EE 119 Homework 6

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Due Tuesday, March 9th 2010
(Please submit your answers in EE119 homework box located in 240 Cory Hall)

1. Captain James Cook is sailing through the south pacific on a mission from the Royal society to observe the passage of Venus across the sun. He has a telescope with him, but he doesn't know how good it is, so he brings you along to help him figure it out. The eyepiece of the telescope is 2 cm in diameter and has a focal length of 4 cm. The clear aperture of the exit pupil is 0.35 cm. The telescope has an angular magnification of 45. Assume normal visual acuity, which means that the spacing between the cone cells in the eye of the viewer is 0.3 milliradians.
   (a) What is the focal length of the objective lens?
   (b) What is the diameter of the objective lens?
   (c) What is the object field angle? The object field angle is the maximum angle that defines the field of view of the telescope due to the diameter of the eyepiece lens (and not to diffraction).
   (d) What is the image field angle?
   (e) Is the telescope diffraction-limited? Why or why not?
   (f) Captain Cook sees a ship in the distance, and he wants you to tell him if the ship is a pirate ship or a friendly merchant ship. The black flag of the ship has white letters, so the only way to distinguish it from a pirate ship with a skull and crossbones is to read the text on the flag. You can read the text on the flag if you can separate features that are 10 cm apart. Using this telescope you've just analyzed, how close do you have to be to the ship before you can tell Captain Cook if he's dealing with merchants or pirates?

2. Design a Newtonian telescope to resolve the ring around the Saturn. The diameter of the Saturn is 74,500 miles, and it is located 746 million miles away from the earth. If you can resolve one tenth of the size of the Saturn, you can resolve the ring around the Saturn. Assume normal visual acuity and the diameter of the iris of the eye is 4mm. Make sure the telescope is not diffraction limited, which means the resolution is limited by the users' eye, but not by diffraction. In your design, please include: your design flow; a ray trace of the system; focal lengths of the lenses; sizes of the aperture stop, entrance pupil, and exit pupil; all pertinent distances. You may use two lenses with any power and size you desire, *but make the telescope as compact as you can*.

3. A microscope consists of an objective and an eyepiece. The total magnification is 20. The eyepiece has a focal length of 5cm, and the tube length of this microscope is standardized (160mm). You want to use this microscope to look at a sample underneath a glass slide of thickness 2mm. Will this be possible? Why or why not? (Ignore any optical effects of the glass slide).

4. Fresh out of college, you spend the summer traveling in Japan and fall in love with a young girl/guy (your choice) in Tokyo. Your visitor's visa runs out. Desperate to never leave her/him, you seek a work visa and job with the company Nikon in Kanagawa, located in the west of Tokyo Metropolis. At the interview in the microscope department, they ask you to design a microscope with the following characteristics:
    - Resolve 1.0 micron feature size (or lower)
    - Working distance > 5 mm
    - Standardized tube length
    - Not diffraction limited(the resolution is limited by the users eye, and not by diffraction)

    You have to provide a ray trace of your system, the focal lengths of the optics and NA of your objective. You think back to what you learned in EE119 and are relieved that you will surely be able to stay with your new love. As a follow-up question, they ask you what you would need to change about your design if the object side were immersed in oil (n=1.5).

5. You return from your summer travels in Japan and are anxious to show your slides to your family, but you don't have a slide projector. Once again, your EE119 experience comes in handy. You happen to have a lamp and two lenses. The focal length of the projector lens is 20 cm, and the focal length of the condenser lens is 6 cm. The lamp has a coil filament, so you will have to design an illuminator to illuminate the slides uniformly. Assume that you need a projector magnification of M = -100 so your aging grandma's eyes will enjoy your slides.
    (a) Draw a picture of the illumination system with the two thick lenses. The picture does not need to be to scale, but rays should be included to indicate where the filament of the lamp is imaged. Label the lamp, the projector lens, the condenser, the slide and the screen in your diagram. [Hint: put the slides in contact with the first lens, which is the condenser lens.]
    (b) Find the distance between the slide and the second lens, which is the projector lens.
    (c) Find the distance between the projector lens and the screen.
    (d) The light from the filament should be focused on the projector lens – in other words, the image of the filament should be on the projector lens. Find the distance between the filament and the condenser.