

LENSES AND TELESCOPES – PART 2

Purpose: In part 2 of this lab, we will study several properties of simple 2-lens telescopes (i.e. Keplerian telescopes): the field of view (how much you can see through a telescope/lens system), magnification, and telescope aberrations.

In the front of the room, you should see a tape measure, the numbers 1-12 written 6 inches apart, and a 7x7 square grid with a shaded central square.

Telescope construction and optics review

Your instructor will now review part one of the lab. You should copy down the ray diagram for the simple telescope drawn. Label both lenses and all important distances. Below that, briefly explain which lens determines the amount of light gathered by the telescope and why incoming light should enter and leave the telescope as parallel light beams.

Some notes to remember from last time:

Vocabulary note: throughout the rest of this lab, placing something “in front” of a lens means place it near the lens, but on the side closer to the target (e.g. the light source[s]), and “behind” the lens means on the side of the lens opposite where the light source is, closer to you.

Important note: When viewing through the back of the telescope (behind the eyepiece lens), it is important to place your eyes at a place called the eye relief point. This place is where you will see the image of the objective lens filling in the entire eyepiece lens. In other words, you should not see any unfocused background stuff. Make sure you do this from now on!

Use the space below for ray diagrams and notes

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Telescope Field of View (FOV)

Create one of the telescopes listed in table 3 on page 5, and point it at the numbers on the board. Record the leftmost and rightmost numbers you can see on the board. This is a measurement of your field of view. Using your fists, estimate the number of degrees in the telescope's field of view between these two numbers and record that in the "estimate" row.

Next, compute the ANGLE of the field of view by dividing the *distance* between the left and right most numbers -- remember there is a 6 inch gap between each pair of numbers -- by the distance from the objective lens to the board and multiply this final answer by 57.3 to convert the angle into degrees. See the formula below. (*Note: use the same units – inches or cm – for both distances!*) Use the tape measure provided in the front of the class to measure the distance from the objective lens to the numbers on the board.

Computed angle (in degrees) = $57.3 \times (\text{numbers' separation distance}) \div (\text{distance to board})$

Remember, it is critical to have your eye at the eye relief point when doing the FOV measurements!

Spherical aberration

The lenses we are using in this class (as well as the one in each of your eyes) have sphere shaped sides/edges. One of the problems with using spheres is that the light is not brought to the same focus, as was shown in the ray diagram. The light on the outer rings are brought to a focus in one location, while light going through the inner regions are brought to a different focus. As a result of having the focus spread out, the image will look more blurry than it should, if it were all focused at the same place.

We could try to investigate how the spherical aberration depends on the lens diameter, but experience has shown this to be too difficult to do with the equipment available to us. Instead, you will get to torture your lab partner(s).

Have a lab partner read the numbers on the board. The room will need to be fairly dark for this to work. Then shine a flashlight in their eyes while they are reading. You should notice their pupil contracting. Ask them if the numbers get clearer or fuzzier. (If their pupil doesn't contract, try a different, more sober, lab partner.) Then remove the flashlight and have them compare again. Continue this process until you are convinced that the numbers are clearer either with the flashlight shining in their eyes or when it is not shining.

Answer questions 1 and 2 now, on page 3.

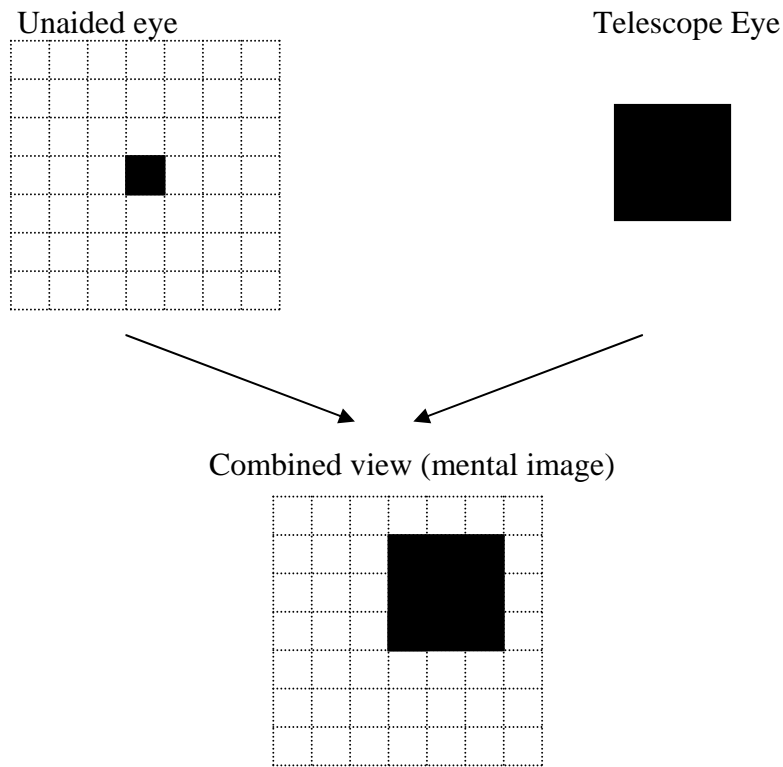
Telescope Magnification

When humans look through a telescope, magnification is one interesting quantity to compute and is the one most often asked about. We will roughly measure the magnification of 3 telescope systems, then predict (and check our prediction) of a 4th telescope. We will compare our answers to the theoretical values. One thing to note: if you use a camera to take a picture of something through a telescope and you don't have an eyepiece, then there is no such thing as "magnification." In this non-eyepiece setup, the "image scale" (which we measured in part I) is the important factor.

Magnification is how much bigger an object appears when viewed with an aid (e.g. telescope) than it does when viewed without an aid. To measure magnification, we will compare an unaided view (in one eye) to a magnified view (in the other eye). Since we will be using both eyes simultaneously to look at two very different objects, do not be surprised if it takes a while to get the hang of it. A small percent of people are unable to combine the two images in their mind as described below, and if that is the case, these people will have to trust their partners' abilities.

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Set up one of the telescopes in table 4. Point the telescope at the shaded square in the center of the grid. With the other eye, look directly at the grid, without viewing through the telescope. Hopefully your brain will allow you to combine the images as shown below.



In the figure shown, the large square fills up 3 small squares on a side, so the magnification is 3 (not 9). It is NOT critical that your mental image of the magnified square overlap with the smaller shaded square, as shown. As long as the big square is entirely located on the grid, you should be able to measure magnification. You can measure EITHER the number of squares along the top/bottom, OR the number of squares along the left/right edge. Whichever you choose, be consistent for all lenses.

Measure magnification for the first 3 telescopes listed. Then predict the magnification for the 4th telescope. After you've made your prediction, get an instructor's signature, measure the magnification of this 4th telescope, and compare all of your answers to the theoretical value:

Magnification formula

magnification = (focal length of objective lens) ÷ (focal length of the eyepiece lens).

Questions

Important note: For all of these questions, refer SPECIFICALLY TO YOUR DATA OR OBSERVATIONS, when drawing conclusions! When appropriate, in your answers, mention the relevant data from tables 3 and 4.

1. [In class, 2 pts] What happens to the clarity and sharpness of the numbers on the blackboard as the flashlight is shined into your lab partner's eyes? What happens to the pupil of the eye as the light shines in their eye? What happens to the clarity and sharpness when the flashlight is removed? What happens to the pupil when the flashlight is removed?
2. [In class, 2 pts] Explain how and why the pupil size and the clarity of the numbers are related.

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[Interesting note: this same effect is why candlelight “soft light” dinners are so romantic. In such lighting, things, including wrinkles, freckles, blemishes, etc., look “soft” and “smooth.”]

3. [In class, 1 pt] Which lens will produce a sharper image (i.e. less spherical aberration): a very rounded lens (i.e. one with a very small f-ratio) or a flatter lens (larger f-ratio). Explain.
4. [In class, 1 pt] How are light gathering power and spherical aberration related to each other and the diameter of the objective lens? Describe. *Hint: As light-gathering power gets larger, while focal length stays constant, do images get clearer or fuzzier? ?*
5. [Homework, in class time permitting, 1 pt] How does your telescope’s magnification depend upon the focal length of its eyepiece lens? Sample answer: as ___ increases ___ decreases. (You fill in the blanks.)
6. [Homework, in class time permitting, 1 pt] How does your telescope’s magnification depend upon focal length of its objective lens?
7. [Homework, in class time permitting, 1 pt] How does the field of view depend upon the focal length of the eyepiece lens?
8. [Homework, in class time permitting, 1 pt] How does the field of view depend upon the focal length of the objective lens?
9. [Homework, in class time permitting, 2 pts] Based on your answers to the previous two questions, which combination of objective lens and eyepiece lens theoretically should give the largest field of view? Which setup actually did?
10. [Homework, in class time permitting, 2 pts] A peephole in a door is frequently made of two lenses, just like the telescopes we made in class. Which lens has the larger focal length – the one you look through, on the inside, or the one on the outside of the door? Justify your choice.
11. [Homework, in class time permitting, 2 pts] Compare your data for magnification and field of view (Tables 3 and 4) to determine if they are related. If they are related, how are they related? Describe.
12. [Homework, in class time permitting, 2 pts] You probably noticed (or soon will) that the eyepieces with longer focal lengths have a larger physical length (i.e. barrel). Why is this so?

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Table 3 [3 pts] – Field of View

Objective Lens	D		C		C	
Eyepiece Lens	A		A		B	
Field of View	Left #	Right #	Left #	Right #	Left #	Right #
Estimated angle of field (deg)						
Computed angle of field (deg)						
Percent difference						

Distance to the board _____ (include units)

Table 4 [4 pts] -- Magnifications

Objective Lens	D	C	C	D	
Eyepiece Lens	A	A	B	B	
Measured Magnification				Pred: Act:	Get a signature before measured
Calculated Magnification					
Percent difference					