the code over several times, calculating the fractional uncertainty to see how far off I was from a good estimate. Once I found the fractional uncertainty to be well within 1% consistently, I recorded the measurement.

I recorded the standard error, the number of measurements I took, and the average with spread.

For Loop

Please see homework 4 folder: forLoop.m

$N = 1,000$

Standard Deviation: General case

$$time = 1.3924E - 04s \pm 7.8805E - 06s \tag{9}$$

Standard Error: If you make M=1000 measurements

$$time = 1.3924E - 04s \pm 2.4920E - 07s \tag{10}$$

Case: When executed 5 times

$$time = 1.4618E - 04s \pm 5.6786E - 06s \tag{11}$$

Consistent with estimated uncertainty

$N = 1,000,000$

Standard Deviation: General case

$$time = 0.134s \pm 0.0014s \tag{12}$$

Standard Error: If you make M=10 measurements

$$time = 0.1348s \pm 4.4072E - 04s \tag{13}$$

Case: When executed 5 times

$$time = 0.135s \pm 0.0019s \tag{14}$$

Consistent with estimated uncertainty

Dot Operator

Please see homework 4 folder: dotOperator.m

$N = 1,000$

Standard Deviation: General case

$$time = 3.3115E - 05s \pm 1.5714E - 05s \tag{15}$$

Standard Error: If you make M=10000 measurements

$$time = 3.3115E - 05s \pm 1.5714E - 07s \tag{16}$$

Case: When executed 5 times

$$time = 6.1633E - 05s \pm 3.9784E - 05s \tag{17}$$

Consistent with estimated uncertainty

$N = 1,000,000$

Standard Deviation: General case

$$time = 0.0097s \pm 5.8806E - 04s \tag{18}$$

Standard Error: If you make M=100 measurements

$$time = 0.0097s \pm 5.8806E - 05s \tag{19}$$

Case: When executed 5 times

$$time = 0.0099s \pm 1.7676E - 04s \tag{20}$$

Consistent with estimated uncertainty