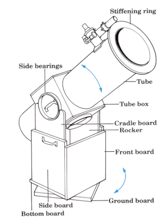
Name: ___________________________
Partner(s): ________________________
1102 or 3311: ______
Desk # ____________
Date: _____________



Telescopes

Purpose

- Investigate the characteristics of telescopes: light gathering power and magnification
- Identify the different types of telescopes
- Identify the different types of telescope mounts

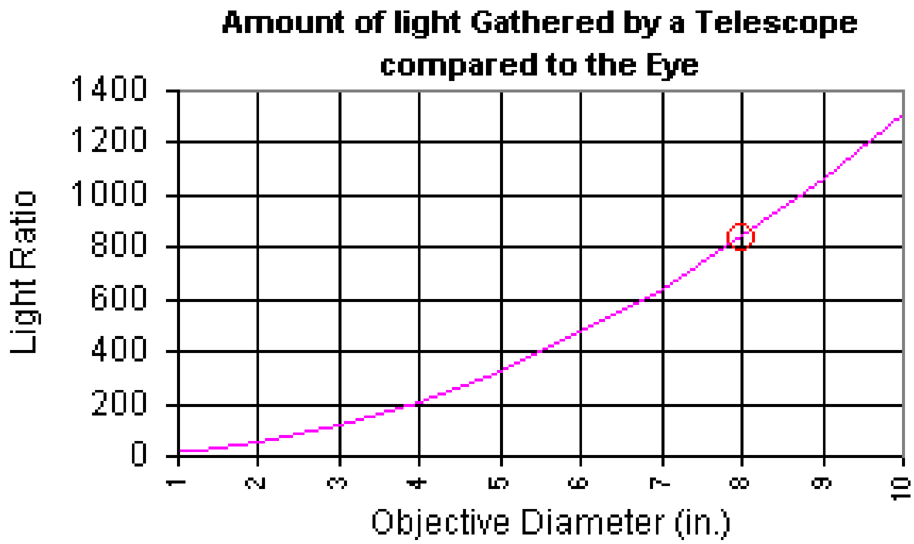
Equipment

- Various telescopes around the room

Characteristics of Telescopes: All telescopes have the same purpose **-** to collect light and bring it to a point of focus so it can be magnified and examined with an eyepiece. A telescope's ability to collect light is directly related to the diameter of the lens or mirror - the aperture - that is used to gather light. Generally, the larger the aperture, the more light the telescope collects and brings to focus, and the brighter the final image. Your eye works the same way. When you are out in the dark, the pupil of your eye (the black part) grows larger. The result is that more light enters your eye.

The telescope's magnification, its ability to enlarge an image, depends on the combination of lenses used. The eyepiece performs the magnification. Since almost any telescope can achieve any magnification by using different eyepieces, it's the aperture, or light-gathering power, that is a more important feature than magnification.

The graph below shows the "light gathering power" of a telescope compared to your eye when your pupil has a diameter of 7mm. This is for telescopes in the range of 1inch to 10inches. For example, an 8-inch telescope collects 800 × more light than your eye.



Types of Telescopes:

A **Refractor telescope** is a long, thin tube where light passes directly from the front objective lens to the eyepiece at the opposite end. Moving the eyepiece in and out controls focusing.

The image is reversed left to right and top to bottom in an astronomical telescope. If a "diagonal" eyepiece holder is used (see below) then the mirror flips one of these directions back again.

Colour correction is required, since light of different colours will focus at different points if a single objective lens is used. Achromatic, apochromatic, fluorite, and ED multi-element objective lens designs handle the colour correction.

Newtonian Reflectors use two mirrors: a concave parabolic primary mirror to collect and focus incoming light onto a flat secondary mirror that in turn reflects the image out of an opening at the side of the main tube and into the eyepiece. Moving the eyepiece in and out controls focusing.

The secondary mirror and its support structure (thin metal vanes) obstruct some of the light but since the primary mirror is large this is not much of a problem.

The image is reversed left to right and top to bottom by the primary mirror, then the secondary mirror flips one of these directions back again (which one depends on the orientation of the telescope).

Colour correction is not required.

Catadioptrics (Schmidt-Cassegrain) use a combination of a large, thin aspheric Schmidt correcting lens and two highly polished mirrors - a large spherical primary mirror and a smaller specially shaped secondary mirror. The two mirrors "fold" the optic path (the light travels *three* times the length of the telescope tube) then the light passes out an opening in the centre of the primary mirror, out the back of the telescope and forms an image for the eyepiece. Moving the entire primary mirror back and forth inside the telescope controls focusing.

The image is reversed left to right and top to bottom. If a "diagonal" eyepiece holder is used then the mirror flips one of these directions back again.

Colour correction is not required.

Telescope Eyepieces: The focal length of the eyepiece controls the magnification of the image - the ***smaller*** the focal length the ***larger*** the magnification. Astronomers usually have a number of different eyepieces for their telescopes.

- Low power eyepieces for observing the Moon
- Medium power eyepieces for observing galaxies and nebula
- High power eyepieces for observing the other planets and their moons

Diagonal eyepieces let you view objects at a 90° angle from the direction the telescope is pointing, instead of looking "straight through", thereby allowing comfortable viewing. It does not provide any additional magnification.

Finder Scopes: It is often difficult to find an object while looking through the eyepiece because astronomical telescopes typically are viewing an extremely small section of the sky. For this reason most telescopes have a smaller, low-power "finder" scope attached along the axis of the main telescope tube. This finder scope is used to point the main tube at the object, which can then be centered in the field of view of the telescope with only minor pointing adjustments.

Question 1:

a) Fill in the table for each of the telescopes present in the room.

Telescope name	Type	Length of tube (cm)	Aperture (mm)	Focal length (mm)	Finder: Yes/no

b) Look at a student on the other side of the corridor. Give the name of the telescope you used and draw a sketch of what you see. (Note any reversing/mirroring/upside down effects in your image.)

Question 2: Magnification is a number that describes the factor an object was magnified, where 1x is no magnification at all.

$$\mathrm{MA} = \frac{f_o}{f_e}$$

Here f_o is the focal length of the objective lens and f_e is the focal length of the eyepiece.

a) A telescope has a focal length of 1200mm. In order to observe the craters of the Moon, you use an eyepiece of focal length 10mm. Calculate the magnification.

b) The Ptolemy crater is 140km wide. What is its angular size as seen from the Earth? What is its angular size using the telescope described in the previous question?

c) The maximum useable magnification for a telescope is 2 times the diameter of the primary optic (aperture) in mm, depending on the quality of the sky. A department store telescope has a 60mm diameter lens. What is the maximum magnification of this telescope?

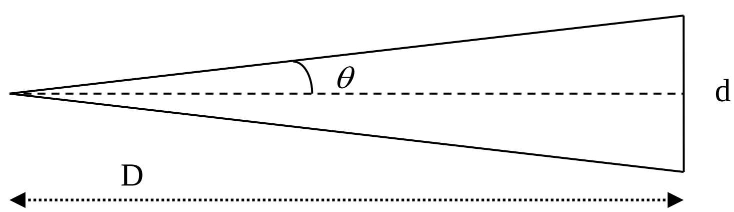
d) Fill in the following table with the values of the different magnifications. The focal length is sometimes written on the tube.

Telescope	**Focal length (mm)**	**Max magnification**	**Magnification with 25mm eyepiece**	**Magnification with 4mm eyepiece**

e) Which telescope/eyepiece combinations exceed the maximum magnification for a given telescope?

Question 3: **(ASTR 1102 only)** Field of view.

Binoculars: John's 10 x 50 binoculars (10 power, 50 mm objective lens) have the following stamped on them: 96 m at 1000 m. This is the measured width of the field of view at the distance given. This can be converted into an angular field of view using trigonometry as follows:



$$\tan q = \frac{d/2}{D}$$

When you do the math for small θ, you find that

$$\text{field of view} = 2\theta \approx \frac{d}{D} = \frac{96}{1000} = 0.096\ \text{rad} \times \frac{180^\circ}{\pi\ \text{rad}} = 5.5^\circ$$

Since the moon is about 0.5°, this is about 11 moon diameters - quite a large field of view.

a) Tania's 7×35 binoculars (7 power, 35mm objective lens) state: 140m at 1000m. Calculate the field of view for these binoculars.

The field of view of a telescope and eyepiece combination is defined as: "The angular diameter of the circular field as seen through the eyepiece". This is often stated mathematically as:

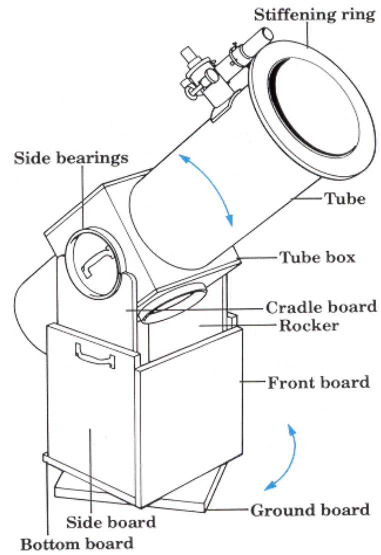
$$\text{field of view} = \text{field of view of the eyepiece} \times \frac{f_e}{f_o} = \text{field of view of the eyepiece} \times \frac{1}{MA}$$

b) You are using an eyepiece with a 50° apparent field, and the power (or magnification) of the telescope with this eyepiece is 100x. Calculate the field of view seen by the observer.

c) Which allows a wider field of view, lower power eyepieces (40mm) or higher power eyepieces (13mm)? Explain.

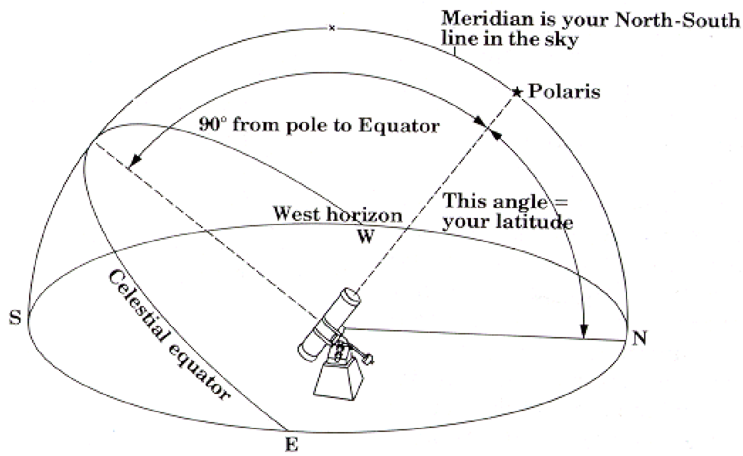
Question 4: Mounting Systems

Alt-azimuth. The typical field of view of a telescope is about the size of your small fingernail at arms length - a very small patch of sky, so all telescope assemblies need to be held steady for observing. Galileo, who invented the first mounted telescope, already knew this fact.



Alt-Azimuth mounts are very simple in design, but one has to manually keep the telescope on the object of interest. This involves moving the telescope "up-and-west" as the object rises, and "down-and-west" as the object sets. This type of mounting is not recommended for astrophotography because it is very difficult to continuously aim the telescope precisely. However, it is the least expensive mount and is still very good for visual observing and making drawings or sketches of celestial objects.

An **Equatorial Mount** is set up so that the entire mechanism rotates around the Celestial Pole just as the sky does. The mount only has to move the telescope in Right Ascension as time goes by to "track" objects rising in the east and setting in the west.



In order to ensure the rotation axis of the mount is precisely aligned with the rotation axis of the Earth, a small "polar-alignment telescope" is often built right in to the axis of rotation. If the mount does not have a separate polar-alignment scope, then the "finder scope" must be used to accurately align the axis of rotation to the Celestial Pole. This type of mount is ideal for long-duration astrophotography, although the weight and setup time are larger than other types of mounts.

A computerized **Fork Mount** telescope has to continually adjust for the changing position of the object of interest by automatically moving the telescope East-to-West as well as South-to-North or North-to-South to follow objects that are either rising in the east or setting in the west. It must therefore have two accurate motor drives and a computer control system to run both motors.

Polar alignment is not necessary, so another alignment procedure must be used to ensure the pointing accuracy of the two motors is set properly. This configuration is good for short-duration astrophotography. It cannot be used for long-duration astrophotography because the camera (or CCD detector) is always parallel to the horizon, not rotating with the curved line the objects follow. This causes any long duration image to suffer from "field rotation". However, there are some software packages that can account for this, rotating a set of short duration images appropriately to remove the unwanted effects.

a) Why did Galileo need a telescope mount to be able to draw diagrams of the Moon?

b) You have an Alt-Azimuth mount and you want to observe the rising Moon. What do you see in the telescope if you do not move it? Which direction do you need to move the telescope to follow the Moon (increasing/decreasing Alt, increasing/decreasing Azimuth)? Draw a bowl diagram like on page 7.

c) You have an equatorial mount and you want to observe the rising Moon. What coordinate needs to be adjusted so that the Moon stays in the field? Explain.

d) Draw the Questar telescope and show which axis should point toward Polaris.

e) Explain the term tracking.

f) Why is it better to have a computerized fork mount to perform short-duration photography?

g) What is meant by "any long duration photography will suffer from field rotation"?

h) Fill in the following table.

Telescope name	Type of mount	Judicious use of this telescope

Conclusion: What did you learn today? Write a 3 to 5-line summary.

Instructor's initial: __________