SESSION SIX: TELESCOPES

BUYING BINOCULARS—PART 1

***StarWatch* 121, December 13, 1998—revised 2012**

If you are contemplating buying a telescope as a Christmas gift, consider binoculars instead. Binoculars offer a wide range of advantages over telescopes, not the least of which is cost. They are simply cheaper. The person that you're buying them for probably doesn't know much about the sky either. She or he will have to begin learning the brighter stars and constellations before becoming successful with a higher-powered instrument. Why not help ensure that this transition is successful by beginning the exploration of the heavens with a highly portable, wide field, low magnification, easy-to-focus device that makes it fun to locate objects in the sky? You will also be using two eyes rather than one which will produce a more comfortable view. Binoculars are also multipurpose. Use them anywhere anytime for bird-watching, for whale-watching, for astronomy. They are also adjustable, meaning that the distance between the eyes can be quickly modified to accommodate each person's specific pupillary distance. If the binoculars are being purchased for astronomy, consider the addition of an astronomical field guide, small sky atlas, software/freeware that depicts the heavens, or a smart phone application. It will give the recipient a solid foundation to start his or her astronomical pursuits. Purchase binoculars from a reputable dealer, such as Skies Unlimited in Pottstown, PA, www.skiesunlimited.net/, Orion Telescopes and Binoculars, www.telescope.com, or Oceanside Photo and Telescope (OPT), www.optcorp.com. Don't buy from a high-volume discount superstore. With optics, you usually get what you pay for, and customer service should be part of the equation in case there are problems with the product that was purchased.

BUYING BINOCULARS—PART 2

***StarWatch* 121, December 20, 1998—revised 2012**

For people who are really "into" astronomy, the optics they use are a very personal matter. Lack of knowledge often makes it difficult for the gift giver to make the right choices. If you are really concerned about ensuring maximum satisfaction, you may want the recipient to choose his or her own binoculars. This becomes almost essential if you wear glasses and cannot adjust the focus of the binoculars so that you can view images without them. In order to see the full field of view, binoculars must throw the tightest bundle of focused light back far enough so that it intercepts the eye. With glasses the eye is farther away from this position, and the light bundle may fall short, resulting in a restricted field of view. This makes for an uncomfortable and frustrating observing experience. Binoculars that are designed for astronomy should produce a light bundle which at its smallest diameter is between 5 to 7 millimeters across. To calculate what is called the exit pupil diameter, take a standard binocular, such as a 7x50 model. Divide the first number (7) into the second number (50) and you'll have your answer. These number designations, such as 7x35 or 10x50, explain more. The first numeral tells you the magnification, while the second number states the diameter of the light-gathering objective in millimeters. There are 25.4mm per inch. The larger the objective, the more light the binocular will gather. You'll see fainter objects. The higher the magnification, the bigger the observed object will appear; but this will always be at the expense of a smaller field of view and more noticeable shaking as you try to hold your binoculars in a steady manner to view the sky.

PURCHASING A TELESCOPE—PART 1

***StarWatch* 164, October 17, 1999—revised 2012**

I have always put off thinking about the Holidays until after Thanksgiving. However, if you're in the market to purchase a telescope, October is the time to start pondering your options. Here are some ideas to consider. Stay away from department store varieties like Wal-Mart and K-Mart. You'll pay too much and probably get a piece of junk in return. Regionally, a much larger retailer exists about an hour south of the Lehigh Valley in Pottstown. You can call Skies Unlimited at 1-888-947-2673. The company claims "honest advice from real astronomers," and having been down to their Pottstown store several times, I can personally say that they deliver in a no pressure environment. Access their website at www.skiesunlimited.net/. Here are a few tips to remember. If you are not willing to spend at least three or four hundred dollars on your new telescope, then invest your money in a good pair of binoculars. See the articles on the previous page. Keep in mind that a telescope's main function is **to gather light and not to magnify an image**. Good telescopes are designed to collect a sufficient amount of light so that an object can be clearly seen at some reasonable magnification. You'll probably get the biggest bang for your buck if you purchase a reflecting telescope that uses mirrors to focus light rather than lenses. Unless you have money to burn, start with a smaller, instrument: a 2-inch to 4-inch refractor or a 4-inch to 8-inch reflector. You can always upgrade later and give away or sell your telescope to a deserving novice.

PURCHASING A TELESCOPE—PART 2

***StarWatch* 164, October 24, 1999—revised 2012**

Every telescope is a compromise. The type of instrument purchased should be based upon where you live, where you plan to conduct your observations, and what you enjoy observing the most. The aperture of a telescope simply represents the light-gathering element, either a series of lenses for a refractor, or mirrors for a reflector. Catadioptric systems incorporate both lenses and mirrors resulting in far greater portability, but generally higher costs. The focal length of a telescope is simply the distance that it takes light to come to a focus after being refracted or reflected by the optical elements in its path. Divide the aperture into the focal length, using the same units of measurement, and the focal ratio (F/ratio) results. Everything remaining equal, the longer the F/ratio, the higher will be your magnification. Keep in mind that 50 power per inch of aperture is a reasonable expectation for magnification. If you live in a city and plan to observe from an urban environment, then your options are limited because of light pollution. Concentrate on bright objects, such as the sun (with proper filtration), the moon, the planets, and double stars. Your best bet might be a 2-inch to 4-inch refractor with a focal ratio of F/9-15. If your penchant is for deep-sky objects such as galaxies, nebulae, and star clusters, or beautiful views of eclipses, you should consider a 4-inch to 8-inch, F/4 to F/7 reflector. You should live in a rural setting or be prepared to haul your equipment to such a location to maximize its potential. Accessories should include additional eyepieces so that you will have several choices of magnification. You'll also need a star atlas, planisphere, or software package, so that you will have maps to help you identify what is currently visible in the sky and how to locate the objects slated for observation that evening.

THE 100-BILLION MILE TELESCOPE SALE

***StarWatch* 195, May 21, 2000—revised 2012**

An ad touting the sale of "Super-Powerful 100-billion miles Deep Space Telescopes" in last Thursday's paper, D2, was the inspiration for this week's article. The price of the telescope was only $29.95, reduced from $199.95, and it offered to bring "the moon, Mars, Venus, etc. right into your living room." Continuing, the promotional said that the telescope could "track comets streaking across the heavens." Comets don't streak or run. They don't even skip or hop. They move night after night slowly against the background of more distant stars as their positions change and our observing platform, the Earth, revolves around the sun. "See meteors flame through the skies..." Meteors can streak, flame, and sputter, but their rapid motion makes them impossible to follow through a telescope. Then I read the real eye-opener. "Be absolutely spellbound in your ringside seat as asteroids collide in fiery explosions…" There has never been a single real time observation in the history of astronomy which has detailed the collision of two asteroids. In July of 1994 telescopes were trained on Jupiter as 20 fragments of Comet Shoemaker-Levy 9 fell into its atmosphere. This telescope may have barely seen the largest dark splotches made by the icy fragments, but the impacts were only visible through satellites that could image the nighttime hemisphere of the planet. It's sad to think that telescopes are still being marketed with this old-fashioned type of hype. The ad ended with a disclaimer that "results vary depending upon weather and eyesight." Results will be disappointing regardless of how good your eyesight or the weather conditions are. Caveat emptor! Let the buyer beware, is the rule here!

EMPTY MAGNIFICATION

***StarWatch* 795, November 13, 2011**

Last week, I wanted to continue a dialogue on telescopes, since the holidays are fast approaching and scopes have an affinity to find themselves under Christmas trees; but a freak Halloween snowstorm which blanketed the East Coast stole the show. Clean up still continues, but the snow is gone and almost everybody has had their electricity restored. I wanted to say a few words about magnification since it is considered so important to people purchasing their first scopes. It should never be the prime consideration for owning any telescope, but it does have its place in using a telescope properly. Mathematically, magnification equals the focal length of the telescope divided by the focal length of the eyepiece. The focal length is simply the distance that light takes to come to a precise focus. Both the telescope and the eyepiece play a role in how powerful a telescope's magnification can become. Because of the nature of light, images are brought to a focus as a series of dots or diffraction disks similar to a newspaper photograph. Larger aperture scopes produce smaller diffraction disks and can tolerate higher powers. The observer looking at an image in the eyepiece is totally oblivious to this fact, but the analogy is an accurate one. Every time the magnification is doubled, the field of view and the brightness of the image become one quarter of their original value which is a function of inherently larger diffraction disks. If a person looks more closely at a newspaper photo, there comes a point where no new information can be gleaned, and at even closer distances, less detail is perceived. Likewise, simply "jacking up the power" in telescopes produces "empty magnification" where no new detail can be revealed. The upper limits of magnification are about 50-60 power per inch of light gathering aperture. Beyond this point the magnification becomes empty, in other words, useless.

SHOP UNTIL YOU DROP

***StarWatch* 767, May 1, 2011**

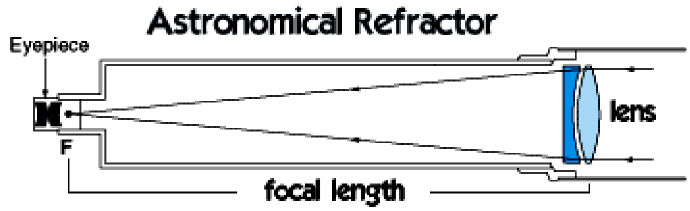
Last week, I spoke about the Meteorite Men and how I was nearly tempted into bankruptcy by an attractive woman touting rocks from outer space. What I didn't tell you was that in addition to that attraction, there were nearly 150 other dealers selling astronomical gear at this year's Northeast Astronomical Forum (NEAF), the biggest vendor convocation in the US. Sponsored by the Rockland Astronomy Club and held in the spacious Rockland Community College gym in Suffern, NY, this year marked NEAF's 20th anniversary. Last year was my first experience, a real jaw-dropper. I honestly felt like a kid in a candy shop, so much "stuff" and so little time. I wandered aimlessly from booth to booth until it was time to leave. I didn't buy anything, but I spent a great deal of energy, time, and some money putting into motion the ideas that I had garnered from this event. One of those concepts was to refurbish and upgrade several different telescopes that I own so that they would all work with one mount. That project continues and has met with much success. A great benefit in participating at NEAF is that there is no junk being sold. There are no K-Mart Specials or Wal-Mart telescopes being marketed that were recently mass produced in China and most likely will break upon first contact with a human. That doesn't mean a consumer can't find bargains. Many of the vendors have a reduced price structure because this is the ultimate telescope and gear competition anywhere in America. What will happen if you spend a thousand dollars on a telescope, mount, and a few additional eyepieces, is that you will walk away with genuine astronomical equipment capable of producing great views of the universe. NEAF is an event truly worth considering if you are thinking about making astronomy a serious hobby and purchasing the gear that will produce memories to last a lifetime.

I. **Basic telescope terminology**

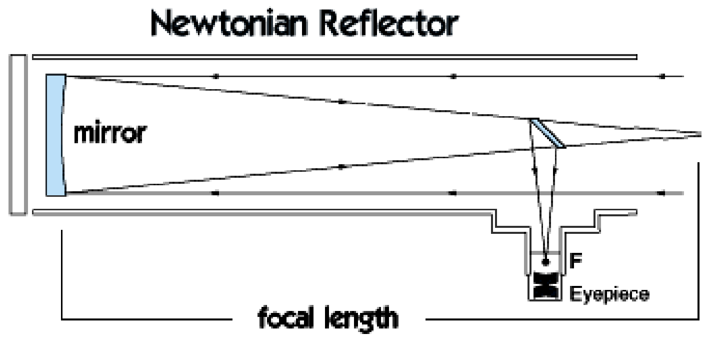
A. **Aperture:** The diameter of the light collecting area of the telescope. A telescope with a lens or mirror six inches in diameter would have an **aperture** of six inches.

B. **Focal length:** The distance from the center (lens) or surface (mirror) of the light collector to the position of best focus of the image.

1. Refractor: A lens or series of lenses brings light to a focus



2. Reflector: A mirror or series of mirrors brings light to a focus



C. **Focal ratio:** The aperture of a lens or mirror divided into its focal length. The focal ratio of a telescope is the key to understanding the usefulness of a particular instrument. See magnification and field of view for a clearer explanation of this concept.

Aperture (in inches)	Focal Length (in inches)	Focal Ratio	Usefulness
3.5	50.4	F/14.4	lunar & planetary
6	24	F/ 4	wide field
8	56	F/ 7	all-purpose
10	100	F/10	all-purpose
26	442	F/17	lunar & planetary
200 (Hale, USA)	1000	F/5	wide field

F/1-F/5, wide field--star clusters, nebulas; F/6-F/10, all-purpose; F/11-F/30, narrow field—lunar and planetary

II. The Purpose of Building Telescopes

A. **To gather light:** Simplistically, a telescope could be defined as a light bucket. The amount of light gathered by a lens or mirror in comparison to the eye can be expressed as $16D^2$, where D is the aperture of the lens or mirror expressed in inches. This equation does not take into consideration light losses due to transmission or reflection, which may be considerable. A more realistic approach might be $9D^2$. The following table lists the light gathering capabilities for various apertures.

Aperture in inches		$9D^2$	$16D^2$
(6.4 mm) ¼	(human eye)	---	1
2	(small refractor)	36*	64*
4	144*	256*	
8	576*	1024*	
12	1300	2300	
(3 m) 96	(Hubble, USA)	83,000	147,000
(5 m) 200	(Hale, USA)	360,000	640,000
(10 m) 400	(Keck, USA)	1,440,000	2,560,000

*Note that as the aperture doubles, the light grasp quadruples.

B. **Magnification:** The ability to make an image appear larger than its apparent unaided dimensions.

1. Magnification = focal length of telescope/focal length of eyepiece
2. The longer the focal length of the system, the higher the potential is for magnification. A 6-inch, F/12 (fl = 72 inches) telescope will produce a higher magnification than a 10-inch, F/5 system (fl = 50 inches) using the same eyepiece.
3. **Limits of useful magnification:** 6X to 60X per inch
   a. **Upper limits:** An image of an extended object, such as the sun, moon, or a planet can be said to be composed of a structure of tightly packed dots--diffraction disks-- similar to a newspaper or magazine photograph. If a newspaper picture is positioned across the room from an observer, a certain amount of detail is perceived in the image. As the observer approaches the picture, it appears larger or magnified over its original dimensions, and more detail can be seen. A position will be reached, however, where there will be no more increase in the amount of information seen in the image. At this point any further magnification is **empty.** If the observer continues to decrease his/her distance to the photo, even though the magnification increases, the detail in the image will suffer.
   b. **Lower limits:** The diameter of the emerging light cone coming from the eyepiece (called the exit pupil) becomes larger as the magnification of the system decreases. If the exit pupil diameter exceeds the aperture of the eye's pupillary diameter, then the observer is not utilizing the full capabilities of the optics which she/he is employing. The lowest magnification used on a telescope should be governed by the largest exit

pupil size which the eye can fully accept. For middle-aged individuals, who do not smoke, 5 mm is generally considered the acceptable value. Mathematically, exit pupil is defined as aperture divided by magnification.

4. **Magnification and aperture:** A telescope with a larger aperture will produce an image composed of smaller diffraction disks (dots) and therefore allow a higher magnification to be applied to that image before deterioration sets in.
5. **Doubling the magnification** will cause the field of view and image brightness to decrease to one quarter of its original value. One can literally magnify an image beyond its level of detection by the human eye.

C. **Resolution:** The ability of an optical system to separate objects of close angular measure so that they may be seen by the observer.

1. Angles: A circle contains 360 degrees, each of which can be broken into 60 parts called minutes. Each minute of arc can be further divided into 60 seconds. Therefore a circle contains over one million seconds of arc (1,296,000 seconds precisely).
2. **Mathematically,** resolution may be expressed by two basic formulae.

   a. **Rayleigh criterion** = **5.45 seconds of arc**/aperture in inches

   The Rayleigh criterion is based upon theoretical concerns dealing with the physics of light.

   b. **Dawes' limit** = **4.56 seconds of arc**/aperture in inches

   Dawes' limit is based upon the subjective observations of W. R. Dawes, a 19th century British astronomer.

3. Resolution potentials of various apertures

Aperture in inches		Resolution: seconds of arc Rayleigh	Dawes
(6.4 mm) ¼	(human eye)	21.8*	18.24*
2		2.73	2.28
4		1.36	1.14
8		0.68	0.57
(3 m) 96	(Hubble, USA)	0.057	0.048
(5 m) 200	(Hale, USA)	0.273	0.023
(10 m) 400	(Keck, USA)	0.014	0.011

*The best resolution of the human eye is about two minutes of arc. Normally it is about five minutes.

4. One second of arc resolution on the moon equals about a one-mile separation on the lunar surface. A resolution of one half second represents the practical limit of resolution for large aperture telescopes due to atmospheric turbulence (called seeing). It also exemplifies the importance of operating large instrumentation above the earth's atmosphere, where full resolution capabilities can be obtained.

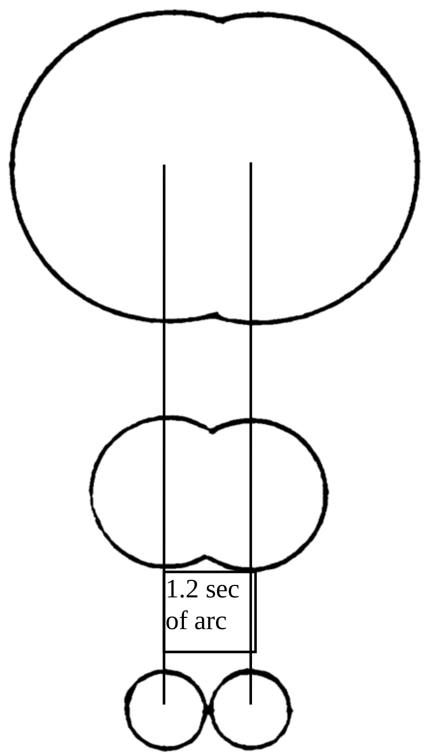
*5. **The relationship of magnification of extended objects to resolution:** It is important to realize that the number representing the resolution in seconds of arc also specifies the angular size of the diffraction disks which compose the image. Applying this reasoning to magnification, it can be seen that the smaller the aperture, the coarser the dot structure of the image will become. Higher magnifications will be less successful with smaller aperture scopes.

*6. **Resolution as it applies to diffraction disks:** The resolution of a system also dictates the minimum angular separation, or the angular proximity to which detail can be separated into its individual components. As an example, the following series of dots illustrates an exaggerated, but scaled appearance of the same double star system as viewed through three telescopes of different apertures. The two stars have an angular separation of 1.2 seconds of arc. Note that as the aperture increases, the diffraction disks become smaller, eventually revealing the double as two distinct objects. At this point the system is said to be fully resolved.

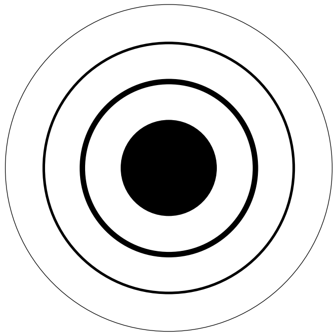
*1. 1-inch aperture (4.56 sec. of arc res.) Double appears as one object through the eyepiece.

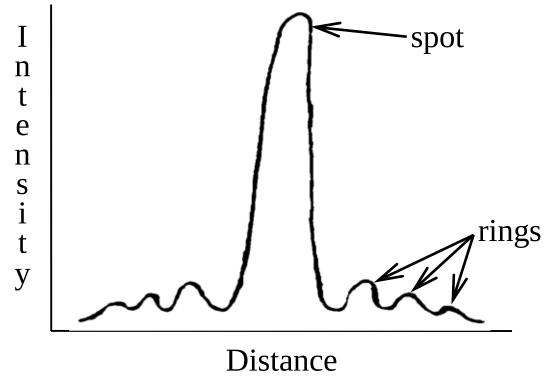
*2. 2-inch aperture (2.28 sec. of arc res.) Image of double appears to be elongated.

*3. 4-inch aperture (1.14 sec. of arc res.) Image is fully resolved.



D. **Contrast:** A telescope with good contra ›server to differentiate between the various subtle s ›mical image. *The diffraction disks are the ke› ›diffraction disks are, in actuality, composed of a disl ›ntric rings of decreasing intensity.





The contrast of an image is dependent upon the amount of light which is contained in the central disk versus the surrounding rings. The light which falls into the rings is wasted and does not go into the formation of the image, but merely serves to "haze" the picture. Contrast is reduced. Again, the analogy of the newspaper photograph is appropriate. The small dots of various shades of gray form the image. The contrast of the photo would be enhanced if the picture were printed on whiter paper and reduced if printed on grayer paper. In the latter case, the detail in the picture would still be there, but it would present more of a challenge to discern, because of the lack of contrast. The contrast of an image can be improved if the greatest amount of light possible is concentrated into the center disk. A reduction in contrast simply means that the telescope is putting more light into the rings surrounding the diffraction disks which compose the image.

*1. **Perfect contrast:** Under ideal conditions no more than 84% of the light will fall into the diffraction disk. Sixteen percent of the light will therefore be found in the rings.

2. **Conditions which may reduce the contrast performance of a telescope:**
   a. The optical perfection of the system: The lower the quality, the lower the contrast.
   *b. The size of an obstruction in the optical path of a telescope reduces contrast. These normally include the secondary mirror, as well as any support structures holding that mirror. As light passes the opaque surface of an obstruction, it is bent slightly causing more light to fall into the rings surrounding the diffraction disk. This phenomenon is called diffraction.

E. **Definition:** The sharpness of the image. Definition is a function of the optical accuracy of the system. The more precise the optical accuracy, the finer the definition will become.

*1. **Astronomically acceptable telescope:** The maximum tolerance for an astronomically acceptable image is 1375 Angstroms of deviation of the optical wave front at the image plane. This is compared to a wavelength of sodium light which has a separation of 5500 Å, which equals one wave. Therefore the minimum rating for a telescope which would produce acceptable images is ¼ wave. One Angstrom equals 0.00000001 cm (10^{-8} cm) or 0.000000004 inch (4×10^{-9} inch). To be astronomically acceptable, a telescopic system must produce an image with an deviation of no more than $^{0.000000004\ inch}/_{Å}$ x 1375 Å = 0.0000055 inch or $^{5}/_{1,000,000}$th of an inch (5.5 x 10^{-6} inch).

*2. **Comparing resolution and definition:** Very often the terms resolution and definition are considered to be the same. This is not true. A 2-inch refractor of superb optical quality will produce images of exceptional clarity and contrast, but it will only resolve objects with a minimum separation of 2.28 seconds of arc. The instrument will still be rather poor with respect to resolution because this is a factor of aperture. A large, optically flawed instrument will give poor definition, but may be fairly adequate with respect to resolution. It will probably not reach the theoretical performance as suggested by Rayleigh or Dawes.

F. **Field of View:** The area of the sky visible through the telescope eyepiece. Generally speaking, the higher the magnification, the smaller the field of view. Since magnification is directly related to focal length, one could also say that the longer the focal length of the telescope, the narrower will be the field of view as witnessed through similar eyepieces.

*1. **Mathematically** field of view = $^{\textbf{apparent field of eyepiece}}/_{\text{magnification}}$

*2. The **apparent field of the eyepiece** represents the measure of the angle of the light cone which the field lens of the eyepiece is producing within the eyepiece barrel. The field lens is the lens of the eyepiece which first intercepts the light cone being formed by the optical system of the telescope. The eye lens of an eyepiece is closest to the eye when looking into an eyepiece.

III. **Atmospheric nomenclature**

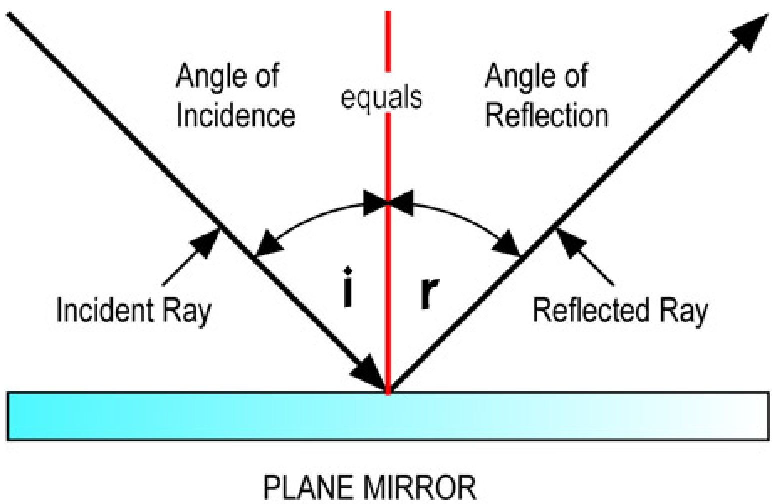
A. **Seeing:** Steadiness of the atmosphere. Visually, good seeing is occurring when the stars do not twinkle (scintillate). Telescopically, images appear steady in good seeing. In conditions of bad seeing, stars scintillate vigorously. Lunar and planetary objects will appear to waver in a similar fashion as objects would appear if viewed down a long stretch of highway on a hot summer's day. Stagnant air, such as may be found on hot, humid summer nights often produces the best seeing conditions, even though few stars are visible. Seeing is usually worse in winter.

B. **Transparency:** Clarity of the earth's atmosphere. When the transparency is excellent, the night sky is black and "ablaze" with many faint stars. Stars of a faint magnitude are visible under good transparency conditions.

1. **Apparent magnitude:** The measure of the amount of light (energy) received from a star or object at the earth's surface. It is usually referred to as just the magnitude of the object in conversation.
2. The difference in intensity between two stars separated by one magnitude in brightness is equal to 2.51. A difference of five magnitudes is an intensity range of 100. 2.51 x 2.51 x 2.51 x 2.51 x 2.51 = 100

3. The more negative the magnitude, the brighter the object. A star of magnitude two is brighter than a star of magnitude three because two is a more negative number than three. Below are found the magnitudes of some common celestial objects.
   a. Sun: - 26.7
   b. Moon: - 12.7 (when full)
   c. Venus: - 4.4 (at brightest)
   c. Sirius: - 1.4 (brightest nighttime star in sky)
   d. Polaris: + 2.0 (North Star)
   e. + 6.0 (faintest star visible to average eye)

Law of Reflection:



Law of Refraction (Snell's Law):

***Dutch astronomer Willebrord Snellius** (1580-1626)*

Snell's law states that the ratio of the sines of the angles of incidence and refraction is equivalent to the ratio of phase velocities in the two media.

refractive index of glass

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1} \qquad \sin\theta_1 n_1 = \sin\theta_2 n_2$$

refractive index of air is 1.

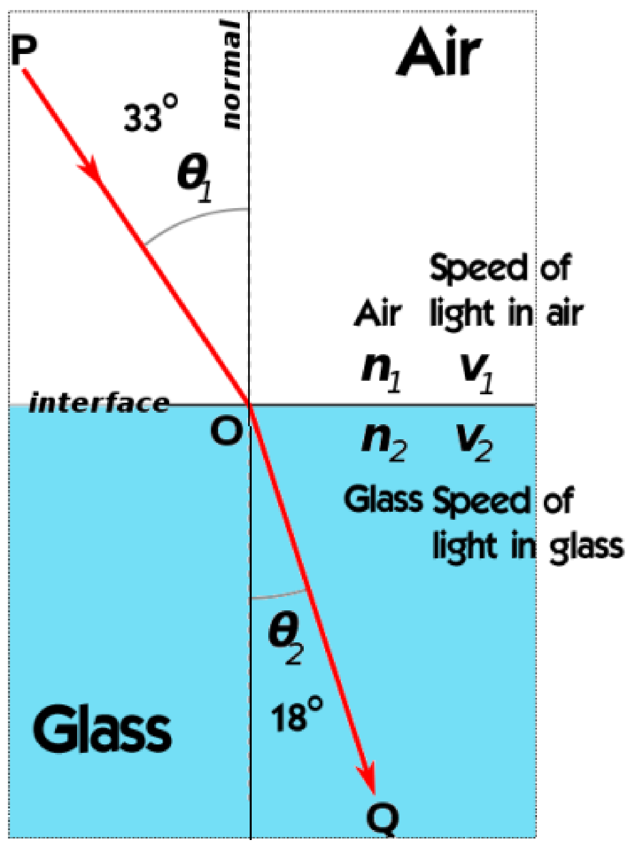
$$\frac{\text{Sin } 33^\circ}{\text{Sin } 18^\circ} = \frac{0.54}{0.30} = \frac{n_2}{1}$$

$$0.54 = 0.30\ n_2$$

$$n_2 = \frac{0.54}{0.30} = 1.8 \text{ (index of refraction)}$$

In the n_2 medium the speed of light is reduced from 3.00×10^5 km/sec to $\frac{3.00 \times 10^5 \text{ km/sec}}{1.8}$

or 1.67×10^5 km/sec



adapted from Wikipedia, the free encyclopedia

WORD LIST FOR TELESCOPES

1. **<u>Aberration</u>:** A defect in the optical system of a telescope caused by the grinding and polishing of the optical system, thermal shock, or limitations created by the physics of light.
2. **<u>Angstrom</u>:** 10^{-8} centimeters (cm) or 1/100,000,000 cm. A unit of measure which has been the traditional way of rating telescope mirror imperfections. An astronomically acceptable mirror is ¼ wave or 2.5 x 10^{-9} centimeters peak to valley.
3. **<u>Angular Measure</u>:** The stating of size or distance in degrees, minutes, and seconds of arc or as a function of time in hours, minutes, and seconds.
4. **<u>Altazimuth Mount</u>:** A mounting system, such as a tripod, which utilizes directions along the horizon and angular measurement above the horizon to find objects in the sky. A Dobsonian mount is altazimuth.
5. **<u>Apochromatic Reflector</u>:** A multiple lensed refractor which is highly corrected for color.
6. **<u>Astronomical Refractor</u>:** Normally a two lensed telescope which produces an astronomically acceptable image, but with some color.
7. **<u>ATM</u>:** An abbreviation for an Amateur Telescope Maker.
8. **<u>Barrel Distortion</u>:** A type of optical aberration which causes straight lines to bulge outward.
9. **<u>Binoculars</u>:** A compact optical device designed for both eyes that produces an erect image, wide fields of view, and low magnifications. Because of their utility, binoculars should really be the first "telescope" that an observer purchases.
10. **<u>Cassegrain Reflector</u>:** An open compound reflector which uses a perforated parabolized primary mirror and a convex secondary to bring an image to a focus.
11. **<u>Catadioptric</u>:** An optical system composed of lenses and mirrors.
12. **<u>Chromatic Aberration</u>:** A natural defect in a lensed system caused by the curvature of the optics which act like a myriad of prisms. Light entering the lens is not only refracted (bent), but also dispersed slightly into a spectrum of colors which comes to focus at different distances in back of the lens.
13. **<u>Circle of Least Confusion</u>:** The position of best focus in a telescope after the light has passed through the eyepiece.
14. **<u>Coatings</u>**: Layers of special molecules that are applied to a lens or mirror to make it more transparent or reflective.
15. **<u>Coma</u>:** An off-axis aberration which causes the stars of an image to look like little comets. The tails point away from the optical axis.
16. **<u>Commercial Telescopes</u>**: Telescopes manufactured by profit companies. Some brand names include Celestron, Meade, Orion, Astrophysics, Stellarvue, Vixen Optical, and Questar.
17. **<u>Compound System</u>:** A reflecting telescope composed of several mirrors with specialized curves. A Cassegrainian reflector is an example of a compound system.
18. **<u>Concave</u>:** A lens which bows inward like a cave.
19. **<u>Convex</u>:** A lens which bows outward.
20. **<u>Crown</u>**: The first lens element in an astronomical refractor.
21. **<u>Dawes' Limit</u>:** A practical guide for predicting the resolution of an optical system based upon extensive observations conducted by the English astronomy William R. Dawes in the 19th century. It is equal to 4.56 seconds of arc/a, where a = the aperture of the telescope in inches.
22. **<u>Declination Axis</u>:** The part of an astronomical mounting system which allows the telescope to be offset from the North Celestial Pole.

23. **<u>Definition</u>:** The ability of an optical system to produce sharp distinct images. It is directly related to the quality of the optical system.
24. **<u>Diagonal</u>:** A flat mirror usually positioned at a 45 degree angle to the light path of the image to facilitate a more comfortable view through the telescope. In a Newtonian reflector the diagonal directs the converging light cone through the telescope tube near the top of the scope. Diagonals are also used at the mirror ends of compound/catadioptric systems, as well as refractors for viewing comfort.
25. **<u>Dispersion</u>:** A characteristic of white light passing through lenses and prisms which causes different wavelengths to be bent at slightly different angles to produce the spectrum of colors.
26. **<u>Diffraction</u>:** A property of light which causes it to be bent when it passes near an opaque obstruction. Gratings with hundreds of lines per millimeter can also cause dispersion of light which produces the spectrum of colors.
27. **<u>Diffraction Disk</u>:** Also called an Airy disk or false disk… It represents the primary area of light amplification at the focus point of the image.
28. **<u>Dobsonian Mount</u>:** A low cost, box like altazimuth telescope mount primarily utilized to support short focus Newtonian reflectors. Their sturdy construction revolutionized astronomy by allowing large aperture, portable instruments to be built and owned by amateurs. The mount was invented by John Dobson in the late 1960's.
29. **<u>Equatorial Mount</u>:** A mounting system which has one axis that can be made to rotate around the North Celestial Pole, the polar axis, and another axis which moves at a right angle to the polar axis and is used to set the declination.
30. **<u>Erect Image</u>:** A view in which up and down are correctly portrayed.
31. **<u>Eye Lens</u>:** The optical component of an eyepiece closest to the eye.
32. **<u>Eyepiece</u>:** The lens or combination of lenses at the viewing end of a telescope that magnifies the image.
33. **<u>Eyepiece Holder</u>:** A circular tube which often contains a rack gear into which the ocular used for magnifying the image is placed.
34. **<u>Eye Relief</u>:** The distance from the eye lens to the circle of least confusion (focus) of an eyepiece.
35. **<u>Field Lens</u>:** The optical component of an eyepiece that is farthest from the eye.
36. **<u>Field of View</u>:** The amount of sky, measured as an angle, visible through an eyepiece.
37. **<u>Finder</u>:** A smaller, wide field telescope mounted parallel to the optical axis of the main scope used for locating and centering objects before they are viewed through the main telescope.
38. **<u>Flint</u>:** The second lens, used for correcting color, in an astronomical refractor. It is composed of a higher density glass than the first lens, called the crown.
39. **<u>Focal Length</u>:** The distance that light must travel from a lens or a mirror before coming to a focus.
40. **<u>Focal Ratio</u>:** The focal length of the telescope divided by the aperture of the telescope when the same units of measurement are employed.
41. **<u>Focuser</u>:** The device that holds the eyepiece and is used to bring the image into shape focus.
42. **<u>Fork Mount</u>:** A telescope support system which can be aligned to the equatorial coordinate system. It places the optical tube assembly between two struts which look like a fork.

43. **<u>Galilei, Galileo</u>:** (1564-1642) The Italian physicist/astronomer/experimenter/entrepreneur who built scientific instruments including the telescope. Galileo was not the inventor of the telescope, but he was the first to publish the observations which he made using the telescopes that he had built. These observations supported the heliocentric theory of Copernicus.
44. **<u>Galilean Refractor</u>:** A lensed telescope which uses a singlet convex lens and an eyepiece composed of a concave lens to produce erect images.
45. **<u>German Equatorial Mount</u>:** A T-shaped arrangement in which the telescope is mounted on the declination axis (the crossbar of the "T"), which in turn is mounted on the polar axis (the shaft of the "T"). Its main disadvantage is that the polar axis must be flipped around when the object is near the meridian (*The Telescope Handbook and Star Atlas* by Neale E. Howard).
46. **<u>Image</u>:** The view which an observer sees at the eyepiece of an optical device.
47. **<u>Inverted Image</u>:** An optical view in which up and down are reversed.
48. **<u>Kepler, Johannes</u>:** (1571-1630) German astronomer and mathematician who first proposed the astronomical refractor from his study of the physiology of the human eye.
49. **<u>Law of Reflection</u>:** In a reflection, the angle of incidence to the normal is equal to the angle of reflection from the normal.
50. **<u>Lippershey, Hans</u>:** (1570-1619) A Dutch optician who made glasses. He is generally considered to be the inventor of the telescope because he was the only individual to present to the Dutch government a working model as required by the patent application. His application was denied because the telescope was considered too general and easy to reproduce.
51. **<u>Magnification</u>:** The increase in size from an object to an image.
52. **<u>Maksutov (Cassegrain) Reflector</u>:** A catadioptric system which uses a very short focal length perforated spherical mirror coupled with a convex secondary mirror and meniscus lens to bring an image to a focus.
53. **<u>Mirror Cell</u>:** A device which holds a telescope mirror and can usually be adjusted to help align the optical system.
54. **<u>Newton, Isaac</u>:** (1642-1727) Mathematician/physicist/philosopher, Newton is considered by many historians as possessing the greatest mind that ever lived. Among Newton's greatest achievements was his understanding concerning the nature of light, the invention of fluxions (Calculus), the quantification of gravity, construction of the first reflecting telescope, the writing of the ***Principia Mathematica,*** and later, the recoinage of England.
55. **<u>Newtonian Reflector</u>:** Invented by Isaac Newton in 1668, this telescope is composed of a parabolized primary mirror and flat secondary diagonal mirror which reflects the converging light cone through the top of the telescope tube. Along with a Dobsonian mount this telescope represents the "biggest bang for the buck."
56. **<u>Normal</u>:** A perpendicular to another plane or line.
57. **<u>North Celestial Pole</u>:** The point of intersection of the Earth's axis with the celestial sphere (sky).
58. **<u>Object</u>:** That which a telescope is observing.
59. **<u>Observatory</u>:** A building which houses a telescope along with the ancillary equipment for its support.
60. **<u>Optical Axis</u>:** A straight line which runs along the center of the cylinder of light which the telescope is collecting and then the cone of light that is being brought to a focus. The optical axis points to the object which is in the center of a telescope's field of view.

61. **Optical Tube Assembly:** OTA… The telescope components in their housing… The telescope itself…
62. **Peak to Valley:** A method of quantifying the optical accuracy of a mirror by designating the deviation from a perfect parabola as the distance from the lowest trough to the highest hill across its surface.
63. **Parabola:** A curve represented by one of the four conic sections that has as its characteristic the ability of bringing all light incident upon its surface to single focus.
64. **Perverted Image:** A telescope which presents a view at the eyepiece in which right and left are reversed.
65. **Pin Cushion:** A type of optical distortion which causes straight lines to bulge inward.
66. **Polar Axis:** The part of a telescope mount which is aligned with and rotates around the North Celestial Pole.
67. **Polaris:** It is also called the North Star, the Pole Star, or Alpha Ursa Minoris. It is the star closest to the North Celestial Pole to which the polar axis of a telescope is aligned.
68. **Primary:** The mirror or lens which first collects the light that will be presented to the observer at the eyepiece end of the telescope.
69. **Rack and Pinion:** A general term used for an eyepiece focuser that uses a small-toothed round gear (pinion) meshed with a larger tooth rack which contains the holder for the eyepiece.
70. **Radius of Curvature:** A position from the primary mirror equal to twice its focal length.
71. **Rayleigh Limit:** A method of quantifying the resolving power of a telescope based upon the wave nature of light.
72. **Reflector:** A general term used for a type of astronomical telescope which employs mirrors to collect light and bring the image to a focus.
73. **Refractor:** A term used for a telescope which uses a lens or a series of lenses to collect light and bring it to a focus.
74. **Resolving Power:** The ability of a telescope to distinguish objects of close angular separation. It is a function of a telescope's aperture.
75. **Richest Field Telescope:** Also called an RFT. A short focal length telescope designed to produce wide fields and low magnifications. It is usually of a Newtonian design.
76. **Schmidt Camera:** A catadioptric, photographic system which employs an extremely short focal length primary mirror and a corrector plate which is placed at the radius of curvature of the primary. The recording sensor is positioned at the focus of the primary mirror.
77. **Schmidt-Cassegrain:** A catadioptric telescope which utilizes a corrector plate to help eliminate the spherical aberration produced by the short focal length primary mirror.
78. **Secondary:** The additional mirror or mirrors other than the primary that assist in bringing an image to a focus. It can be flat or have a curvature.
79. **Seeing:** The steadiness of the atmosphere measured on a scale of 1-10, where one is the poorest and 10 is the best.
80. **Sidereal Nuncius:** (Starry Messenger) The book written by Galileo in the spring of 1610 which highlighted his astronomical observations made through the telescope which he had constructed. The book, written in Italian to reach a wider audience, was published in the spring of 1610.
81. **Spherical Aberration:** A defect of a mirror or lens system ground and polished to the curvature of a sphere. Parallel light rays striking nearer to the optical axis of the mirror will come to focus at a greater distance in front of the mirror than rays of light striking nearer to its edges. The result is an image which is difficult to focus since many regions of focus exist.

82. **<u>Spider</u>:** The secondary mirror holder in a telescope which has an open tube. It usually has four veins which attach to the telescope's tube which gives the spider its name. The spider causes stars to have outward radiating diffraction spikes in photographs.
83. **<u>Telescope</u>:** An optical device which gathers light, utilizing lenses and mirrors or a combination of both, brings this light to a focus, and allows for the magnification of the object that is being viewed.
84. **<u>Transparency</u>:** The clarity of the atmosphere rated on a scale of 1-10 with one being the poorest and 10 being the best.
85. **<u>Wide Field</u>:** A telescope or eyepiece that presents a large area of the sky for viewing at the image end of the telescope. The field of view is measured as an angle.

NOTES

Name ______________________________ Date______________ Moravian University

Name ______________________________ Each person hands in a separate lab exercise.

PHOTOGRAPH OR DRAW A PICTURE THROUGH A TELESCOPE
(10 points)

Instructions: ***NEVER LOOK AT THE SUN WITH YOUR GALILEO TELESCOPE!***
Each person will be responsible for making her or his own drawing **in pencil** and responding to the information on the next page. **Drawings made with a pen will automatically receive a zero.** With a partner, sketch the moon, the Pleiades, or a terrestrial object. A favorite of Moravian classes has been the Star of Bethlehem located on South Mountain, but there are many other interesting objects that can be seen along the horizon or in the sky. Your partner's shoulder can act as a stabilizer so that you can steady your telescope. After your drawing is completed, switch around so your colleague can make an illustration too. Draw the image **EXACTLY** as it appears through your telescope and at the proper scale. The circle below represents the field of view as seen through your instrument's eyepiece. Keep in mind that Galileo's original telescopes, on a scale of 1-10, would have been judged a one, compared to the telescope that you are using today (3 points).

Instrument used:

____

____

What are you observing?

____

____

DRAWING
PHOTO
(Circle One)

Hint: Consider taking a picture through your telescope with your cell phone and using it to render a more accurate drawing.

Note: If one team member photographs, the other team member must make a drawing through the scope.

<u>Instructions</u>: After constructing your drawing, create a jot list with respect to the problems that you have encountered using your telescope. **What frustrated you?** Many people have the misconception that when they look through a scope, the universe will be revealed to them with the clarity of an image taken through the Hubble Space Telescope. The truth is that with telescopes or binoculars, nothing comes easily. Making useful observations or taking good images of the night sky are not simple tasks. Describe six problems that you experienced while using your telescope, and don't be afraid to speak to others about these difficulties (4 points).

1.

2.

3.

4.

5.

6.

<u>Instructions</u>: Based upon the problems that you have experienced observing through your telescope to make your drawing, state four ways in which you would improve the telescope that you were using. How would you make your telescope better? (3 points)

1.

2.

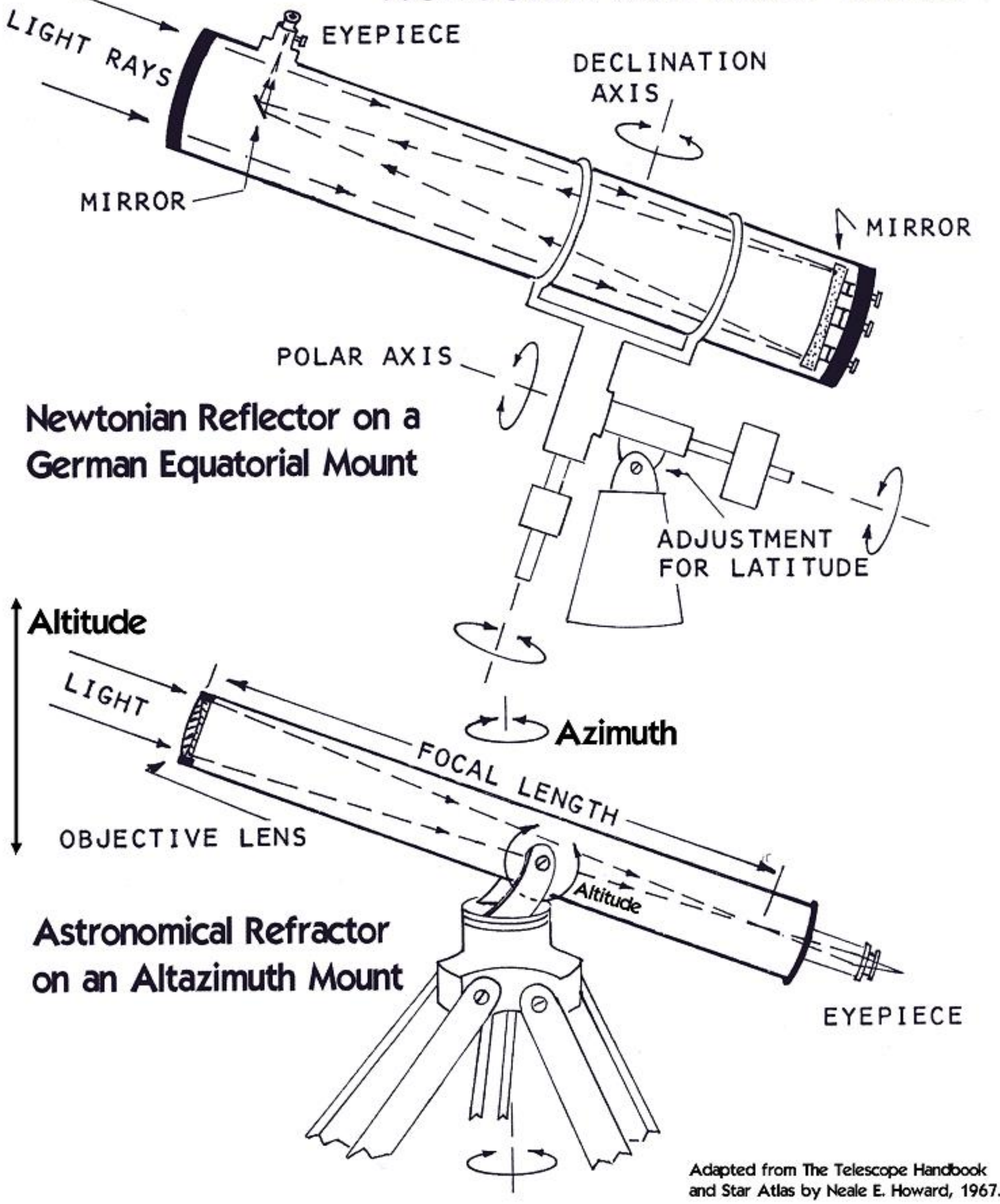
3.

4.

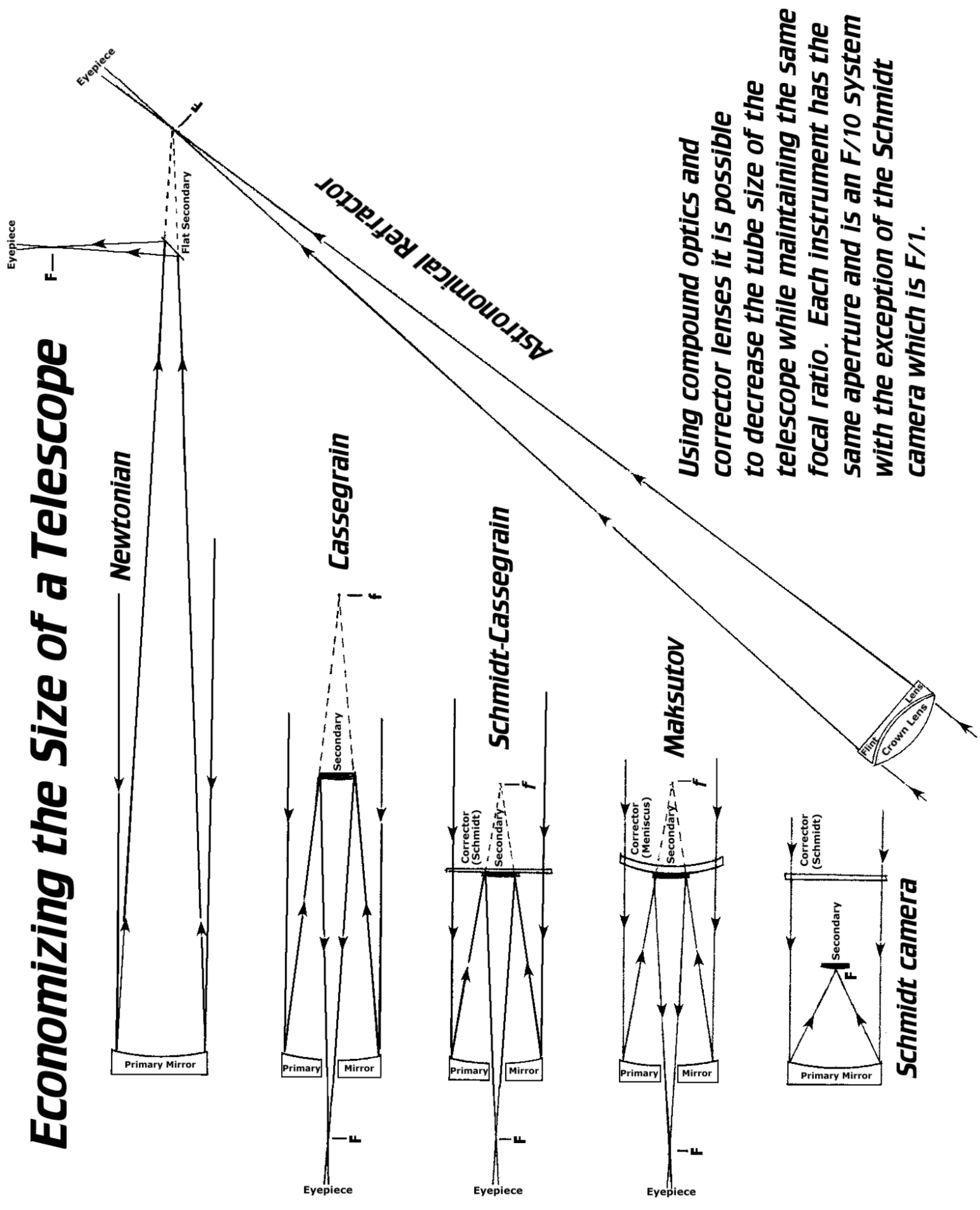
IMAGE FORMATION IN A NUTSHELL

Main reason for building telescopes:	**Telescopes gather more light than the human eye, and therefore, can see fainter objects. This is why telescopes are built. Light gathering = $7D^2$ D = aperture in inches**
Magnification:	**Important, but not the "be all end all" of telescopes. M = focal length of telescope/focal length of eyepiece**
Magnification and focal length:	**A longer focal length or focal ratio (F/?) system will produce higher magnifications using similar focal length eyepieces.**
Magnification and image brightness:	**The inverse square rule ($1/d^2$) applies to magnification. Double the magnification and the brightness of the image is reduced to one quarter of its original value.**
Magnification and field of view:	**This also functions under the inverse square rule. Double the magnification and your field of view is reduced to one quarter of its original area.**
Formation of an extended image (moon planets) **or separation of double stars:**	**Consider an image to be similar to the dot structure of a b/w newspaper photograph. The bigger the dots, the poorer the quality of the picture. In image formation, a central Airy disk is created along with a series of rings which represent light amplifications (bright rings) and light cancellations (dark rings). The rings surround the disk. An Airy disk is called a diffraction disk or a false disk. It does not represent the physical size of the star.**
Magnification and Airy disks:	**The higher the magnification, the larger the Airy disks become. This means that there are upper limits to power (50x-60x per inch). Beyond those limits no new image detail can be revealed and the magnification becomes empty.**
Aperture (diameter of light-gathering mirror or lens) **and Airy disk size:**	**Larger apertures result in smaller Airy disks and a tighter image structure. Larger aperture telescopes tolerate higher magnifications.**
Resolution (ability to view object of close angular separation)**:**	**This is a function of mainly aperture because the larger the light gathering area, the smaller the Airy disks become and the easier it will become to separate double stars or two distinct features on an extended object.**
Contrast (ability to separate various shades of grey/colors)**:**	**Optical excellence rules here because the better the optical quality of the telescope, the greater the amount of light that is concentrated in the Airy disks. In a perfect system, 86% of the light is found in the central disk, 14% in the rings.**
Contrast and obstructions:	**Any obstruction along the optical path of a telescope, such as a secondary mirror or its support structure (spider) diverts (diffracts) light away from the central Airy disk and puts more light into the diffraction rings. High end refractors offer the best contrast of any telescope type because they have no obstructions along the light path.**
Definition (how sharp is the image)**:**	**Optical excellence rules here because all of the light which is being reflected from the mirrors or focused through the lenses comes to a very tight and precise focus. This creates a sharp image, an image with good definition.**
Field of view (the area of sky that you see through the eyepiece)**:**	**It is a function of the magnification of the system and the angle of light (apparent field of view) which is accepted by the eyepiece. fov° = afov° of eyepiece/magnification**

Reflector/Refractor Basics



Adapted from The Telescope Handbook and Star Atlas by Neale E. Howard, 1967.


Economizing the Size of a Telescope
Newtonian
Primary Mirror
Flat Secondary
Eyepiece
F
Cassegrain
Primary
Mirror
Secondary
Eyepiece
F
f
Schmidt-Cassegrain
Corrector
(Schmidt)
Secondary
Maksutov
Corrector
(Meniscus)
Schmidt camera
Astronomical Refractor
Flint
Crown Lens
Lens
Using compound optics and corrector lenses it is possible to decrease the tube size of the telescope while maintaining the same focal ratio. Each instrument has the same aperture and is an F/10 system with the exception of the Schmidt camera which is F/1.

KNOWING YOUR TELESCOPE

1. **Light Grasp** = $0.63 \times \frac{D^2_{telescope}}{d^2_{eye}}$ which approximates $7D^2$

Where D = the aperture of the mirror or lens (up to seven inches) in inches
d = the aperture of the eye in inches. A fully dilated eye = 7mm = 0.28 inch.

2. **Limiting Magnitude** = $8.8 + 5\log D$

Where D = the aperture of the mirror or lens in inches

3. **Resolution** = $\frac{4.56}{D}$ sec. of arc This is called the Dawes' Limit

= $\frac{5.45}{D}$ sec. of arc This is called the Rayleigh Limit

Where D = the aperture of the mirror or lens in inches

4. **Magnification** = $\frac{FL_{telescope}}{fl_{eyepiece}}$

Where FL = the focal length of the telescope
fl = the focal length of the eyepiece

5. **Field of View** = $\frac{\text{apparent field of view of the eyepiece}}{\text{magnification}}$

6. **Exit Pupil** = $\frac{D}{M}$

Where D = aperture of the mirror lens in inches/mm
M = magnification of the eyepiece

TELESCOPES AT A GLANCE

	Astronomical Refractor	Newtonian Reflector	Cassegrain Reflector	Schmidt-Cassegrain Reflector	Gregory Maksutov
Inexpensive and easy to construct		X			
Expensive and difficult to construct	X		X	X	X
Compact telescope	X	X		X	X
Bulky telescope	X	X	X		
Superior light gathering power over refractors in larger apertures		X	X		
All-purpose (star fields and planets)		X			
Wide field, low magnification	X	X			
Narrow field, high magnification	X		X	X	X
Diagonal and spider create more diffraction		X	X	X	X
Color aberrations	X			X	X
No color aberrations		X	X		
Open optical system. Optics difficult to keep clean. Internal air currents degrade image.		X	X		
Closed optical system. Optics stay cleaner. Few internal air currents to degrade image.	X			X	X
Optical parts can get out of alignment		X	X		
Optical parts stay aligned	X			X	X
Can be used for astrophotography	X	X	X	X	X
Has terrestrial applications				X	X

NOTES

Telescopes and Mounting Systems

Name ________________________________ Date ________________ Moravian University

Name ________________________________

NAME THAT TELESCOPE AND MOUNTING SYSTEM

Instructions: Here are the choices that are applicable to the following telescopes and mounting systems found on the previous page. Use as many applicable words as possible with each telescope and mount. The spaces to the right of the letters tells you how many words apply

A. _____, _____

B. _____, _____

C. _____, _____, _____

D. _____, _____, _____, _____

E. _____, _____, _____, _____, _____

F. _____, _____, _____, _____, _____

G. _____, _____, _____, _____, _____

H. _____, _____

I. _____, _____, _____, _____

J. _____, _____

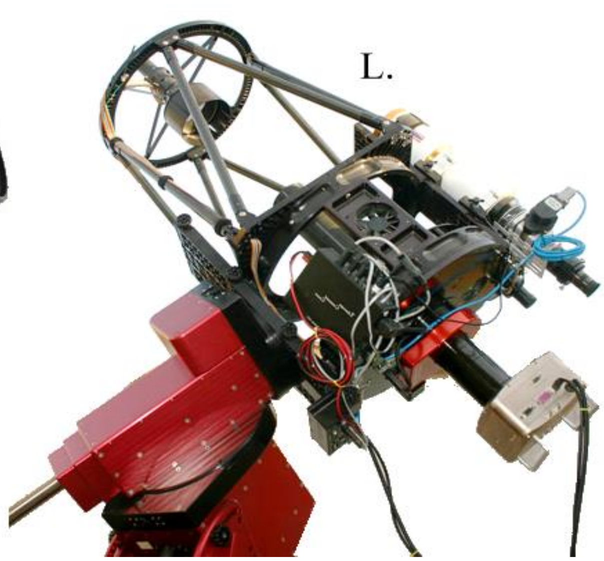
K. _____, _____, _____, _____, _____

L. _____, _____, _____, _____

1. Equatorial mount
2. Altazimuth mount
3. Fork mount
4. Dobsonian mount
5. Reflector
6. Refractor
7. Compound system **(system has concave/convex mirrors)**
8. Catadioptric system **(mirrors and lenses in combination)**
9. Newtonian
10. Cassegrain
11. Schmidt-Cassegrain
12. Maksutov

K.

L.



CAN YOU ANSWER THE FOLLOWING QUESTIONS/STATEMENTS ABOUT TELESCOPES?

THEORETICAL CONSIDERATIONS

1. **A telescope must gather enough light** to ____. This is dependent upon the ________________ of the telescope.

2. **A telescope must resolve objects.** Resolution allows an observer to see objects that are ________________ together. Resolution is a function of a telescope's ________________. The larger the lens or the mirror becomes, the BETTER/WORSE (circle one) the resolution.

3. **A telescope must provide the observer with good definition.** A telescope with good definition shows objects ________________. Definition is dependent upon the excellence of a telescope's ________________ system.

4. **A telescope must provide images with good contrast.** Contrast is the ability of a telescope to _____________________ various shades of grey to make an image more discernable. The more obstructions that are put into the path of the light entering a telescope, the BETTER/WORSE (circle one) the contrast will be.

5. **A telescope must magnify an image.** This means that the image being created by the telescope must appear ________________. Magnification is a function of a telescope's _____________________, as well as its aperture. The longer the fl of the system becomes, the HIGHER/LOWER (circle one) the magnification.

6. **A telescope must produce an acceptable field of view.** The field of view represents the ________________ of the sky under scrutiny. The field of view is an angular measurement given in d/m/s ________________________________ of arc.

7. The most important characteristic of any telescope is to ______________________________ ________________________________. This is the function of a telescope's ________________.

8. The brightness of an astronomical object is designated by its ________________. A telescope which gathers more light will be able to see ________________ objects.

9. A difference of five magnitudes between two stars is equivalent to an intensity difference of ________________. Therefore the intensity difference between two stars separated by a brightness difference of one magnitude is equivalent to ________________.

10. The more positive the magnitude of an object the BRIGHTER/FAINTER (circle one) it becomes.

11. Another word for the size of the lens or mirror is its ________________.

12. The distance that light must travel before coming to a focus is called a telescope's ________________.

13. The diameter of the lens or mirror divided into the distance that the light must travel before it comes to a focus is termed the telescope's ______________________.

14. The ratio of the size of an image as viewed through the telescope, compared to its naked eye appearance, is the ________________ which the telescope produces.

15. The focal length of a telescope divided by the focal length of the eyepiece mathematically defines a telescope's ________________.

16. A 1200mm focal length telescope uses a 20mm eyepiece to produce a magnification of ________________.

17. Telescopes must be able to separate objects of close angular measure. This is called a telescope's _________________.

18. The ability of a telescope to separate objects of close angular measure depends most critically on the telescope's ________________

19. The formula for the Dawes limit for the resolution of astronomical objects equals ____.

20. The theoretical resolution based upon Dawes' limit for the 200-inch Hale reflector on Mt. Palomar is ________________.

21. To be able to distinguish various shades of gray or color hues, a telescope must be able to produce images with acceptable ________________.

22. The clarity and sharpness of an image relates to the telescope's optical quality. This is called ________________.

23. The angular diameter of the sky which is visible through an eyepiece is called the ______________________.

24. The field of view produced at the eyepiece of a telescope having a 1200mm focal length and using an eyepiece of 25mm focal length with an 80 degree apparent field would be ________________.

25. Steadiness of the atmosphere is referred to as _______________.

26. For observers in the Northeast, the season of the year which produces the steadiest atmospheric conditions is ________________.

27. The clarity of the atmosphere, as it relates to the faintest stars that can be observed at one's zenith, is called ________________.

28. Usually on cold and windy winter nights the ________________ can be excellent, but the ________________ is usually horrendous.

29. Why is it impossible for large telescopes to reach their theoretical potential for resolution?
____
____

30. When a star is examined critically in a good telescope, it appears to be composed of a disk surrounded by a series of rings. The name of the disk is called the ________________ disk.

31. The size of the disk of a telescopically viewed star is related inversely to the ________________ of the telescope. In other words, the larger the telescope mirror or lens, the BIGGER/SMALLER (circle one) the false disk.

32. Why is it normally possible to use higher magnification with a larger aperture telescope?
____
____
____

33. The poorer the optical quality of the telescope, the more the light is concentrated into the rings surrounding the diffraction disks which compose the image. The image begins to suffer by losing ________________.

34. When light passes very near an obstruction it will be slightly ________________ from its straight path direction. This phenomenon is known as ________________ and is a good/bad (circle one) situation.

35. Why does the contrast of a telescopic image decrease as the diameter of the obstructions, encountered by the light, increase?
____
____

36. Why does the contrast of an image decrease as the optical components of a telescope decrease in accuracy?
____
____

37. Why do stars have spikes, or appear "starlike" in some telescopes, while other instruments produce disk-like images?
____
____

38. A telescope mirror or optical system is rated against the standard wavelength reference of light which is _______________ Ångstroms. One Ångstrom equals 10^{-8} cm or 10^{-7} meter which equals one nanometer. In nanometers, a telescope's accuracy equals _______________ nm.

39. The maximum acceptable deviation at the focal plane for an astronomically acceptable image is _______________ peak to valley.

THE LAWS OF LIGHT

40. A line segment which is perpendicular to an optical surface is called a _______________.

41. The law of _______________ states that with respect to a normal, the angle of incidence of an approaching light beam will equal the angle of reflection.

42. When light travels from a less dense medium into a medium of greater density, the light ray will be bent TOWARDS/AWAY (circle one) from the normal.

43. The formula $\sin i = n \sin r$ is the mathematical representation for law of _______________, where "i" equals the angle of _______________, "r" equals the angle of _______________ and "n" equals the index of _______________ for the denser medium.

44. The index of refraction indicates how the _______________ of light changes as it is transmitted through various materials of different densities.

45. The entire array of energy from gamma radiation to the radio frequencies is called the _______________ spectrum.

46. The energy frequencies to which the eye responds are called _______________ light.

47. _______________ and _______________ are two descriptive methods of representing the entire array of energy from gamma to radio.

48. The simple bending of one wavelength of light as it moves through mediums of different densities is called _______________.

49. When each component of white light is selectively bent as it is transmitted through a prism or lens, the effect is called _______________.

50. A telescope forms an image composed of a central diffraction _______________ with a series of concentric _______________ surrounding it. The maximum percentage of light that can be concentrated into the disk is 84 percent.

51. The better the optics and the fewer obstructions in the path of the light coming to a focus, the more light gets positioned into the _______________ and the less light into the _______________.

52. A telescope will produce BETTER/POORER (circle one) contrast if more light is concentrated into the central disk and less into the rings.

53. As a telescope's aperture becomes larger, the size of the central disk becomes SMALLER/LARGER (circle one).

54. You can calculate the size of the central disk. This is called a telescopes _______________ and it can be found by dividing the aperture in inches into 4.56 seconds of arc. R = 4.56"/aperture (in inches). This is known as the Dawes limit.

55. A telescope has an aperture of 20 inches and a focal length of 100 inches. The telescope's theoretical resolution is _______________ second of arc.

56. A telescope has an aperture of 20 inches and a focal length of 200 inches. The telescope's theoretical resolution is _______________ second of arc.

57. Because the diffraction disks are smaller in telescopes with larger apertures, these instruments can _______________ objects with small angular diameters.

58. Because the diffraction disks are smaller in telescopes with larger apertures, these telescopes are better suited for HIGHER/LOWER (circle one) magnifications.

59. Useful maximum magnification limits are between 50x to 60x (power) per inch of aperture. Therefore the useful magnifications of an 8-inch reflector are between ___________ and __________ power.

60. If a telescope is being used at a magnification that exceeds the theoretical limitation of the optics, that magnification is called _______________.

61. All things being equal, the longer the focal length of the eyepiece the LOWER/HIGHER (circle one) the magnification.

62. The magnification at the eyepiece of a telescope equals the focal length of the eyepiece divided into the focal length of the _______________.

63. An 8-inch, F/7 refractor is being used with a 25mm focal length eyepiece. What is the telescope's magnification? There are 25.4mm/inch. _______________.

DIFFERENT TYPES OF TELESCOPES

64. The distance that light must travel after being reflected by a mirror or refracted by a lens is termed a telescope's ____________________.

65. The diameter of the light cone that emerges from the eyepiece is called the ____________________.

66. The most important property of a telescope is to ____________________.

67. _______________ How much more light than the human eye will a telescope with an aperture of 10 inches gather? Note that light grasp = $7D^2$, where D is the aperture of the telescope in inches.

68. The lens or mirror which gathers the light in a telescope is normally designated as the _______________ mirror.

69. A telescope employing only lenses is referred to as a _______________.

70. A telescope employing only mirrors is called a _______________.

71. A compact telescope, possessing mirrors and a lens is referred to as a _________________ system.

72. The inventor of the telescope was a Dutch lens grinder who made a "spectacle" of himself. His name was ____________________.

73. ____________________ was the first individual to publish his astronomical observations made through telescopes which he had constructed. His telescopes were far from perfect in their optical design and optical components, but his eyesight was extremely keen.

74. A double convex lens produces a defect or aberration at the focus of a refractor called _______________ aberration.

75. The introduction of a second lens with a different index of refraction causes the problem mentioned in the last statement to become less noticeable. The shape of this lens is ______________________________.

76. A double element refractor is often called an _______________ refractor. The first element is usually referred to as the _______________, while the second lens is often called the _______________ because of the different types of glass which go into the making of these lenses.

77. The first individual to construct a working reflecting telescope was named ____________________. His interest in mirrors, rather than a lens to collect light, stemmed from his desire to free images from _________________________.

78. A smaller wide-field telescope which has its optical axis aligned to the main instrument is called a ____________________ telescope.

79. The part of a telescope which does most of the magnification of the image is referred to as the _______________.

80. This apparatus, called a _______________, supports the telescope tube assembly and allows it to be pointed to any location in the sky.

81. This device supports the secondary mirror in a reflector and is known as a _______________.

82. The simplest and least expensive type of telescope to construct is called a ____________________ reflector.

83. These telescopes (answer to last question) are wonderful when made in short to medium focal lengths. What disadvantage occurs when they are constructed in long focal lengths?
____

84. When the shape of the mirror in a reflector is a specific type of conic section called a _______________, light which reflects near the edge of the mirror comes to a focus closer to the mirror than light striking the mirror nearer to the optical axis.

85. The optical defect mentioned in the last statement is called ___________________________.

86. The problem mentioned above can be corrected by changing the curvature of the primary mirror into a _______________.

87. An optical problem which can be the result of the exposure of the lens or mirror to a rapid change in temperature is called _______________. As the mirror or lens cools, its curvature may change, causing different portions of the objective to focus its light at slightly different positions. This problem can also result from inaccuracies in the mirror grinding and polishing process.

88. A _______________ type of reflecting telescope employs a convex secondary mirror, but no corrector.

89. The secondary mirror of the type of telescope mentioned above serves to increase the _______________ of the telescope without increasing the tube size.

90. With reference to a reflector employing a concave primary and a convex secondary, the primary mirror generally has a LONGER/SHORTER (circle one) focal length?

91. The eyepiece position for this compound reflector, mentioned in the last question, is almost always found IN FRONT/IN BACK (circle one) of the primary mirror.

92. A long focal length reflector which has an ultrashort tube length and uses a lens called a corrector or meniscus to help form the image is called a **c_______________.**

93. The shape of the primary mirror in telescopes that use lenses and mirrors is generally a _______________. It is virtually impossible to parabolize mirrors with focal ratios less than F/3.

94. Specifically, a _________________________ reflector uses a corrector plate while a _________________________ reflector uses a meniscus.

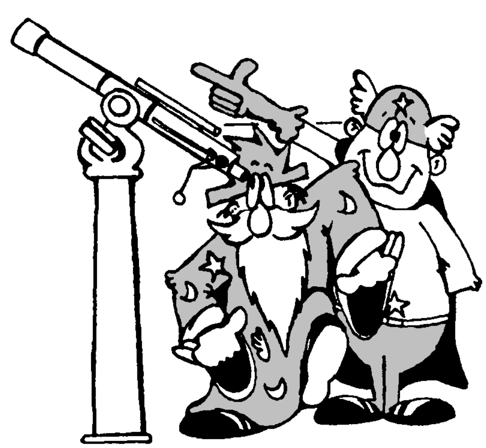
95. Without the corrector plate, the images brought to a focus by these ultracompact telescopes would suffer from _______________ aberration.

96. Think of the corrector as adding the necessary **p**_______________ to the image to bring about a sharp and precise focus.

97. An ultra short focal length catadioptric reflector designed specifically for photographic purposes is called a ____________________. Such an instrument is constructed primarily for patrol work in which SMALL/LARGE (circle one) regions of the sky need to be surveyed for new supernovas, comets, near Earth objects, or the making of star maps.

98. A very short focal length Newtonian reflector can go by the name of a _______________ telescope. This is because it provides a LARGE/SMALL (circle one) field of view.

99. If you are trying to observe a faint astronomical object through a telescope, your best bet is not to look directly at it, but use _______________ vision.



ANSWERS TO SESSION SIX QUESTIONS

THEORETICAL CONSIDERATIONS

1. to view the intended astronomical object, aperture
2. close, aperture, BETTER
3. clearly (distinctly), optical
4. separate, WORSE
5. larger, focal length, HIGHER
6. area, degrees/minutes/seconds
7. gather light, aperture
8. magnitude, fainter
9. 100, 2.51 (fifth root of 100)
10. FAINTER
11. aperture
12. focal length
13. focal ratio
14. magnification
15. magnification
16. 60
17. resolution
18. aperture
19. 4.56 seconds of arc/aperture in inches
20. 0.023 second of arc
21. contrast
22. definition
23. field of view
24. approximately 1.3 degrees
25. seeing
26. summer
27. transparency
28. transparency, seeing
29. Bad seeing conditions increase the size of the diffraction disk which is responsible for resolution.
30. diffraction or Airy or false
31. aperture, SMALLER
32. Larger apertures produce smaller diffraction disks which allow for higher magnification before tolerances are exceeded.
33. contrast
34. bent, diffraction, bad
35. More light is focused into the diffraction rings which are not responsible for the formation of the image.
36. More light is concentrated into the rings and less light goes into the image-forming diffraction disk
37. "Starlike" images are the result of unwanted diffraction caused by the supports which secure the secondary mirror in reflecting telescopes.
38. 5500 Å
39. 1375 Å or ¼ wave

LAWS OF LIGHT

40. normal
41. reflection
42. toward
43. refraction, incidence, refraction, refraction
44. speed
45. electromagnetic
46. visible
47. waves and bullets
48. refraction
49. dispersion
50. disk, rings (circles)
51. disk, rings
52. BETTER
53. SMALLER
54. resolution
55. approximately 0.2 second of arc
56. approximately 0.2 second of arc
57. resolve
58. HIGHER
59. 400x to 480x
60. empty
61. HIGHER
62. telescope
63. about 57x
64. focal length
65. exit pupil
66. gather light
67. 700 times

DIFFERENT TYPES OF TELESCOPES

68. objective
69. refractor
70. reflector
71. catadioptric
72. Hans Lippershey
73. Galileo Galilei
74. chromatic
75. plano-convex
76. astronomical, crown, flint
77. Isaac Newton, chromatic aberration
78. finder
79. eyepiece
80. mount
81. spider or secondary support or holder
82. Newtonian
83. They are too bulky because of excessive tube lengths.

84. sphere
85. spherical aberration
86. parabola
87. astigmatism
88. Cassegrainian (compound)
89. focal length
90. SHORTER
91. IN BACK
92. catadioptric
93. sphere
94. Schmidt Cassegrainian, Maksutov Cassegrainian
95. spherical
96. parabolization
97. Schmidt camera, LARGE
98. richest field or RFT, large
99. averted

NOTES

IDENTIFY THE CELESTIAL OBJECT

(20 points)

Name _________________________________ Date ________________ Moravian University

Instructions: The following astronomical images found on the bulletin boards to the left of Room 106, Collier, represent some common types of objects found in the universe. You will be observing similar objects on Moravian's Sky Deck and at Shooting Star Farm during the semester, but they will look very different than the colorful pictures that are present on the bulletin board. Some of the images were taken with the Hubble Space Telescope, but most of the smaller pictures were imaged by an amateur astronomer. Define the following words listed below to help you in your quest to identify these objects. Some of the words will be used many times while others may not be used at all. For Question 9 on the ***Interstellar*** poster, identify the person in the credits who recently won the Nobel Prize in Physics for the detection of gravity waves. **Google pictures of these basic types of objects to help you in your quest.**

1. **Planet** (four parts): An object…

2. **Star** (Think about energy production here): A self-luminous body that…

3. **Nebula**—there are dark nebula and emission nebula—include both in your general definition

4. **Planetary Nebula:**

5. **Galaxy** (Note the number of stars—and the different shapes along with the definition):

6. **Irregular/Spiral/Elliptical Galaxies**—**Your Choices:** (**size**—small, midsized, huge; **age**—young, old, combination; **shape**, pinwheeled, oval, no specific shape; **gas remaining**—little, lots, in arms
   Irregular: size: age: shape: gas remaining:
   Spiral: size: age: shape: gas remaining:
   Elliptical: size: age: shape: gas remaining:

7. **Universe:** All…

8. **Electromagnetic Spectrum** (speed of travel):

9. **<u>Globular Cluster</u>** (Age and number of stars are key here):

10. **<u>Open Cluster</u>** (Age and number of stars are key here):

11. **<u>Star Field:</u>** A general widefield area of the sky showing stars or other objects of interest.

12. **<u>Supernova Remnant</u>:** The expanding shell of debris which follows the detonation of a massive star signally the end of its thermonuclear life. The remaining object is generally a neutron star.

IDENTIFY THE TYPE OF CELESTIAL OBJECT FROM THE PICTURES

<u>INSTRUCTIONS</u>: All objects will have a minimum of <u>two words</u>—Use the definitions on the previous page

No.	Type of Object	No.	Type of Object
1	Name:	21	
2		22	
3	Name:	23	
4	One word	24	
5		25	
6		26	
7		27	
8		28	
9	He won the Nobel Prize in Physics.	29	
10		30	
11		31	
12		32	
13		33	
14		34	
15		35	
16		36	
17		37	
18		38	
19		39	
20		40	

September 11, 2022

MORAVIAN UNIVERSITY FALL OBSERVING LOG

Did I See It?	Object (Constellation)	Description
Moon	**Moon**	**Know the phase if it's visible.**
Planet	**Mercury**	**Not Visible**
Planet	**Venus**	**Not Visible**
Planet	**Mars**	**Setting in the west at start of semester**
Planet	**Jupiter**	**Visible in the east by mid-October**
Planet	**Saturn**	**Visible in the east**
Planets	**Uranus and Neptune**	**Uranus low in East mid-Sept; Neptune, ESE mid-Oct.**
Star	**North Star/Polaris**	**Find it using the two pointer stars of the Big Dipper, Dubhe and Merak.**
Multiple Star Systems	• **Alcor/Mizar (Ursa Major) The entire system is a sextuplet** • **Epsilon (ε) Lyrae (double-double in Lyra)**	• **<u>Mizar/Alcor</u>: +2.3/+4 (Mizar) /+4.0 (Mizar, Alcor) mag., 86 ly distant, 11' 49" sep. separation.** • **Binocular double with a nice surprise at 200 power. Both stars split into doubles—difficult. Epsilon[1]: +4.7/+6.2 mag., 161 ly, 2.6" separation, Epsilon[2]: +5.1/+5.5 mag., 161 ly, 2.3" separation**
Double Stars **<u>Abbreviations</u>** **<u>Byo</u>: Billion years old** **<u>Myo</u>: Million years old** **<u>Kyo</u>: Thousand years old** **<u>ly</u>: light years** **<u>M</u>: Messier Object** **<u>NGC</u>: New General Catalog** **": seconds of arc** **': minutes of arc**	• **95 Herculis (Hercules)** • **Zeta (ζ) Lyrae (Lyra)** • **Albireo, β Cygni (Cygnus)** • **17 Cygni (Cygnus)** • **61 Cygni (Cygnus)** • **Gamma (γ) Arietis (Aries)** • **Eta (ε)Cassiopeiae** • ***Sigma (σ) Cassiopeiae*** • **Delta (δ) Cephei** • **Nu (ν)Draconis**	• **<u>95 Hercules</u>: +4.8/+5.2 mag., 412 ly, 6" separation** • **<u>Zeta Lyrae</u>: +4.36/+5? mag., 152 ly, 44" separation** • **<u>Albireo</u>: +3.2/+5.8 mag., 430 ly distant, 35.3" sep. Best color contrast for a double star in the heavens.** • **<u>17 Cygni</u>: +5.1/+9.3 mag., 69.2 ly distant, 26.3" sep.** • **<u>61 Cygni</u>: +5.2/+6.1 mag., 11.41 ly distant, 31" sep.** • **<u>Gamma Arietis</u>: +4.58/+4.64, 164 ly, 7.6" separation** • **<u>Eta Cass</u>.: +3.44/+7.51 mag., 19.4 ly, 10.1" sep.** • ***<u>Sigma Cass</u>.: +5.0/+7.1 mag., 5000 ly, 3.1" sep.*** • **<u>Delta Cephei</u>: +6.3/+7.5 mag., 887 ly, 40" sep.** • **<u>Nu Draconis</u>: +4.87/+4.89 mag., 98.9 ly, 62" sep.**
Visual/Binocular Open Clusters	• **Ursa Major Cluster** • **M45 Pleiades (Taurus) best at low magnifications**	• **<u>UMC</u>: Sirius/Big Dipper minus Dubhe and Alkaid. The sun is moving through it right now.** • **<u>M45</u>: New open cluster, 440 ly, 50-100 Myo, 1000+ stars, notice all of the blue stars.**
Open Clusters	• **M11 (Wild Duck)** • **M29** • **M39** • **M52** • **M103** • **NGC 457 (ET Cluster)** • **Double Cluster of Perseus also called NGC 869/884 NGC 869 NGC 884** • **NGC 752**	• **<u>M11</u>: Scutum, +6.3, 6200 ly, 220 Myr, 2900 stars** • **<u>M29</u>: Cygnus, +7.1, 4000 ly, 10 Myr** • **<u>M39</u>: Cygnus, +5.5, 800 ly, 250 Myr** • **<u>M52</u>: Cassiopeia, +5.0, 5000 ly, 35Myr** • **<u>M03</u>: Cassiopeia, +7.4 mag., 8,800 ly, 25 Myr** • **<u>NGC 457</u>: Cassiopeia, +6.4, 7900 ly, 21Myr** • **Very new double cluster. Visible with unaided eye from suburbs, more than 300 blue super giants in each. <u>NGC 869</u>: +3.7, 7500 ly, 12.8 Myo, related to NGC 884 NGC 884: +3.8, 7500 ly, 12.8 Myo, related to NGC 869** • **<u>NGC 752</u>: Andromeda, +5.7, 1300 ly**

Moravian University Fall Observing Log, cont.

Did I See It?	Object (Constellation)	Description
Globular Clusters	• **M13, Great Globular Cluster in Hercules.** • **M56 (Lyra)** • **M92 (Hercules)** • **M05 (Ophiuchus)** • **M15 (Pegasus)** • **M02 (Aquarius)**	• **M13: +5.8 mag., 22,200 ly, 11.65 Byo, 300,000-500,000 stars. Like a mini galaxy, globulars may have been the "stuff" that formed galaxies. M13 is the second finest globular in the heavens, pop 300,000-500,000 stars.** **Note: The universe is estimated to be 13.8 Byr old.** • **M56: +8.3 mag., 32,900 ly, 13.7 Byr** • **M92: +6.3 mag., 26,700 ly, 11 +/- 1.5 Byr** • **M05: +6.7 mag., 24,500 ly, 10.6 Byr** • **M15: +6.3 mag., 33,000 ly, 12 Byr** • **M02: +6.3 mag., 33,000 ly, 13 Byr**
Planetary Nebulae	• **M57 Ring Nebula (Lyra)** • **M27, Dumbbell Nebula, also called the Appole Core Nebula (Vulpecula)**	• **M57: +8.8 mag., 2300 ly, 7Kyo. The most prominent planetary nebula. IT LOOKS LIKE A SMOKE RING. It was created when a dying star expelled its outer layers of gas. A white dwarf lies at its center; its UV light causing the ring to fluoresce (glow).** • **M27: +7.5 mag., 1360 ly, 10Kyo. One of the finest planetary nebulae in the sky. It is about 10,000 years old. The largest white dwarf star discovered (48,000 miles) lies near its center about half the diameter of Jupiter. It is visible, but very faint in bright moonlight.**
Nebula	**M17, The Swan Nebula. It is also called the Omega Nebula (Sagittarius)**	**M17: +6.0 mag., 5500 ly, 1Myo. It is a region of ionized (glowing) hydrogen gas. Through a telescope, it has a distinctive swan like appearance under clear, moonless conditions. Star formation is occurring here.**
Galaxy	**M31, Great Andromeda Galaxy (Andromeda)**	**M31: +3.44 mag., 2.5Mly, 10Byo. Largest galaxy of our local group with about 600 billion to one trillion stars. For most individuals, it is the most distance object that can be seen with the unaided eye. A major collision with another galaxy occurred about 8 Byr ago. The Andromeda and Milky Way galaxies will collide in about 3.45 Byr, forming a super galaxy.**
Satellite Galaxies	**Andromeda Galaxy Satellites** • **M32** • **M110**	 • **M32: +8.1 mag., 2.5 Mly, dwarf elliptical/little gas or dust and with no current star formation happening. A supermassive black hole lies at its center.** • **M110: +8.9, 2.7 Mly, dwarf elliptical/NO supermassive black hole at its center**
Other		

August 24, 2023

MORAVIAN UNIVERSITY SPRING OBSERVING LOG

Did I See It?	Object (Constellation)	Description
All Sky	Constellation ID	Find them with the green laser/ Don't bring down a plane.
Moon	Moon	You better know the phase if it's visible
Planet	Mercury	Visible in evening, mid-January and mid-May
Planet	Venus	Not Visible in the spring evening
Planet	Mars	Not Visible in the spring evening
Planet	Jupiter	Not Visible in the spring evening
Planet	Saturn	Not Visible in the spring evening
Planets	Uranus and Neptune	(U) High Jan., (N) SW Jan. (U) SW by Apr. (N) gone
Stars	Betelgeuse (Orion)	Red supergiant star—3500K/575 ly, M2Iab
	Rigel (Orion)	Blue bright supergiant star—11,000K/860 ly, B8Iab
	Sirius (Canis Major)	Brightest nighttime star—10,000K/8.9 ly, A1V
Multiple Star Systems	• Alcor/Mizar triple system (Ursa Major) • Beta Monocerotis	• <u>Alcor/Mizar</u>. Mizar also has a gravitationally bound star orbiting it. • <u>β Mon</u>: A +4.6 / B-C +5.4 +5.6/, BC separation 2.8", A-B/C separation 7.4", 690 ly, 34 Myo
Double Stars	• Eta-η Cassiopeiae (Cassiopeia)	• <u>η Cas</u>: +3.44/+7.51 mag., 19.42 ly, 12" separation RA: $00^h\ 49^m\ 06^s$; Dec.: +57° 48′ 55″
------------------------	• 30 Arietis (Aries)	• <u>30 Ari</u>: +6.58/+7.17 mag., 135 ly, 38.1" separation RA: $02^h\ 37^m\ 01^s$; Dec.: +24° 38′ 50″
<u>Abbreviations</u>	• 32 Eridani	• <u>32 Eri</u>: +4.8/+6.1 mag., 290 ly, 6.8" separation RA: $03^h\ 54^m\ 18^s$; Dec.: −02° 57′ 17.0″
Byo: Billion years old	• Mintaka (δ Orionis)	• <u>Mintaka</u>: +2.4/+6 mag., 1200 ly, 53" separation Belt star farthest to the NW; top belt star
Myo: Million years old	• Rigel (Beta-β Orionis)	• <u>Rigel</u>: +0.13/+6.7 mag., 773 ly, 9.5" sep., very difficult. Orion's lower right knee (blue supergiant)
Kyo: Thousand years old	• 145 Canis Majoris also called the winter Albireo	• <u>145 CMa</u>: +5/+5.84 mag., 27" separation RA: $07^h\ 16^m\ 37^s$; Dec.: −23° 18′ 56″ optical double (two stars in the same line of sight), colorful.
ly: light years	• Castor (α Geminorum)	• <u>Castor</u>: +1.9/+3.9 mag., 51 ly, 7" separation Fainter of the two head stars of the Gemini twins
M: Messier Object	• 38 Geminorum (Gemini)	• <u>38 Gem</u>: +4.8/+7.3 mag., 350 ly, 7.3" separation RA: $06^h\ 54^m\ 39^s$; Dec.: +13° 10′ 40″
NGC: New General Catalog	• Iota-ι Cancri (Cancer)	• <u>ι Cnc</u>: +4.02/+6.57 mag., 330 ly, 30.6" separation RA: $08^h\ 46^m\ 42^s$; Dec.: +28° 45′ 36″
": seconds of arc	• Tegmine, (Zeta-ζ Cancri)	• <u>Tegmine</u>: +5.58+5.99 mag., 84 ly, 5.06" separation RA: $08^h\ 12^m\ 13^s$; Dec.: +17° 38′ 52″
': minutes of arc	• Theta-θ Cancri (Cancer)	• <u>θ Cnc</u>: +6.4/+6.4 mag. 500 ly, 5" separation RA: $08^h\ 31^m\ 35.7^s$; Dec.: +18° 05′ 40″
	• 24 Comae Berenices called the spring Albireo	• <u>24 Com</u>: +5.11/+6.33 mag., 610 ly, 20.1" separation Colorful double, spectral types K0, A9. RA: $12^h\ 35^m\ 58^s$; Dec.: +18° 17′ 10″
	• 35 Comae Berenices	• <u>35 Com</u>: +5.1/+9 mag., 30" separation, optical dble. double +5.1/7.2 mag., 324 ly, 1" separation RA: $12^h\ 54^m\ 07^s$; Dec.: 21° 09′ 19″
	• Algieba (Gamma-γ Leonis)	• <u>Algieba</u>: +2.37+3.64 mag., 130 ly, 4" separation RA: $10^h\ 19^m\ 58^s$; Dec.: +19° 50′ 29″

Moravian University Spring Observing Log, cont.

Did I See It?	Object (Constellation)	Description
Double Stars **Abbreviations** **Byo: Billion years old** **Myo: Million years old** **Kyo: Thousand years old** **ly: light years** **M: Messier Object** **NGC: New General Catalog** **": seconds of arc** **': minutes of arc**	• **54 Leonis (Leo)** • **19 Lyncis (Lynx)** • **Delta-δ Cephei (Cepheus)** • **Nu-ν Draconis (Draco)** • **Cor Caroli (α Canis Venatici)** • **Kappa-κ Bootis (Bootes)** • **Xi-ξ Bootis (Bootes)** • **Polaris (α Ursae Minoris) North or Pole Star**	• **54 Leo: +4.5/+6.3 mag., 290 ly, 6.3" separation RA: $10^h\ 56^m\ 30^s$; Dec.: +24° 39′ 39″** • **19 Lyn: +5.8/+6.9 mag., 14.8" separation along with a third component at mag. +7.6 at 3.5' separation. RA: $07^h\ 24^m\ 11^s$; Dec.: +55° 14′ 59″** • **δ Cep: +4.04/+6.3 mag., 887 ly, 41" separation RA: $10^h\ 19^m\ 58^s$; Dec.: +19° 50′ 29″** • **ν Dra: +4.88/+4.88 mag., 99ly, 62" separation RA: $17^h\ 32^m\ 11^s$; Dec.: +55° 11′ 03″** • **Cor Caroli: +2.90/+5.60 mag., 115 ly, 19" separation RA: $12^h\ 56^m\ 02^s$; Dec.: +38° 19′ 06.167″** • **κ Boo: +4.54/+6.69 mag., 155 ly, 13.5" separation RA: $14^h\ 14^m\ 04^s$; Dec.: +51° 32′ 38″** • **ξ Bootis: +4.76/6.78 mag., 22.1 ly, 4" separation RA: $14^h\ 52^m\ 09^s$; Dec.: +19° 01′ 58″** • **Polaris: +2.02/+8.7 mag., 430 ly, 18" separation, very difficult because of the magnitude difference.**
Visual/Binocular Open Clusters	• **Ursa Major Cluster** • **Hyades (Taurus): Aldebaran not part of it.** • **M45 Pleiades (Taurus) best at low magnifications**	• **UMC: Sirius/Big Dipper minus Dubhe and Alkaid. The sun is moving through it right now.** • **Hyades: Old open cluster which is composed of the "V" in the head of Taurus minus Aldebaran, 150 ly distant, 300-400 stars, 625 Myo.** • **M45: New open cluster, 440 ly, 50-100 Myo, 1000+ stars, notice all of the blue stars.**
Open Clusters	• **NGC 457 (ET Cluster-Cass.)** • **Double Cluster (Perseus) Also called NGC 869/884** **NGC 869** **NGC 884** • **M41 (Canis Major)** • **NGC 2264: Christmas Tree asterism in Monoceros** • **M46 (Argo Puppis)** • **M47 (Argo Puppis)** • **M48 (Hydra)** • **M44, Beehive or Praesepe (Cancer)** • **M67 (Cancer)** • **M35 (Gemini)** • **M36 (Auriga)** • **M37 (Auriga)** • **M38 (Auriga)**	• **NGC 457: +6.4, 7900 ly, 21Myo** • **Double Cluster. Very new. Visible with unaided eye from suburbs, more than 300 blue super giants in each.** **NGC 869: +3.7, 7500 ly, 12.8 Myo related to NGC 884** **NGC 884: +3.8, 7500 ly, 12.8 Myo related to NGC 869** • **M41: +4.5, 2300 ly, 190 Myo, 100 members, large angular diameter, 4° south of Sirius.** • **Christmas Tree: total brightness +3.9 mag., about 1/2 degree across and contains about 40 stars** • **M46: +6.1, 5400 ly, 300 Myo, 500 stars (faint)** • **M47: +4.2, 1600 ly, 78 Myo, 50 stars** • **M48: +5.5, 1500 ly, 300 Myo, 56 stars** • **M44: +3.7, 550 ly, 600 Myo, 100 stars. Very large ang. dia., related to Hyades (similar movement).** • **M67: Old, many faint stars, 3.2-5 Byo, 2,700 ly** • **M35: +5.3, 2800 ly, young, 100+ members, large and rich.** • **M36: +6.3, 4100 ly, 25 Myo, 60 members** • **M37: +6.2, 4500 ly, 450 Myo, 500 members** • **M38: +7.4, 4200 ly, 220 Myo, 500 members?** •
Globular Cluster	**M3, (Canes Venatici)**	**Bright globular—500,000 stars, 8 Byo, 33,900 ly**

Did I See It?	Object (Constellation)	Description
Stellar Nursery, Emission and Dark Nebulae	M42 (Orion nebula)	Great Nebula in Orion, trapezium is birthing region with stars 10^5 years old, 1350 ly, 300 solar masses
Supernova Remnant	M1, Crab Nebula (Taurus) Charles Messier's first object	1054 AD supernova depicted on West Mesa in Chaco Canyon pictograph, 6500 ly distant, diameter is 11 ly
Planetary Nebula	Eskimo, NGC 2392 (Gemini)	It is a bipolar, double-shell planetary nebula. Small but distinct and bluish in color
Galaxy	M33, (Andromeda)	Largest galaxy of local group, 2.4 Mly, 6 x 10^8 stars
Satellite Galaxies	M32, M110 (Andromeda)	Satellite galaxies of the Andromeda Galaxy
Two Galaxies very close together	M81/M82 (Ursa Major)	Two galaxies very close together—M81, spiral galaxy, 11.8 Mly and M82, irregular galaxy, 12 Mly. A starburst is being triggered by the nearness of M81.
Galaxy	Whirlpool (Canis Venatici-hunting dogs)	Two spiral galaxies in collision near the end of the handle of the Big Dipper, 25 Mly distant
Other Objects		

October 4, 2020

Contest Rules for Photographing the Moon

1. **One Free Point**: Students will photograph the moon and submit what they believe to be their best image to **beckerg@moravian.edu**. The student will make the decision. Screenshots submitted by students **will not** receive any credit.
   Example: **Team #, Student's Last Name**
2. **One Free Point** will be given to a team member for the best team image.
   Example: **Best—Team #—Student's Last Name.**
3. **One Free Point** will be given to the student with the best class image. The class will make this determination at a future time.
4. **One Free Point** will be given to the student that your instructor thinks has submitted the best photo.

Consider the following concepts in judging photographs.

1. **Use an eyepiece without a reticle** (crosshair). Finder eyepieces all have crosshairs. A photograph showing the reticle detracts from the beauty of the image.
2. **Consider an eyepiece with a longer focal length**, 20mm or greater, to make centering the image easier in the camera lens and telescope.
3. **Does the image intersect the eyepiece's field of view?** The camera lens or the moon was not in the center of the field of view.
4. **Definition:** Sharpness of the image should be considered. If the image is not sharply focused, detail will be lost.
5. **Contrast:** Are the shades of grey well separated? Some phones will allow users to enhance or subdue the contrast if not.
6. **Magnification:** Is there too much magnification? Does the amount of magnification detract from or enhance the image? Increasing the magnification of the picture by enlarging it on your smartphone screen or using a shorter focal length eyepiece is only an issue if the amount of magnification obtained becomes empty. Empty magnification occurs when the image is magnified beyond the point where no new detail is revealed.

September 21, 2023

Telescope Observation Teams/Quiz Template

Date of Quiz: ____________________Total Points: _________

1. **<u>Type/Aperture of Telescope</u>:** ______________________________

Names ________________, __________________,
________________, ________________, _________________
Problems:

2. **<u>Type/Aperture of Telescope</u>:** _____________________________

Names ________________, __________________,
________________, ________________, _________________
Problems:

3. **<u>Type/Aperture of Telescope</u>:** ____________________________

Names ________________, __________________,
________________, ________________, _________________
Problems:

4. **<u>Type/Aperture of Telescope</u>:** ____________________________

Names ________________, __________________,
________________, ________________, _________________
Problems:

5. **<u>Type/Aperture of Telescope</u>:** ____________________________

Names ________________, __________________,
________________, ________________, _________________
Problems:

NOTES