Key
Do Not Remove !!

GS 104 Laboratory # 3
LIGHT AND TELESCOPES

Introduction

We are here, but the sun and other stars are way out there. How do we learn about them? The only way is through **remote sensing**. There are two categories of remote sensing. One is **active** -- we can go to the sun and planets with probes, such as Cassini or the Mars Lander, which are very expensive. Or we can look **passively** at the information sent here from the objects in the distance. When you see a star or planet in the sky you might say 'what a beautiful light in the heavens'. But what sorts of information can you uncover about that beautiful light? This week we explore the major aspects of how astronomers use light to explore strange new worlds.

Goals and Objectives

- To gain an understanding of what sorts of information astronomers have available to them from the stars.
- To become familiar with the role and importance of making astronomical observations and how they are made.
- To learn about some basic wave properties with regards to light and various telescope designs.

A Description Of How A Wave Travels

Let us consider the 'life cycle' of a wave. A wave usually begins with an oscillating (vibrating) object. The wave forms when the oscillations are linked to the object's surroundings via *coupled vibrations*. Once formed, the wave travels from its origin to its destination. Of course, the wave must be detected by some sort of detector in order for it to reveal its past history. How can you detect the simple harmonic motion of a wave using a detector? To help you understand this, consider the following rather lengthy example:

A stone is thrown into a quiet pond. Near the edge of the pond, a small duckling is floating serenely. A water wave is produced where the stone was cast; it travels away from that point, eventually to reach our duckling. As the wave passes our friendly waterfowl, it bobs up and down, oscillating with simple harmonic motion. Our fine, feathered friend knows by experience that there was a disturbance in its quiet little world.

To investigate if our duckling is indeed oscillating with simple harmonic motion, let us consider placing a harness about the quacking bird, tying a string to the harness, running the string over a pulley, and measuring the motion of the pulley over time. Refer to Figure 1.

The (vertical) position of the infant waterfowl can be deduced from the number of degrees the pulley has turned over time from its initial position. A graph of its position over time should reveal a graph similar to what you will plot in one of the other exercises.

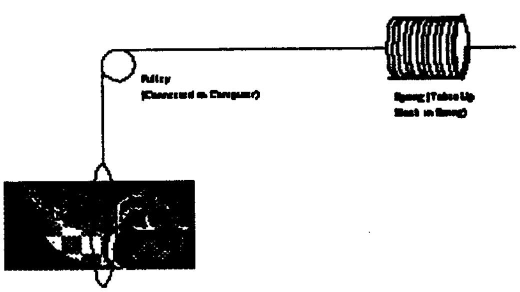


Figure 1

Laboratory Jump-Start Activity

1. Astronomers know a good deal about the star Rigel: its distance to us, the details of its motion, its mass, its density, its temperature, its energy output, and its elemental composition. Clearly, we have not visited this star (or any other star besides our own). Certainly there are no Rigelians sending us updates about their star to us via messages in bottles. Conjecture about what form the information is in that allows us to deduce these things. Exactly what clues from this information do we have in order to deduce these parameters: a star's motions, mass, density, temperature, energy output, and composition.

2. Planets are a bit different than stars. Many decades before we visited our planets with spacecraft, we knew their basic terrain, chemical composition, and atmosphere. Again, conjecture as to how we deduced these things and what information was available to do it.

DURING THIS LAB, YOU WILL BE USING DISCHARGE LAMPS.
PLEASE READ THE WARNING BELOW.

WARNING: THE LAMPS HAVE A LIMITED LIFE. **TURN THESE LAMPS OFF UNLESS YOU ARE ACTUALLY USING THEM.**
WARNING: KEEP CLEAR OF THE LAMP WHEN IT IS OPERATING. THE HIGH VOLTAGE IS DANGEROUS.
LEAVING DISCHARGE LAMPS ON LONGER THAN 60 SECONDS AT A TIME MAY RESULT IN **DEDUCTION OF POINTS** ON YOUR LAB!

Part A – Waves Transfer Energy

Electromagnetic energy or "light" can have many different wavelengths, some invisible to the eye. Heat is one of these invisible light waves. "Heat waves" are referred to as *infrared waves*. The heat lamp works this way: Electricity from the wall outlet heats up the lamp's filament, which causes the electrons in all the atoms of the filament to oscillate at many different rates of vibrations or *frequencies*. Each oscillating electron couples its vibrations to its surroundings in the form of oscillating electric and magnetic fields. These fields are self-creating, and leapfrog their way out into the room. This is, of course, the electromagnetic-magnetic wave we call *light*. Some of the frequencies of the waves emitted by the lamp are visible, but many more are infrared waves.

These activities should convince you that waves transfer energy and illustrate the concept of coupled vibrations. The apparatus consists of two demonstrations. The first one is a heat lamp, and the second is a set of tuning forks.

Activity 1: Heat Lamp

Place your hand in front of the lamp. Describe what you feel.

Warmth

Activity 2: Tuning Forks

Working with light waves isn't always easy, so sometimes we use other types of waves such as sound waves. Find the tuning forks (of the same frequency). Pick up both forks holding them by the handle only. Listen to one fork and verify that it is quiet. Now strike the other fork with the rubber hammer. Place the two forks close together, but not touching. Hold them with their tangs parallel about one fork's width away. After a few seconds, place the fork you listened to earlier to your ear and listen again. Record your observations and consider the following questions in the spaces provided:

What did you hear?

I heard the second tuning fork vibrating. The 2nd tuning fork absorbed some of the sound energy.

What do you hear if you use two forks with different frequencies?

The 2nd tuning fork will not vibrate. The 2nd tuning fork does not absorb the sound energy.

Why is a "dog-whistle" inaudible to most humans?

Dog whistle sound is at too short a wavelength to be absorbed by the human ear.

Questions:

1. **The Latin prefix *infra* means "below or beneath." Knowing the meaning of 'infra'... Is the frequency of *infrared* higher or lower than visible light (also referred to as ROYGBIV) and in particular *red* light? (Isn't the word infrared odd -- a mixture of Latin and English.)**

The frequency of infrared is lower than red light.

2. **When you placed your hand in front of the heat lamp were you convinced that waves, (infrared waves in particular), transfer energy from one place to another? In detail, how were the infrared waves detected by your hand? (Hint: If you try to make electrons in your hand oscillate, they will strongly resist. This resistance manifests itself, ultimately, to exciting your nerves.)**

Infrared light causes the electrons in my hand to oscillate. This transfers energy of motion to ~~my~~ the molecules in my hand, raising the temperature of my hand.

3. **Describe what happens to the mechanical energy of vibration of each of the two tuning forks initially and after the few seconds you held them close to one another. How does the mechanical wave energy transfer from one fork to the other?**

When a vibrating tuning fork is held close to a tuning fork of the same note, the 2nd tuning fork will absorb energy from sound waves generated by the first tuning and will begin to vibrate. The 2nd tuning fork will not absorb energy as well if it is tuned to a different note.

4. **A so-called 'black light' is actually an ultraviolet (part of the electromagnetic spectrum) light source. By ultraviolet, we mean light invisible to humans. Conjecture on how those 'black light' posters work. How is it we see green light from the poster when it is illuminated with invisible light?**

The poster absorbs the UV light and re-radiates it at longer wavelengths visible to humans.

Part B – Speed of a Wave

We have devised a way to measure the speed of light the same way you might measure the speed of your car on those 'odometer test areas'. You measure the distance and the time it takes to go that distance. To get the speed, you divide the distance by the time. Unfortunately, this experiment is too challenging for this laboratory. Our Modern Physics students do this experiment. Here is what they did last year:

> In the speed of light experiment, we place a *modulated* laser (one that pulses on an off rapidly) at one end of the hall. At the other end, we place a mirror where the light reflects back down the hall. Near the laser, we place a detector that measures the difference in time between when the laser sends a pulse and when it arrives from down the hall and back. The length of the hall is 51.4 meters, so the light travels a total distance of 102.824 meters. The time recorded is 3.45×10^{-7} seconds. Thus, the speed of light is 2.98×10^{8} meters/second. Note that the accepted value is 2.99897×10^{8} meters/second.

So, measuring the speed of light this way is too difficult. Hence, we will do a similar experiment using sound waves instead.

Activity: Speed of Sound

You will use a computer-controlled black box containing a speaker and microphones. A wave (actually a series of pulses) will be generated by the computer and speaker. Each pulse will travel a known distance, reflect off a wall, and return to the black box. The microphone contained in the black box will register each pulse. The time difference between when each pulse leaves the box and when it is registered by the microphone is measured by the computer.

Step 1: Using the computer, measure the time between when each pulse leaves the box and the microphone 'hears' the pulse. The average time (in seconds) for pulses to travel the round trip distance: ____________ seconds.

Step 2: Measure the distance (in meters) between the microphones. Do this to within the nearest millimeter (0.001 meter).
The distance (in meters) between the box and the wall: _______________ meters.
The 'round-trip distance' (in meters) that each pulse travels: ______________ meters.

Step 3: From the definition of velocity (speed) = distance/time, compute the speed of the sound wave in air. (Show work below) Your measured velocity (speed) of the sound wave in air: ______________ meters/second

Questions:

1. Assume the black box microphones were turned around to point at the opposite wall. If you did this experiment again using this "new" distance, how (if at all) would it change the speed of sound? Would it go faster? Slower? Or no change? Explain your thoughts.

2. Verify your thoughts about question #1 by determining the speed of sound for the reconfigured black box set-up "pointing to the opposite wall." What value did you get? How close is it to the original speed you determined? Why might these numbers differ? (hint, what might be some possible sources of error?)

3. What are the implications of the observation that light doesn't travel instantaneously from the distant stars to our telescopes?

4. Calculate how long it takes for light from our Sun to reach Earth? (Hint: refer to last weeks' lab for distance from Earth to Sun and use speed of light given above.)

C – White Light and the Visible Light Spectrum

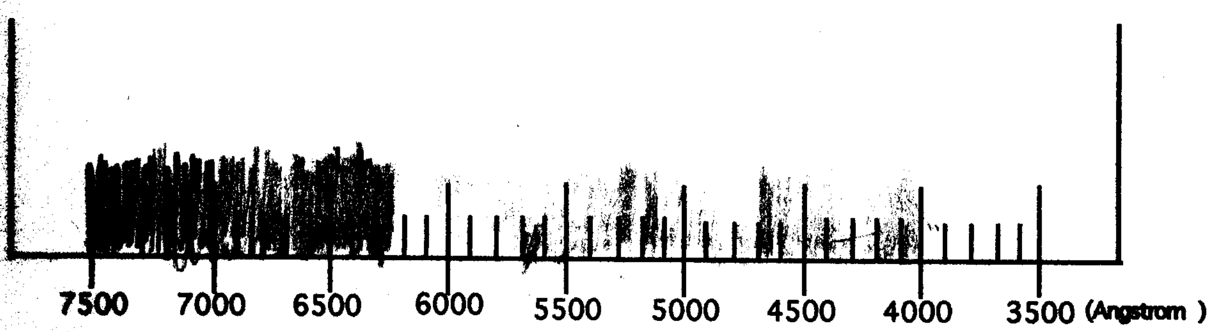
Light from the stars and planets can contain a wealth of information about the object it came from. It **is not so easy** to look at starlight, so we will have to be creative. This station consists of several light **sources** and a set of spectroscopes. **A spectroscope measures the wavelength of a light wave.** If **there** are many light waves of differing wavelengths, the spectroscope will register all the (visible) **wavelengths**. Your job is to measure the wavelengths present in each source.

Activities: ROYGBIV Spectrum of incandescent tungsten lamp.
The first source is an incandescent tungsten filament lamp. It should be noted that a hot tungsten **filament** acts as a *black body* light source. With your instructor's help, set up the spectroscope with **this source**. You should see a full *spectrum* or range of visible wavelengths. We apologize for the **different** scales on the spectroscopes and charts (Angstroms, nanometers and others) You will have to **add** (or remove) zeros to the scales to come up with numbers in this range. The ranges below should **cover** 750 to 400 nanometers.

Make observations of the incandescent filament lamp. Measure the *range of wavelengths* that **comprise** 'red light' in nanometers (billionths of meters). Repeat this for orange, yellow, green, blue, **and** violet. **Note, the origin of the familiar abbreviation of ROYGBIV**

Red light	750	to	670	nanometers
Orange light	670	to	630	nanometers
Yellow light	630	to	610	nanometers
Green light	610	to	520	nanometers
Blue light	520	to	470	nanometers
Indigo light	470	to	440	nanometers
Violet light	440	to	400	nanometers

Using the graphic below mark (preferably in color) the appropriate ROYGBIV wavelengths.



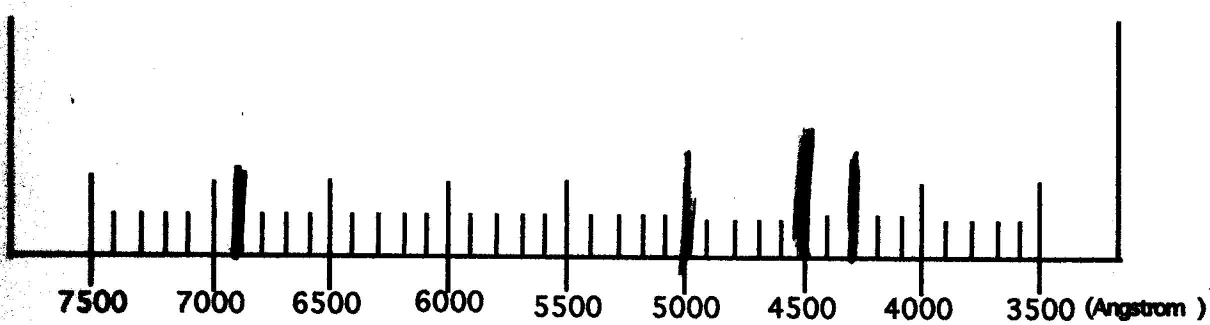
(To obtain nanometers divide Angstrom units by Ten)

Activity: Star Composition

Astronomers learn a vast amount of information about a star from analyzing the electromagnetic spectrum that emits from it. Comparing a stars spectrum to the spectrum of known gases (as viewed on Earth in a laboratory) allows scientists to theorize about the stars compositional makeup. A star whose spectrum closely matches that of a hydrogen filled discharge lamp (as viewed in a lab) is, with a high degree of confidence, assumed to be composed of Hydrogen gas. In this activity you will be given two unknown "stars" (actually they are gas filled discharge lamps) and you will have to compare their spectrum with known spectrum and deduce the stars composition.

Alpha Star

Turn on the discharge tube for **Alpha Star** (you are using the discharge tube as a model of an unknown star comprised of a single gaseous element) Make observations of the colors and placement of **Alpha Star's** spectrum. Record your observations on the graph below. Be sure to carefully observe the number (wavelength) under the colored spectral line and place your "colored" line in the corresponding place on the graph. Note: there is no "correct" or standard means for placement of ROYGBIV with Red being placed either at the right side or left side, BUT once a side has been chosen then the rest of the sequence must follow in appropriate order of wavelength. So it is either ROYGBIV or VIBGYOR. This point is brought up because we are using a spectroscope and a table of known spectrums each with a different orientation (life isn't always easy is it?)



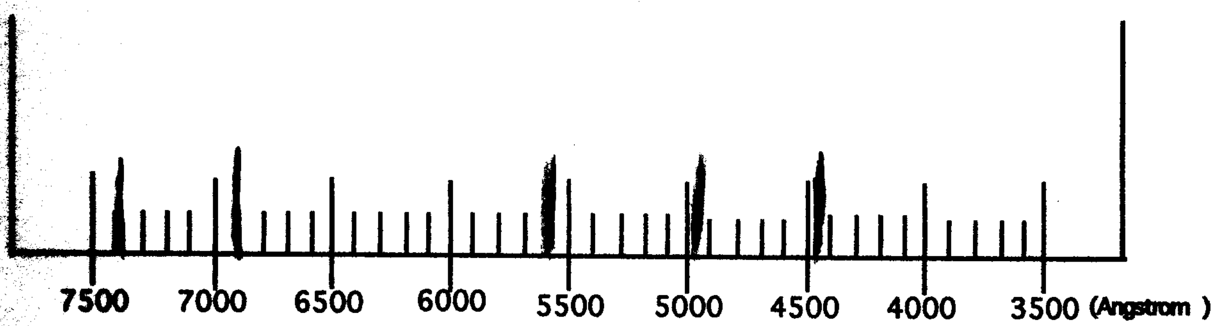
(To obtain nanometers divide Angstrom units by Ten)

After drawing the spectrum of Alpha Star, compare it to the chart of spectrums from known gases. **What gas do you think Alpha Star is predominately made of?** If there are more than one possibility list them all. Explain your reasoning. How confident are you?

Hydrogen

Beta Star

Turn on the discharge tube for **Beta Star** (you are using the discharge tube as a model of an **unknown star** comprised of a single gaseous element) Make observations of the colors and **placement** of **Beta Star's** spectrum. Record your observations on the graph below. Be sure to **carefully** observe the number (wavelength) under the colored spectral line and place your "**colored**" line in the corresponding place on the graph. Note: there is no "correct" or standard **means** for placement of ROYGBIV with Red being placed either at the right side or left side, **BUT once** a side has been chosen then the rest of the sequence must follow in appropriate **order** of wavelength. So it is either ROYGBIV or VIBGYOR. This point is brought up **because** we are using a spectroscope and a table of known spectrums each with a different **orientation** (life isn't always easy is it?)

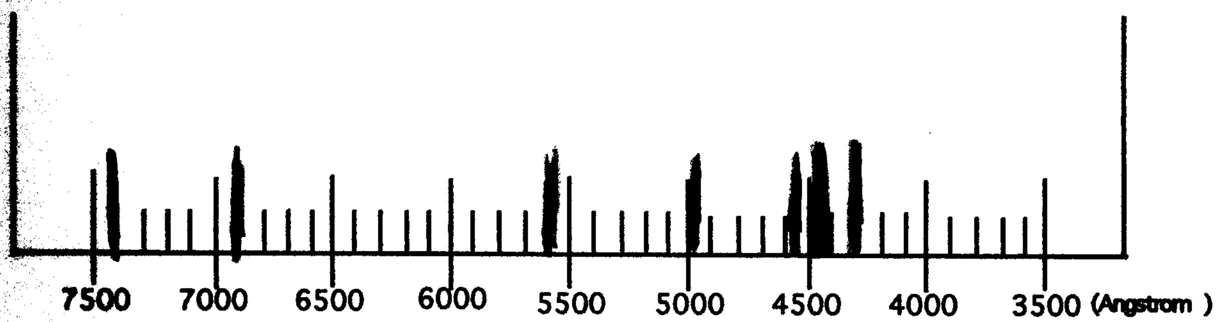


(To obtain nanometers divide Angstrom units by Ten)

After drawing the spectrum of Beta Star, compare it to the chart of spectrums from known gases. **What gas do you think Beta Star is predominately made of?** If there are more than one possibility list them all. Explain your reasoning. How confident are you?

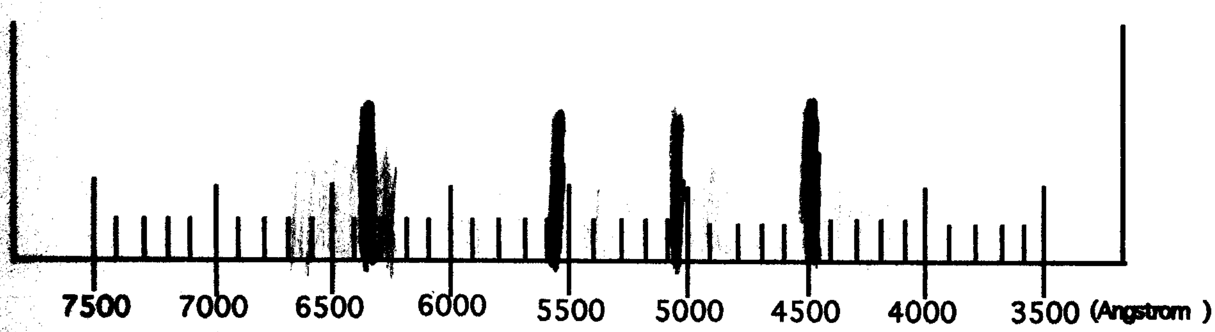
Mercury

On the graph below draw the spectrum of a third Star, which is composed of a mixture of Alpha Star and Beta Star gases.



(To obtain nanometers divide Angstrom units by Ten)

Fluorescent Star: Observe the fluorescent lamp through the spectroscope. Record careful **observations** on the graph below and compare it to the chart of known gases.



(To obtain nanometers divide Angstrom units by Ten)

What gas do you think is inside a fluorescent tube lamp?

Mercury

Questions:

1. **Compare the incandescent and fluorescent light sources. Note the wattage of each lamp and visually compare their brightness. Explain why their brightness and wattages don't jive. (The one with the lower wattage appears brighter!)** (*Hint*: **Hold your hand next to each lamp.**)

The 60-Watt incandescent bulb turns most of the electrical energy it consumes into heat, not visible light. The fluorescent bulb converts most of the energy it uses to visible light and much less to heat.

2. **A *continuous spectrum* is one in which all wavelengths (colors) are represented. A *discrete spectrum* is one that does not have all wavelengths represented; rather it has only a discrete number of wavelengths. Look up the spectrum of the sun. (A poster is hanging up in the lab room.) Is the spectrum discrete or a black body spectrum?**

It is a continuous spectrum missing discrete wavelengths.

3. **Did the different gasses in the discharge tubes (Alpha and Beta Stars) produce the same spectrum or a 'signature' spectrum different from each other?**

Different

4. **It turns out that each gaseous element has a unique spectrum. How can light be used to determine what is inside a star?**

By looking at the discrete wavelengths of light missing from a stellar absorption spectrum, the composition of the star can be found by comparing the emission lines of elements to the absorption lines.

Part D – Lens and Image Characteristics

In this activity you are provided with two different lenses and you supply your powers of observation.

WARNING: HANDLE LENSES ONLY BY THEIR EDGES. PLACE LENSES ONLY ON A SHEET OF PAPER TO PREVENT SCRATCHING. IMPROPER HANDLING OF THE LENSES MAY RESULT IN DEDUCTION OF POINTS ON YOUR LAB!

The curvature of the lens greatly affects the magnifying ability. Investigate the large curvature (the thin one) and small curvature lens (the thick one). (Here we refer to the *curvature* as how much the thickness changes between the center and the edge of the lens. This is different from the radius of curvature often quoted for lenses.)

Focus a scene through the windows on the opposite wall. To do this hold a lens against the far wall facing the windows, then move the lens slowly away from the wall until you see an image form on the wall. This is illustrated in Figure 2. Note the distance from the image to the lens and the image's **magnification** in particular.

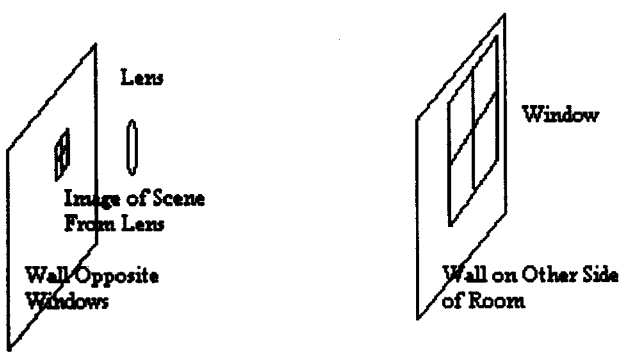


Figure 2.

Describe the image that you see. In your description use terms like somewhat magnified or greatly magnified, upright or upside-down.

The field of view is how much of a scene that can be imaged. If you can see more of a scene, the field of view is larger. Look at a piece of graph paper on the table through the small and large lens. Hold both lenses the same distance away; maybe 4 cm? Compare the **field of views** of the two lenses.

Measure the focal length of the provided lenses. When an object is placed sufficiently far enough away to call it 'infinitely far away', the image will form at the location of the focal length of the lens. Choose an object very far away (>10 meters) such as objects outside the windows or a light bulb on the other side of the room. Hold the lens flat against the wall opposite your object (the wall needs to be light in color). Move the lens slowly away from the wall until an image of the object forms on the wall. Carefully measure the distance (in meters) from the lens to the wall. This is the focal length. Report the focal length in your report. Don't forget to measure *both* lenses.

The focal length of the large curvature (the thin one) is _______________ meters.
The focal length of the small curvature (the thick one) is _______________ meters.
The diameter of the large curvature (the thin one) is _______________ meters.
The diameter of the small curvature (the thick one) is _______________ meters.

The f-number of a lens is (focal length in meters)/(diameter of lens in meters). A lens with an f-number of seven is written: f/7. Determine the f-number for the long and short curvature lenses. Please don't confuse f-number with the focal length.

The f-number of the large curvature (the thin one) is _______________ (no units).
The f-number of the small curvature (the thick one) is _______________ (no units).

Questions:

1. Deduce and relate the relationship between the curvature of a lens, the magnification of the image it creates, and its focal length.

2. Which has the better field of view, a large curvature or a small curvature lens?

3. What affects the field of view?

4. What is the relationship between the f-number and the field of view?

5. Why do National Geographic photographers use those really wide lenses?

6. Suppose we have a lens that is 0.02 meters in diameter. We then, using black tape, cover up the edges of the lens so that light can pass through only the inner 0.01 meters (in diameter). What happens to the f-number? Does it increase or decrease?

Part E – Telescopes

WARNING: TELESCOPES ARE EXPENSIVE PRECISION INSTRUMENTS. **DON'T BUMP OR JAR THEM. DON'T TOUCH ANY GLASS OR REFLECTIVE METAL SURFACES!** IMPROPER HANDLING OF TELESCOPES MAY RESULT IN **DEDUCTION OF POINTS** ON YOUR LAB!

Being the Earth-dwelling creatures that we are, we don't always have the luxury of popping up into orbit every time we want too look at the stars (see the 'Observing The Night Sky' lecture activity). Below are descriptions of smaller, Earth-based telescopes.

The refracting astronomical telescope is made of two converging lenses (see Figure 3). Incoming parallel rays from a distant star are focused to an intermediate image. The eyepiece lens is then used to prepare the light to be viewed by your eye. Your eye's lens focuses the light onto the retina forming an image that your brain can interpret. Notice that since the intermediate imag is inverted, the 'sky' will appear 'backwards'. The magnification of a telescope is large if the intermediate image is large and if this image is viewed through an eyepiece (magnifying glass) of large magnification. The magnification of a refracting astronomical telescope is the ratio of the focal length of the objective to the focal length of the eyepiece.

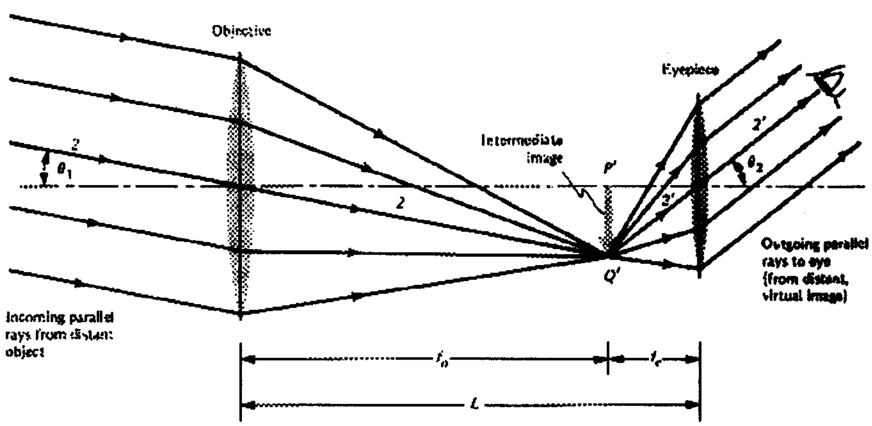


Figure 3: Diagram of a refracting astronomical telescope.

For terrestrial purposes, such as looking for whales or spying on your neighbor, the inverted image of the refracting astronomical telescope is rather inconvenient. To produce an erect image is simply to insert, between the objective and the eyepiece, an erecting system, which inverts the intermediate image. The erecting system can be a simple converging lens (Figure 4), however the telescope becomes rather long (of the type favored by pirates). A erecting system that allows a shorter telescope is the combination of prisms shown in Figure 5 Binoculars are specified by both their magnification and objective diameter. Thus, a 7 X 35 binocular has magnification 7 and objective diameter 35 mm.

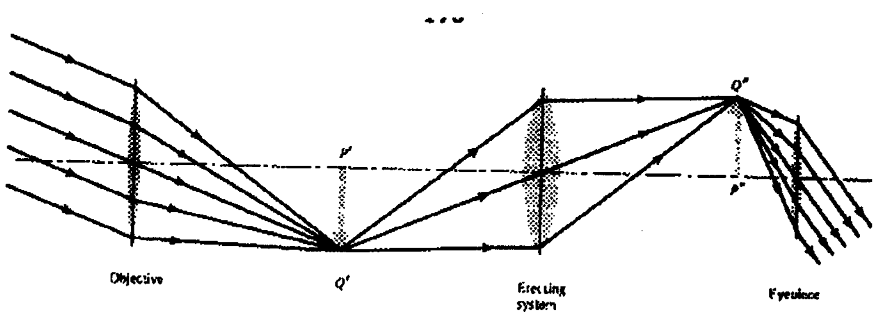


Figure 4: Diagram of a refracting terrestrial telescope.

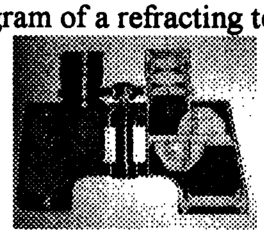


Figure 5: A cut away view of binoculars.

An alternative approach avoids the erecting system by using a diverging eyepiece, as in the Galilean telescope (Figure 6). Its advantage is that the distance between the lenses is actually less than a terrestrial telescope. However, the field of view is limited, so this technique is used in small, inexpensive opera glasses (but it was good enough to enable Galileo to discover four of Jupiter's moons).

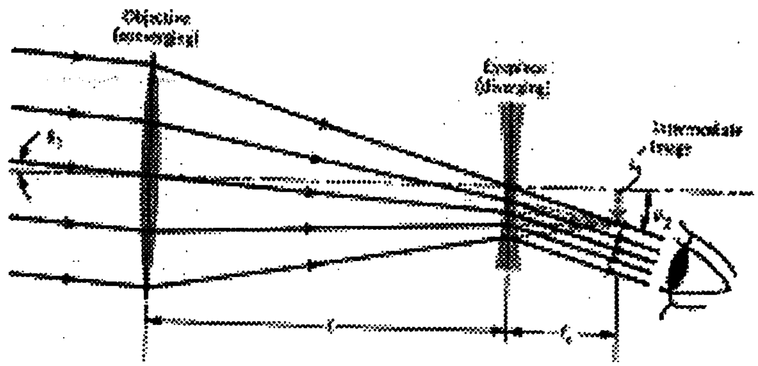


Figure 6: Diagram of a Galilean telescope.

The preceding telescopes all use objective lenses (so-called refracting telescopes). Large diameter lenses, however, create numerous problems. A technique that avoids all these difficulties is to use a concave, focusing mirror as the objective (the so called primary mirror). A smaller, secondary mirror is normally used to enable you to look through the telescope without putting your head in the way of the incoming beam. There are a variety of such reflecting telescopes, a few of which are pictured in Figure 7. In the very large reflecting telescopes, the astronomer (or a detector) can actually sit at the focal point of the primary mirror. Figure 7a shows a Newtonian telescope, Figure 7b shows a Cassigrain telescope, and Figure 7c shows the Gregorian telescope. Each has their advantages and disadvantages.

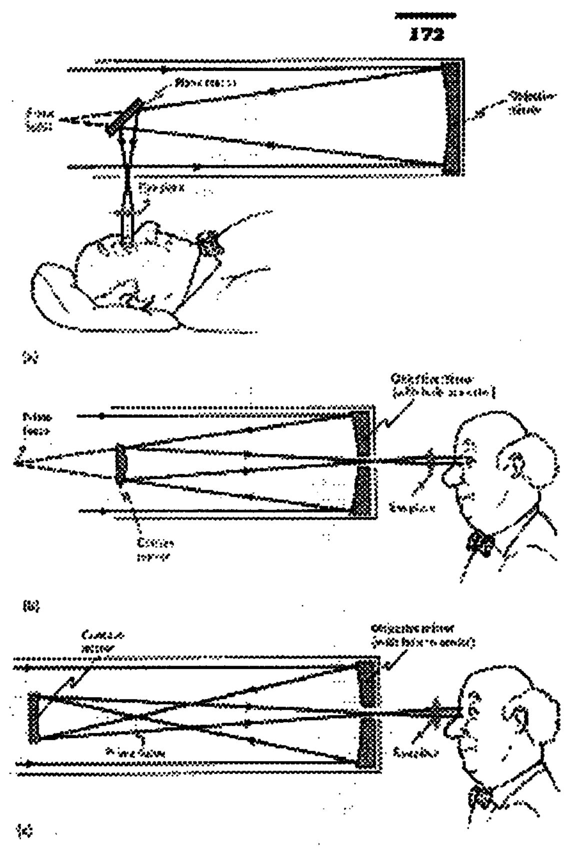


Figure 7: Diagrams of reflecting telescopes.

A technique to avoid the weight and cost of a single large mirror is to use a number of smaller mirrors in concert. The light collected by each of the separate mirrors is focused to a common image. The mirrors' sensitive alignment is accomplished by means of laser beams that accurately detect each mirror's position, computers that rapidly calculate any required position change, and motors that continually realign the mirrors. The Multiple Mirror Telescope on Mount Hopkins, Arizona, has six 1.8-meter mirrors that combined have the light gathering ability of about one 4.5-meter mirror.

PLEASE BE CAREFUL AROUND TELESCOPES!

Don't bump them or pick them up. Don't touch any glass or reflective metal surfaces!

Activity:
Build your own telescope using the lenses and mounts. Choose only one. Here are some tips.

The Refracting Astronomical Telescope: Use one of the 5cm focal length lenses as the eyepiece, and the 20 cm focal length lens as the objective, separated by about 25 cm, with the eyepiece close to your eye. It may help to brace your hand against something, say the window frame. Notice the orientation and size of the image and the field of view and compare them to those obtained with the Galilean telescope. With a third hand you can try inserting the other 5 cm focal length lens about 5 cm in front of the eyepiece as a field lens.

The Galilean Telescope: Here use the -5 cm focal length (diverging) lens as the eyepiece, and the 20 cm focal length lens as the objective. The spacing between the lenses should be about 20 cm - 5 cm = 15 cm. It may help to brace your hand against something, say the window frame. Notice the orientation and size of the image and the field of view. Reverse the positions of the two lenses and look through them. Notice the large (wide) field of view, useful for a peephole in a door. (Of course, unless you live in a castle, you probably don't have doors 15 cm thick. Actual peepholes use shorter focal length lenses.)

Questions: Use the space below or an additional page to record your work.

1. Examine the telescopes and categorize them as to their type. For each, draw a sketch and identify the objective (mirror or lens), the eyepiece, and any other important internal mirrors or lenses.

2. In a short paragraph, discuss this activity. Describe the telescopes you looked at and describe the one you built.

Post Assessment

In small groups, discuss the following questions. Formulate answers in your group, and then each of you should write their own answers to the questions.

1. What sorts of information do astronomers have available to them from the stars? In what form does it come?

2. At the beginning of this week's lab, we asked 'how do astronomers know so much about the star Rigel. Based on what you have done today, what is your answer? How could we know its distance to us, the details of its motion, its mass, its density, its temperature, its energy output, and its elemental composition? (We don't expect a short answer!)

GS106 Lab 3 Answer Key - How We Use Light in Astronomy

Pre-Lab Reading Questions

Life Cycle of a Wave: 1) initialized as oscillating vibrations ("disturbances"), 2) wave travel from origin to destination, 3) detection of wave by sensing device

Reflecting vs. Refracting Telescopes: A reflecting scope employs a set of mirrors and an eyepiece (ocular), whereas a refracting scope employs a set of refracting lenses

Reflection: bouncing light waves off of smooth surfaces (e.g. a mirror)

Refraction: transmitting and bending light waves through a transparent medium (e.g. a lense)

Refracting Telescope Example = Galilean Telescope (see Fig. 3.6 of your lab exercise)

Reflecting Telescope Example = Newtonian Scope (see Fig. 3.7 of your lab exercise)

Lense Warning: Don't bump, jar, or handle lenses under penalty of death.

Field of View: the area of a scene that is imaged by a lens

Three Light Sources Used: (1) incandescent tungsten filament lamp (e.g. a good ol' light bulb) = continuous / black body source ("rainbow spectrum"), (2) fluorescent lamp (mercury-gas charged) = discrete spectrum, (3) neo gas lamp = discrete spectrum

Accepted Value of Speed of Light: ~3.0×10^8 m/sec

Pre-Lab Assessments

A star's physical properties are determined by careful astronomic measurements of the star's: light, geometric position in space, change in position over time, characteristic electromagnetic spectrum ("spectroscopy" = stu of electromagnetic spectrums)

Planet deductions were originally made on the basis of: (1) visual analysis of the reflected light from the planet (using telescopes), (2) basic calculations of the planet's distance and size based on spatial geometry, ar (3) mathmatical calculations based on Newtonian physics.

1 - Wave Transfer of Energy

Heat Lamp - heat is transferred by infrared radiation through the atmosphere to your hand (your hand feels th heat)

Tuning Forks: source of sound waves... remember a wave is a wave, regardless of the type of wave that it is.

Infrared = electromagnetic energy with wavelengths longer than the red portion of the visible spectrum (wavelength range of infrared = ~>8000 nm)

The heat lamp sends infrared radiation through the atmosphere via wave energy.

How a hand feels "heat" from the heat lamp: the waves are transmitted from the heat lamp, through the atmosphere, to your skin. The wave energy excites the electrons in the cell tissue of your skin, which in turn excites the nerve endings in your body, and tells your brain "ouch, that's hot!"

Tuning Fork Experiment: the vibrational mechanical "sound" energy is transfered via wave transmission from one tuning fork to another, causing a resonant vibration in the second fork. The second fork begins vibrating "sympathetically" with the first. Your ears work the same way, sound vibrations vibrate your ear drums, which in turn send signals to the brain for interpretation.

Black light poster experiment: black light consists of ultraviolet radiation source (comprised with electromagnetic wavelengths shorter than the blue end of the visible spectrum... thus black light is technically "invisible" to the eye). The paint pigment in the black light poster is photochemically excited by the UV radiation (from the black light) at the atomic level, with electrons bumped from their normal atomic positions As the electrons are bumped or excited, they cause the poster paint to "glow" and give the characteristic "blac light" effect.

UV radiation and sun burn: the sun emits visible, infrared, and ultraviolet radiation as a result of burning it's hydrogen fuel. The UV radiation from the sun travels through space as a wave at the speed of light, beaming your skin at the beach on a sunny day. The UV radiation in turn excites the electrons in the cells of your skin which your cells do not necessarily like. The net result in tissue damage, better known as "sun burn".

2- Speed of a Wave

speed of a wave = distance traveled / time of travel

Speed of Sound Experiment:

1-way distance from wall to microphone: 1.5 m
2-way travel distance from micropone to wall to microphone: 3.0 m
Average 2-way travel time: 0.008577 sec
Speed of sound in air: V = 3.0m/0.008577 sec = 349.77 m/sec

Verification of Speed of Light Experiment by Physics Students

Speed = distance / time

total distance = 102.824 m
travel time = 3.45×10^{-7} sec

calculated speed of light = 102.824 m /3.45×10^{-7} sec =

2.98×10^8 m/sec

Room temperature ~ 22 degrees C ; 22 C speed of sound should be 343.2 m/sec. I determined 349.77 m/sec, so there is a discrepancy! We haven't accounted for room humidity, and also there is some error with the apparatus set up.

The implications for distant stars: since light is traveling through space over time, the light that we see at the farthest reaches of the universe was emitted from stars billions of years ago... when we look in space, we lool back in time!!!!

3 - White Light and the Visible Spectrum

Wavelengths of visible spectrum (continuous spectrum)

Red	750-680 nm
Orange	680-635 nm
Yellow	635-575 nm
Green	575-520 nm
Blue	520-460 nm
Violet	460-400 nm

Hydrogen lamp activity I

visible lamp color = pink / reddish

spectrocope results: discrete spectrum (individual bands of colors)

Wavelengths for hydrogen lamp: 450 nm, 500 nm, 570 nm, 700 nm (discrete bands)

Activity II

Fluorescent Lamp: mixture of continuous spectrum (ROYGBIV) and discrete spikes at 450 nm, 570 nm, and 610 nm. The discrete spikes are the result of mercury gas that is used in the fluorescent lamp tube.

Mercury Lamp Comparison: visible light is light blue in color, spectroscopic light is discrete with spikes at 4 nm, 560 nm, 590 nm, and 640 nm.

Questions:

The spectroscope wavelengths are off a little from the chart due to light mixing and poor quality of the spectroscopes.

List of colors in order from long to short: ROY G BIV

Comparison of incandescent and fluorescent light sources:

incandescent: wattage = 34 w, less bright, hotter next to lamp, more energy released as heat
fluorescent: wattage = 15 w, more bright, cooler next to lamp, less energy released as heat

Summary of spectrum types

incandescent = continuous
fluorescent = combination of continuous and discrete (mercury gas in tube)
hydrogen and mercury lamps = discrete

How is light used to analyze stars?

Different gases / elements emit different spectral signatures, depending on their composition. By matching the stars spectra to known experimental data (from known gases), we can deduce the composition of a distant star.

Spectrum of the Sun: it is a continuous, black body spectrum

4- Lens and Image Characteristics

Thick Lens / Thin Lens Comparison (image, field of view)

Thin (small curvature) Lens: inverted image, larger magnification, smaller field of view, long focal length

Thick (large curvature) Lens: inverted image, smaller magnification, larger field of view, short focal length

Focal length of thick lens: 0.10 m (10 cm)

Focal length of thin lens: 0.20 m (20 cm)

Diameter of thick lens: 0.038 m

Diameter of thin lens: 0.038 m

f-no. of thin lens = 0.20 m / 0.038 m = 5.26

f-no. of thick lens = 0.10 m / 0.038 m = 2.63

Questions

Relation between lens curvature, magnification and focal length:

large curvature (thick one): F.L. is shorter, magnification is smaller, field of view is larger
small curvature (thin one): F.L. is longer, magnification is larger, field of view is smaller

Field of view comparison:

Field of view is effected by the focal length of the lens and the curvature of the lens

Relationship between f-no. and field of view: as F No. Increases, field of view decreases, Magnification increases

National Geographic Question: photographers use large fields of view to capture big landscapes and magnificant images.

Consider a lens with diameter diminished from 0.02 to 0.01 m, what will happen to the f no?
Since f no. = focal length / diameter, then f no. is inversely proportional to lens diameter. As diameter is cut in 1/2, the f no. will double, assuming that the focal length is constant.

5 - Telescopes

Compare scopes that are in the lab with the figures on p. 351 to determine the types we have available (there are refracting and reflection scopes here).

Describe the telescope that you made...

Post Assessment

Moral of the Story for Star Analysis: astronomers study stars by looking at the electromagnetic spectrum emitted from the star over time. This provides information on the composition of the star, it's motion pattern distance, etc. With careful observation of star "light" (in all forms of EM radiation), we can catalog and stud stars.

The electromagnetic spectrum from stars is analyzed using both visible light telescopes and other telescopes (e.g. x-ray spectrum, infrared spectrum, gamma ray spectrum)