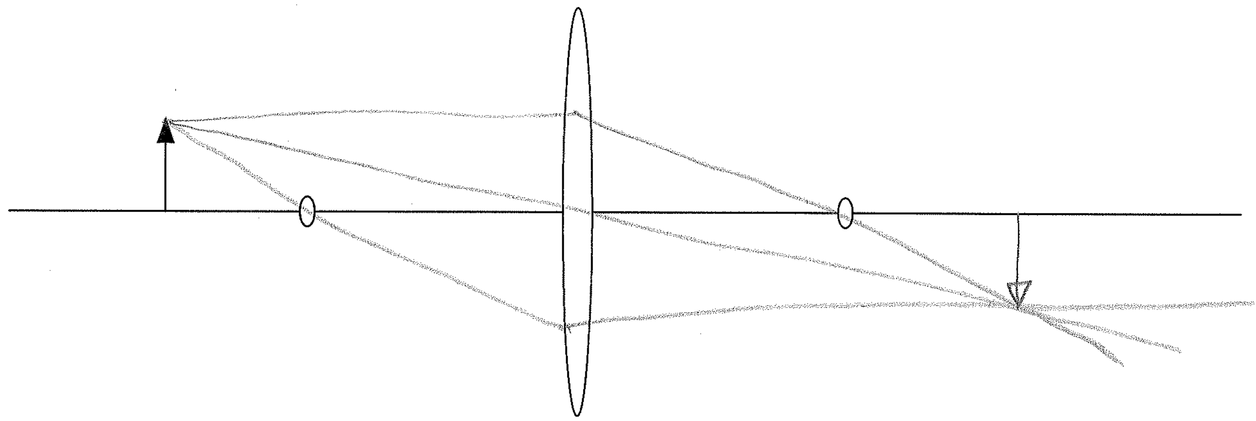
Physics 2120 Test 3

Spring 2010

Name:

- Show all work to receive full credit. Answers must have appropriate units.
- Keep numbers out of your equations until as late as possible. Box-in Final answers.
- Ask if you do not understand the statement of a given problem.

1. An object is placed 10 cm from a converging lens of focal length 6 cm.
(a) On the diagram below use a ray drawing to locate the position of the image.[4 points]



(b) Use the lens equation to find the position of the image analytically. [5 points]

$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$ → $\frac{1}{d_i} = \frac{1}{6} - \frac{1}{10}$

$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$ $d_i = 15$ cm

(c) Is the image real or virtual? Is the image upright or inverted? What is the magnification of the image? [4 points]

Image is real, inverted and $m = -\frac{d_i}{d_o} = -\frac{15}{10}$
$= -1.5$.

(d) A diverging lens of focal length -10 cm is placed 10 cm to the right of the converging lens. Use the lens equation to find the position of the resulting image for the two lens system. [4 points]

Use $d_o = -5$ $f = -10$

$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{1}{-10} - \frac{1}{-5} = \frac{-5+10}{50} \Rightarrow d_i = 10$ cm.

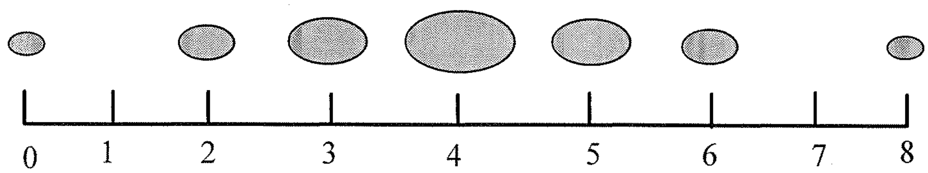
(e) What is the total magnification for the two lens system? [2 points]

$m_T = m_1 \times m_2 = -1.5 \times \left(\frac{10}{-5}\right) = -3$

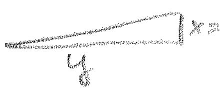
(f) Can the image through the two lens system be displayed on a screen? [1 point]

yes.

2. The figure below shows the diffracted spots of laser light of wavelength 630 nm incident on a pair of slits of equal width, a, and separation d. The scale under the pattern shows a ruler with centimeters spacing. The center bright spot is at 4 cm on the scale. The screen on which the pattern is projected is 1.4 m from the slots.



(a) By considering the position of the first diffracted maximum, determine the slit spacing d. [7 points]



$\lambda = d\sin\theta = d\frac{x}{y}$

$\Rightarrow d = \frac{y\lambda}{x} = \frac{1.4\times 630\,nm}{1\times10^{-2}} = 88.2\,\mu m$

(b) Explain why the third diffracted order is missing and use the position of the suppressed order to determine the width of the slit opening.[7 points]

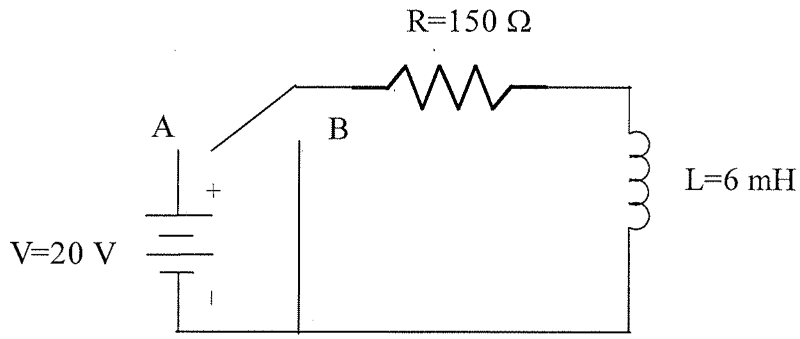
The 3 diffracted order is missing because the single slit opening gives a minimum at the position of the 3rd maximum.

$\lambda = a\sin\theta = a\frac{x}{y} \Rightarrow a = \frac{\lambda y}{x} = \frac{630\,nm\times 1.4}{3\times10^{-2}} = 29.4\,\mu m$

(c) If the entire experiment were submerged under water of refractive index n=1.33, what would you expect to happen to the spacing of the pattern on the screen? [Hint: consider path length difference and the effect of refractive index on the light][6 points]

Under water the wavelength would be smaller $\lambda \to \frac{\lambda}{n}$. Thus, to get the same path difference required for a maximum or a minimum would be smaller and the pattern would contract ie spacing on screen would be finer

3. A resistor-inductor circuit as shown in the figure below is set up.



(a) At time t=0 the switch is thrown to position A. What current flows through the circuit at times 0, 20μs, and 40 μs? [4 points]

$I = I_{max}\left(1 - e^{-\frac{t}{\tau}}\right)$

$\tau = \frac{L}{R} = \frac{6\times10^{-3}}{150} = 40\mu s$

$t = 0 \quad I = 0.$

$t = 20\mu s \quad I = \frac{20}{150}\left(1 - e^{-\frac{20\mu s}{\tau}}\right) = 52.5mA$

$t = 40\mu s$ $84.3mA$

(b) At t = 40 μs what is the rate at which energy is being drawn from the battery? [4 points]

$Power = VI = 20V \times 84.3mA$

$= 1.59$ Watts

(c) At t = 40 μs what is the rate at which energy is being dissipated in the resistor? [4 points]

$Power = I^2 R = (84.3mA)^2\, 150$

$= 1.07$ Watts

(d) At t = 80 μs the switch is thrown quickly to position B. What is the voltage across the inductor when the switch is thrown? [4 points]

I at $80\mu s = 0.115A$. loop rule $20 - 0.115 \cdot R - \Delta V_L = 0$

$\Delta V_L = 2.71$ Volts

(e) What is the current in the circuit at t = 120 μs (i.e. 40 ms after the switch is thrown from A to B). [4 points]

$I = I_0' e^{-\frac{t}{\tau}} = 0.115 e^{-\frac{40\mu s}{40\mu s}} = 0.042$ Amps

$= 42mA.$

4. A Helium-Neon laser emits light at power 12.0 mW and wave-length 633 nm. The laser beam is focused until its diameter matches the 1 μm diameter of a perfectly absorbing polystyrene sphere placed in its path.

(a) What is the beam intensity at the sphere's location? [4 points]

$$\text{Intensity} = \frac{\text{Power}}{\text{Area}} = \frac{12\times10^{-3}}{\pi(0.5\times10^{-6})^2} = 1.52\times10^{10}\ \frac{W}{m^2}$$

(b) What is the radiation pressure on the sphere? [4 points]

$$P = \frac{I}{c} = 51\ \frac{N}{m^2}$$

(c) What is the magnitude of the radiation force on the sphere? [4 points]

$$\text{Force} = P \times \text{Area of cross section} = 51 \times \pi(0.5\times10^{-6})^2$$
$$= 4\times10^{-11}\ N$$

(d) What is the magnitude of the acceleration that the radiation force alone would give to the sphere? [4 points] The mass of the sphere is 6.3×10^{-14} kg.

$$F = ma \Rightarrow a = \frac{F}{m} = \frac{4\times10^{-11}}{6.3\times10^{-14}} = 635\ \frac{m}{s^2}$$

5. You stare into the back of a soup spoon of radius of curvature 7 cm. "Gosh, I'm gorgeous," you think, "I wonder where my gorgeous image appears to be?" your face is 12 cm from the spoon.

(a) What is the focal length of the convex spoon? [3 points]

$f = -3.5$ cm (half radius of curvature)

(b) Where is the image located? [4 points]

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = -\frac{1}{3.5} - \frac{1}{12} = \frac{-15.5}{42}$$

$$d_i = -\frac{42}{5.5} = -7.5\ cm$$

(c) Is the image upright? [3 points]

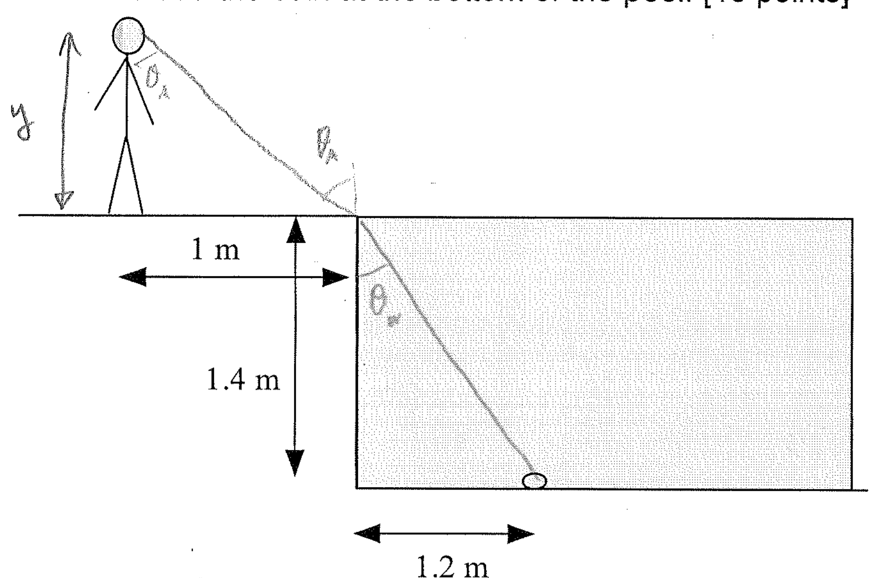
$$m = -\frac{d_i}{d_o} = -\frac{-7.5}{12} = +0.54$$

ie upright & minified

(d) Is the image real or virtual? [1 point]

Image is virtual.

6. A coin is located at the bottom of a swimming pool that is 1.4 m deep. The coin is 1.2 m from the edge of the pool. You are standing on the flat surface surrounding the (completely full) pool at a distance of 1 m from the edge (see figure). Estimate how tall you must be in order to see the coin at the bottom of the pool. [10 points] $n_{water} = 1.33$



$$\theta_w = \tan^{-1}\left(\frac{1.2}{1.4}\right) = 40.6^\circ$$

$$n \sin\theta_w = 1 \sin\theta_r \Rightarrow \theta_r = \sin^{-1}(n \sin\theta_w) = 53.9^\circ$$

$$\frac{1}{y} = \tan\theta_r \Rightarrow y = \frac{1}{\tan\theta_r} = 0.58\ \text{m.}$$