EE119 Introduction to Optical Engineering
Spring 2003
Midterm Exam

Name: Solutions

Signature: _____

SID: _____

CLOSED BOOK. ONE 8 1/2" X 11" SHEET OF NOTES, AND SCIENTIFIC POCKET CALCULATOR PERMITTED.

TIME ALLOTTED: 80 MINUTES

Fundamental constants you might need:

Planck's constant, $h = 6.62 \times 10^{-34}$ J-s

Permittivity of free space, $\varepsilon_o = 8.85 \times 10^{-12}$ F/m

Permeability of free space, $\mu_o = 1.26 \times 10^{-6}$ H/m

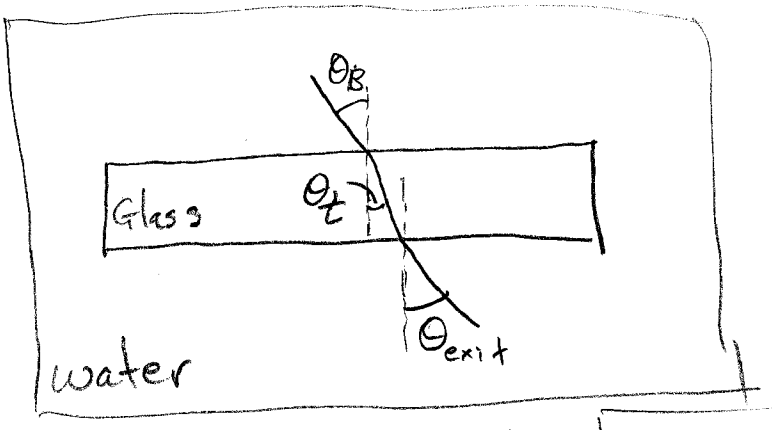
Speed of light in vacuum, $c = 2.998 \times 10^{8}$ m/s

Electron charge, $e = 1.6 \times 10^{-19}$ C

Free electron mass, $m_o = 9.1 \times 10^{-31}$ kg

Electron volt, $1\ eV = 1.6 \times 10^{-19}$ J

1) Brewster's angle [20 points].
   a) Determine the Brewster angle for external reflection at the surface of a glass plate with n=1.5850 immersed in water with n=1.33. [5 points]
   b) At what refraction angle will the beam traverse the plate when light is incident at the polarization angle? [5 points]
   c) Calculate the Brewster angle for light exiting the glass plate. [5 points]
   d) For light incident on the plate under the conditions described above, if the incoming beam is p-polarized with intensity I_0, what is the intensity of the emerging beam? [5 points]



a) $\theta_B = \tan^{-1}\left(\frac{n_{glass}}{n_{water}}\right) = \boxed{50^\circ}$

b) $n_{water}\sin\theta_B = n_{glass}\sin\theta_t$

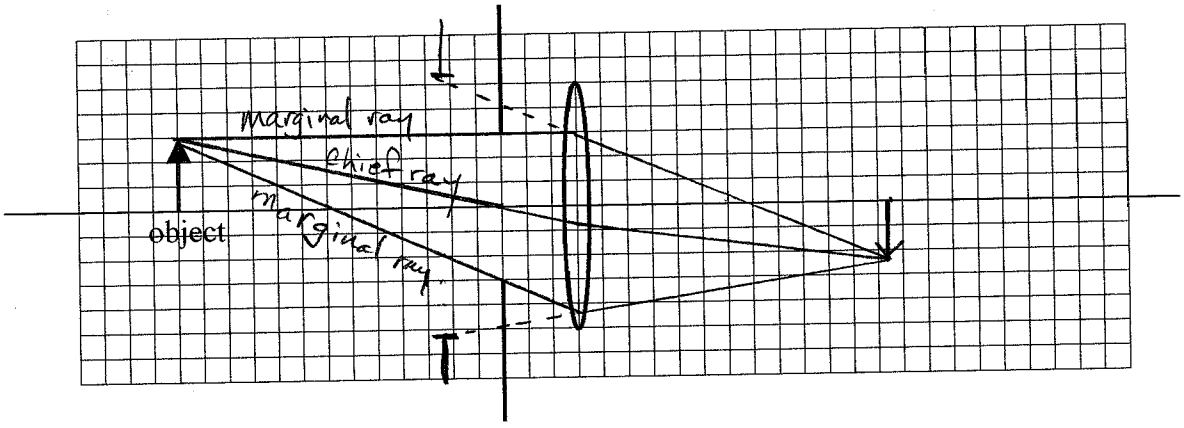
$\theta_t = \sin^{-1}\left\{\frac{n_{water}}{n_{glass}}\sin\theta_B\right\} = \boxed{40^\circ}$

c) $\theta_{exit} = \tan^{-1}\left(\frac{n_{water}}{n_{glass}}\right) = \boxed{40^\circ}$ same!

d) $I_{emerging} = I_0$

2) A thin lens with an aperture of 5 cm and a focal length of +3.50 cm has a 3.0 cm diameter stop located 1.50 cm in front of it. An object 1.50 cm high is located with its lower end on the axis, 8.0cm in front of the lens. [30 points]

a) Determine and sketch below the position and size of the entrance and exit pupils. [10 points]
b) Determine and sketch below the position of the image point and the magnification. [10 points]
c) Sketch the chief ray and two marginal rays from the tip of the object. [10 points]



a) Entrance pupil is at aperture stop

Exit pupil:

$$\frac{1}{d_2} = \frac{1}{f} + \frac{1}{d_1} = \frac{1}{3.5} - \frac{1}{1.5} \quad : d_2 = -2.625$$

$$M = \frac{d_2}{d_1} = \frac{-2.625}{-1.5} = 1.75$$

Diameter = 3cm × 1.75 = **5.25 cm**

location **2.625cm** in front of lens.

b) $$\frac{1}{d_2} = \frac{1}{f} + \frac{1}{d_1} = \frac{1}{3.5} - \frac{1}{8} \quad : d_2 = 6.22\text{cm}$$

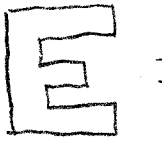
$$M_T = \frac{d_2}{d_1} = -0.778$$

$$h_2 = -1.5 \times 0.778 = -1.167$$

3) Your uncle has a far point at 2 meters. His eye is 2.0 cm long, but the overall power of his eye is not known. [20 points]
   a) Is he nearsighted or farsighted? [5 points]
   b) Specify the lens (in diopters) necessary to correct his vision. Be sure to give the correct sign. [10 points]
   c) After getting his new glasses, Uncle Lee is happy and has normal visual acuity. As he is driving down the freeway, he is trying to read a sign far ahead of him. The letters on the sign are 20cm high. At what distance from the sign will he be when he can first read it? [5 points]

a) Nearsighted

b) $P = -\frac{1}{2}$ Diopters

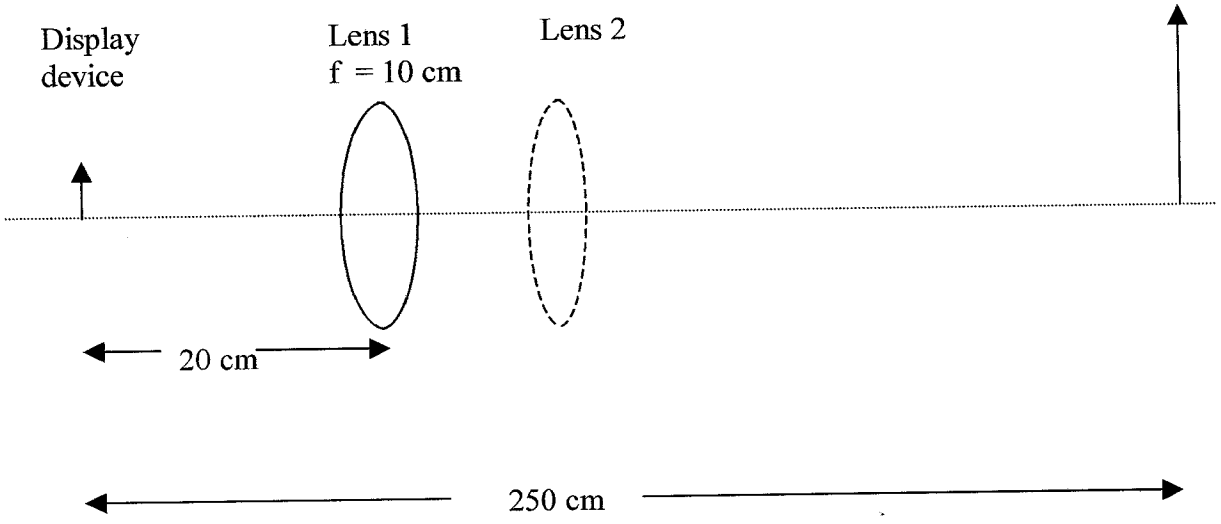
c)  $\frac{4cm}{} = 1'$

$1' = \frac{\pi}{180 \cdot 60}$ rad $= 0.2909$ mrad

$0.2909 \times 10^{-3} \cdot z = 4cm$

$z = 1.375 \times 10^{4} cm = 137.5$ m

4) You are the lens designer for a hot new video display startup company in Fremont. You must design a 2 lens system to project an uninverted image with a magnification of 50 onto a screen 250 cm away from the top-secret display device invented by the company founder. The mechanical designer tells you that Lens 1 must be located exactly 20 cm away from the object, but you have freedom to choose where to place Lens 2. The purchasing department already bought 5000, 10 cm focal length lenses that fit into the mechanical mount for Lens 1. Your job is determine the focal length and position for Lens 2. Give your answer for its position in terms of the separation between Lens 1 and Lens 2. [30 points.]



① Image formed by lens 1

$\frac{1}{d_2} = \frac{1}{f_1} + \frac{1}{d_1} = \frac{1}{10} - \frac{1}{20} = \frac{1}{20}$: $d_2 = 20\,cm$ $M = -1$

② Remaining distance from intermediate image to screen is 210 cm. $-d_1 + d_2 = 210$. $M_2 = \frac{d_2}{d_1} = -50$

$-d_1 - 50d_1 = 210$: $d_1 = -\frac{210}{51} = -4.118\,cm$

$d_2 = 205.88\,cm$

③ find f_2. $\frac{1}{f_2} = \frac{1}{d_2} - \frac{1}{d_1} = \frac{1}{205.88} + \frac{1}{4.118}$: $\boxed{f_2 = 4.037\,cm}$

Separation = 20cm + 4.118cm

= $\boxed{24.118\,cm}$