

Magnification and Field of View: An Introduction

Materials Needed—

- Schmidt–Cassegrain telescope (mounted)
- Two extenders (straight or bent)
- Three eyepieces with different focal lengths (e.g., 40 mm, 17 mm, 10 mm)
- Graph paper (metrically ruled, preferably)
- Meter stick
- Tape
- Calculator

Introduction— Telescopes allow us to see things at different scales according to the magnification of a particular telescope–eyepiece combination. In this exercise you will experiment with different eyepieces attached to a telescope. You will see how these alter the size of their fields of view and their respective magnifying powers.

Optical systems like telescopes give you an *angular* field of view, measured in degrees ($^{\circ}$), the standard unit of angular measure. For instance, when you hold your thumb finger close to your eye, it appears large, whereas when you hold it at arm’s length it appears much smaller. This is due to a change in your finger’s angular size with respect to your eye, and obviously not to a change in the finger’s width or length.

Degrees can be divided into smaller units. There are 60 *arcminutes* (denoted $60'$) in a degree and 60 *arcseconds* (denoted $60''$) in an arcminute. Thus, $1^{\circ} = 60' = 3600''$. The angular size of your thumb at arm’s length is $\sim 1^{\circ}$, whereas the angular size of the full Moon is $.5^{\circ} = 30'$, which is why you can cover up the Moon with your thumb!

The total field of view of your unaided eyes should be the hemisphere in front of you, with a diameter of roughly 180° (most of us cannot see the 180° hemisphere behind us!) The fields of view that you can see through a telescope are much smaller than 180° , which allows astronomers to see fine details not normally visible to the unaided eye.

Procedure—

1. On your piece of graph paper, measure and record the height of one of the grid squares using your ruler.
2. Tape your piece of graph paper to a wall, and set up the telescope far from the wall. Point at the paper. Using your meter stick, record the distance between the telescope and the piece of paper.
3. You have three eyepieces, each with a different focal length. The focal length is the distance separating a lens from where it focuses incident light (think of burning ants with a magnifying glass¹). Make a table with a row for each eyepiece. Record the focal lengths that are on the sides of the eyepieces.
4. Rather than measuring the magnification of the telescope–eyepiece combinations directly, it is easier to measure the size of the field of view that one sees when looking through the telescope. For each eyepiece:
 - (a) Attach it to the end of the telescope and bring it into focus so that you can see the graph paper.
 - (b) Using the grid squares as a guide, how wide is your field of view in length units (cm and mm)? Record this in your table. (Also note how the brightness of the grid changing as you change eyepieces.)
 - (c) Using simple trigonometry and the distance between your telescope and target, convert the width (height) from your previous step to an angular size for each field of view (FOV):

$$\tan(FOV) = \frac{\textit{opposite}}{\textit{adjacent}} \quad (1)$$

$$\rightarrow FOV = \tan^{-1} \left(\frac{\textit{opposite}}{\textit{adjacent}} \right) \quad (2)$$

$$\rightarrow FOV = \tan^{-1} \left(\frac{\textit{height}}{\textit{distance}} \right) \quad (3)$$

5. The telescope you are using also has a focal length (all curved mirrors and lenses do). For this telescope, the focal length is $f_o = 1200$ mm (the focal length of the objective mirror). The *magnification* for a given eyepiece–telescope pair is the ratio between the focal length of the telescope (f_o) and the focal length of the eyepiece (f_e).

$$M = \frac{f_o}{f_e} \quad (4)$$

Calculate and record the magnification for all three eyepiece–telescope pairings.

¹ No actual ants were hurt in the making of this activity.

Questions—

1. Which of these eyepieces has the largest field of view? Could you see the whole Moon through it?
2. Which of these eyepieces has the smallest field of view? Could you see the whole Moon through it?
3. Looking at your table, how does increasing the focal length of an eyepiece affect the field of view? What about the magnification?
4. Does the choice of eyepiece affect the perceived brightness of the target? Why?