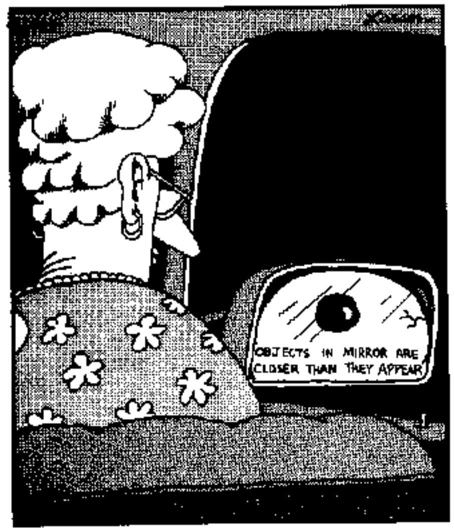
Physics 4L Spring 2010 — Problem set 1
Due Tuesday 26 January in class



From Wolfson: Chapter 30 problem 36 (the flashlight beam comes out of the water some distance from the edge of the lake; the figure for problem 37 gives you an idea of the geometry, except you are not right at the edge of the water.)

Chapter 30 problem 54.

Additional problems:

1. Rearview mirrors on cars are curved rather than flat so that the image is reduced and you can view a larger area. You can form a reduced image with either a diverging (convex) or a converging (concave) mirror; why are only diverging (convex) mirrors used as rearview mirror? Justify your answer with ray diagrams.

2. What type of mirror, diverging (convex) or converging (concave), is used as a magnifying mirror? Does such a mirror always produce a magnified image? Is the magnified image real or virtual? Justify your answer with ray diagrams.

3. Blue and red laser beams traveling through the air strike a flat slab of glass with incidence angle 50°. The index of refraction for the glass is 1.680 for the blue light and 1.621 for the red light. Will either beam undergo total internal reflection in the glass? Justify your answer. Find the angle at which each beam exits the glass if it does.

4. The chambered nautilus considered in class has a region of photosensitive tissue 1 cm in diameter. (a) How close can the nautilus get to the 1-m tall seaweed and still view a complete image of the seaweed if the nautilus's pinhole is 1 cm in front of the photosensitive tissue? (b) If you assume that the same amount of light still goes through the pinhole, does the image get brighter or dimmer as it gets larger?

Self-test problem appears on the next page.

Please also complete a short electricity and magnetism diagnostic test online, due Sunday, Jan. 31 at 8 p.m. (please complete it *before* reading any of Wolfson Ch. 20). As with the mechanics test, this diagnostic test will help me know how much background the class has on these topics. However, I fully expect that many of you have very little or no background in this subject, so don't worry at all if you find that you are completely unfamiliar with the material on the test!

From the link to the E&M test on the Assignments web page, log in with:
username = student   password = Physics4L

You will receive full credit (equivalent to three homework problems) if you answer all of the questions, regardless of whether your answers are correct. If the question deals with unfamiliar material, choose the answer that seems most plausible to you. You may skip questions 18, 28, 29, and 31 (we won't cover those).

Lab-related material: In addition to the problem set, some problems and questions are assigned as part of the preparation for the lab, which you do in your lab notebook. You'll probably find it convenient to work on these while working on the problem set. This week, you can also work ahead of time with a study group on the ray tracing exercises at the end of the first lab, if you prefer that to doing them in lab.

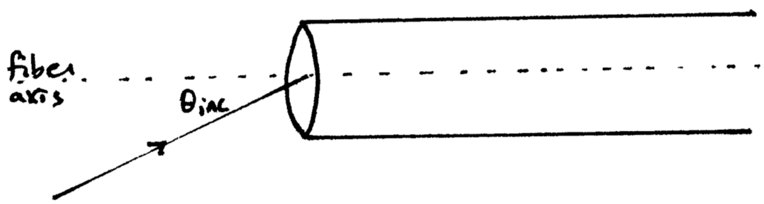
Not required but highly recommended: Try to review the material from the first class the same day or the next day (Tuesday or Wednesday). If you have to a question, post that question on the course web site under "Forums;" I'll look at those before finalizing Thursday's class. I would encourage you to do this each week.

Self-test problem, week 1 Name: ______________________________________

You may spend up to 25 minutes on this problem. Do your work on this sheet in the space provided and turn it in separately. Do not work with others or refer to the textbook, though you may consult the equation sheet posted online. Your score on this problem will not be included in your homework grade; it is solely for feedback to you. (However, you *will* receive credit for one homework problem for completing it.)

A cylindrical optical fiber made of glass with refractive index 1.50 is used to guide the light collected by a medical endoscope. It is inserted into the artery of a patient (with the endoscope on the end). The index of refraction of the surrounding blood is essentially the same as that of water, 1.33. Assume for the purpose of this problem that the fiber axis is perfectly straight.

Light is incident on the flat end of the endoscope from the blood at an angle to the axis of the fiber as shown in the figure. It travels into the glass, and then reflects from the glass-fluid interface to continue traveling along the fiber.



(a) What is the maximum angle θ_{axis} that a light ray going into the fiber can make with the fiber's axis and undergo total internal reflection along the fiber?

(b) To make the angle larger, so that the fiber can collect light from a larger area, would you want to surround the fiber with cladding material with index of refraction larger than 1.33, or smaller than 1.33? Explain the logic of your answer briefly. Your explanation can be purely qualitative or can involve calculations, either is fine as long as it is rigorous!

(If you need more space, continue on the back)

Physics 4L, Spring 2010 — Problem set 2
Due Tuesday 2 February in class

Problems from Wolfson:
Chapter 31 "For Thought and Discussion" question 14
Chapter 31 problem 24
Chapter 31 problem 26
Chapter 31 problem 52. In your solution, include a ray diagram with the object and image distances and focal length shown reasonably close to scale.
Chapter 31 problem 53
Chapter 31 problem 54

Additional problems:
1. (a) Catherine Crouch's contact lens prescription is -3.00 diopters. Is she nearsighted or farsighted? As part of your answer, explain the meaning of the negative sign in her prescription.
(b) When she is wearing them, her contact lenses create images of distant objects at the farthest distance where she can see clearly without contact lenses. If she is *not* wearing her contact lenses, what is the maximum distance at which she can read a computer screen clearly?
(By the way: those of you with the same vision shortcomings can try this – from your prescription you should be able to calculate the maximum distance at which you can read a book or a computer screen pretty accurately. If you're interested, we can discuss the reasons for small discrepancies ...)

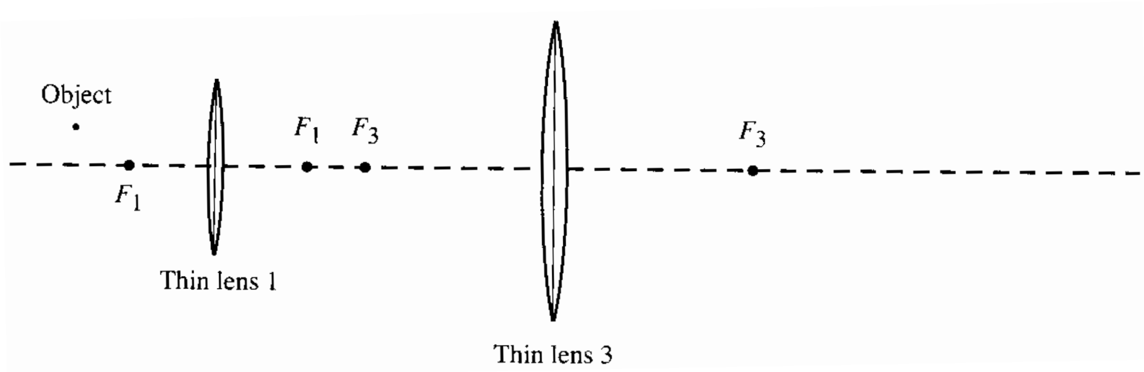
Also turn in part of Lab 2 warmup assignment (on back of this sheet):
The Lab 2 warmup assignment is longer than usual, so turn the part on the back of this sheet to be graded so that you get some problem set credit for it. Make a copy of your work to bring to lab. Feel free to get help with the prelab assignment just as with the rest of the problem set.

Self-test problem appears on the last page.

For extra credit: Show algebraically (with a calculation, not with rays) that a diverging lens can only form a reduced image.

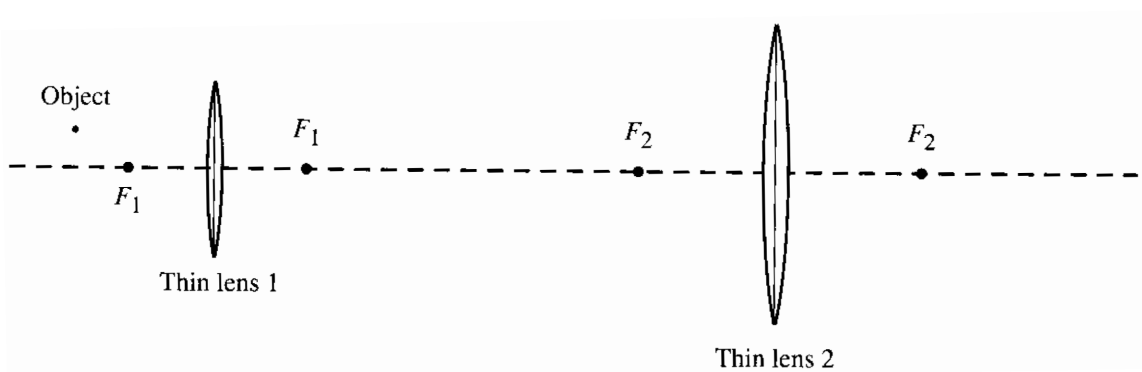
From Lab 2, Problem 2 Warmup "The Compound Microscope" (modified from *Tutorials in Introductory Physics*, McDermott *et al*, Pearson)

1. The diagram below shows an arrangement of a small object and two thin convex lenses analogous to that used in a typical compound microscope (though not to scale). On the diagram, construct rays showing the image formed by lens 1, then use that image as the object for lens 3 and construct rays showing the image formed by lens 3. (There is no lens 2 in this diagram.)



2. Think of lens 1 as the objective lens and lens 3 as the eyepiece lens of a microscope. Does the eyepiece lens form an image that could be projected on a screen? If so, where should the screen be placed? If not, is it possible to adjust (reposition) lens 3 so that its image could be projected on a screen?

3. The diagram below shows another possible arrangement of a small object and two thin convex lenses. On the diagram, construct rays showing the image formed by lens 1, then use that image as the object for lens 2 and construct rays showing the image formed by lens 2.



4. Think of lens 1 as the objective lens and lens 2 as the eyepiece lens of a microscope. Does the eyepiece lens form an image that could be projected on a screen? If so, where should the screen be placed? If not, is it possible to adjust (reposition) lens 2 so that its image could be projected on a screen?

Self-test problem, PS 2 Name: ______________________________________

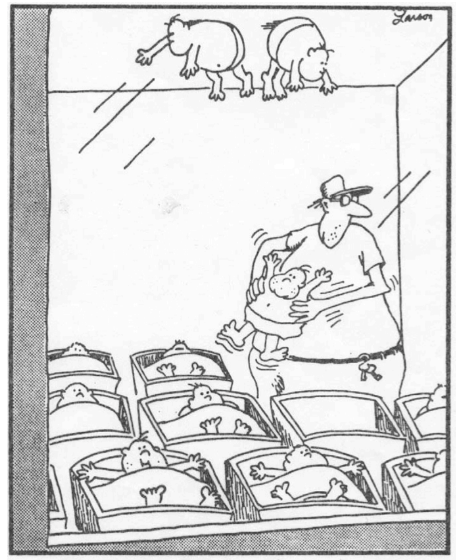
You may spend up to 25 minutes on this problem. Do your work on this sheet in the space provided and turn it in separately. Do not work with others or refer to the textbook, though you may consult the equation sheet posted online. Your score on this problem will not be included in your homework grade; it is solely for feedback to you. (However, you *will* receive credit for one homework problem for completing it.)

(a) If Amy Bug (former Physics 3 professor) holds a physics textbook 30 cm in front of her glasses (prescription +2.25 diopters), where is the image of the page created by her glasses? Is the image virtual or real? Upright or inverted?

(b) Is Amy Bug nearsighted or farsighted? Explain briefly why.

(c) The distance from Amy Bug's retina to the lens of her eye is 23 mm, and the distance from the lens of her eye to her glasses is 2.0 cm. What is the focal length of her eye's lens, if the image is in focus? (You may calculate either the focal length in air or the focal length in the eye, as long as you clearly specify which you calculated. Be sure to account for the effect of the index of refraction of the contents of the eye (n_{eye} = 1.34).)
Note: You do not need to include a ray diagram in your solution, but do provide a diagram showing the locations of the glasses, the image formed by the glasses, the eye lens, and the retina, and label the diagram with the distances you used in solving this problem.

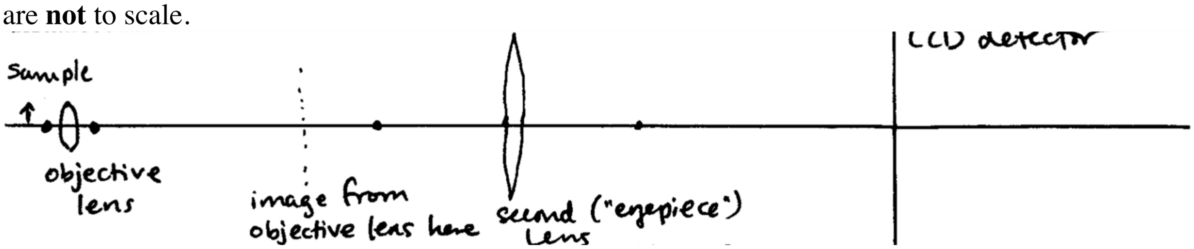
Physics 4L, Spring 2010 — Problem set 3
Due Tuesday 9 February in class, except the self-test problem, which is due Thursday 11 February in class


Late at night, and without permission, Reuben would often enter the nursery and conduct experiments in static electricity.

If you feel you need more practice with vectors: I recommend problems 21, 44, and 46 from Chapter 20. **These are not required and you should not hand them in,** but I will include them in the problem set solutions.

Wolfson problems:
Chapter 20, problems 43, 49, and 52

Additional problems:
1. You are using a microscope that produces an image on the light-sensitive detector of a CCD camera rather than an image viewed with your eye through an eyepiece. The microscope is equipped with a 40x objective lens (i.e. the objective produces an image that is magnified to 40 times the sample's size) and a second converging lens that produces an additional 2x linear magnification of the real image produced by the objective lens. The arrangement of the sample, the two lenses, and the CCD detector is shown in the figure below; the distances in the figure are **not** to scale.



(a) Compared to the image produced by the objective lens, is the image on the CCD camera upright or inverted? Compared to the original sample, is the image on the CCD camera upright or inverted?
(b) The focal length of the eyepiece lens is +10 cm. Find the distance from the eyepiece lens to the CCD detector and the distance from the eyepiece lens to the image formed by the objective lens.
(c) The sample is 2 mm from the objective. How far apart are the objective lens and the eyepiece lens?
Do **not** try to use the Wolfson formulas about compound microscopes for this problem; they do not apply (this microscope uses lenses differently)! Just consider image formation by the series of two lenses.

2. An electric field strength of $3x10^6$ N/C is strong enough to ionize air molecules and create a spark. This phenomenon is referred to as "dielectric breakdown" and is the mechanism by which lightning occurs.
(a) How much excess charge can you put on a metal sphere of 10 cm radius in air without causing breakdown in the neighboring air?
(b) If enough charge was present to cause breakdown, where would breakdown be most likely to occur?
(c) Compared to a 10 cm sphere, can you put more or less charge on a metal sphere of 1 mm radius without causing breakdown?

(Problem set continues on the back)