Physics 213 Midterm test #1
September 23 2016

Name (please print): ____________________________

This test is administered under the rules and regulations of the honor system of the College of William & Mary.

Signature: ______________________________________

Show all work to receive credit, and circle your final answers. This exam is closed book, and you can use calculators only for simple arithmetical operations.

Problem 1 (20 points)

When measured using red light (λ_r=656nm), the focal length of a lens is f_r=15.54*mm*. How will this number change if the measurements are repeated with blue light (λ_b=486nm)? The refractive indices of glass are n_r=1.514 and n_b=1.522 correspondingly.

$$\frac{1}{f_r} = (n_r - 1)\underbrace{\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}_{\text{same}} \; ; \; \frac{1}{f_b} = (n_b - 1)\underbrace{\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}_{\text{same}}$$

$$\frac{f_b}{f_r} = \frac{(n_r - 1)}{(n_b - 1)} = \frac{0.514}{0.522} = 0.985$$

$$f_b = 15.30 \text{ mm}$$

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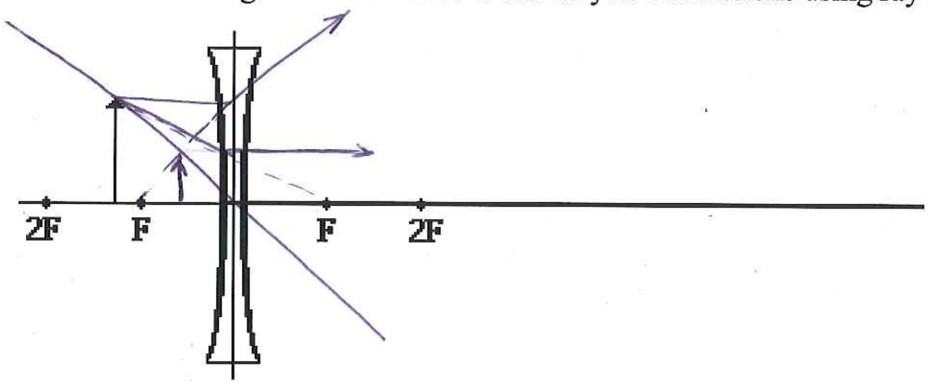
Problem 2 (30 points)

a) Calculate the position of the image produced by an object is located at the distance 1.3**F** from the ~~convergent~~ di lens (focal length –**F**), as shown. What is the magnification of the lens? Is the image real or virtual? Confirm you conclusions using ray tracing.



b) Suppose one needs to invert the image, without changing its dimensions. What value of magnification corresponds to such action? Can you do that using a single convergent lens with focal length 2**F**? If yes, at what distance from the first lens should it be located?

a) $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ $\quad \frac{1}{1.3F} + \frac{1}{d_i} = -\frac{1}{F}$ $\quad d_i = -0.565F$

$M = -\frac{d_i}{d_o} = 0.435$

Virtual, erect image

b) In order for a convergent lens to invert an image without changing its size $M = -1$

$d_i = d_o = 2$ [focal length] $= 4F$

So the second lens must be placed 4F from the image, or $4F - 0.565F = 3.435F$ from the first lens.

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Problem 3 (50 points)

a) An amateur scientist wants to study a small rock, and to see it better he needs a magnifying glass. He possess two lenses of the same diameter (25mm), one with the focal length 30mm, and the other with 240mm. How far from the rock he needs to place each lens to achieve the magnification of M=3?

b) Which lens would provide the better image quality, in your opinion?

c) What are the values of diffraction-limited angle resolution for each lens? For estimates use yellow light wavelength λ=550nm.

d) If this person decides to use these two lenses to build a telescope, which one should be an objective, and which one the eye piece, and at what distance from each other they must be placed? What would be the angular magnification of such telescope?

a) For a lens to act as a magnifying glass, it needs to produce a virtual image ($d_i < 0$)

$M = 3 \Rightarrow d_i = -3 d_o$

$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \quad \frac{1}{d_o} - \frac{1}{3d_o} = \frac{1}{f} \quad d_o = \frac{2}{3} f$

for $f = 30mm \quad d_o = 20mm$

$f = 240mm \quad d_o = 160mm$

b) The second lens is likely to be flatter, and thus introduce less aberrations

c) Since the diffraction limit is determined by the size of the lens, it is the same for both

$\Delta\theta = \frac{1.22\lambda}{D} = \frac{1.22 \cdot 550 \cdot 10^{-9} m}{25 \cdot 10^{-3} m} = 2.7 \cdot 10^{-5} rad \approx 1.54 \cdot 10^{-3}$ degree

d) Longer focus length lens must be the objective, and the other - the eye piece.

$d = f_o + f_e = 270 mm$

$M_\theta = f_o / f_e = 8$

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