Physics 123 section 2 CID ____________

Homework 29

Score ________ / 30

1. (5 pts) Imagine that you are using a lens with a focal length of 15 cm as a magnifying glass to look at (not cook) an ant which is sitting on your finger. You put your eye up to the lens and adjust the position of the ant until the image of the ant is 25 cm from you. (a) What is the lateral magnification M of the image? (b) What is the angular magnification m?

2. (5 pts) You make a microscope out of two lenses: an objective with a focal length of 4.21 mm and an eyepiece with a focal length of 24.2 mm. You mount them to either end of a 42 cm long tube. What is the magnification of the microscope?

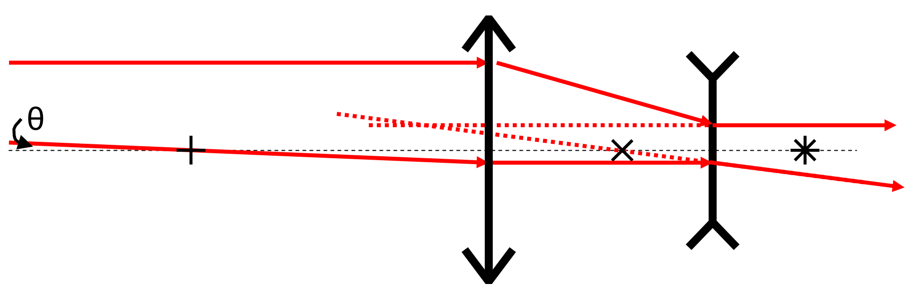
3. (4 pts) In a Galilean telescope, the eyepiece lens has a negative focal length. This has the advantage of producing a positive angular magnification (i.e. the image is not inverted). The layout of such a telescope is shown in the figure below. As you can see, the lenses are spaced such that one of the focal points of the objective lens (marked with plus signs) is on top of one of the focal points of the eyepiece (marked with an x).

Before we begin, consider what would happen if you stood in front of the telescope and looked at some object (mars, for example) with your eyes at the location of the left-most focal point of the objective. If the optical axis runs into the bottom of mars, and the two red lines come from the top of mars, the angle marked θ in the figure is the angular size of mars as viewed with the naked eye.

(a) The upper line, which runs parallel to the optical axis, is bent by the objective such that it is traveling toward the focal point a distance f_0 away. Because of the way we've placed the lenses, this point is a distance $-f_e$ to the right of the eyepiece (this is a positive number, because the eyepiece has a negative focal length). After passing through the second lens, what angle does this beam make with respect to the optical axis?

(b) The lower ray passes through the focal point on the left side of the objective. In this limit as θ is really small, in terms of θ, f_e, and f_o, what angle does this ray make with respect to the optical axis after passing through the eyepiece? (Note that for smallθ, $\sin\theta \approx \tan\theta \approx \theta$.

(c) The dotted lines illustrate that by tracing backward, we can determine the position and size of the virtual image formed by the telescope. In the limit as the object (and therefore the virtual image) are extremely far away from you, what is the angular magnification of this telescope in terms of θ, f_e, and f_o?



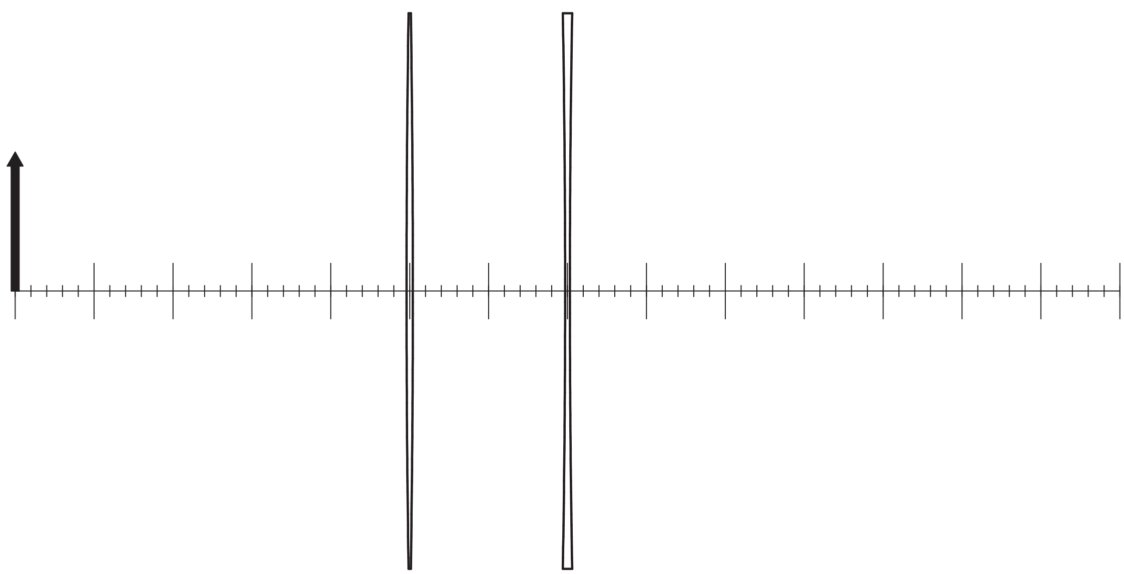
4. (4 pts) I want to make a telescope using a 50 mm focal length eyepiece and a 500 mm focal length objective. (a) How far apart should the lenses be mounted? (b) What will the angular magnification of the telescope be?

5. (4 pts) I look at the moon through a telescope with an angular magnification of 250x. (a) Will the image of the moon be closer to me than the moon or further away? (b) Will the lateral size of the image be bigger or smaller than the actual size of the moon?

Now lets consider what happens if I look at an object through a pair of arbitrary lenses with arbitrary focal lengths. The way to work this is to first consider just the first lens (the one closest to the object) as if the second lens weren't there. We find where the image from the first lens would form, and then that acts as the object for the second lens. The one tricky part is if the image from the first lens is on the opposite side of the second lens. In this case we have a "virtual object." All our equations still work, but the object distance p will simply be negative. The magnification of the final image will just be the magnification of the image of the first lens (relative to the object) times the magnification of the second image (relative to the first image, which acted as the object for the second lens).

When drawing rays, if we have a virtual object, instead of drawing rays which come from the virtual object and go through the lens, we would draw rays which were going as if to converge on the virtual object, but then interact with the second lens. For example, I would draw a ray which is going toward the "virtual object" which strikes the center of the second lens. This line will continue through without deflection. I would also draw a ray going to the virtual object which was traveling parallel to the principle axis. When this line hits the lens it bends and goes through the focal point on the far side of the lens (if it is a converging lens) or bends as if it were coming from the focal point on the near side of the lens (if it is a diverging lens). There is also a third line a can draw, but you can figure that out yourselves.

6. (8 pts) A converging lens with a focal length of 16 cm is placed 25 cm from an object. A diverging lens with a focal length of -14 cm is placed 10 cm behind the converging lens, as shown in the figure below. (a) Draw rays on the figure below to find the location of the final image as viewed by someone to the right of the diverging lens. (b) Calculate the location of the final image relative to the diverging lens, indicating whether it will be on the same side of the diverging lens as the object or the opposite side. (c) Calculate the magnification M for the final image relative to the object. (Note: In past semesters students have noted that you can get the right answer using a trick where you treat the second lens as a converging lens. It's a good trick, but I recommend you don't use it unless you already understand the straightforward way to work this problem really well.)



Extra problems I recommend you work (not to be turned in)

- I look at the moon through a telescope with an angular magnification of 300x. What is the diameter of the image of the moon, and how far away is the image of the moon?

- If you have access to three flat mirrors, place them such that they are at right angles to each other (like the three sides coming together at one corner of a cube). This is known as a corner reflector. Now look at the mirrors as you move around the room. You should be able to see your image at the center of the mirrors no matter where you stand. Why?