Physics 431 Optics

Practice Midterm Exam – Example Problems

(There will be four to five problems for you to solve in 60 minutes.)

Name: _____

Signature:_____

SID: _____

CLOSED BOOK. ONE 8 1/2" X 11" SHEET OF NOTES (double sided is allowed), AND SCIENTIFIC POCKET CALCULATOR PERMITTED (No laptop/netbook etc.)

TIME ALLOTTED: 60 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 = 1.6×10^{-19} J

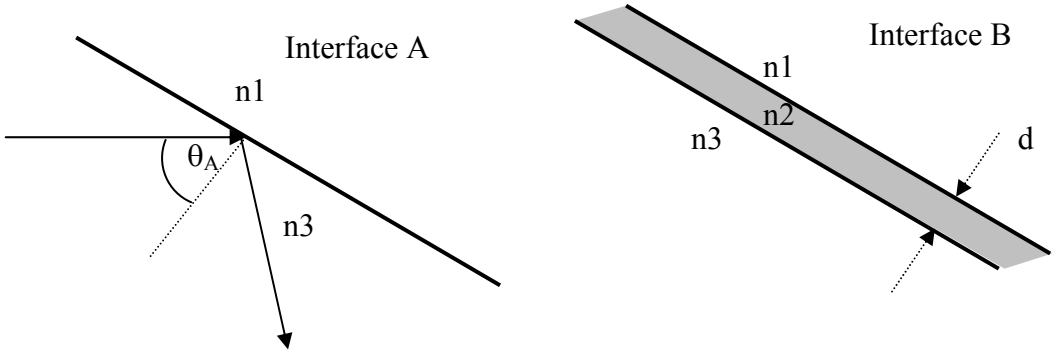
Photon energy $E = h\upsilon$; Photon momentum $\hbar k$

Photons and Waves - Basics

- A metal has a work function of 4.3 V. What is the minimum photon energy in Joule to emit an electron from this metal through the photo-electric effect? What are the photon frequency in Terahertz and the photon wavelength in micrometer? What is the corresponding photon momentum? What is the velocity of a free electron with the same momentum?

Total internal refraction/Snell's law

- A small source of light at the bottom face of a rectangular glass slab 2.25 cm thick is viewed from above. Rays of light totally internally reflected at the top surface outline a circle of 7.60 cm in diameter. Determine the refractive index of the glass.
- Brewster's angle.
  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.
  b) At what refraction angle will the beam traverse the plate when light is incident at the polarization angle?
  c) Calculate the Brewster angle for light exiting the glass plate.
  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?
- Consider the two interfaces as shown below. Interface A is between transparent materials with index n1, and n3. Interface B is also between these same two materials, but a layer of transparent material with index n2, where n1<n2<n3, and uniform thickness, d, is placed in between. We are interested in comparing the angle of incidence at which light is totally reflected by Interfaces A and B. Let θ_A be the critical angle for Interface A. Is the angle of incidence at which light is totally reflected from the composite Interface B increased compared to θ_A and if so, by how much. Express your answer in terms of n1, n2, n3 and d. [Hint: For composite Interface B, if a ray is not totally reflected at the n3-n2 interface, you must consider what happens at the n2-n1 interface.]



- A 2 mm diameter, 633 nm laser beam is directed at a 1 cm thick glass slab with polished, parallel surfaces. (a) What is the light wavevector k inside the glass? (b) What is the light angular frequency ω inside the glass? (c) Calculate the critical angle θ_{crit} for total internal reflection.

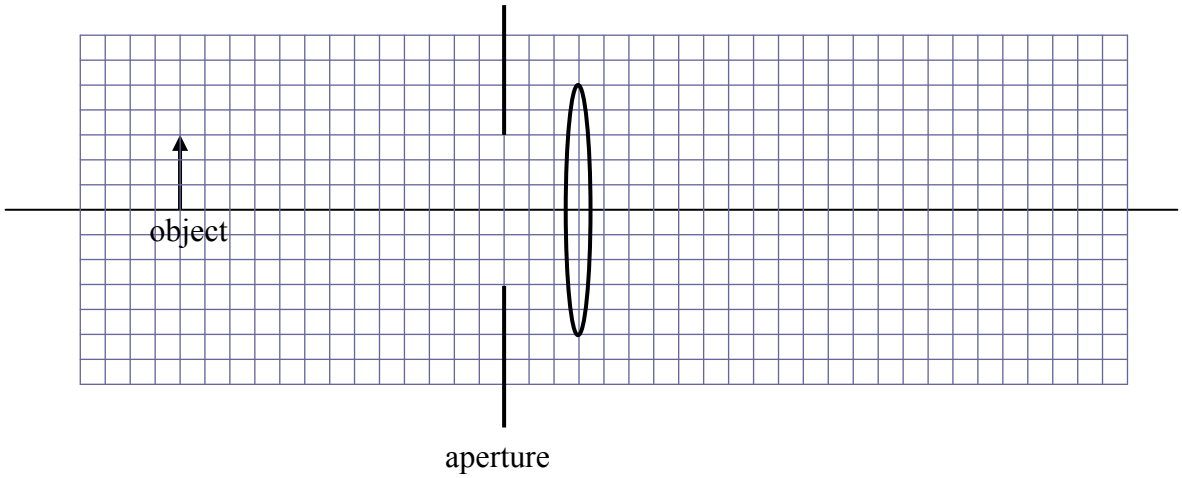
  Now assume light in the slab hits the glass-air interface at $\frac{1}{2}\theta_{crit}$. (d) Find the optical path length (OPL) in the glass and (e) estimate the dimensions of the beam's cross-section in the glass.

Lens Maker Formula/Imaging

- A person whose face is 25 cm away looks into the bowl of a soupspoon and sees his/her image reflected with magnification –0.064. What is the approximate radius of curvature of the spoon?

- 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.

  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. [5 points]
  c) Sketch the chief ray and two marginal rays from the tip of the object. [10 points]



Aperture stop/Exit pupil/ Image formation

A thin lens with an aperture of 4.80 cm and a focal length of +3.50 cm has a 3.0 cm 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. (a) Locate the position and size of the exit pupil (b) Determine the position and magnification of the image, and draw the two marginal rays and the chief ray from the top end of the object.

Thin lens combination

You are the lens designer for a hot new video display startup company in East Lansing. 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 a large number of 10 cm focal length lenses that fit into the mechanical mount for Lens 1. Your job is to 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.