SIERRA COLLEGE OBSERVATIONAL ASTRONOMY
LABORATORY EXERCISE

Lab N07: Telescope optical designs

NAME	GROUP

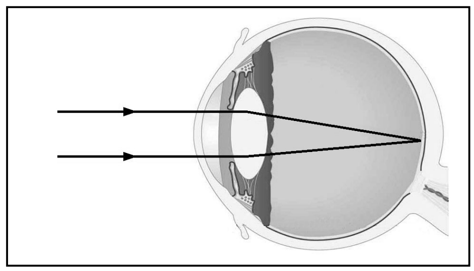
OBJECTIVE:

- Learn about the optical elements used in telescope design.
- Learn about different types of telescopes.
- Learn about eyepieces.

INTRODUCTION:

Telescopes gather the light of faint objects and produce images of them. (You may wish to review Lab N01.) To produce such images, telescopes use lenses or mirrors that either work to *converge* (bring together) or *diverge* (spread apart) the faint beams of light. *Plano* (flat) mirrors or lenses have no focusing effect on a light beam, but can be important in redirecting the beam as needed.

The telescope's eyepiece must make sure the beams of light leaving the telescope are parallel, because the human eye can only interpret the light if the light enters the eye in the form of parallel beams. (See the eye figure to the right.)



Telescopes that use objective lenses are called refracting telescopes—in particular *Galilean refractors* and *Keplerian refractors*. Telescopes that rely upon objective mirrors are called reflectors, such as *Newtonian reflectors* or *Cassegrain reflectors*.

Another design consideration in a telescope is how rapidly the optical system brings the light to a focus. The *F-ratio* is the ratio of the telescope's objective focal length to diameter—see Equation 1. The F-ratio is important in setting how much a telescope magnifies.

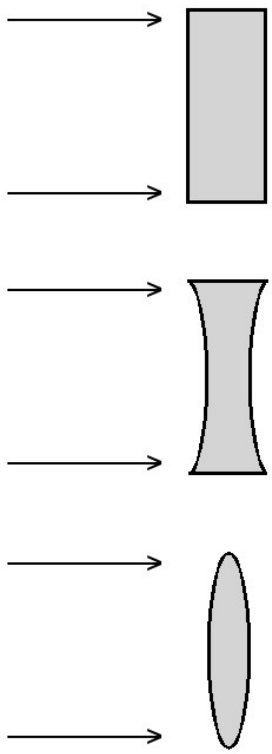
Equation 1:

$$\text{F-ratio} = F_o / D_o$$

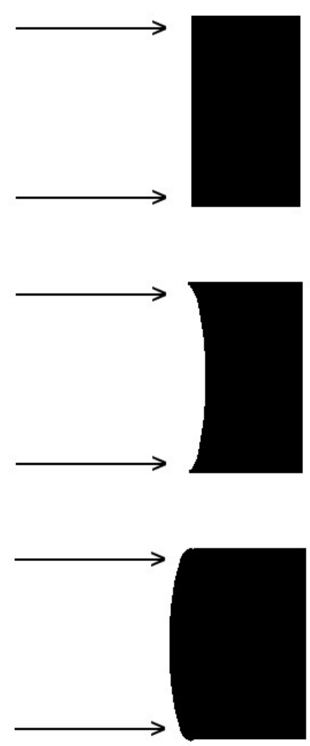
When light passes through a lens, the different wavelengths (colors) refract by different amounts. As a result, the telescope is not perfect at focusing all the wavelengths simultaneously. This is called *chromatic aberration*. In part to address this, telescope eyepieces are sometimes quite sophisticated. Instead of being made out of one piece of glass (i.e., a *simple lens*), they can be made out of many glass elements, each of a different shape and a different kind of glass. These are called *compound lenses.*

PROCEDURE I: Ray tracing optical elements

1. To the left of the three transparent glass elements below, write which is a converging, diverging, or plano lens. Then using a ruler, carefully draw the paths of the exiting beams of light. For the appropriate diagram, indicate the focus point of the element.



2. Repeat all parts of step #1, this time for the beams reflected from the mirrors.



3. Lenses can also be used to transform converging or diverging beams into a nonfocusing beam. This is what eyepieces do. Use your ruler to show the beams of light being turned into parallel beams.

PROCEDURE II: Ray tracing inside a telescope

4. In Figure 1 (below), use your pencil and ruler to trace the beams of light to a focus point, indicated by the point at the right of the sketch, labeled "F."

5. At the point that the beams of light enter the concave eyepiece, redraw the lines to continue to the right in parallel beams. Label your diagram, "Galilean Refracting Telescope" after the "Figure 1:" at the top of the drawing.

Figure 1: ____

6. In Figure 2 (below), use your pencil and ruler to trace the beams of light to a focus point, indicated by the point at the right of the sketch, labeled "F." This time, continue your lines through the focus point, to the convex eyepiece lens.

7. At the point that the beams of light enter the eyepiece, redraw the lines to continue to the right in parallel beams. Label your diagram, "Keplerian Refracting Telescope" after the "Figure 2:" at the top of the drawing.

   The Keplerian telescope design allows for larger magnification and field of view, but still suffered from problems such as chromatic aberration.

Figure 2: ____

8. In Figure 2, clearly and neatly label the objective lens and the eyepiece.

9. In Figure 3 (below), extend the beams of light to the concave mirror. Then, reflect the focusing beams back to the left, to the focus point labelled "F_1."

10. Where each light beam strikes the plano 45° mirror, reflect the beams vertically upwards to the second focus point (labelled "F_2") and extend the beams to the convex eyepiece.

11. Show the light emerging from the eyepiece as parallel beams. Label your diagram, "Newtonian Reflecting Telescope" after the "Figure 3:".

Figure 3: ____

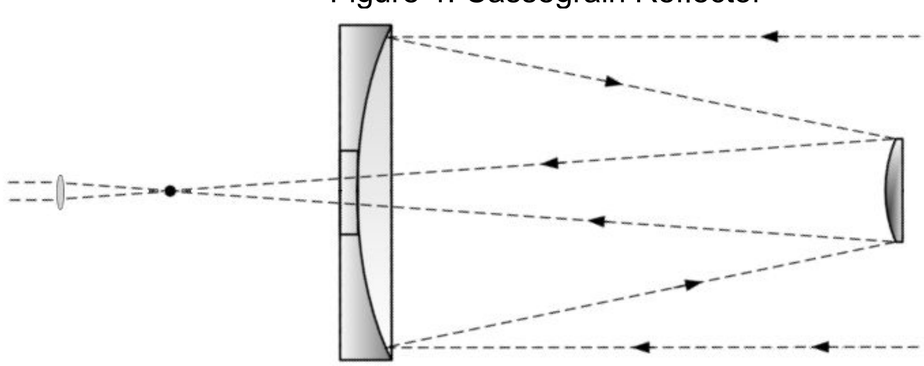
12. In Figure 3, clearly and neatly label the objective mirror and the eyepiece, and the 45° mirror.

13. Figure 4 shows the internal optics of a modified reflector, called a Cassegrain reflector. The light is folded, much like in binoculars, to provide a compact design. Notice that the secondary mirror is convex, and is not plano.

    Clearly and neatly label the objective and the eyepiece, and the secondary mirror.

    Our scopes have an additional correcting lens (not shown) that the secondary mirror is mounted on. This correcting lens improves the overall optics. As such, our telescopes are "Maksutov-Cassegrain" reflectors.

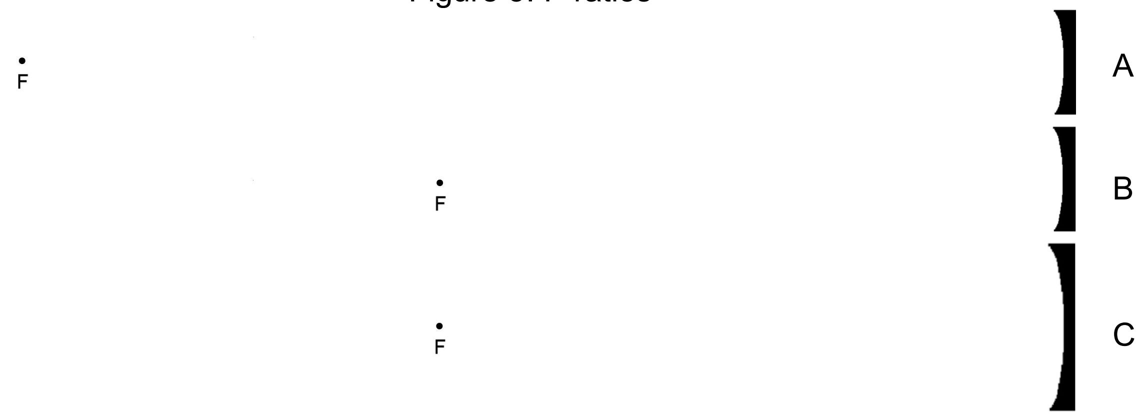
Figure 4: Cassegrain Reflector



PROCEDURE III: Focal ratio

14. Figure 5 shows three different concave mirrors, and their focal points. For each, measure their diameters and focal lengths (distance from the center of the mirror surface to the focal point). Record your results in Table A. Use correct units.

Figure 5: F-ratios



15. Complete Table A by calculating the F-ratios of the three mirrors. Use correct units.

Table A: F-ratios

	Mirror A	**Mirror B**	**Mirror C**
Diameter			
Focal length			
F-ratio			

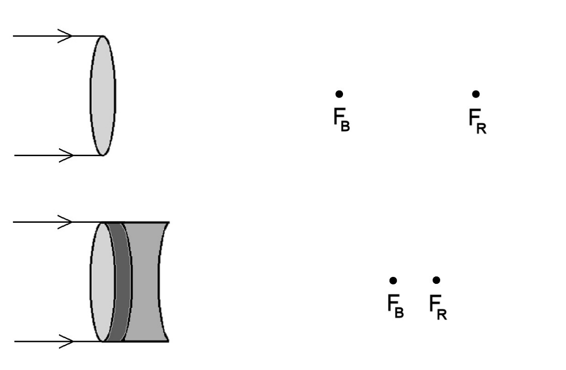
PROCEDURE IV: Compound lenses and chromatic aberration

16. The top of Figure 6 (next page) shows a simple glass lens. Because of the effects of chromatic aberration, the red light focal length (F_R) is at a different point than the blue light local length (F_B). Using a red pencil, draw lines from the incoming beam (which consists of both red and blue light), through F_R, to the dashed vertical line at the right.

17. Using a blue pencil, draw the lines for the blue light, from the lens, through F_B, to the dashed vertical line.

18. Repeat the process with both red and blue pencils for the more technologically sophisticated, compound lens, in the lower part of Figure 6.

Figure 6: Chromatic aberration



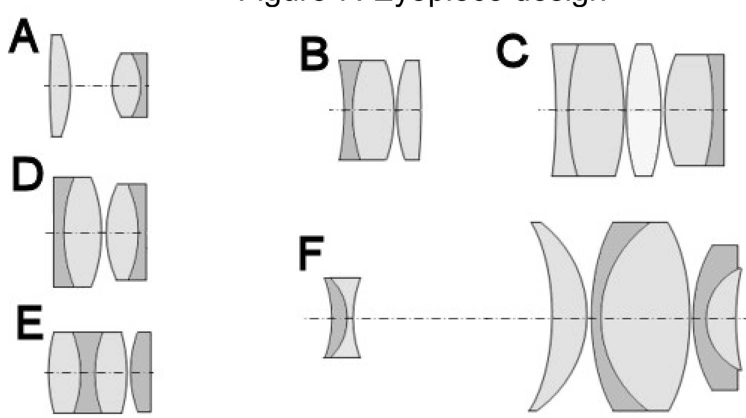
19. Notice that at no point are both beams simultaneously in focus. The closest they get is somewhere between F_B and F_R. Which lens (simple or compound) does a better job at focusing all the light at some point?
(Hint: which set of beams become more tightly bundled?)

Your answer: ___________________

20. Figure 7 shows the structure of several different types of eyepiece design. Refer to the caption underneath the figure. Which two eyepiece designs have the most pieces of separate glass in their construction? It should be no surprise that these two designs are among the most expensive!

Eyepiece: _____________________ Eyepiece: _____________________

Figure 7: Eyepiece design



A = Kellner, B= König, C = Erfle, D = Plössl, E = Orthoscopic, F = modified Nagler.

VOCABULARY:

Converging
Diverging
Plano
Parallel beams
Galilean refractor
Keplerian refractor
Newtonian reflector
Cassegrain reflector
F-ratio
Chromatic aberration
Simple lens
Compound lens