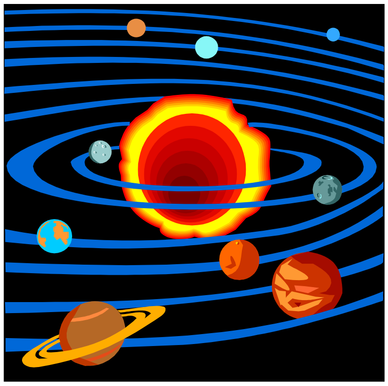
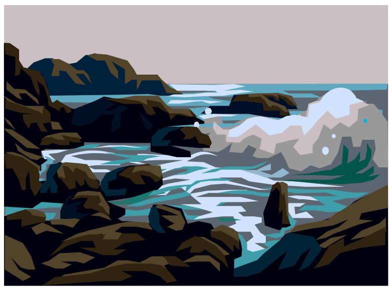
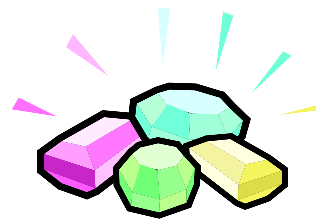
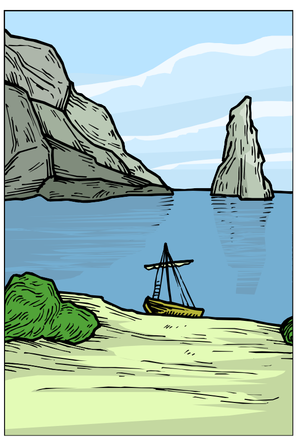




Earth Science 104

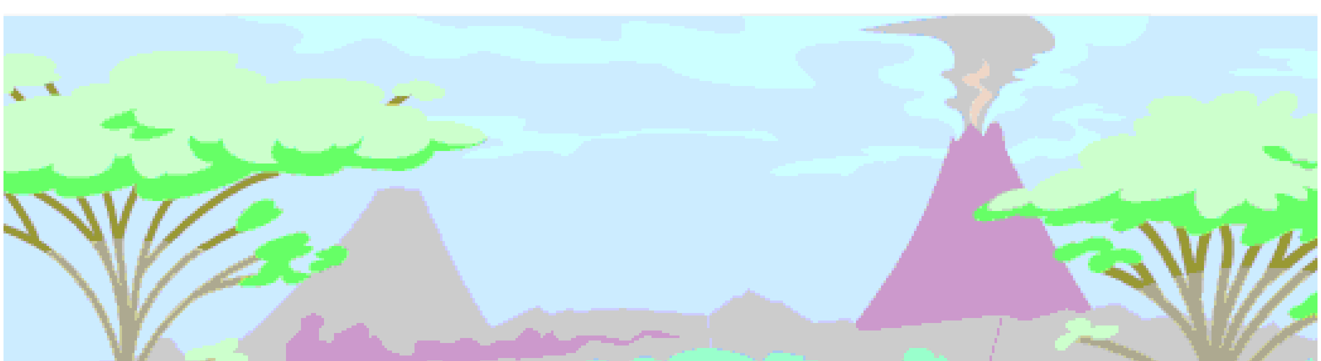




Laboratory Manual

2017-2018

(Updated March 2018)



ES104 Earth System Science I

Spring 2018 (updated 03/07/18)

Laboratory Manual

Table of Contents

ES 104 Laboratory # 1
MODELS AND SYSTEMS

Introduction

We use models to represent the natural world in which we reside. Throughout human history, models have also been used to represent the solar system. From our reality here on Earth, we take part in an Earth-Moon-Sun system. The relationship between their positions at various times determines some common phenomena such as seasons, moon phases, and day length. In this lab, you will use physical models to explore these relationships.

Goals and Objectives

- Create scale models and make sketches that reasonably portray observations of components of the Earth-Moon-Sun system
- Use physical models to determine the reasons for the phases of the moon, the seasons, and the length of the day

Useful websites

- http://home.hiwaay.net/~krcool/Astro/moon/moonphase
- http://www.ac.wwu.edu/~stephan/phases.html
- http://csep10.phys.utk.edu/astr161/lect/index.html
- http://www.astro.uiuc.edu/projects/data/Seasons/seasons.html
- http://www.relia.net/~thedane/eclipse.html

Name_______________________________________

Lab day ______Lab Time______________________

Pre-lab Questions – Complete these questions before coming to lab.

1. Define the following terms:
   A. Phases of the Moon

   B. Full Moon

   C. New Moon

   D. Orbit

2. What is the distance from the Earth to the Moon?

3. How long does it take the Moon to revolve around the Earth?

4. Define the following terms (draw diagrams to illustrate your answers):
   A. Waxing moon

   B. Waning moon

5. What is the difference between "waning moon" and "third quarter phase"?

Part A - A Model of the Sun-Earth-Moon System
Phases of the Moon

You will construct a physical model of the Sun-Earth-Moon system. Materials for your model will be at the appropriate activity station. The purpose of this model is to investigate the ***phases** of the moon*, which include new, first quarter, full, and third-quarter (or last-quarter). Refer to your textbook (Fig. 21.25, p. 656, *Earth Science,* Tarbuck and Lutgens, 14th ed.) to see how they appear in the sky.

Use a small sphere affixed to a stick to model the moon. Figures 1, 3, 5 and 7 represent the view of the model as if you were far from Earth, but above the North Pole. A lamp acts as Sun. Position Moon, Earth and Sun (lamp) at the locations indicated in figures, placing Earth about half a meter (50 cm) from Sun.

On Figure 1, blacken in the shadowed part of the moon.

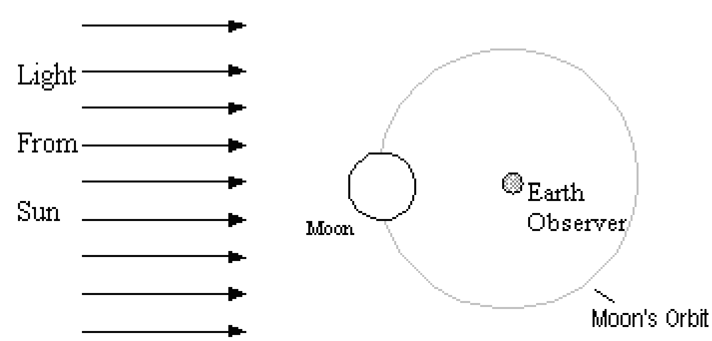


Figure 1: A top view of the Sun-Earth-Moon model.

Locate the 'observer on a stick' cut out and use the 'observer' to represent you standing on Earth's surface. This observer represents how "we" here in Monmouth, Oregon would view the moon phases. Your job is to deduce what the 'observer on a stick' located on the Earth will see. On Figure 2, **blacken in the shadow of the moon's face** that the 'observer on Earth' sees when looking into the sky.

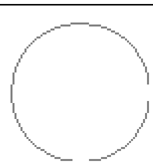


Figure 2: The way a person on the Earth would observe the moon.

The **phase** (see above) of the moon is

______________________________.

Figure 3 represents another top view of the model. Holding Moon at the new location as indicated below, **blacken in the shadowed part of the moon on the figure below**.

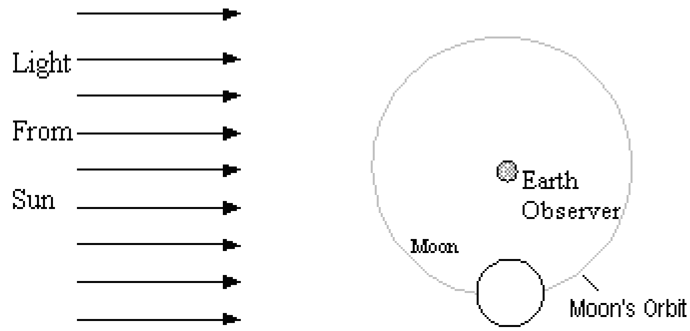
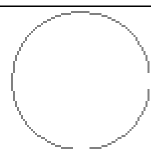


Figure 3: A top view of the Sun-Earth-Moon model.

What does the 'observer on a stick' see now? To indicate this, **blacken in the shadow of the moon's face in Figure 4.**



The phase of the moon is

__________________________________.

Figure 4: The way a person on the Earth would observe the moon.

Move the Moon to the location shown below in figure 5.
Blacken in the shadowed part of the moon in figure 5.

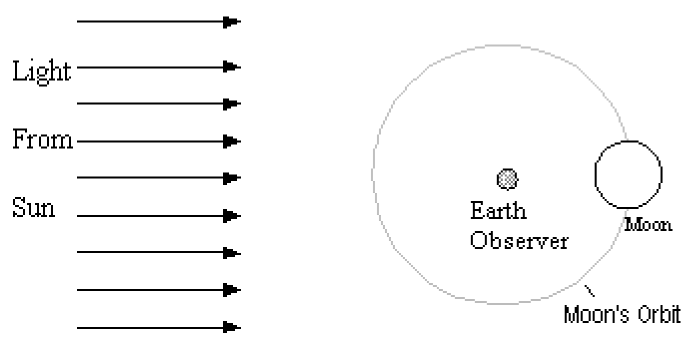
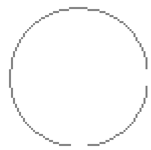


Figure 5: A top view of the Sun-Earth-Moon model.

Again, **blacken in the shadow of the moon's face** in Figure 6 when it is in the position shown in figure 5.



The phase of the moon is

_________________________________.

Figure 6: The way a person on the Earth would observe the moon.

Move the Moon to the position shown in figure 7. Once more **blacken in the shadowed part of the moon** when it is located as shown in Figure 7.

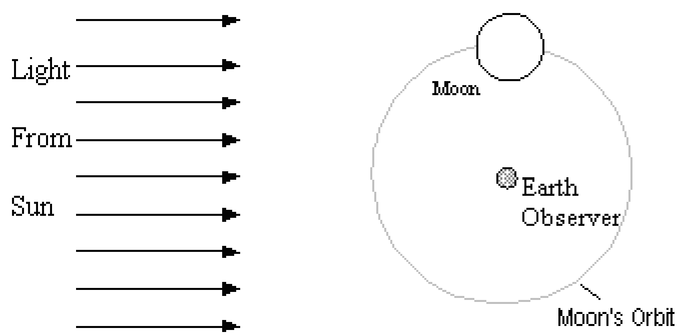
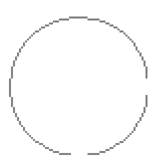


Figure 7: A top view of the Sun-Earth-Moon model.

When an observer looks into the sky, what will they see when the moon is located as it is in Figure 7?

Indicate what they see in Figure 8, below.



The phase of the moon is

_________________________________.

Figure 8: The way a person on the Earth would observe the moon.

Mental Exercise:

Now construct drawings 2A, 4A, 6A, and 8A for an observer viewing Moon from the Southern Hemisphere (for example, from a position "down under" in Australia) to correspond to the location of Moon as shown in figures 1, 3, 5, and 7. To model this **new frame of reference**, take your observer on a stick and "walk" him down to Australia when Moon is in the locations shown in the 'top view' figures. (Note the observer should now be up-side-down.). In the spaces provided below, **draw the four corresponding Moon views for this new observer position.**

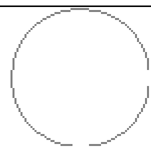


Figure 2A: How a person on the Earth in **Australia** would observe the moon.

The phase of the moon is

______________________________.

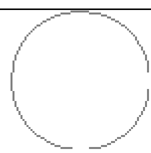


Figure 4A: How a person on the Earth in **Australia** would observe the moon.

The phase of the moon is

______________________________.

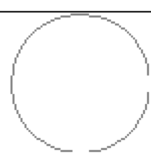


Figure 6A: How a person on the Earth in **Australia** would observe the moon.

The phase of the moon is

______________________________.

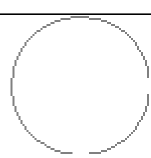


Figure 8A: How a person on the Earth in **Australia** would observe the moon.

The phase of the moon is

______________________________.

Questions:

1. Assuming the Earth-Moon-Sun position is the same, does the phase of the moon change when viewed from the Northern Hemisphere compared to the Southern Hemisphere? If we in Monmouth, Oregon view a first quarter moon phase, what phase will people in Australia view when they see the moon on the same evening? Consider whether Moon's position and orbital direction with respect to Earth (top view figures) is the same whether you are in Australia or Oregon.

2. What is the time in days between a full moon and a new moon?

3. What is the time in days between two successive full moons (i.e., from one full moon to the next full moon)?

4. What is the orbital period of Moon around Earth (in days)?

5. How long does it take Moon to move around Sun (in days)?

6. If the full moon is on the western horizon, approximately what time of day must it be? HINT: Where is Sun in relation to you when you are gazing westward at a full Moon?

   The time of day will be ____.
   (Generally speaking, such as: mid-morning, sunset, dawn, noon, midnight, etc.)

Draw in and label the locations of the **full moon** and the **new moon** in Figure 10. **Fill in the shadowed part of Moon** in each case. (HINT: use Figures 1 and 5 as a guide.) **Label one curved arrow *waning*** -- where Moon is getting closer to a new moon. **Label the other curved arrow *waxing*** -- where it is building up to a full moon.

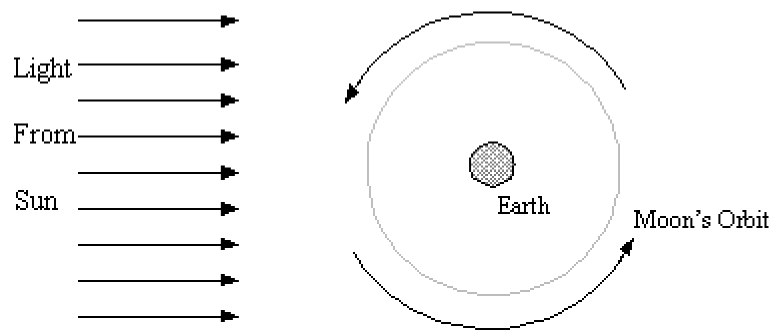


Figure 10: A top view of the Sun-Earth-Moon model.

7. Write a brief explanation as to why we see the phases of the moon.

8. The color of material (rock and dust) that covers the moon is primarily light colored. Suppose all of Moon's material was black. Would we see moon phases? Explain.

9. Assume you are "camped" on Moon closest to Earth for a one-month stay. Will you be able to see Earth? Will there be phases of Earth, as we see Moon phases? Explain. (HINT: use your observer and model.)

Part B – The Seasons

The Baroque composer Antonio Vivaldi wrote a pervasively familiar set of concertos called "The Seasons". Each of the set of four is devoted to one of the four seasons -- spring, summer, and autumn, winter. Concerto No. 1 mimics songs of birds, spring thunderstorms, and a spring zephyr. In the summer concerto, Vivaldi uses changes of meter (first 3/8 and later 4/4 time) to describe the exhaustion caused by the summer heat. Autumn, the season of harvest, Vivaldi uses the motifs of a tribute to Bacchus -- God of Wine -- via a feverish dance and The Hunt using the horns to herald the event. In Concerto No. 4, the frigid winds blow in an almost melodyless illustration.

The Venetians of Vivaldi's time all understood the effects and moods of the seasons, but how did they come about? In this activity, we look closely at an explanation.

First, we must dispel an old misconception. Figure 11 shows a sketch of Earth's orbit from a top view far above the sun. The orbit of Earth is not a perfect circle, it's a 'squashed circle'; the orbit is slightly elliptical. However, the 'squashed-ness' of the orbit -- its *eccentricity* -- is greatly exaggerated in Figure 11. **The common misconception is that when Earth is at point A (where it is closer to Sun) it is summer on Earth.** If you have ever gone to South America or Australia in January (our winter), you would discover it is summer there! The misconception would have it summer in both the northern and southern hemispheres when Earth is closest.

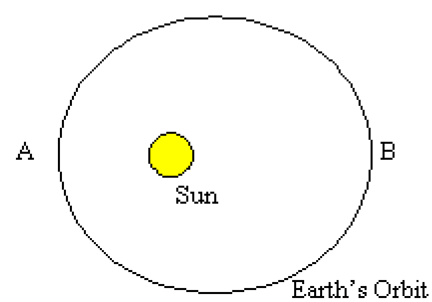


Figure 11

The common misconception fails on another point. The orbit of our planet is so close to a perfect circle that you probably cannot draw a circle on paper more circular than Earth's orbit -- not even with a compass! The *eccentricity* of Earth's orbit is 0.0167. The *eccentricity* of perfectly circle is zero, whereas a 'flattened circle', flattened until it is just a line, has an *eccentricity* of one. The eccentricity of our orbit is much closer to zero than to one, nearly a perfect circle.

Activity 1: Investigate differences in the surface temperature of Earth at the equator and poles.

1. If the shape of the orbit is not the reason for seasons (see pg 1.9), briefly speculate on why you think the Earth heats up more at the equator than near the north or south poles.

Many people have the conception that the Polar Regions are cooler than the equator because they are further away and therefore the Sun's energy is "weaker" when it strikes the Polar Regions. Let's explore this reasoning.

2. The Sun is 93,000,000 miles away from the equator. The radius of Earth is a little less than 4000 miles. How much further (in percent) does the energy of the Sun have to travel before reaching the polar region? (4,000 is what % of 93,000,000?) Show your calculations.

3. How important do you think this added distance (4,000 miles) is in temperature between the poles and equator? (Consider the value calculated in question 2 above, the percent difference in distance.)

Now examine a model of Sun's energy striking Earth. A light is positioned several inches away from the equator of a globe. With a piece of graph paper, measure the area of light striking the globe at the equator and at the polar region.

4. Are the two areas equal?

5. Now suggest a reason why the poles may be cooler than the equator regions. HINT: Remember the graph paper from your model above. Or see Figure 12, and note the shaded bands of incoming radiation at the equator (middle band), and in high latitudes (upper and lower bands).

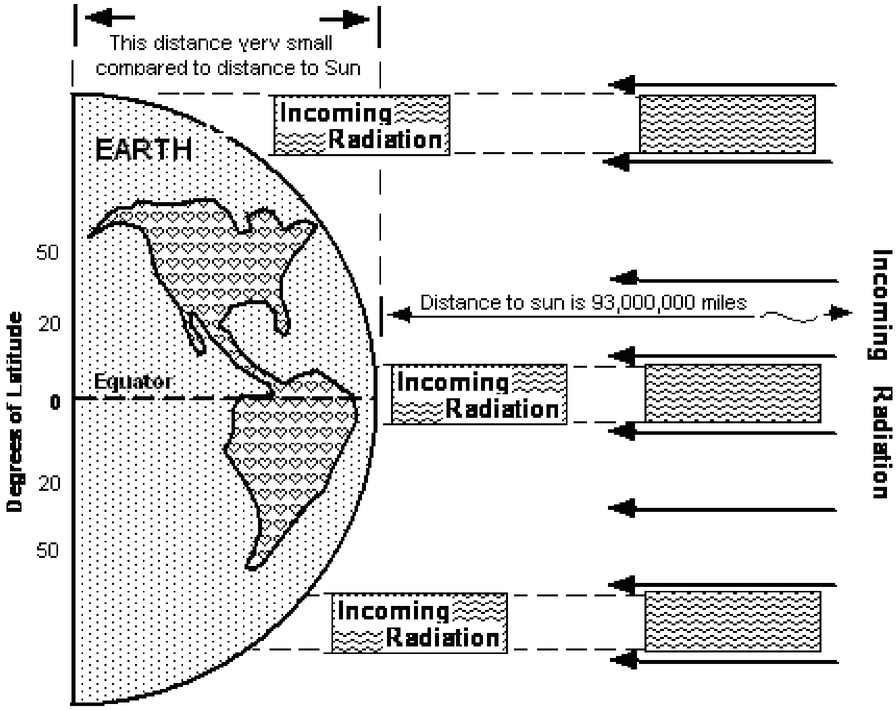


Figure 12: Schematic representation of Earth-Sun system emphasizing input of solar radiation. Earth's radius is about 4000 miles.

Activity 2: Model of Earth's seasons

Use a 'globe and a lamp to 'build' a Sun-Earth system model. The model will not be to scale. It should look something like Figure 13 below.

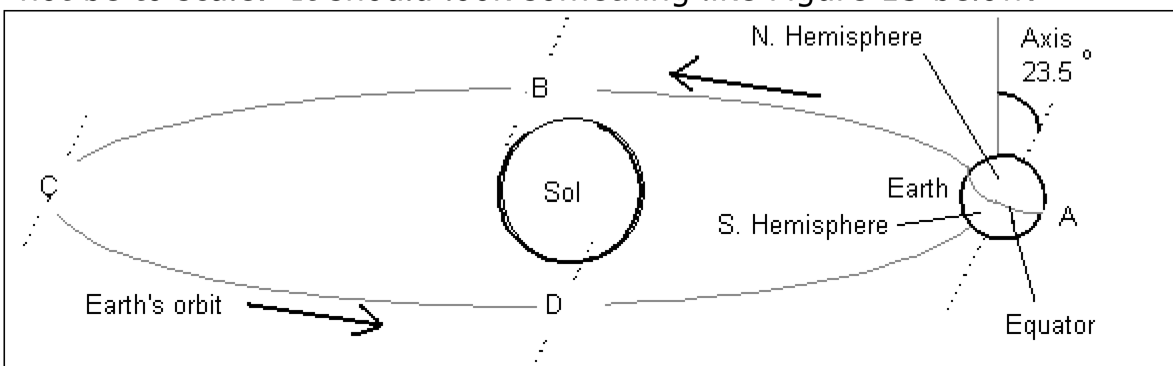


Figure 13: A perspective view of the Sun-Earth system. *Sol* is the official name of our star according to the ASA star registry.

Successively place 'Earth' at locations A, B, C, and D. **Note that the direction of the tilt of the axis of Earth should not change. The axis will always lie along the same line as indicated.** (This is a result of conservation of angular momentum -- it is the same reason why the axis of a gyroscope will always tend to point along the same line.). Deduce what season it must be in the northern hemisphere.

Questions:

1. Complete the table using your observations:

Location of Earth in Figure 13	Season in the Northern Hemisphere	Season in the Southern Hemisphere
A	.	.
B	.	.
C	.	.
D	.	.

2. At which location(s), A, B, C, and/or D, does more direct or concentrated sunlight (and therefore more infrared radiation) hit the surface of Earth at the following places?
   Monmouth, Oregon The Equator

3. Why do the northern and southern hemispheres have opposite seasons?

Activity 3: Examine the two models provided, Model A and Model B. Complete the table by answer the questions for each model.

	MODEL A	**MODEL B**
What does the model demonstrate?		
List each part of the model, and indicate what it represents.		
What is distorted or "misrepresented" in this model? What are its limitations?		

Name_______________________________________

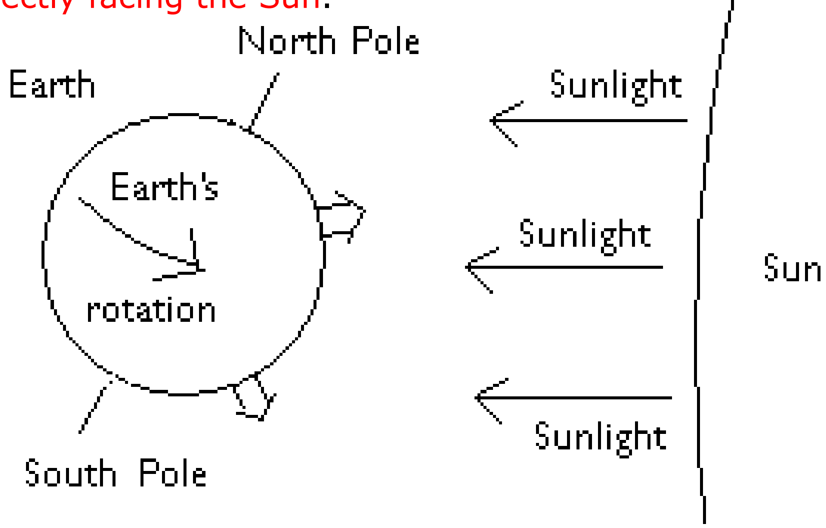
Lab day _______Lab Time_______________________

POST-LAB ASSESSMENT

No scientific hypotheses or models represent all aspects of a system with 100% accuracy. To make systems understandable, all scientific models and hypotheses make simplifying assumptions. These simplifying assumptions can often lead to shortcomings of a model. Consider the model of the Sun-Earth-Moon system that you used to understand the phases of Moon.

1. How often does this model predict that solar eclipse and lunar eclipses should occur?
2. What simplifying assumption in our model results in this erroneous prediction?
3. How could you revise the model to make its predictions of eclipses more accurate?

4. Imagine that you want to power your home in Monmouth using solar energy. In order for your solar panels to collect as much energy as possible, what direction should your solar panels face (north, south, east, or west)? ____________________________
On the picture below, note a house in Monmouth, draw the solar panels on it on the side of Earth most directly facing the Sun, to justify your answer. If you lived in Australia, what side of your house should have the solar panels? __________________
Include the solar panels on the Australia house, also on the side most directly facing the Sun.



ES 104 Laboratory # 2
INVESTIGATING THE SOLAR SYSTEM

Introduction

We have sent unmanned spacecraft through the solar system, landed robot space probes on Mars, Venus, and the Moon, have landed people on the Moon, and have sophisticated telescopes to obtain data. We know that each planet and satellite (moon) has unique physical characteristics that set them apart from one another. We also know our solar system exhibits some regular patterns. During this laboratory you will try to discover some of these patterns. Much of the numerical data about our solar system, such as planetary size or distance from the sun, is so large that you will need to work with scale models. By studying planetary data we can compare and contrast conditions on other planets and their satellites (moons) to those of earth.

Goals and Objectives

- Describe similarities and differences among planets of our solar system
- Create scale models and make sketches that reasonably portray observations of components of the solar system
- Create graphs to communicate and interpret data from a variety of sources
- Use internet resources which contain current information on the solar system and cosmos

Useful Websites

- http://www.nineplanets.org
- http://pds.jpl.nasa.gov/planets
- http://photojournal.jpl.nasa.gov/index.html
- http://www.noao.edu/

Name____________________________________

Lab day ______Lab Time_____________________

Pre-lab Questions – Complete these questions before coming to lab.

1. Define the Astronomical Unit (AU).

2. If the distance from Monmouth to Washington D.C. is 2870 miles, convert this distance to units of AUs.
   (Show calculations with units.)

3. List the planets in order of increasing distance from the sun.

4. What are the three types of materials that make up the planets?

5. Which planet is the largest in the solar system?

6. Which planet is covered in liquid water?

7. Which planet is the hottest planet?

Part A – Scale Model of The Solar System

An *astronomical unit*, AU, is the average distance the Earth is from the Sun. That distance is 93,000,000 miles, 8.3 light-minutes, or 150,000,000 kilometers. It is convenient to work with AUs because the real distances are in numbers that can be cumbersome to deal with. Table 1 below shows the mean distance of the planets from the Sun (orbital distance) in AUs. Alternatively, you might find the orbital distances in terms of light-minutes more illuminating (pun intended). Choose which system of units you feel more comfortable with.

Your group will construct a scale model of the solar system based on average distance to the Sun. Your model must fit in the hallway (54 meters long), the classroom, or outside (weather permitting). You must decide the scale you will use for your model. (HINT: a good scale to start with is 1 AU = 3 floor tiles)

Table 1: Solar System Data

Planet	**Radius of Planet** (Kilometers)	**Mean Distance from the Sun** (AU)	**Radius of Planet** (millionths of AU)	**Mean Distance from the Sun** (Light-Minutes)
Mercury	2439	0.39	16	3.25
Venus	6052	0.72	40	6.00
Earth	6378	1.00	42	8.33
Mars	3393	1.52	23	12.6
Jupiter	71,492	5.20	477	43.3
Saturn	60,268	9.54	402	79.5
Uranus	25,559	19.20	170	160
Neptune	24,766	30.10	165	250
Pluto *	1137	39.40	8	328
Sun	696,000	N/A	4,640	N/A

*The IAU has changed the definition of "planet" so that Pluto no longer qualifies. There are now officially only eight planets in our solar system. Of course this change in terminology does not affect what's actually out there. It is much smaller than any of the official planets and now classified as a "dwarf planet". Pluto is smaller than seven of the solar system's moons (the Moon, Io, Europa, Ganymede, Callisto, Titan and Triton), is composed of about 1/3 ice, and has a highly eccentric orbit. http://www.nineplanets.org/ 9-7-2006

Questions:

1. What scale did you use for your distance?

2. What pattern did you notice about the spacing of the planets from the Sun?

3. Draw a sketch of your model (with spacing **generally to scale**) below.

4. What general pattern did you notice about the relative sizes of the planets?

5. Which planets have the greatest number of satellites (moons)? Note that not all of the satellites in our solar system are shown. In fact new satellites are being discovered every few years.

Table 2: Planet Data

	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto*
Mass ($\times 10^{24}$ kg)	0.3302	4.869	5.975	0.6419	1,898.6	568.46	86.83	102.43	0.0125
Radius (km)	2439	6052	6378	3393	71,492	60,268	25,559	24,766	1137
Mean Density (kg/m^3)	5,427	5,204	5,520	3,933	1,326	687	1,318	1,638	2,050
Orbital Distance (10^6 km)	57.9	108.2	149.6	227.9	778.3	1427.0	2869.6	4496.6	5913.5
Orbital Period (days)	87.969	224.7	365.25	686.98	4330.6	10,747	30,588	59,800	90,591
Rotational Period (hours)	1407.6	5832.5	23.934	24.62	9.92	10.5	17.24	16.11	153.3
Ave. Surface Temperature (Kelvin)	440	737	288	210	165	134	76	72	50
Surface Pressure	10^{-15} bars	92 bars	1.014 bars	0.008 bars	>>100 bars	>>100 bars	>>100 bars	>>100 bars	3 micro-bars
Atmospheric Composition	98% He 2% H2	96.5% CO_2, 3.5% N_2	78% N_2, 21% O_2, 1% H_2O	95.32% CO_2, 2.7% N_2	90% H_2, 10% He	96% H_2, 3% He	83% H_2, 15% He 2% CH_4	80% H_2, 19% He 1% CH_4	methane & N2

Table 3: Density of Common Materials.

Material	Density
Air	1.2 kg/m^3
Water or Water-Ice	1000 kg/m^3
Typical Rocks	3000 kg/m^3
Metal at High Pressure	10,000 kg/m^3

*see footnote page 2.3

Part B – Classifying the Planets

Study the solar system information in Table 2. The table provides information scientists believe to be true about the planets in the solar system based on the latest technology to help them. By looking carefully at the data in this table you should be able to find some patterns, similarities, and differences among the planets in our solar system. **The following questions will assist you in thinking about what is considered a pattern, similarity, and difference.**

Questions:

1. Which planet would float in water? ________________________
   (***Hint***: Less dense objects float in denser fluids.)

2. How long is a day on Jupiter? __________, (answer in Earth hours)

   on Venus? ________________, on Mars? ________________

3. How many Earth years go by before one Mars year has passed? ___
   Show work here.

4. Which two planets account for 90% of the total mass of all of the planets?

________________________ and ___________________________

5. Which planet seems unusually hot, considering its distance from Sun?

____

By looking at the data in table 2, suggest a reason for this extreme high temperature.

You should also look over Table 3 which contains density information and investigate densities of the air, water, rock, and lead ore samples (lead ore approximates the density metal at high pressure). Because all of the samples have the same volume, you can investigate the effect of density directly by picking each one up and comparing their masses.

6. Compare the density of materials to the density of water. (Density = Mass/Volume and the samples chosen all have similar volumes). Pick up each sample and guess how its density compares to water. For each sample, note in the spaces below how many times larger or smaller you think the density is compared to water.
   a. Air seems to be ______________________ times **less dense** than water.
   b. Rock seems to be ______________________ times **more dense** than water.
   c. Metal at high pressure seems to be ______________________ times **more dense** than water.

7. How do your guesses compare to Table 3?

8. What estimates can you make about the bulk composition of each planet **based upon its density**? Table 3 provides information about the density of common materials found on Earth. Compare the **density** of metal, rock, water ice, and gas (in table 3) to the *mean density* of each planet **from table 2**.

(HINT: You can answer in terms of *mostly* metal, rock, ice, or gas; or *combinations* of these.) ***Rely on tables 2 and 3****; not other information.*

Table 4:

Planet	Deduced Composition
Mercury	.
Venus	.
Earth	.
Mars	.
Jupiter	.
Saturn	.
Uranus	.
Neptune	.

On page 2.9, make four tables: each table should contain all of the planets, and be based on a different property of the planets. Use properties of the planets (in table 2) to group them into general categories. Write the property used for the classification in each table, and column headings for how you divided the planets using that property. For example, using the property of density, you could place the planets into two groups, *high density planets* and *low density planets*. Or perhaps the density data suggests that low, medium and high density groupings are more appropriate. Let the data be your guide to the number and types of groups that a particular property requires. (*The tables are not lists in an order, but divisions into groups of similar characteristics, based on the properties of the planets.*)
Write any general statements you can draw from your study of properties that could be cited as patterns in the solar system.

Part C – Graphing Planetary Data
Sometimes graphs can give you a different perspective about data that reading a table cannot. In this activity you will graph selected data from Table 2 (page 2.5). Graph paper is provided at the end of this lab (on pages 2.11 and 2.12), or you can use a spreadsheet to make a chart.
Activity: Choose one of the data sets below from Table 2

- _______________Mean Density vs. Orbital Distance from Sun
- _______________Surface Temp. vs. Orbital Distance from Sun
- _______________Orbital Period vs. Orbital Distance from Sun
- _______________Rotational Period vs. Orbital Distance from Sun
- _______________Mass vs. Orbital Distance from the Sun

Each person in your group should make a different graph of one of these sets of data. Write the person's name next to their choice. When you are completed, present your graph and your conclusions about your graph to the rest of the members of your group. On the back of this sheet, *report the topic and results of **each** graph* (the conclusions presented by your group member). Consider the following questions: What does each graph tell you? Is there a relationship between the two quantities being graphed? If a relationship exists, try to construct an explanation for the relationship. Also, be sure to include your graph and your conclusions with your report.

Write the name of the property used to categorize the planets.
Subdivide each area to categorize the planets based on properties

Table A: ___________________	**Table B: ___________________**
Table C: ___________________	**Table D: ___________________**

General Statements about categories:

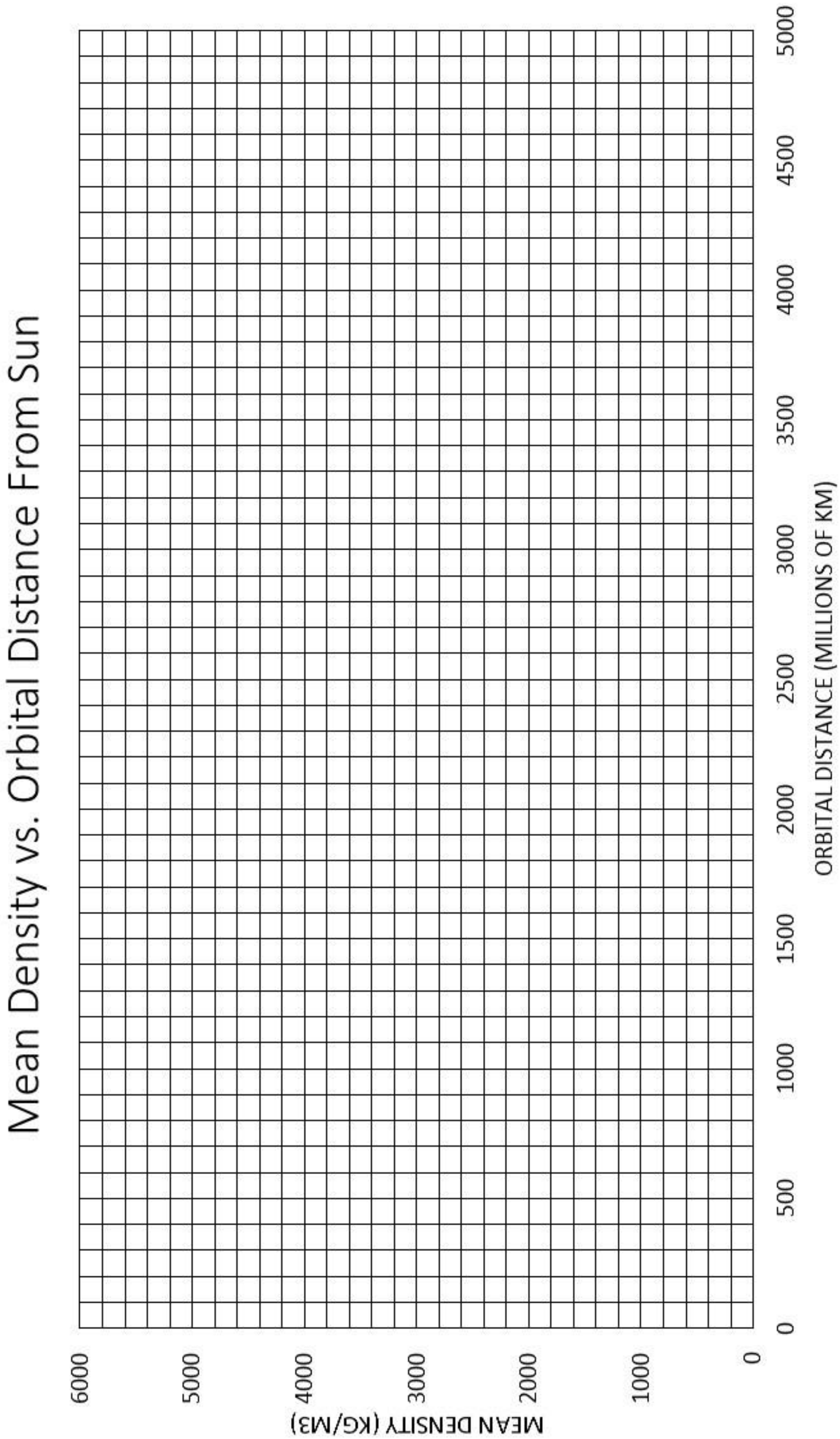
Name_______________________________________
Lab day _______Lab Time_______________________

POST LAB ASSESSMENT

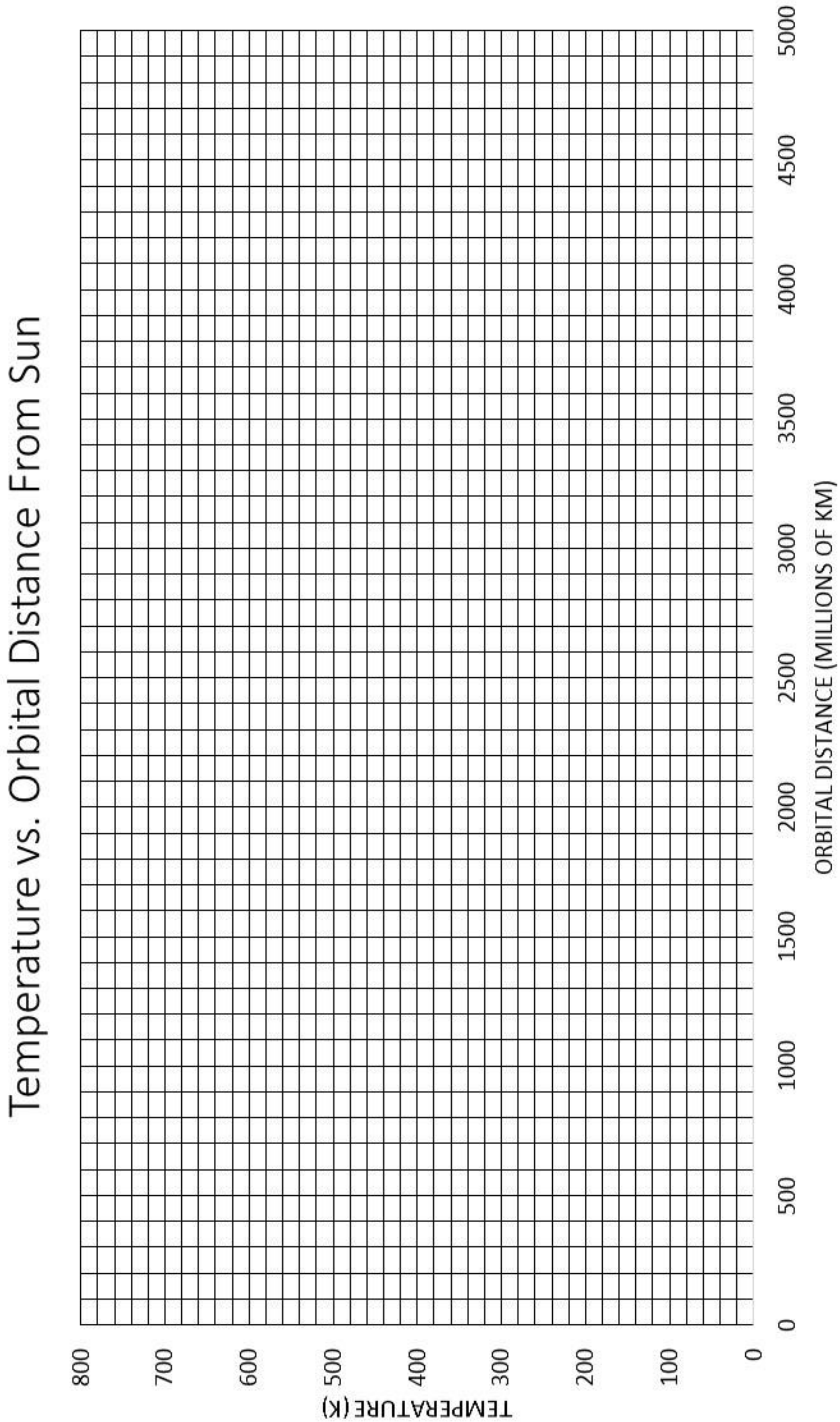
1. Consider the uniqueness of Earth compared to the other planets in our solar system. Make a table that identifies the characteristics Earth shares with other planets and characteristics that are unique to Earth.

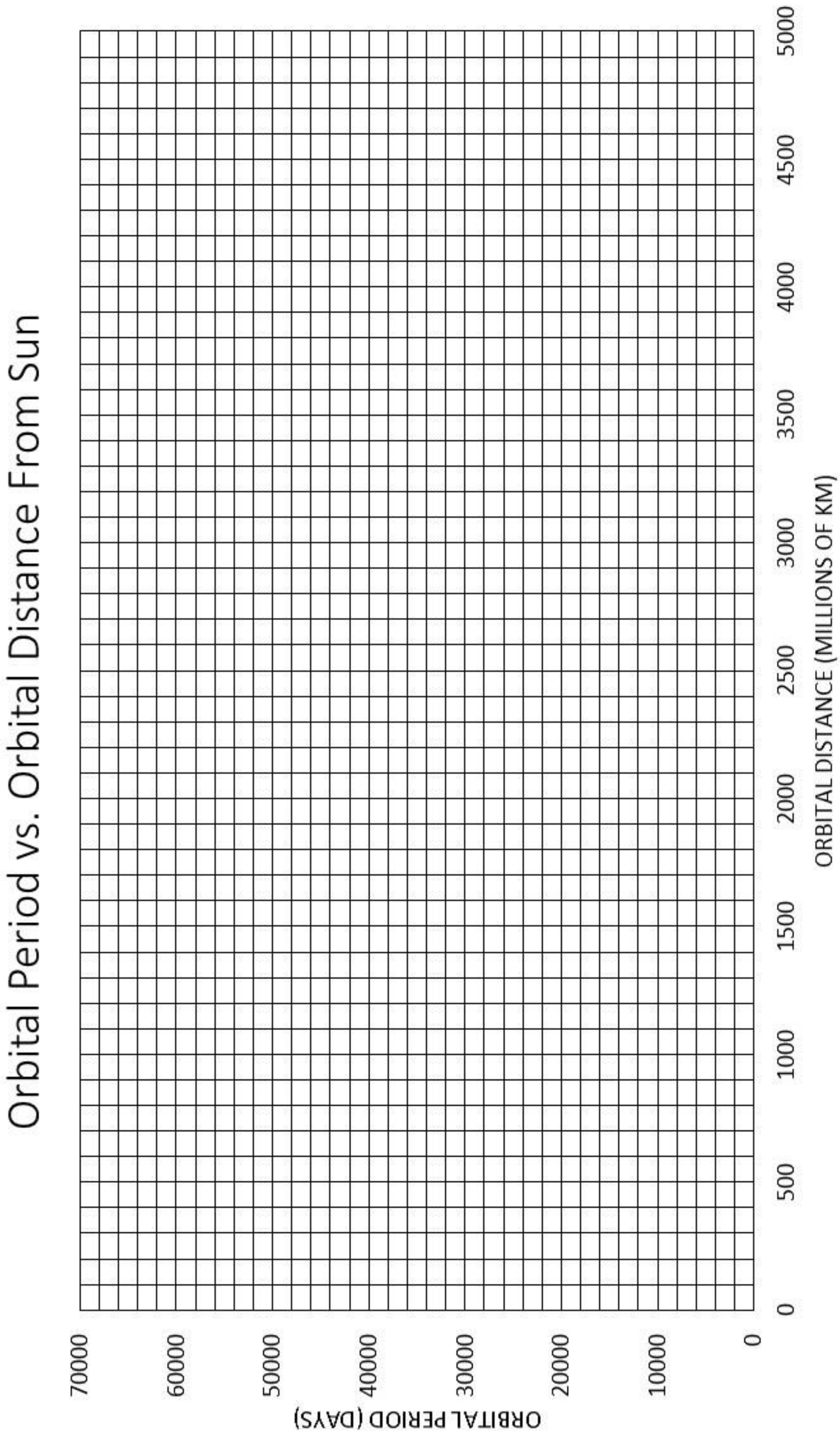
Earth Characteristic	Planets that share this characteristic with Earth	Planets that are different in this characteristic
Mass		
Density		
Atmospheric composition		
Another characteristic (write your choice)		

2. In the past two labs, you have explored information in a number of ways: physical models, pictorial models (sketches/diagrams), data tables and graphs. Which did you find most useful in your investigations, and why do you think it was useful for you?



Mean Density vs. Orbital Distance From Sun
MEAN DENSITY (KG/M3)
0
1000
2000
3000
4000
5000
6000
ORBITAL DISTANCE (MILLIONS OF KM)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000


Temperature vs. Orbital Distance From Sun
TEMPERATURE (K)
800
700
600
500
400
300
200
100
0
ORBITAL DISTANCE (MILLIONS OF KM)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000


Orbital Period vs. Orbital Distance From Sun
ORBITAL PERIOD (DAYS)
0
10000
20000
30000
40000
50000
60000
70000
ORBITAL DISTANCE (MILLIONS OF KM)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

Additional Assignment: Solar System Investigation

Information about the cosmos as well as understanding of the cosmos is changing at a very rapid pace. To incorporate the latest knowledge (facts), ideas, and theories about the universe, it is necessary to access the latest information available. There are many excellent internet sites available with current information which is updated regularly. You will be assigned a cosmic body or phenomena to be investigated using one or more of these internet sites. To access your information use an internet search engine of your choice and key in specific terms such as: astronomy and (your assigned topic).

Next week (lab meeting) you are required to turn in a 1-2 page PRINTOUT OF THE INFORMATION OBTAINED and give a 1-2 minute oral presentation to the lab-class covering the information. BE SURE TO FOCUS ON RECENT INFORMATION, but also include a summary of what is currently known about your assigned cosmic body.

Note; occasionally two students will be assigned the same cosmic body…so be sure to touch base with your colleague so as not to repeat information during the oral talk.

POSSIBLE COSMIC TOPICS

Sun______________________
Mercury__________________
Venus____________________
Earth's Moon _____________
Mars______________________
Mars Moons ______________
Jupiter___________________
Jupiter Moons____________
Saturn___________________
Saturn Moons____________
Uranus___________________
Uranus Moons____________
Neptune_____________________
Neptune Moons______________
Pluto_________________________
Kuiper Belt__________________
Asteroids____________________
Comets______________________
Meteorites___________________
Stars _________________________
Black Holes__________________
Galaxies_____________________
Nebulae _____________________
Hubble Telescope____________

ES 104 Laboratory # 3
LIGHT AND THE ELECTROMAGNETIC SPECTRUM

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 Expedition Rovers, 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 from that beautiful light? This week we explore the major aspects of how astronomers use light to explore strange new worlds.

Goals and Objectives

- Gain an understanding of what sorts of information astronomers have available to them from the stars.
- Become familiar with the role and importance of making astronomical observations and how they are made.
- Learn about some basic wave properties with regards to light.
- Learn about fluorescence and ways in which it is used.

Useful Websites

- http://www.lon-capa.org/~mmp/applist/Spectrum/s.htm
- http://mo-www.harvard.edu/Java/MiniSpectroscopy.html
- http://www.school-for-champions.com/science/sound.htm
- http://imagers.gsfc.nasa.gov/ems/waves2.html
- http://archive.ncsa.uiuc.edu/Cyberia/Bima/spectrum.html

Name____

Lab day _______Lab Time________________________

Pre-lab Questions – Complete these questions before coming to lab.

Define the following terms and answer the questions:

1. Frequency

2. Wavelength

3. Period (in relation to waves, not geologic time!)

4. What is the speed of light in **meters** per second?

5. How far is Earth from Sun in miles? How far is Earth from Sun in kilometers?

6. The equation for velocity is v=d/t (distance over time). If you were traveling at the speed of light, how long would it take you to get from Sun to Earth in minutes? (Show your calculations, with units.)

7. What conditions are necessary to produce continuous, absorption, and emission spectra?

Light and Light Sources

There are billions upon billions of stars in the sky yet, due to their distance, the only star we can visit is our Sun. This distance, however, does not prohibit us from learning a considerable amount of information about these stars. Our primary source of this information is the electromagnetic (EM) spectrum, of which visible light is just a small but important slice that we can perceive with our human eyes. Also included in the EM spectrum are different frequencies that our eyes cannot perceive, such as gamma rays, x-rays, ultraviolet rays, infrared rays, microwaves, and radiowaves. Just as our human eye is sensitive to only a portion of this spectrum, our telescopes are only sensitive to particular portions of EM spectrum as well. Thus, we end up with infrared telescopes, visible light telescopes, ultraviolet telescopes, and so on.

When we investigate the universe in the EM spectrum we find that there are many different ways in which light can be produced and altered. Some examples of light that we encounter in everyday life that are produced in very different ways include sunlight, the light from incandescent bulbs, fluorescent tubes, and "neon" lights. All of these light sources produce light in different ways. Incandescent lamps emit light because of the temperature of the lamp filament, resulting in what we often call a "warm" light. Fluorescent lamps emit a "cool" light because the emission process is different from that of incandescence. The same photograph taken under incandescent light will look very different from that taken under fluorescent light because of these differences (and are often "corrected" by settings in the camera or in software afterwards). In addition, objects will also look different in sunlight due to the different frequencies of light contained in the solar spectrum.

Incandescent Bulb
Continuous Spectrum

Gas Discharge Tube
Emission Spectrum

When light from an incandescent bulb is viewed through a very fine grating or a prism, we see characteristic bands of color that we call the spectrum of the light. The spectrum we see emitted from an incandescent bulb consists of colors that blend into one another through a continuous spectrum of red-orange-yellow-green-blue-indigo and violet (ROYGBIV). This continuous spectrum has no colors missing.

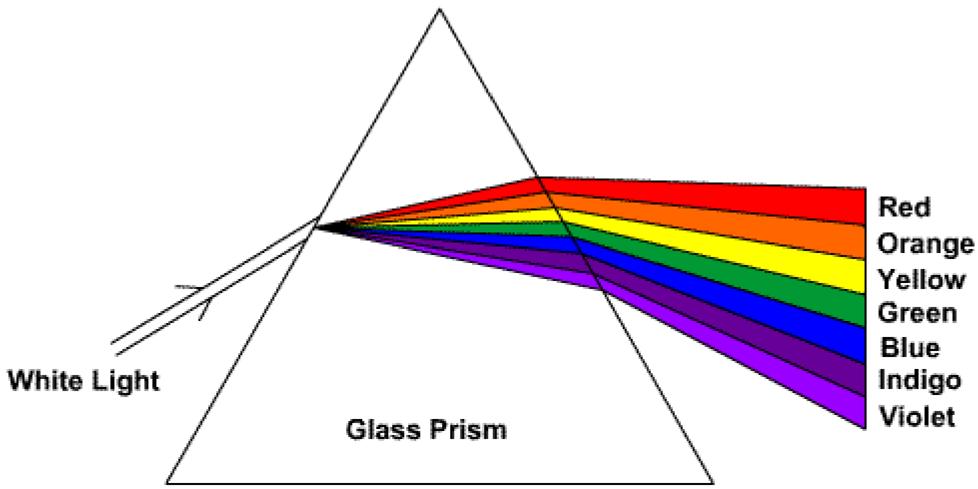


Figure 1. The continuous spectrum produced by white light such as that produced by an incandescent bulb. (Image courtesy of www.school-for-champions.com)

When we investigate the spectrum emitted by most stars, we see a nearly continuous spectrum, but one that has a series of black bands within that spectrum. Those black band indicate section of the continuous spectrum that are being blocked by something or many somethings. The “somethings” creating those black bands are elemental gases within the outer portions of the star. Through laboratory analyses we have found that each element blocks (or filters out) specific frequencies of light. Each element always blocks out the same light frequencies. Thus, each element has something of a unique “bar code” that it creates when filtering a continuous light source. Scientists can use this “bar code” to identify which elements are present in distant stars. This nearly continuous spectrum with missing black bands is known as an absorption spectrum (also sometimes known as a dark line spectrum).

Another way of producing light is to energize a gas at low pressure. We can do this by putting the gas in a glass cylinder and, by having electrodes at both ends; we pass high voltage electricity through it. The result is a glowing tube of gas with a specific color. True neon bulbs yield a characteristic reddish-orange glow, and are often used for advertising signs in store windows. If, however, you see other colors of glowing gas in those advertising signs, this indicates the use of a gas other than neon. If we look at this glowing gas through a prism or grating, just as we did our other light sources, we get a very different spectrum. This emission (also known as bright line) spectrum typically consists of just a few bright lines within a predominantly black background. Just as the absorption spectrum of a particular element yields a unique "bar code" that allows us to identify it, the emission spectrum of a particular element yields a unique "bar code" of bright lines. In fact, we find that the absorption and emission spectra of a particular element are reverse images of each other. (Fig. 23.3, p. 697, *Earth Science,* Tarbuck and Lutgens, 14^{th} ed.).

Part A – Investigating Light Spectra

Procedure:
Go to http://phet.colorado.edu/sims/black-body-radiation/black-body-radiation.swf and run the simulation called "Blackbody Spectrum". (Use Internet Explorer or Firefox to launch).

This simulation has you look at graphs of Intensity vs. Wavelength for the emissions from materials at various temperatures. Virtually every object in the universe is emitting a range of wavelengths from the EM spectrum (including you and me!). In this exercise you will look at range of emissions including the Sun (very hot) to the Earth (relatively cool). As you change the temperature (using the slider or entering a number in the box) you will see the graph change. The peak of the graph is maximum intensity of emissions for that object and corresponds to a particular wavelength. Even though we may perceive visible light from an object, the color or colors we see may not necessarily correspond to the maximum EM wavelength being produced by that object. For example, we may see light from an object yet its peak electromagnetic emissions may be in the UV or IR wavelengths.

Note: You may need to use the + & - controls to get the intensity graph to fit on the screen.

1. Set the temperature slider to approximately 5800K (Kelvin) which equates to the temperature of the sun.

a. Find the wavelength of the peak of the intensity curve: _______ µm

b. What color(s) does this correspond to? ___________ ___________

c. Sunlight usually appears yellowish to us. Does this make sense in terms of this graph?

2. Now set the temperature slider to the level of **light bulb**. This simulates the spectrum emitted by a typical incandescent light bulb.

a. What is the temperature of the light bulb? ________________K

b. The peak intensity corresponds to which wavelength? ____________μm

c. Does this peak correspond to visible light?Circle one:**YES NO**

d. If the peak is at wavelengths longer than visible light, then it is probably in the infrared (IR) region of the EM spectrum. If it is at wavelengths shorter than visible light, then it is in the ultra-violet (UV) region. IR radiation is typically equated with heat. <u>How efficient is this light bulb in providing visible light? What type of energy does the light bulb primarily produce?</u>

3. Set the temperature slider to Earth. Yes, Earth has its own characteristic temperature as well.

a. What is the characteristic temperature of Earth? ______________K

b. What is the associated wavelength of this temperature (peak?)

___________ μm (<u>you will need to **zoom out on the horizontal scale** and **zoom in on the vertical scale** to see this peak</u>).

c. In what region of the spectrum (uv, visible, infrared) would you need to have a detector to measure the temperature of Earth?

Part B – Ultraviolet Light and Fluorescence

Fluorescence is a term we encounter every day; in things like fluorescent lights, fluorescent highlighting pens, etc.; but what is it? This section will allow us to look at how fluorescence is created, some examples of fluorescence, and ways in which fluorescence is used. Though fluorescence can occur with a variety of wavelengths, one common and useful example is when ultraviolet radiation (which is out of the range of visible human perception) is shifted into slightly longer wavelengths and yields visible light.

Webster's dictionary defines fluorescence as "the emission of radiation, especially of visible light, by a substance during exposure to external radiation, as light or x-rays." The key concept here is that some form of EM radiation of one wavelength interacts with a material which then re-emits that radiation at a different wavelength. The re-emitted wavelength is often slightly longer in wavelength than the original source, though there are a few exceptions to this generalization. Fluorescence is different from reflection, in which a material bounces back the same wavelength it has received.

We most frequently hear the term "fluorescent" in reference to the lights that we use in the office and home. So what is fluorescent about them? Strange as it may seem, the EM radiation in a fluorescent tube does not start as visible light. By passing high voltage electricity through the tube, mercury vapor is energized until it emits EM radiation. The EM radiation thus produced is primarily within the ultraviolet spectrum and cannot be perceived by the human eye. Invisible UV radiation would not be very helpful for helping illuminate our homes, so something needs to happen in order to produce visible light! The key is the phosphor coating bonded to the glass of the fluorescent tube. Every fluorescent tube you have ever observed has some sort of white-ish coating on the glass. That coating interacts with the UV light and, through fluorescence, shifts the wavelength into the visible spectrum. This produces the light that we can use.

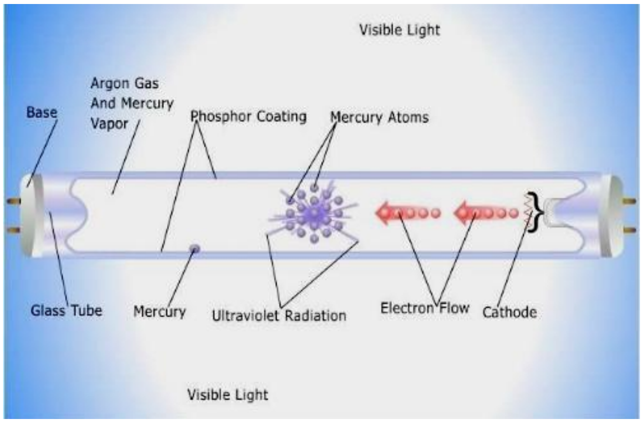


Figure 2. Schematic of a typical fluorescent tube.

One of the first examples of fluorescence observed by scientists was by the mineral fluorite which, as you might expect, glows when exposed to under UV radiation. The term "fluorescence" was named after this property of fluorite. Many other minerals display this quality as well. In addition, many organic materials also exhibit fluorescence. Those of you who watch detective shows on television may be familiar with investigators using UV lights at the scene of a crime to help detect various bodily fluids. Biologists and enthusiasts of scorpions also use UV lights to detect them at night (most scorpions are nocturnal hunters). Because of the composition of their bodies, scorpions exhibit a characteristic blue-green glow when observed under UV light.

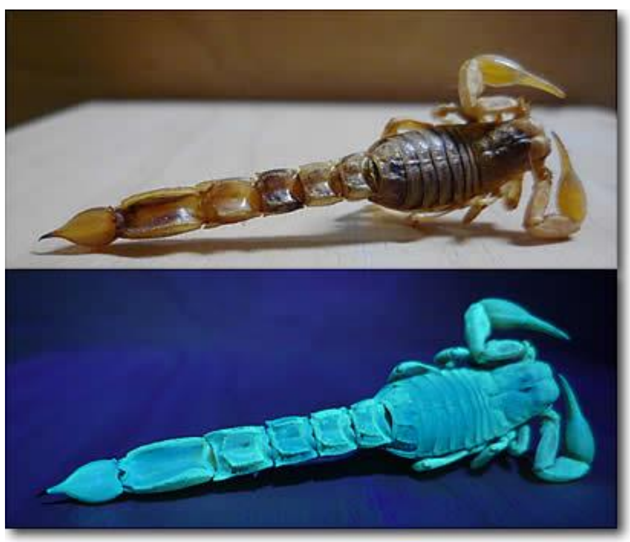


Figure 3. A scorpion under visible light (top) and under ultraviolet light (bottom). The blue-green glow of scorpions under a "black" light is a result of fluorescent compounds shifting the wavelength into the visible spectrum.

Activity 1: Ultraviolet light

A so-called 'black light' is actually an ultraviolet light source. By ultraviolet, we mean light of a wavelength just shorter than the visible part of the spectrum.

1. Why does the poster glow with green light when it is illuminated with **invisible** light?

You may have also noticed that your clothing, particularly white clothing, glows when illuminated by a black light (an ultraviolet light source). This is because detergent manufacturers put fluorescent chemicals in laundry detergents. To demonstrate this fact, shine the black light on the sample of laundry detergent.

2. Why does including fluorescent chemicals in detergent make your clothes look 'whiter and brighter'?

3. Every summer we hear news reports that wearing a t-shirt does not provide very good protection from getting a sunburn. In fact, a new t-shirt directly off the store shelf only has a sun protect factor (SPF) of about 6 (which means you can stay out 6 times longer in the sun before burning than if you were not wearing the t-shirt). This probably conflicts with our own experiences, however, as most of us never even get a hint of a tan under our t-shirts, much less a sun burn. What those news reporters fail to tell their readers/listeners is that washing your t-shirt in standard laundry detergent 5-6 times will result in your t-shirt being approximately SPF 60. Why does washing your shirt increase its SPF factor?

Part C – White Light and the Visible Light Spectrum

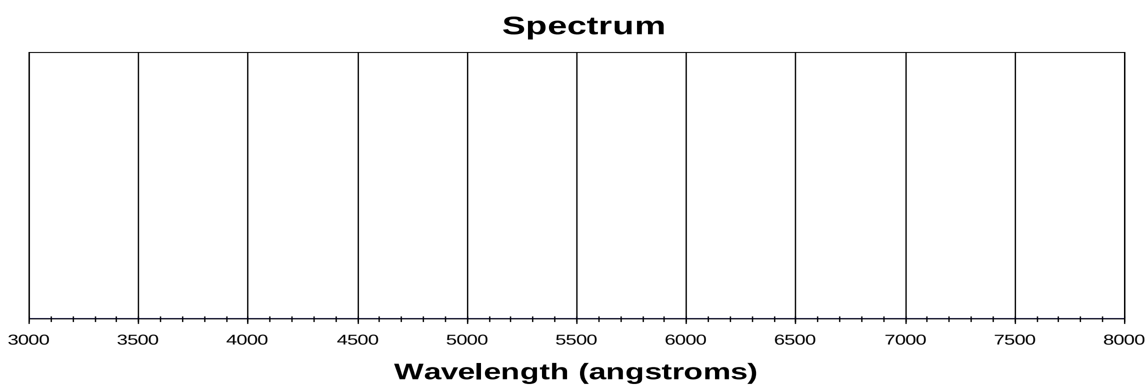
Light from the stars and planets can contain a wealth of information about the object it came from. It is not so easy to look at starlight, so we will have to be creative. This station consists of several light sources and a set of spectroscopes. A spectroscope splits light into its visible component wavelengths and measures the wavelength of the light waves. Your job is to measure the wavelengths present in each light source.

Activity 1: ROYGBIV Spectrum of incandescent tungsten lamp.
The **first source** is an incandescent tungsten filament lamp. With your instructor's help, use the spectroscope to view this source. You should see a *full spectrum* or range of visible wavelengths. Be sure to note that units in the spectroscopes are nanometers, and the wall charts are in angstroms. You will have to convert to compare these, using the following factor: 1 nanometer = 10 angstroms (e.g. 750 nanometers = 7500 angstroms).

Make observations of the incandescent filament lamp with the spectroscope. Record the ***range of wavelengths*** that comprise each color of light, in nanometers (billionths of meters). Red is done for you.

Red light from __750____ to ____640_____ nanometers
Orange light from __________ to ______________ nanometers
Yellow light from __________ to ______________ nanometers
Green light from __________ to ______________ nanometers
Blue light from __________ to ______________ nanometers
Violet light from __________ to ______________ nanometers

On the graph below, mark (in color) the appropriate ROYGBV wavelengths.



Activity 2: 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 spectra and deduce the star's composition.

PLEASE READ THE WARNING BELOW.

WARNING:

KEEP CLEAR OF THE LAMP WHEN IT IS OPERATING.

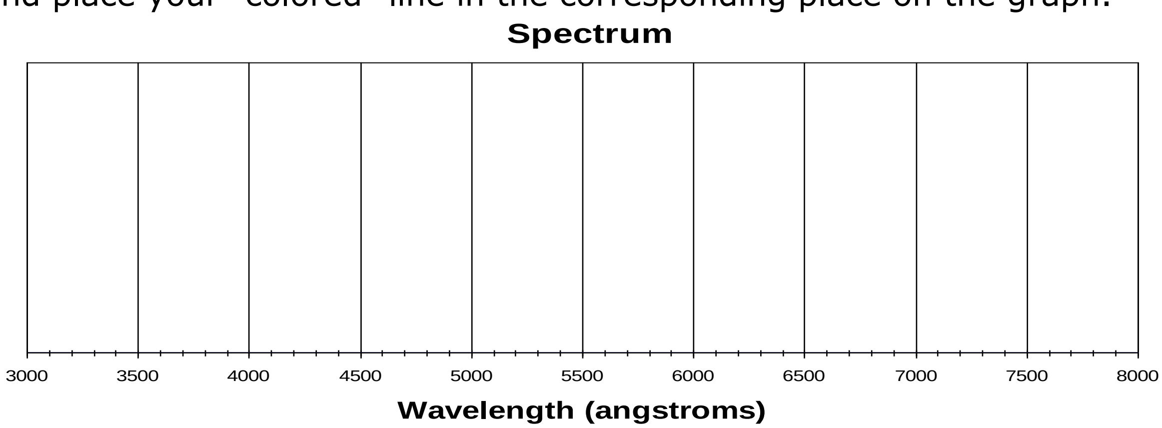
THE HIGH WATTAGE IS DANGEROUS.

TURN THESE LAMPS OFF UNLESS YOU ARE ACTUALLY USING THEM.

THE LAMPS HAVE A LIMITED LIFE. LEAVING DISCHARGE LAMPS when you are not using them MAY RESULT IN **DEDUCTION OF POINTS** ON YOUR LAB!

Alpha Star

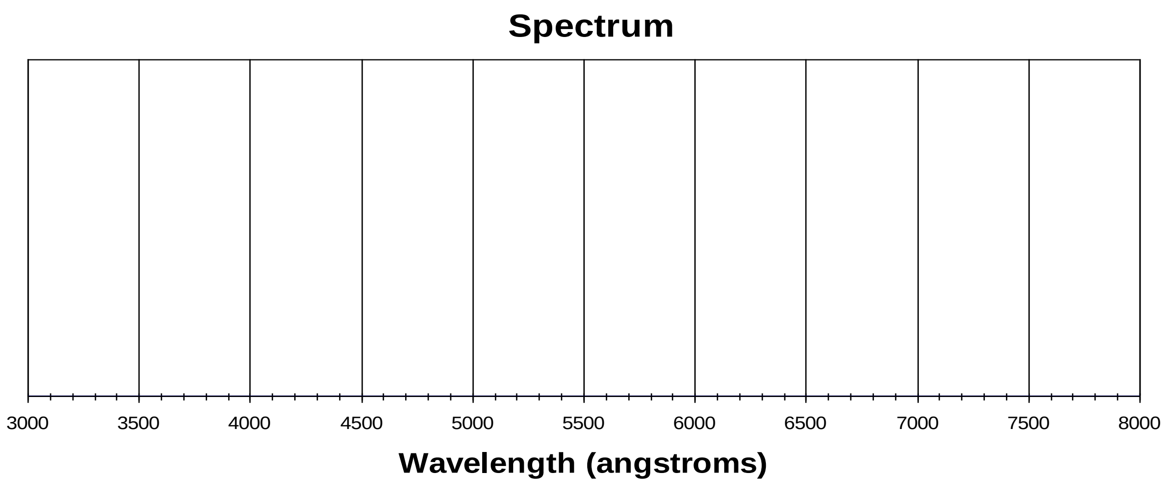
Turn on the discharge tube for **Alpha Star** (you are using the discharge tube as a model of an unknown star comprised of a **single** gaseous element). Make observations of the colors and placement of **Alpha Star's** spectrum. Record your observations on the graph below. Be sure to carefully observe the number (wavelength) under the colored spectral line and place your "colored" line in the corresponding place on the graph.



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

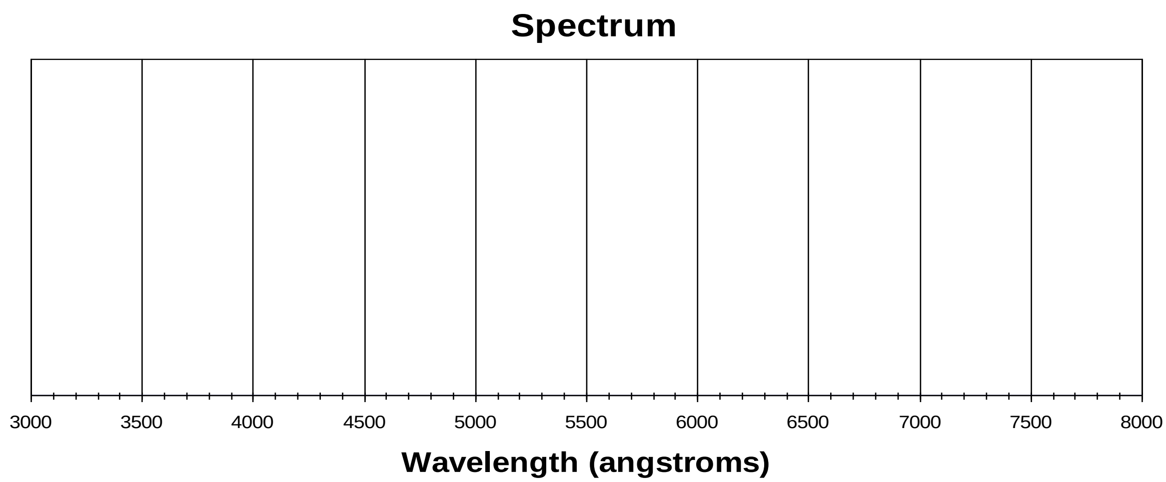
Beta Star

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). As above, 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. Be sure to maintain consistency with regards to where red is place (be it either at the right side or left side).

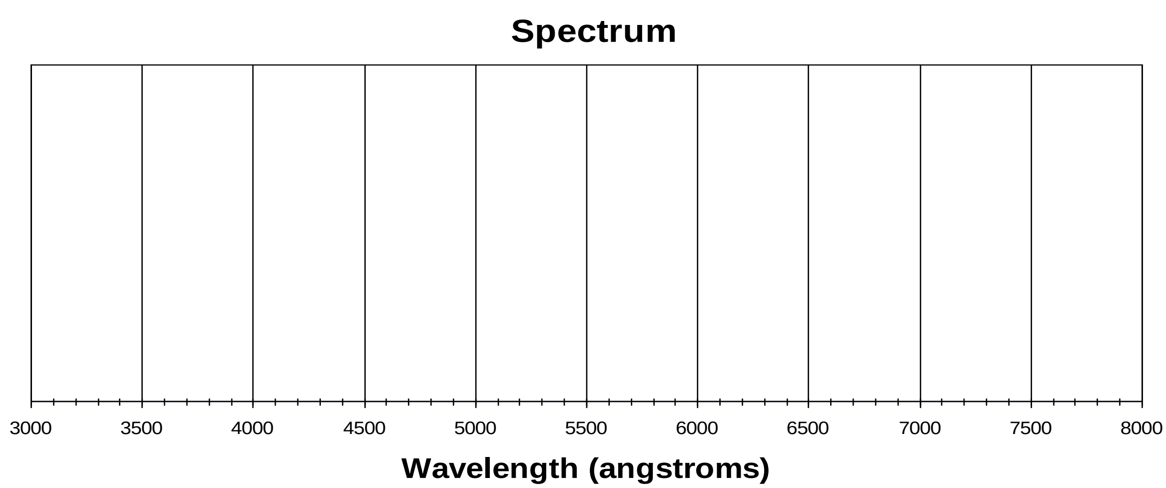


After drawing the spectrum of Beta Star, compare it to the chart of spectrums from known gases. **What gas do you think Beta Star is predominately made of?** If there is more than one possibility list them all. Explain your reasoning. How confident are you?

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



Fluorescent Star: Observe the fluorescent lamp through the spectroscope. Carefully record Fluorescent Star's spectrum on the graph below and compare it to the chart of known gases.



What gas do you think is inside a fluorescent tube lamp? (Perhaps it is a mixture, where Alpha Star and Beta Star were each only one gas. If you think so, list more than one element, and explain why you think this.)

Activity 3:

Compare two light sources of the same wattage: The wattage of the lamp tells you how much electrical power the lamp is consuming. Visually compare the brightness of the incandescent and fluorescent lamps. Why does the fluorescent lamp appear brighter than the lamp with the incandescent bulb? Consider the glowing material and its physical state (*Hint*: Hold your hand next to each lamp.)

Questions:

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

A *continuous spectrum* is one in which all wavelengths are represented (an uninterrupted band of colors). A *discrete spectrum* does not have **all** wavelengths represented; some wavelengths are missing. Your textbook described two types of discrete spectra: *bright line emission spectrum* (like the discharge tubes create) and *dark line absorption spectrum*. Look at the spectrum of the Sun on the poster from which you obtained the known spectrums of gases. Notice that the solar spectrum is missing discrete wavelengths (these are represented by black bands); it is a dark line absorption spectrum.

2. What relationship do you notice between the missing wavelengths from the solar spectrum and the emission spectrums of the gases on the chart ?

3. What does this tell you about the wavelengths at which each gas emits and absorbs light?

4. Based on the solar absorption spectrum, identify at least two gases present on the Sun.

Name______________________________________

Lab day _______Lab Time_______________________

POST LAB ASSESSMENT

1. Some special forces units in the military are instructed to not use laundry detergent that has "brighteners" in it. Why would they be given these instructions? (consider our investigations of laundry detergent in this lab).

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

3. Suppose that someone gave you a sample of an unknown gas. How might you go about identifying it *using techniques learned in today's lab?* (outline a procedure with detailed steps)

ES 104 Laboratory # 4
INTRODUCTION TO PLATE TECTONICS

Introduction

The Theory of Plate Tectonics has revolutionized the science of Geology in the last 40 years. The theory states that the outer surface of Earth consists of seven major lithospheric plates and numerous smaller ones, and these plates move around on a ductile layer referred to as the asthenosphere. The boundaries between the lithospheric plates, which are where they interact with one another, are characterized by distinctive topographic features and catastrophic geologic processes such as earthquakes and volcanism.

Goals and Objectives

- Introduce some of the basic ideas of Plate Tectonics
- Study the Plate Tectonic setting of the western United States and parts of the adjacent Pacific Ocean basin
- Describe the relation between earthquakes, volcanoes, and plate boundaries
- Learn to use map scales to convert map measurements to real-world distances

Useful Websites

- http://emvc.geol.ucsb.edu/downloads.php
- http://vulcan.wr.usgs.gov/Glossary/PlateTectonics/Maps/map_juan_de_fuca_ridge.html
- http://www.ucmp.berkeley.edu/geology/tectonics.html
- http://terra.chemeketa.edu/Faculty/fraa/geology/topics/tectonics/photos/htmls/world-sea-floor2.html
- http://terra.chemeketa.edu/Faculty/fraa/geology/topics/tectonics/photos/htmls/pacific-sea-floor.html
- http://vulcan.wr.usgs.gov/Glossary/PlateTectonics/Maps/map_plate_tectonics_world.html

Name____

Lab day _______Lab Time________________________

Pre-lab Questions – Complete these questions before coming to lab.

Briefly define the following key words, drawing diagrams where necessary, and answer the questions.

1. Lithosphere

2. Asthenosphere

3. Divergent Plate Boundary

4. Convergent Plate Boundary

5. Transform Plate Boundary

6. At what type of plate boundary is western Oregon located?

7. What type of plate boundary is found in southern California?

8. On the back of the page, sketch a cross-section of Earth, showing the internal structure. Include inner core, outer core, lower mantle, upper mantle, asthenosphere, lithosphere, moho, oceanic crust, continental crust (you may need an inset for the relationship of the last few items).

Part A—"The Earth's Fractured Surface" Map
Examine the National Geographic map "The Earth's Fractured Surface", and answer the following questions:

1. What type of crust is present where most divergent plate margins occur?

2. Name some areas that have chains of **active** volcanoes?

3. If these are associated with plate boundaries, use the term that describes the type of plate boundary.

4. Look at the Pacific Northwest area. What tectonic plates are there or nearby which may affect that area. (There are several.) Describe the type of boundaries that exist between these plates. (One type for each pair of plates that touch one another.)

5. The margin of the Pacific Ocean basin is often referred to as the "Ring of Fire". What evidence is shown on the map to justify this name?

6. List some areas that have single or small groups of active volcanoes.

Examine the Hawaiian Islands and surrounding area. Notice the alignment of the Hawaiian Islands and submerged seamounts of the Hawaiian Ridge extending to Midway Island and beyond. This linear string has an abrupt bend, and continues as the Emperor Seamounts to the Aleutian Trench.

7. What does the yellow circle with the arrow pointing to the northwest represent? (The red triangle in the center is the symbol for an active volcano.)

8. Record the information this symbol gives about Hawaii.

9. How can this information help you understand the formation of the Hawaiian Ridge?

10. Midway Island is in the Hawaiian-Emperor chain. The volcanic rocks on Midway Island are dated at 27 million years old. It is the small island just north and slightly east of the 's' of 'Midway Is.' on the map. Determine the rate **in inches/year** (rate = distance/time) and direction of plate motion of the Pacific Plate over the last 27 million years. Show your calculations with units.

11. Compare your calculated value to the map data about plate movement at the Hawaiian hotspot.

12. If your finger nails grow about 7.5 mm a month (they do), is the rate of motion of the Pacific Plate comparable to this? (Is the plate motion in the same ballpark as fingernails, or is it more comparable to how fast you can walk, or drive…). Show calculations to verify your answer.

13. Suiko Seamount (referred to in your textbook) has yielded an age date of 65 million years. It is located at 44.5° N, 170.3° W (approximately beneath the second "R" in the word "EMPEROR"). Based on the available age data and the distribution of the Hawaiian Islands chain and the Emperor Seamount chain, **discuss how** the movement of the Pacific Plate **has changed direction through time**.

14. Is this change in motion consistent with other seamount chains in the Pacific Ocean? Explain.

Find the locations of the eruptions listed in “Notable Volcanic Eruptions of the 20th Century” (Chart in the upper right corner of the map).

15. At what type of plate boundary have the vast majority of the volcanic eruptions in the 20th century occurred?

16. Consider the Iceland eruption of 1963. What **two** factors may have contributed to this eruption?

17. Find the locations of earthquakes listed in “Notable Earthquakes of the 20th Century”. Does there seem to be a relationship between the magnitude of a given earthquake and the type of plate boundary where it occurred? What is this relationship?

Part B – "Living on the Edge" Map

Examine the National Geographic map entitled **"Living on the Edge"** and answer the following questions:

1. Study the earthquake patterns along the **Cascadia Subduction Zone** in N. California, Oregon, and Washington. Describe the area has had the largest number of earthquakes; area of the least?

2. In comparison to other subduction zones worldwide, the Cascadia Subduction Zone has a distinct lack of earthquakes. In fact, there has never been an instrumentally recorded earthquake on the boundary between the down-going Juan de Fuca plate and the overriding North America plate. What are two possible scenarios for motion between the Juan de Fuca and North America plates that would lead to a lack of earthquakes on the Cascadia Subduction Zone?

3. Read inset information on the map indicating that a large earthquake occurred in the geologic past along offshore Oregon. How do your reasons above relate to this earthquake?

4. Using the Earth's Fractured Surface map, compare the Cascadia and Aleutian subduction zones and speculate on why they have such different earthquake activity.

5. Read the information on the map about the Cascade volcanoes. Would you consider the Cascades to be active volcanoes? Explain.

6. Locate Long Valley Caldera in eastern California. Note that Mt. St. Helens shows a similar cluster of earthquakes. Suggest a reason why there have been such a large number of earthquakes in the Long Valley Caldera region.

Part C – Studying the San Andreas Fault, California

Study Figure 1 below, and answer the questions on the following page. **Put arrows on the map below** (Figure 1) along opposite sides of the San Andreas Fault to show the relative sense of movement along the San Andreas Fault. You may want to color the labeled units different colors to help you see their relationship to the fault movement.

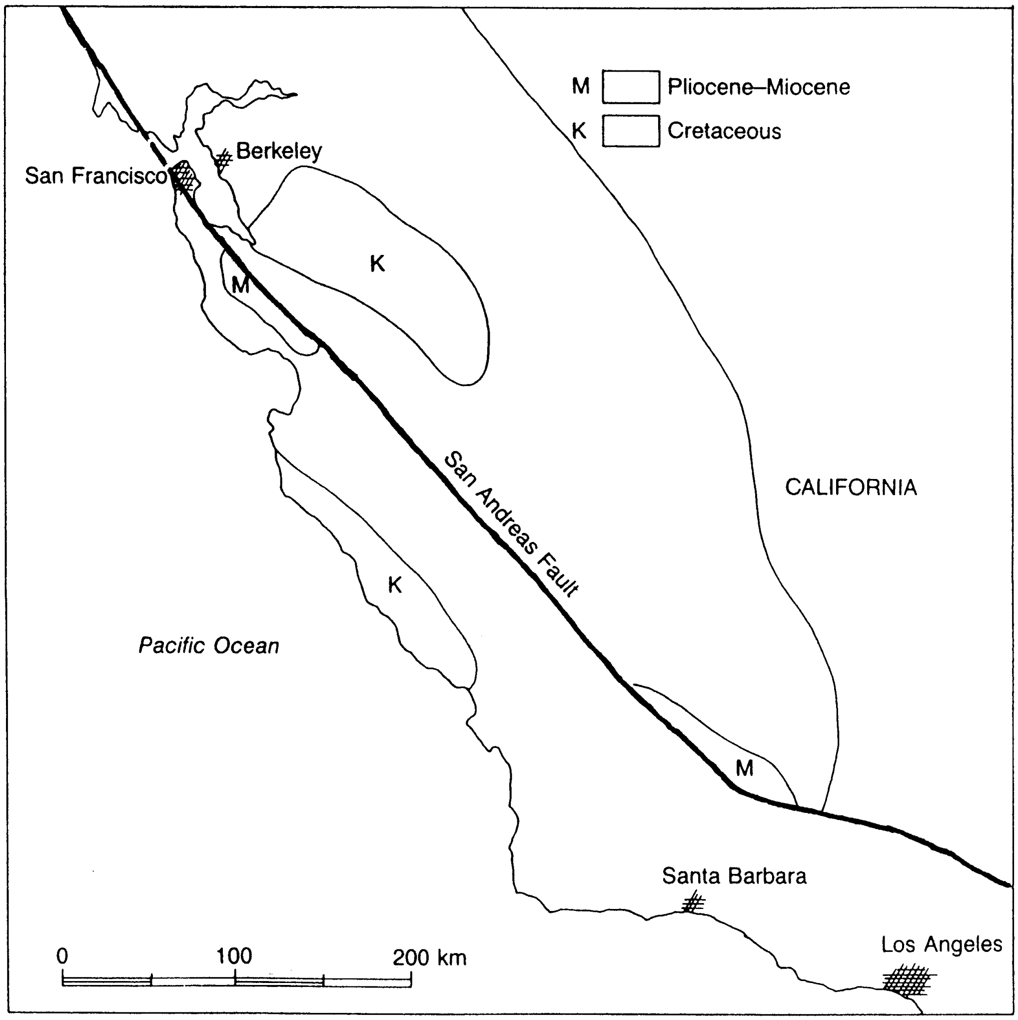


Figure 1: Generalized geologic map of central western California showing the San Andreas Fault.

1. What kind of **plate boundary** is the San Andreas Fault?

2. It is possible to estimate the average annual rate of movement along the San Andreas Fault by recognizing rocks older than the fault that have been offset by the fault. Note that Pliocene-Miocene (M) rocks, dated as being 25 million years old, have been cut and offset by the fault. You can determine how far they moved using the graphical scale at the bottom of the map, Figure 1. What is the average annual rate of fault movement in centimeters per year (cm/yr)? Show all your work, including units.

3. The average yearly rate of movement on the San Andreas Fault is very small. Does this mean that the residents of southern California are safe from earthquake damage caused by earthquakes on this fault? Explain.

4. The movement along the San Andreas Fault associated with the 1906 San Francisco earthquake was about 5 meters. Assuming that all of the displacement along the San Andreas Fault over the last 25 million years was produced by earthquakes with 5 meters of displacement, calculate the average recurrence interval (number of years between earthquakes) for these earthquakes. Show all your work, including units.

Name____

Lab day _______Lab Time________________________

POST LAB ASSESSMENT

Today, we can directly measure motion of the plates using Global Position System.

1. What is different about using GPS to measure the plate motion rates, instead of calculating the rate using rock ages and hotspot tracks?

2. The GPS rates and hotspot track rates generally agree with each other. What does this fact tell you about plate motions over long time periods?

3. Suppose the Earth's tectonic engine ground to a halt. What would be the implications for the geologic phenomena that you examined in the lab today? Be sure to justify your predictions fully.

ES 104 Laboratory # 5
EARTHQUAKES:
Epicenter Determination, Seismic Waves, and Hazards

Introduction

Earthquakes are vibrations of the Earth caused by large releases of energy that accompany volcanic eruptions, explosions, and movements of the Earth's crust along fault lines. The earthquake vibrations are waves of energy that radiate through the Earth away from the **focus**. These waves of energy can be recorded on a seismograph, which produces a recording called a **seismogram**. Seismographs record the two types of **body waves**: **Primary** waves (P-waves) and **Secondary** waves (S-waves). They also detect **Surface** waves called Love waves (L-waves) and Rayleigh waves (R-waves).

Travel-time curves are graphs that indicate how long it takes each type of seismic wave to travel a distance measured on the Earth's surface. The difference between the S-wave arrival time and the P-wave arrival time corresponds to the distance of the seismograph station from the earthquake focus. This time difference can be converted easily into distance using the travel-time curves (Figure 2).

Goals and Objectives

- Learn to locate an earthquake epicenter using p-wave and s-wave arrival time differences and travel time curves.
- Describe the relation between earthquakes, volcanoes, and plate boundaries.
- Understand earthquake-induced liquefaction and landslide hazards and how they relate to site geology.
- Know the essential components of a seismometer and how seismometers record earthquakes.

Useful Websites

- http://quake.wr.usgs.gov/info/1906/got_seismogram_lp.html
- http://www.jclahr.com/science/earth_science/tabletop/earthshaking
- http://www.sciencecourseware.org/VirtualEarthquake/VQuake Execute.html
- http://www.imsa.edu/programs/e2k/brazzle/E2Kcurr/Quakes/Virtual /VirtualObjectives.html

Name______________________________________

Lab day ______Lab Time_____________________

Pre-lab Questions – Complete these questions before coming to lab.

Briefly define the following key words.

1. Earthquake

2. Primary Wave

3. Secondary Wave

4. Epicenter

5. Richter scale

6. Tsunami

Question for Thought—write a few sentences to explain:

7. How do earthquakes relate to plate tectonics?

Part A – Epicenter Determination

The epicenter of an earthquake is the point on the Earth's surface at or above the earthquake's focus. In this exercise, you will determine the location of the epicenter of an earthquake that was recorded on seismograms at three different locations (Figure 1).

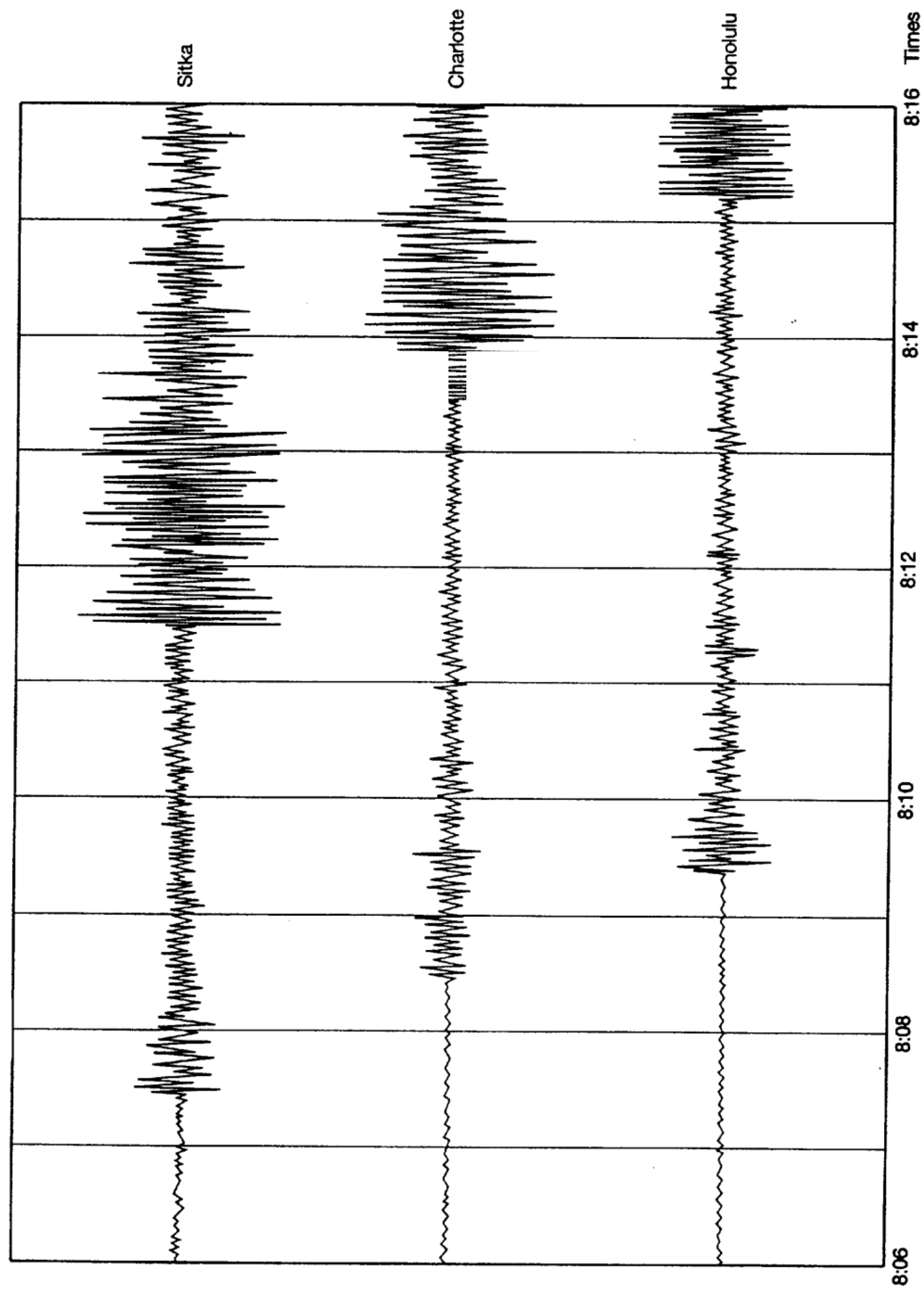


Figure 1: Seismograms recorded at three different locations for the same earthquake.

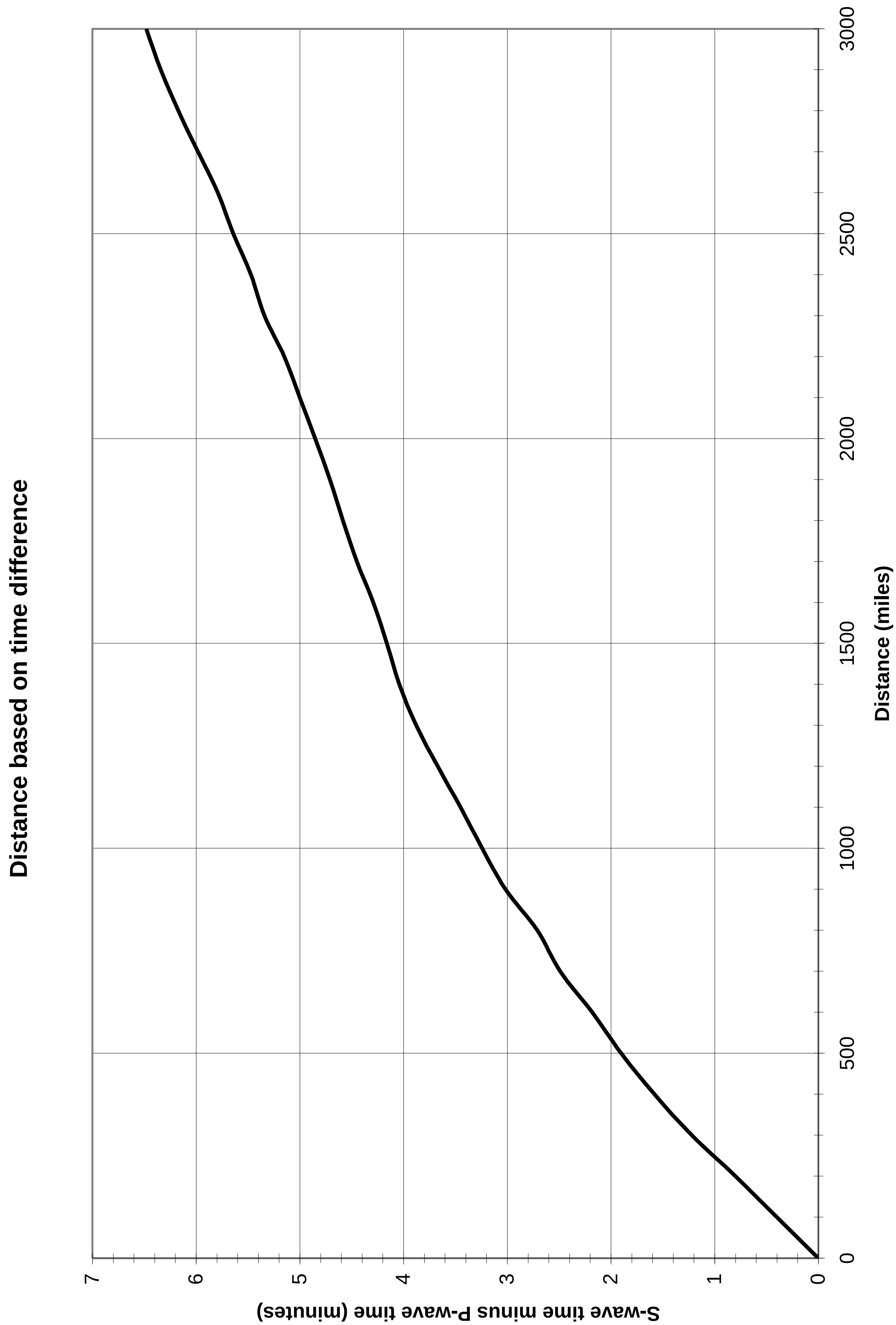


Figure 2: Travel-time graph to determine the distance to the epicenter.

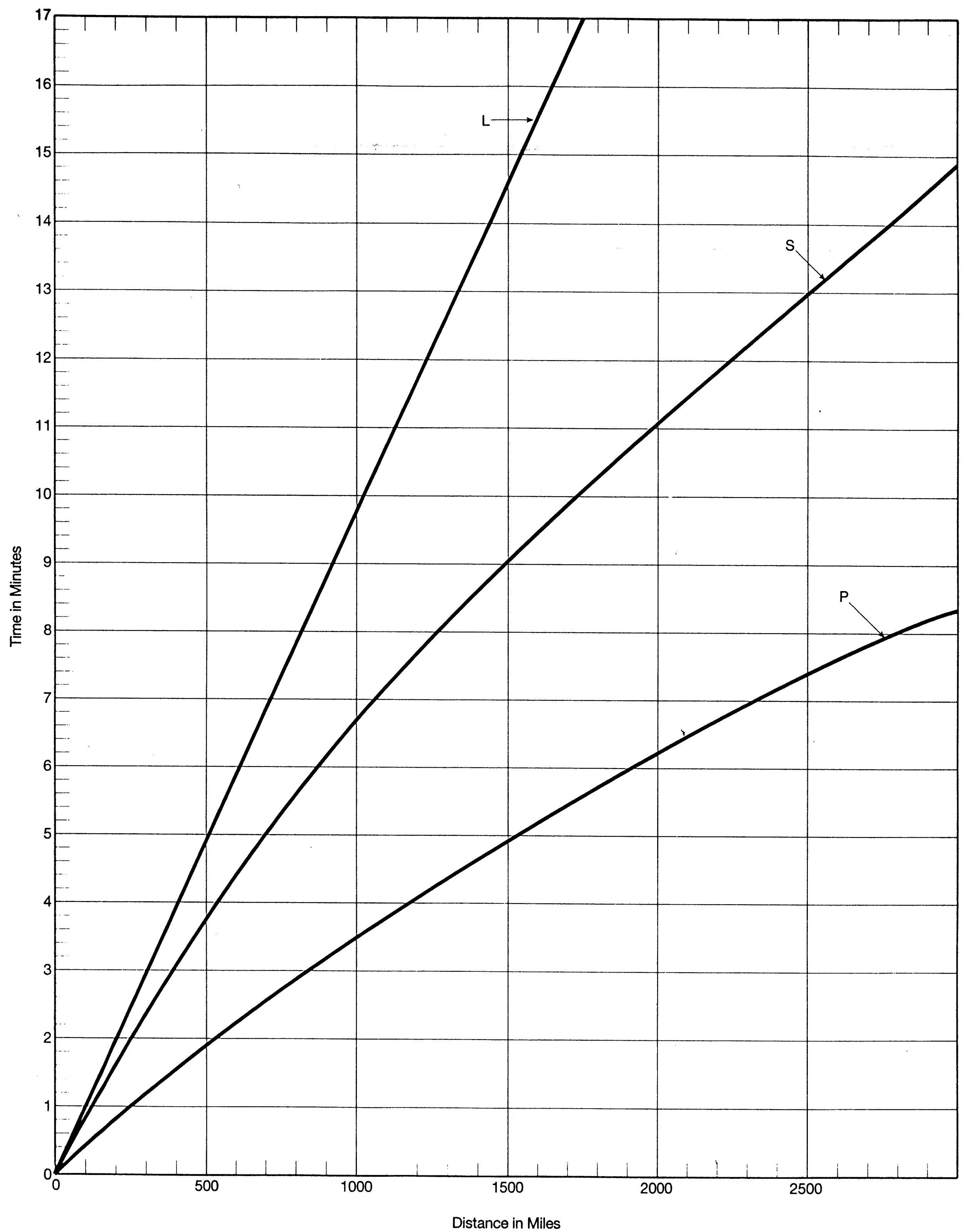


Figure 3: Travel-time curves for P-waves, S-waves, and L-waves.

1. Use Figure 1 to estimate to the **nearest tenth of a minute** (don't convert to seconds), the times of the **first arrival** of the P-waves and S-waves at each station: Sitka, Charlotte and Honolulu. Times show it arrived after 8 AM. Find the time difference, (subtract P-wave arrival time from the S-wave arrival time) to determine the difference in travel time of P-wave and S-wave.

Location of seismic station	**First P-wave Arrival** (time as hour: minute.tenths)	**First S-wave Arrival** (time as hour: minute.tenths)	**Difference in arrival time between S & P**
Sitka, AK			
Charlotte, NC			
Honolulu, HI			

2. Using Figure 2, the distance based on difference of arrival time, estimate the distance from the epicenter of the earthquake to each station. Record in the table below.

Location	**Distance (miles)**
Sitka, AK	
Charlotte, NC	
Honolulu, HI	

3. To find the earthquake's epicenter using the distances you just obtained, follow these steps:
   a. Locate and mark the three seismic stations on the world map, Figure 4 (page 5.8):

Sitka, AK: 57° N latitude, 135° W longitude
Charlotte, NC: 35° N latitude, 81° W longitude
Honolulu, HI: 21° N latitude, 158° W longitude

b. On Figure 4, draw a circle around each seismic station you located with a radius of the distance the epicenter was from that station (as you determined and recorded on page 5.6). Use a drafting compass to draw each circle, and use the scale at the bottom of the map to set the radius to the proper distance. The circles you draw should intersect at one point, which is the epicenter. (If the three circles do not intersect at a unique point, estimate a point equal distance between the three circles.) The location of the epicenter is:

Latitude ___________Longitude _______________

4. Use the data from a single station to determine when the earthquake occurred. From Figure 1, you know when the P-waves began to arrive. From Figure 2, you know how far away it was. And from Figure 3, you can find out how long it took to arrive. So, you can determine the **origin time** of the earthquake.
Note the station you chose to use. _________________________
Show your calculations.

Origin time: _________________________________
(Hint: the earthquake occurs before it arrives at a station)

5. What time would you estimate did the L-waves from this earthquake begin to arrive at the **Sitka** station? (Use Figure 3)

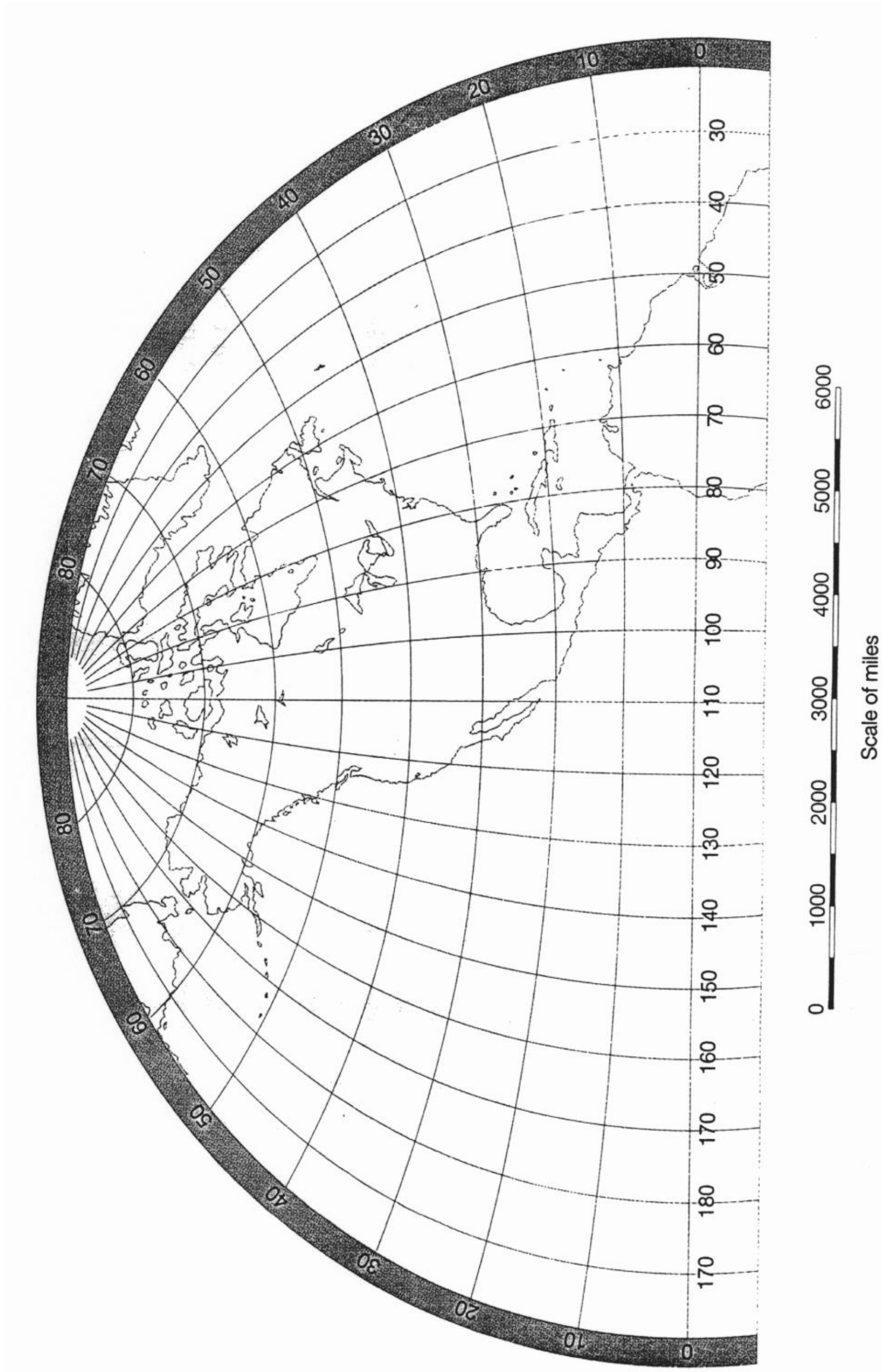


Figure 4: Map of Earth, for use in plotting data and locating the earthquake's epicenter.

Part B – Liquefaction

(Note: This Activity to Be Determined by Instructor)

During earthquakes, soils and sediments saturated with water can lose their shear strength and begin to act like a fluid. This process is called liquefaction. In this experiment, you will cause sand saturated with water to liquefy.

Directions (Your instructor may do this as a class demonstration.)

1. Remove the 1 kg mass from the sand-containing column if the previous group has not already done so. If you cannot locate the 1 kg mass, it may be buried in the sand. Dig around until you find it.

2. Lift the column containing only water approximately 2 feet off the tabletop. You should see water flow up through the bottom of the sand in the other column. Allow water to flow into sand-containing column until all of the sand is suspended in the water. This, by the way, is how quicksand forms!

3. Place the water-containing column back on the table. Watch as the sand settles out of the water. This settling process causes the sand to be very loosely packed. Loose packing of sediment deposits increases the likelihood of liquefaction during an earthquake.

4. Once the water level in the sand-containing column has dropped to the surface of the sand, **gently** place the 1 kg mass on the sand. The 1 kg mass represents a building constructed on loosely packed, water-saturated sediment.

5. To simulate an earthquake, strike the sand-containing column sharply with the rubber mallet, aiming for the black X. Be careful not to hit the vertical plastic tubes on the outside of the column.

Questions

1. What happened to the 1 kg mass when the column was struck with the rubber mallet? Given this result, what sorts of hazards does liquefaction pose to buildings during an earthquake?

2. In order for liquefaction to take place during an earthquake, the soils and sediments need to be saturated with water. How do you think the depth to the water table relates to the liquefaction hazard in a particular location? (Note: the water table is the top of the zone of sediments in the subsurface that are completely saturated with water. If you drill a water-well in your backyard, you hope that your well will reach the water table.)

3. Based on your observations while preparing for the liquefaction experiment, in what types of locations do you think you would find loosely-packed, liquefaction-prone sediment deposits? Can you think of any towns or cities in Oregon that might be built on these types of sediment deposits?

4. Remove the 1 kg mass from the sand. Firmly tap the side of the sand-containing column several times while watching the sand closely. Place the mass back on the sand and strike the X on the side of the sand-containing column. What happened to the mass this time? Why?

5. Does this result suggest any ways that liquefaction prone building sites could be prepared before construction to reduce damage due to liquefaction during a future earthquake?

Part C – Earthquakes Hazards

Examine the *Geologic Map of the West Salem Area* and the Earthquake Hazard Maps for this area. Answer the following questions:

1. Locate Minto Island (central) and McNary Field (southeast) on the *Geologic Map of the West Salem Area* (which includes the western part of downtown Salem, as well as the city of West Salem). These areas are underlain by sediments labeled Qal, Qtlw, and Qlg. Write the name of the formation, and a brief description of the amounts of gravel, sand, silt and clay in each formation.
   a. **Qal**

   b. **Qtlw**

   c. **Qlg**

2. Explain how the abundance/concentration of groundwater contained in these sediments may change in relation to the proximity of the Willamette River.

3. How does the type of sediment (Qal, Qtlw, or Qlg) relate to the liquefaction potential and relative earthquake hazard potential of these areas? (Refer to the *Liquefaction Susceptibility Map* and *Relative Earthquake Hazard Map* of the Salem area to support your answer.) What is the relationship between sediment grain size and liquefaction hazard?

4. How does site proximity to a river relate to liquefaction hazard? (If you completed Part C, use your liquefaction observations from Part C in your answer,).

5. Using the *Geologic Map of West Salem Area*, locate areas along the Willamette River that are underlain by Eocene-Oligocene sedimentary rocks (Toe). Would you build a beautiful new home overlooking the Willamette River in these areas? Why or why not? (Hint: Examine the *Liquefaction Susceptibility Map*, *Landslide Susceptibility Map*, and *Relative Earthquake Hazard Map of the Salem area*.)

Fill in the following table by writing in "yes" or "no" for each of the following conditions at each of the three locations found on the Geologic Map of the West Salem Area.

Location	**Located on surface sediments (non-bedrock units on map)**	**High risk of Landslides (see landslide susceptibility map)**	**High risk of Liquefaction (see liquefaction susceptibility map)**	**Located in Zones A and B on the Earthquake Hazard Map.**
Fairview Hospital (Fairview Home on some maps)				
Marion Square Park				
Salem Heights and Morningside Schools				

Rank the three locations above from greatest to least susceptible to earthquake damage:

Part D - Seismometers

Seismometers are instruments designed to measure and record ground motion during an earthquake. The record kept by the seismometer is called a seismogram. Examine the seismometer at Lab Station B. The heart of the seismometer is a mass (the washers and magnets on the eye bolt in the bottle) suspended on a spring. During an earthquake, the housing of the seismometer (bottle, PVC pipe, and base) move, but the mass remains roughly stationary due to its inertia. To record the motion of the bottle relative to the mass on the spring, a coil of wire is wrapped around the bottle. The magnet on the bolt produces a changing magnetic field as it moves inside the wire coil. The changing magnetic field produces an electrical voltage in the coil. The computer measures the voltage and creates a plot of voltage vs. time; the larger the voltage, the larger the velocity of the mass.

1. Given that the purpose of the seismometer is to measure motion during an earthquake, why is the mass on the spring suspended in oil? (Hint: consider how long the mass would vibrate after an earthquake if no oil were present.)

2. Real seismometers are extremely sensitive to ground motion and therefore record ground motion due to sources other than earthquakes. What sorts of natural and human-caused ground motions might show up as noise on a seismogram?

3. This seismometer is set up to measure vertical ground motions. Draw a picture of a seismometer that could measure horizontal ground motions. (You only need to draw the mass and whatever is attaching the mass to the seismometer housing).

Making Earthquakes

You are going to simulate earthquakes and record them on this seismometer. To simulate the earthquakes, you will drop 1 kg and 0.2 kg masses onto the wooden squares attached to the plywood base. The differing masses correspond to earthquakes of different size. Energy from the mass hitting the table will travel down the plywood base as an elastic wave where the wave will move the seismometer. The seismometer will then make a record of its motions. During a real earthquake, energy released at the focus of the earthquake travels to distant seismometers through seismic waves.

Directions

1. <u>Do not mess with any of the electronics attached to the seismometer!!!</u>
2. Delete all previous data runs on the computer (Use the menu command *Experiment>Delete ALL data runs*).
3. Press *Start* to begin recording data from the seismometer.
4. Carefully drop the 1 kg mass from a height of 6.5 centimeters above the wooden block labeled 1. Use a ruler to measure the height precisely.
5. Carefully drop the 1 kg mass from a height of 6.5 centimeters above the wooden block labeled 2.
6. Now repeat the drops at the two wooden blocks using the 0.2 kg mass. Be sure to keep the drop height at 6.5 centimeters.
7. Press *Stop* on the computer to stop recording data.
8. Adjust the horizontal and vertical scales on your seismogram so that all four earthquakes fit on the graph. Print your seismogram and label the 4 earthquakes with the mass dropped and the location of the earthquake.

Questions

1. Look at the seismogram that you made. How does the amplitude of the ground motion recorded by the seismometer relate to the magnitude of the earthquake (or in this case, the size of the mass dropped)?

2. How does the amplitude of the ground motion recorded by the seismometer depend on the distance to the earthquake epicenter for a given earthquake magnitude?

3. Use this observation to explain why earthquake magnitude scales must correct for the distance from the seismometer to the earthquake epicenter to assign a magnitude to an earthquake using ground motion amplitudes recorded on a seismogram.

4. Compare the duration of strong shaking between the 1 kg earthquake and the 0.2 kg earthquake.

5. How does the duration of shaking relate to the earthquake magnitude? How do you think this affects the amount of damage that occurs to buildings during an earthquake?

Name______________________________________

Lab day ______Lab Time______________________

POST LAB ASSESSMENT

The Global Positioning System consists of a network of satellites that send out signals that are picked up by GPS receivers, such as the models used for navigation by hikers or in cars. The GPS receivers have a database indicating the location of each satellite. The satellite sends a signal of the time of broadcast. To determine their position, the GPS receivers use the known locations of the satellites, the time signals the satellites send to the receiver, and the speed of radio waves.

1. Explain how the GPS receiver calculates its position. (see above)

2. Why does it use at least four satellite signals to determine its position.

3. In lab 4 and lab 5, you have learned a great deal about earthquakes and earthquake hazards. Using this information, explain all of the factors that should be considered in determining the earthquake hazard at a given building site.

ES 104: Laboratory # 6
PHYSICAL PROPERTIES OF MINERALS AND MINERAL IDENTIFICATION

Introduction

Minerals are naturally occurring, usually inorganic, solids that possess a definite chemical composition and a specific, orderly arrangement of atoms. This lab will help you to develop the ability to identify common minerals found at the Earth's surface. Although there are literally thousands of minerals, there are only a small number of minerals that are common rock forming, ore, and industrial minerals. These constitute a large part of the Earth's crust. Identification is accomplished by testing and observing the physical properties studied in the first of part of this laboratory. The second part of the lab will focus on describing the physical properties of a mineral and on identifying minerals using the physical properties.

Objectives

- Recognize and describe the physical properties of minerals
- Develop and use a mineral identification key to name minerals
- Identify minerals using physical properties

Useful Websites

- http://www.rockhounds.com/rockshop/xtal/part2.html
- http://geology.csupomona.edu/alert/mineral/shape.htm
- http://mineral.galleries.com/minerals/property/physical.htm
- http://mineral.galleries.com/minerals/cleavage.htm
- http://webmineral.com/help/Luster.shtml

Name____
Lab day _______Lab Time_______________________

Pre-lab Questions – Complete these questions before coming to lab.

Briefly define the following key words.

1. Element	7. Cleavage
2. Mineral	8. Fracture
3. Color	9. Crystal form
4. Streak	10. Density
5. Luster	11. Magnetism
6. Hardness	12. Effervescence

1. How is density calculated? (Show formula with units.)

2. What is the difference between a silicate and non-silicate mineral? Include some examples of each type of mineral.

Part A: Activities Focusing on Physical Properties

Minerals exhibit certain diagnostic properties, called physical properties, which can be tested and observed, thereby leading to the correct identification of the mineral. Many (but not all) of these properties are unique to a given mineral. One of the keys to identifying minerals is observing a combination of physical properties displayed by a mineral. You must be sure of the meaning of each of the physical properties. On the following pages, you will study these properties: luster, color, streak, heft, density, hardness, cleavage, fracture, crystal form, magnetism, and effervescence in dilute, cold hydrochloric acid (HCl).

STATION #1: Luster and Color

1. Study the various mineral specimens provided. Of the four specimens **in the luster box,** how many can be grouped into each of the following luster types?

   __________ Metallic __________ Nonmetallic-glassy

   Describe <u>Luster</u> in your own words.

2. Study the mineral specimens of quartz (Sample #3) provided in the **color** box. What is the reason for the variety of colors that quartz exhibits? (**HINT**: Think about what a single drop of food coloring does to a glass of water.)

3. Is color a reliable physical property to help identify a given mineral specimen? Keep in mind your observations in question 2 above. Explain your answer.

STATION #2: Other Physical Properties

In this station you will examine Streak, Magnetism, and Effervescence

1. Describe in your own words:

   Streak—

   Magnetism—

   Effervescence—

2. Examine the collection of samples provided and complete the data table by recording the following observations for each sample:

Sample Number	Streak Color	Magnetic Character	Reaction to HCl
#1			
#2			
#13			

STATION #3: Cleavage, Fracture, and Crystal Form

Study the collection of single mineral samples. Several samples exhibit cleavage (#5, #6, and #13), one shows fracture (#3), and one demonstrates crystal form (#4).

Cleavage and **Fracture** are related to how a mineral breaks apart. They are controlled by the internal atomic arrangement of the mineral.

1. Is cleavage or fracture (which one) controlled by planes of weak chemical bonding?

2. Briefly explain these in relation to crystal structure of the atoms.

Crystal Form is also controlled by the internal atomic structure but is not related to how a mineral breaks. With a magnifying lens, look at the crystal form shown by sample 4. **Sketch it** here ↓.

3. What is Crystal Form?

Study the minerals listed below, and complete the data table. For each, describe the cleavage in terms of the number of directions, or write 'none' if the mineral does not have cleavage, and **determine the angle between them *<u>if</u>* there is more than one direction of cleavage**. Also, provide a simple sketch of the sample emphasizing the cleavage, or lack of it.

Sample Number	# of Directions	Angle between cleavage planes (90º or not 90º)	Sketch showing cleavage angle
#3			
#5			
#6			
#13			

STATION #4: Density
The density of a mineral can be estimated by hefting the mineral in your hand. Some minerals will feel heavier than others for a given sample volume. This is a **subjective** determination. For mineral identification, it is **better to measure** the mineral sample's mass and volume and calculate the density. Any person doing the determination should get the same answer: **the answer is objective** and not subjective. The concept that anyone doing the experiment should get the same answer is fundamental to science.

Density can be calculated with a high degree of accuracy (although your measurement may not seem so because you are using a relatively primitive method). The density of any substance is the mass per volume, shown by the equation:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Step 1: Find the mass of your specimens using the balance. Record in the table on page 6.7, including units.

Step 2: Determine the volume of the specimens by displacement of water in a graduated cylinder. Record with units in the table on page 6.7.

Step 3: Use the equation to determine the density of the specimens.

Table for density measurements and calculations:

Sample number	1) Mass of sample	2)Volume of sample	3) Density of sample	*Show work here (include units):*

1. The density of quartz is 2.65 g/cm^3. If you have 2.65 grams of quartz, what is the volume of the specimen, in cm^3?

2. What would be the volume of 1 gram of quartz? Show work here. (Include units: they help you set up the equation.)

Specific gravity (S.G.) is a term quite similar to density. Specific gravity is a unitless comparison of a mineral's density to the density of liquid water. Water has a specific gravity of 1. Specific gravity can be thought of as the number of times the mineral is heavier than the same volume of water. For example, if a mineral has a specific gravity of 3.47, it is 3.47 times heavier than an equal volume of water.

3. If a substance had a specific gravity of 2.54, would it float or sink in water?

4. Is the specific gravity of ice greater or less than 1?

5. Is the specific gravity of oil greater or less than 1?

STATION #5: Hardness

Hardness is the resistance of a mineral to scratching. It is determined by comparing the ability of a mineral to scratch or be scratched by other minerals of known hardness. In 1812, Friedrich Mohs developed a non-linear scale of ten commonly available minerals as a standard for comparison. This scale is shown at the right.

1. Talc
2. Gypsum
3. Calcite
4. Fluorite
5. Apatite
6. Orthoclase
7. Quartz
8. Topaz
9. Corundum
10. Diamond

Because you do not have samples of each of these minerals available, the following hardness guide is useful to bracket the hardness of an unknown sample.

Hardness Guide:

Hardness (H)	'Code'	Description
less than 2.5	<2.5	Mineral can be scratched by fingernail (H fingernail = 2.5).
2.5 to 3.5	2.5-3.5	Mineral cannot be scratched by fingernail, and mineral cannot scratch penny (H penny = 3.5).
3.5 to 5.5	3.5-5.5	Mineral can scratch penny, and cannot scratch glass (H glass = 5.5).
greater than 5.5	>5.5	Mineral can scratch glass.

Determine the hardness for the small group of minerals provided and complete the data table.

Sample	Hardness (use <u>code</u> from table above)
#3	
#7	
#13	
#14	

Describe how differences in hardness might be useful in mineral identification. Use some examples.

Part B: Activities focusing on Mineral Description and Mineral Identification

Description

You are now ready to collect a complete set of data of the physical properties useful in mineral identification. Determine the physical properties of each sample and record your observations in the data table provided on the following page. **Complete the table of specimen properties before trying to identify the minerals by name.** This is more important than the name! After listing the properties, use these and the 'Mineral Identification Key' on pages 6.11, 6.12 and 6.13 to determine which minerals you have. Be sure to notice the footnote information provided in the key.

Identification

Mineral identification is a process of elimination based on determinations of physical properties. In this activity, you will use an identification key for the minerals that you described. To use a key to identify minerals, you will be given a series of choices about the properties of a mineral. For most of the identification process, the choices will be "either this or that". Compare your determinations of mineral properties with the mineral identification tables in the following pages.

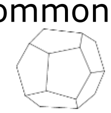
To identify the fifteen 'unknown' minerals, follow the divisions of the key tables: first choose the proper table by the luster of the mineral. Notice Table 2a is for identifying those minerals that have a metallic luster. Table 2b and 2c are for minerals that do not have metallic luster: Table 2b is for minerals that are light-colored, and 2c is for minerals that are dark colored. Each table for luster is divided into two sections: softer than glass, and harder than glass. These sections are further divided by the absence or presence of cleavage, and the characteristics of the cleavage if it is present.

After you have identified the minerals, you should concentrate on a small number (1-3) of properties for each mineral to help you remember how to identify it. These are considered "diagnostic properties" for that mineral. A particular mineral will have a set of properties that are diagnostic for it. Some properties that are diagnostic for certain minerals are of no significance for other minerals. This is especially true for color, or some special properties like magnetism or effervescence in hydrochloric acid.

Mineral Description Table

Sample #	**Luster:** Metallic/ Non-metallic/ Submetallic	**Hardness** Describe using range code in guide on pg. 6.8	**Crystal form** (if it shows) **Cleavage:** # of planes and angle of intersection.	**Streak** Color of it, or 'none' if H>6	**Color** and **Other properties** (if present)	**MINERAL NAME**— complete properties for all minerals before beginning to name any
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						

Table 2a: Mineral Identification Key—Metallic Luster

Hardness	Cleavage	Diagnostic Physical Properties	Mineral Name
Harder than glass	Absent	Brass yellow color, tarnishes brown to green; **greenish or brownish black streak**; cubic or pyritohedron crystals common;  **H = 6 – 6.5**, S.G.=5.0	**Pyrite** FeS_2
		Pale brass yellow to whitish gold color; dark gray streak; radiating masses and "cockscombs:" common; H = 6 – 6.5, S.G.=4.9	**Marcasite*** FeS_2
		Dark gray to black color, dark grey to black streak; **magnetic**; massive or "grainy"; may have 'submetallic' luster; H = 6‡, S.G.=5.2	**Magnetite** Fe_3O_4
		Silver to gray color, **red-brown streak**; may be composed of glittery flakes; H=5-6.5, S.G.~5	**Hematite** Fe_2O_3
Softer than glass	Present	Silver gray color, **gray streak**; **cubic cleavage** (three directions at 90^{o}), but may be distorted; H = 2.5 (cannot be scratched by fingernail); **S.G. = 7.4 – 7.6**	**Galena** PbS
	Absent	Golden yellow color, **tarnishes to purple**; Greenish black to dark gray streak; H = 3.5 – 4, S.G.=4.2	**Chalcopyrite*** $CuFeS_2$
		Copper to dark brown color, **tarnishes to green**; copper streak; H = 2.5 3; S.G. = 8.8–8.9	**Copper*** Cu
		Dark gray color; dark gray streaks; **marks paper easily**; greasy feel; H = 1; S.G. = 2.1-2.3	**Graphite*** C

* These minerals are not included with ES 104 lab specimens.

‡ The hardness of some samples is less than this table indicates, due to alteration

Table 2b: Mineral Identification Key— Nonmetallic Luster, Light Colored

Hardness	Cleavage	Diagnostic Physical Properties	Mineral Name
Harder than glass	Present	White to pink color; **two directions of cleavage at 90º; H=6**‡, SG=2.55; subparallel banding (exsolution lamellae) may be present on cleavage faces	**Potassium Feldspar** † (Orthoclase) $KAlSi_3O_4$
		White to blue-gray color; **two directions of cleavage at nearly 90º; H=6**‡, S.G.=2.65; may have striations (parallel grooves) on cleavage faces	**Plagioclase Feldspar**† $NaAlSi_3O_8$ to $CaAl_2Si_2O_8$
	Absent	White, gray, or pink color; usually massive; may have hexagonal prism with pyramid crystals; transparent to translucent; glassy luster; conchoidal fracture; **H=7**, S.G.=2.65	**Quartz** † SiO_2
		Olive green to yellow-**green color**; granular masses; grains glassy with conchoidal fracture; H=7‡, may be less from alteration, S.G.=3.3-4.4	**Olivine** † $(Fe,Mg)SiO_4$
Softer than glass	Present	Colorless, yellow, blue, green, or purple; four directions of cleavage **(octahedral)**; transparent to translucent; **H=4**, S.G.=3.2	**Fluorite*** CaF_2
		White, gray, or pink color; three directions of cleavage not at 90º (rhombohedral); fizzes in dilute HCl if powdered; H=3.5–4, S.G.=2.85	**Dolomite*** $CaMg(CO_3)_2$
		Colorless, white, yellow, or gray; rhombohedral cleavage (**three directions, not at 90º**); **fizzes** in dilute HCl; H = 3, S.G.=2.72	**Calcite** $CaCO_3$
		Colorless, white or gray; **cubic cleavage** (three directions at 90º); salty taste; dissolves in water; **H = 2.5**, S.G.=2.1-2.3	**Halite** NaCl
		Colorless, clear brownish or yellowish color; one direction of cleavage; usually **thin, elastic, transparent to translucent sheets;** H=2.5, S.G.=2.8. May be submetallic	**Muscovite**(mica)† $KAl_2(AlSi_3O_{10})(OH)_2$
		Colorless to white; massive, or one good direction of cleavage (and two poor) forming thick; nonelastic, translucent sheets; **H = 2**, S.G.=2.3	**Gypsum** $CaSO_4\ 2H_2O$
	Ab-sent	White earthy masses resembling chalk; plastic and sticky when wet; H=1–1.5, S.G.=2.6	**Kaolinite*** $Al_4Si_4O_{10}(OH)_8$

*These minerals are not included with ES 104 lab specimens.

† Minerals important to formation of igneous rocks: study these carefully because they will be used to help identify igneous rocks in the next two labs.

‡ The hardness of some samples is less than this table indicates, due to alteration

Table 2c: Mineral ID Key—Nonmetallic Luster, Dark Colored

Hard-ness	Cleav-age	Diagnostic Physical Properties	Mineral Name
Harder than glass	Present	Dark gray to blue-gray color; two directions of **cleavage at ~90º; H = 6**‡, SG=2.62-2.76; striations (parallel grooves) may be present on cleavage faces	**Plagioclase Feldspar**† $NaAlSi_3O_8$ to $CaAl_2Si_2O_8$
		Black to dark green color; two directions of cleavage intersecting at 87º and 93 º; often massive in appearance; **H = 5.5**‡, S.G.=3.1-3.5	**Augite** (Pyroxene)† Ca, Mg, Fe, Al Silicate
		Black to dark green color; two directions of **cleavage intersecting at 60 º and 120 º**; often massive or splintery in appearance; H=5.5‡, S.G.= 3.0-3.3	**Hornblende**† (Amphibole) Na, Ca, Mg, Fe, Al Silicate
	Absent	Dark gray to smoky brown color; usually massive; transparent to translucent; glassy luster; **conchoidal fracture; H = 7**. S.G.=2.65	**Quartz**† SiO_2
		Black, dark **green**, olive green color; granular masses; single grains are glassy with conchoidal fracture; H = 7‡, S.G.=3.27-4.37	**Olivine**† $(Fe,Mg)SiO_2$
		Dark red to brownish-red color; translucent; often has smooth, parallel fractures resembling cleavage; **H = 7**, S.G.=3.5-4.3	**Garnet*** Fe, Mg, Ca, Al Silicate
		Dark gray to black color, dark grey to black streak; **magnetic**; massive or "grainy"; may have 'submetallic' luster; H = 6‡, S.G.=5.2	**Magnetite** Fe_3O_4
		Grayish to dark brown to yellow-brown color; **yellow-brown streak**; amorphous; opaque, earthy appearance ; H = 1.5–5.5, S.G.=4.37	**Limonite*** $Fe_2O_3\ nH_2O$
Softer than glass	Present	**Dark brown to dark green color**; one direction of cleavage; usually in **thin, elastic, transparent to translucent sheets; H = 2.5–3**, S.G.=2.95-3.0. May be submetallic.	**Biotite** (Mica)† $K(Mg,Fe)_3AlSi_3O_{10}(OH)_2$
		Dark green to green color; one direction of cleavage; usually in thin, opaque, curved sheets; often massive with greasy feel; H=2.5, S.G.=2.6-2.9	**Chlorite*** Mg, Fe, Al Hydrous silicate
	Absent	Dull red to gray color; **reddish-brown streak**; opaque, earthy appearance; H=1.5–5.5, S.G.=5.2	**Hematite** Fe_2O_3
		Grayish or dark brown to yellow-brown color; **yellow-brown streak**; amorphous; opaque, earthy appearance; H = 1.5 – 5.5, S.G.=4.37	**Limonite** $Fe_2O_3\ nH_2O$

* These minerals are not included with ES 104 lab specimens.
† Minerals important to formation of igneous rocks
‡ The hardness of some samples is less than this table indicates, due to alteration

For your information... **Mineral uses and some mineral facts:**

<u>Barite</u>	principle source of barium and sulfate for chemical industry; used in petroleum industry as drilling mud
<u>Calcite</u>	used for manufacture of cement and lime for mortars, used as soil conditioner, used as flux for smelting metallic ores, building industry
<u>Chalcopyrite</u>	important ore of copper; oxidized surfaces show iridescence.
<u>Feldspars</u>	used in manufacture of porcelain; source of aluminum in glass industry
<u>Fluorite</u>	flux in making steel; used in chemical industry for hydrochloric acid; high-grade ore is used in making optical equipment
<u>Galena</u>	most important ore of lead; lead is used in batteries, in metal products as an alloy, in glass making; used to be the principal ingredient in paints. The Romans used lead for indoor plumbing, which may have resulted in lead poisoning of the higher, classes and contributed to the downfall of the Roman Empire.
<u>Garnet</u>	semi-precious gemstone, used in abrasive products (sand paper)
<u>Graphite</u>	this is the "lead" of pencils, also used in protective paints in foundries, batteries, and electrodes; in fine powder form, it is used as a lubricant
<u>Gypsum</u>	plaster (wall board, sheet rock); used in Portland cement; soil conditioner for fertilizer
<u>Halite</u>	table salt; source of Na and Cl for the chemical industry
<u>Hematite</u>	most important ore for steel making; used in pigments, some use as gemstone
<u>Kaolinite</u>	used for brick, paving brick, drain tile, ceramic products, and as filler in glossy paper
<u>Magnetite</u>	minor ore of iron
<u>Olivine</u>	some used as gem (peridot); used in casting industry because of refractory properties (means high melting temperature)
<u>Quartz</u>	some use as gemstone; in sand form, used in mortar, concrete, as flux, and for abrasive products. Artificial quartz is now used in radios and for optical instruments (quartz permits both the transmission and reception on a fixed frequency).
<u>Sphalerite</u>	most important ore of zinc; galvanized metals are covered with zinc to prevent rusting.
<u>Talc</u>	used in manufacture of paint, paper, roofing materials, rubber, cosmetic powders, and talcum powder; used as insulators in electrical industry

Name____

Lab day _______Lab Time_______________________

POST-LAB ASSESSMENT

1. Describe the procedure you use for identifying a mineral and arriving at its name.

2. Name the physical property that is described by each of the following statements:
   a. Breaks along smooth planes:
   ____
   b. Scratches glass:
   ____
   c. A red-colored powder on unglazed porcelain:
   ____

3. **Describe** the shape **and sketch** a mineral that has three directions of cleavage that intersect at 90°.

4. How many directions of cleavage do the feldspar minerals (potassium feldspar and plagioclase) have?
   ____

5. How would you tell the difference between a crystal face and a cleavage plane?

6. Which would tell you more about a mineral's identity: luster or hardness? Why?

ES 104: Laboratory # 7
IGNEOUS ROCKS

Introduction

Igneous rocks form from the cooling and crystallization of molten rock material. This can occur below the surface of Earth forming *intrusive rocks* (also called *plutonic rocks*) or on or above the surface as *extrusive rocks* (also called *volcanic rocks*). As a generalization, extrusive igneous rocks cool rapidly when compared with intrusive igneous rocks.

The rate of cooling has a profound influence the size of the crystal grains formed in the igneous rock, so the **textures** of igneous rocks tell us much about the rate of cooling of the rock and thus whether their origin is plutonic or volcanic. If cooling is slow, atoms have plenty of time to migrate to the growing nuclei of growing crystals, thereby enlarging these mineral grains. So, a longer cooling time results in larger crystal grains. Intrusive igneous rocks have *coarse-grained textures*, including *pegmatitic* (crystals larger than 10 mm). Because of their rapid cooling, extrusive igneous rocks generally have fine-grained textures, including *porphyritic*, *glassy*, and *frothy*.

In addition to texture, the mineral **composition** also determines the appropriate classification of an igneous rock. Determining composition of an igneous rock is not always easy, particularly because as the texture gets finer, the individual mineral grains become too small to be seen easily. In these cases, the color of a rock becomes helpful. As a general rule, dark rocks are typically *mafic* and light colored rocks are typically *felsic*. NOTE: be aware that there are a few important exceptions to this general rule.

Be sure to define the terms in italics in your notes.

Objectives

- Learn to recognize the major types of igneous rocks
- Understand the significance of texture and composition in the formation of igneous rocks

Useful Websites

- http://csmres.jmu.edu/geollab/Fichter/IgnRx/Ighome.html
- http://seis.natsci.csulb.edu/basicgeo/IGNEOUS_TOUR.html
- http://geology.csupomona.edu/alert/igneous/ignrxs.htm

Name______________________________________

Lab day ______Lab Time______________________

Pre-lab Questions – Complete these questions before coming to lab.

1. What are the three main classes of rocks and how does each of them form?

2. Draw and label a diagram of the rock cycle **on the back** of this sheet. Be sure to show the three classes of rocks and how the relate with one another.

3. What are the differences between an extrusive and intrusive igneous rock?

4. Define the following igneous rock terms:

   a. Coarse grained

   b. Fine grained

   c. Porphyritic

   d. Felsic

   e. Mafic

   f. Magma

   g. Lava

Part A – Identification of Igneous Rocks

Classification of igneous rocks is based on texture (grain size) and chemical composition (often related to color). Identify the rocks in the study set using the rock identification chart. Begin by describing the texture and color of the rock. Use a ruler to measure the average grain sizes. You should be able to identify minerals present in the coarse-grained and porphyritic rocks. To identify visible mineral grains, use the same mineral identification procedures that you used in Lab 6. Fill in the identification table (Table 2) with your observations, then use the classification chart (Table 1) to assign correct names to the lab specimens. **Do not copy information from table 1 onto table 2 that you cannot see in the rocks**. The abbreviations in table 1 are defined at the bottom.

Table 1: Igneous Rock Classification
See footnotes below for abbreviations

Chemical Composition to right→	**Felsic (light colored** except obsidian**)**	**Intermediate**	**Mafic (dark colored)**	**Ultramafic (green)** (light-colored exception)
Mineral content to right→ / **Texture** shown below	10-20%QUARTZ K-SPAR>PLAG <15% FERRO-MAGS†	NO QUARTZ PLAG> K-SPAR >20% FERROMAGS	NO QUARTZ NO K-SPAR SOME PLAG +>40% FERRO-MAGS	NO QUARTZ NO K-SPAR NO PLAG 100% FERROMAGS
Very coarse grained most grains > 10 mm across	PEGMATITE	DIORITE	GABBRO	PERIDOTITE
Medium and coarse grained (average grain size 1 – 10 mmacross)	GRANITE	DIORITE	GABBRO	PERIDOTITE
Fine grained (average grain size < 1 mm across)	RHYOLITE	ANDESITE	BASALT	--
Porphyritic (large grains imbedded in fine grained matrix)	PORPHYRITIC RHYOLITE	PORHYRITIC ANDESITE	PORPHYRITIC BASALT	--
Glassy	OBSIDIAN		--	--
Frothy, foamy‡	PUMICE		SCORIA	

†**FERROMAGS** = Ferromagnesian silicate minerals: biotite, hornblende, augite, olivine
PLAG = Plagioclase Feldspar; **K-SPAR** = Potassium Feldspars: orthoclase, microcline
‡**FROTHY** or **FOAMY** rocks are mostly made of void space. They will have very low densities and there will be no visible mineral crystals.

Table 2: Igneous Rock Description Table.

SAMPLE #	**TEXTURE ‡** (see note below)	**CHEMICAL COMPOSITION*** (see table 1 and note below)	**MINERALS †** *(If you can see them,* list name and % *Or write 'too small to see' if you cannot)*	**ROCK NAME** (see table 1)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

‡If the rock is medium-grained, coarse-grained or porphyritic in texture, then identify the minerals present and state their relative percents in the mineral column.

*Be sure your chemical composition is from Table 1, don't just state color.

†Only include information in this column that you can see in the rock specimens

Part B – Igneous Rock Varieties

Sample A: Observe the textural characteristics in an **igneous rock with larger crystals in a fine-grained matrix**.
Examine Sample A and answer the following questions.

1. What is the term used to describe this texture? (see prelab)

2. Describe and identify the mineral that forms the larger crystals.

3. Identify the rock (use correct name from Table 1 on page 7.3).

4. Describe the cooling history of this rock. Support your interpretation with observations of the textural features in the sample. See your textbook for additional information.

Sample B: Observe the textural characteristics in a **fine-grained igneous rock**.
Examine Sample B and answer the following questions.

1. Can you identify any of the minerals present in this sample?

2. What problem do you encounter when trying to identify minerals in a fine-grained rock?

3. Identify the rock (use correct name from Table 1 on page 7-3).

4. Compare this Sample B with Sample A. List two features that would help you distinguish these two rocks.

Sample C: Observe the textural characteristics in a **coarse-grained igneous rock**.

Examine Sample C and answer the following questions.

1. Identify (name) the different mineral grains present in this rock, and give a brief description of each one (color, shape, cleavage, relative size).
   a.

   b.

   c.

   d.

(more?)

2. Identify the rock (use correct name from Table 1 on page 7.3).

3. Describe the shape and relative size of the quartz grains. Can you see crystal faces? Is it larger or smaller than the other minerals?

4. Describe the shape and size of the pink mineral grains. Since cleavage is consistent throughout a single mineral grain, you can use the extent of a flat, shiny cleavage surface to determine the boundaries and shape of the individual mineral grains.

5. Based on your observations, do you think the quartz crystallized before or after the pink mineral? Explain. Where do the dark minerals fit into the crystallization sequence?

6. Using Bowen's Reaction Series, predict the first two minerals to be consumed upon melting of **this (Sample C)** rock.

Name______________________________________

Lab day ______Lab Time______________________

POST-LAB ASSESSMENT

1. Describe the procedure you would follow to determine the name of a specific igneous rock.

2. What factor determines the size of the crystals in igneous rocks?

3. What general principles can be used to determine the order in which mineral crystals form in a cooling magma? Consider the crystallization histories of rocks A and C (in part B) of this lab, and include some of your observations of these rocks in your answer.

ES 104: Laboratory # 8
VOLCANISM AND VOLCANIC LANDFORMS

Introduction

Volcanoes are classified into several major types depending on the size and shape of the landform. A *shield volcano* forms a gently sloping dome built of numerous highly fluid lava flows of basaltic composition. A *composite volcano* or *stratovolcano* forms a conical shaped mountain with steep sides composed of interbedded layers of viscous lava and pyroclastic material. The lavas in a composite volcano consist of andesite, dacite, and rhyolite. *Pyroclastic* refers to volcanic ash or any other airborne particles ejected from a volcano. *Cinder cones* are generally steep sided, conical shaped hills primarily composed of pyroclastic material with minor lava flows. The Cascade Range of the western United States contains all three volcanic forms.

During this lab, you will compare two very different volcanic areas – Hawaii and Mount St. Helens. You will make observations, accumulate a database, organize it into tabular form, and make direct comparisons. It is likely you will need your textbook to make some interpretations of the data, so be sure to bring it to lab.

Objectives

- Compare the morphology of two different types of volcanoes.
- Determine the tectonic setting of two specific volcanoes.
- Examine volcanic rock types in context of their volcano type.

Useful Websites

- http://hvo.wr.usgs.gov/
- http://www.soest.hawaii.edu/GG/HCV/kilauea.html
- http://www.nps.gov/havo/
- http://vulcan.wr.usgs.gov/Volcanoes/Hawaii/framework.html
- http://www.fs.fed.us/gpnf/mshnvm/
- http://vulcan.wr.usgs.gov/Volcanoes/MSH/
- http://pubs.usgs.gov/gip/msh//

Name_______________________________________

Lab day ______Lab Time______________________

Pre-lab Questions – Complete these questions before coming to lab.

1. What are the differences between cinder cone volcanoes, shield volcanoes, and stratovolcanoes? (see lab intro for information)

2. What type of volcano is Mt. Hood? How do you know? What distinguishes it?

3. What is the difference between a pyroclastic volcanic deposit and a lava flow?

4. What is the difference between volcanic ash and lapilli?

5. Define viscosity and explain how it relates to composition of lava flows?

6. Do all volcanoes erupt in the same way and have the same shape? Why or why not?

Part A – Tectonic Environment

Volcanoes occur in a variety of tectonic settings. In this activity, you will examine the tectonic setting of the Hawaiian volcanoes and Mount St. Helens. Study the National Geographic map entitled ***The Earth's Fractured Surface*** to compare the tectonic settings of the volcanic areas. Consider the following information and complete the comparison chart below:

a. Type of crust on which the volcano occurs (oceanic or continental)
b. Name of plate on which the volcano occurs
c. Proximity to plate boundaries (along plate margin or intraplate)
d. Relation to other volcanoes in the area (isolated, in middle of chain, at end of a chain, in center of a wide volcanic area)
e. Summarize the plate tectonic setting

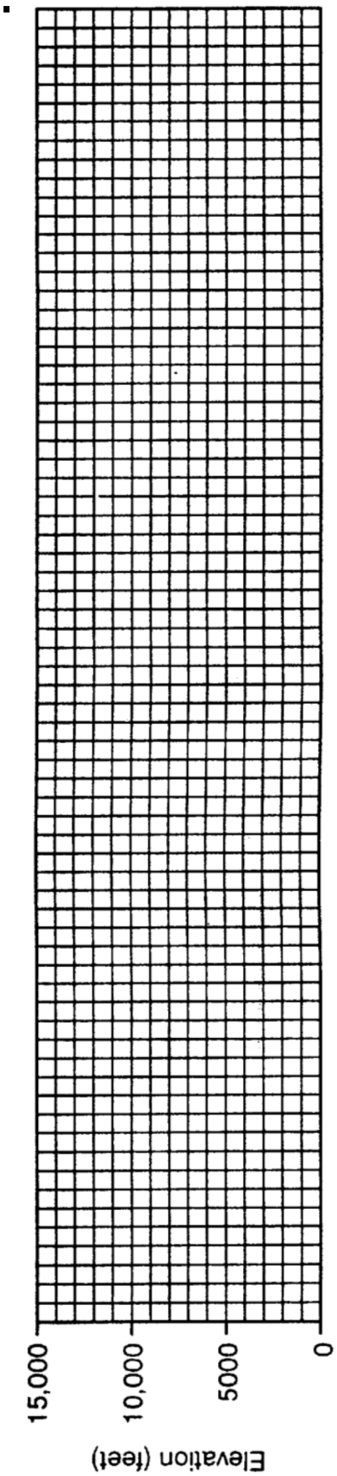
Table 1: Tectonics comparison chart.

Points of	**Hawaiian Volcanoes**	**Mt. St. Helens**
a) Type of Crust		
b) Plate		
c) Proximity to Plate Boundaries		
d) Relation to other volcanoes		
e) Summary		

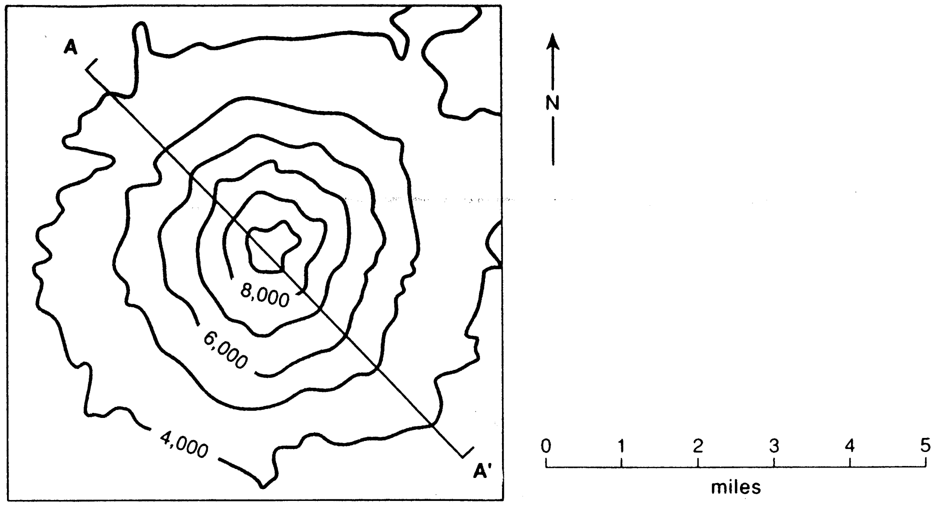
Part B – Topography

Volcanoes are classified based on their topographic expression. This activity focuses on the topography on Mauna Loa, on the island of Hawaii, and Mount St. Helens. Figure 2 shows topographic maps of each volcano drawn at the same scale. Construct topographic profiles of both volcanoes on Figure 1. (A-A' of Mount St. Helens, and B-B' of Mauna Loa). **Place the peaks of the volcanoes near the center of the horizontal axis.**

Figure 1: Grid for constructing topographic profiles.



(A)



(B)

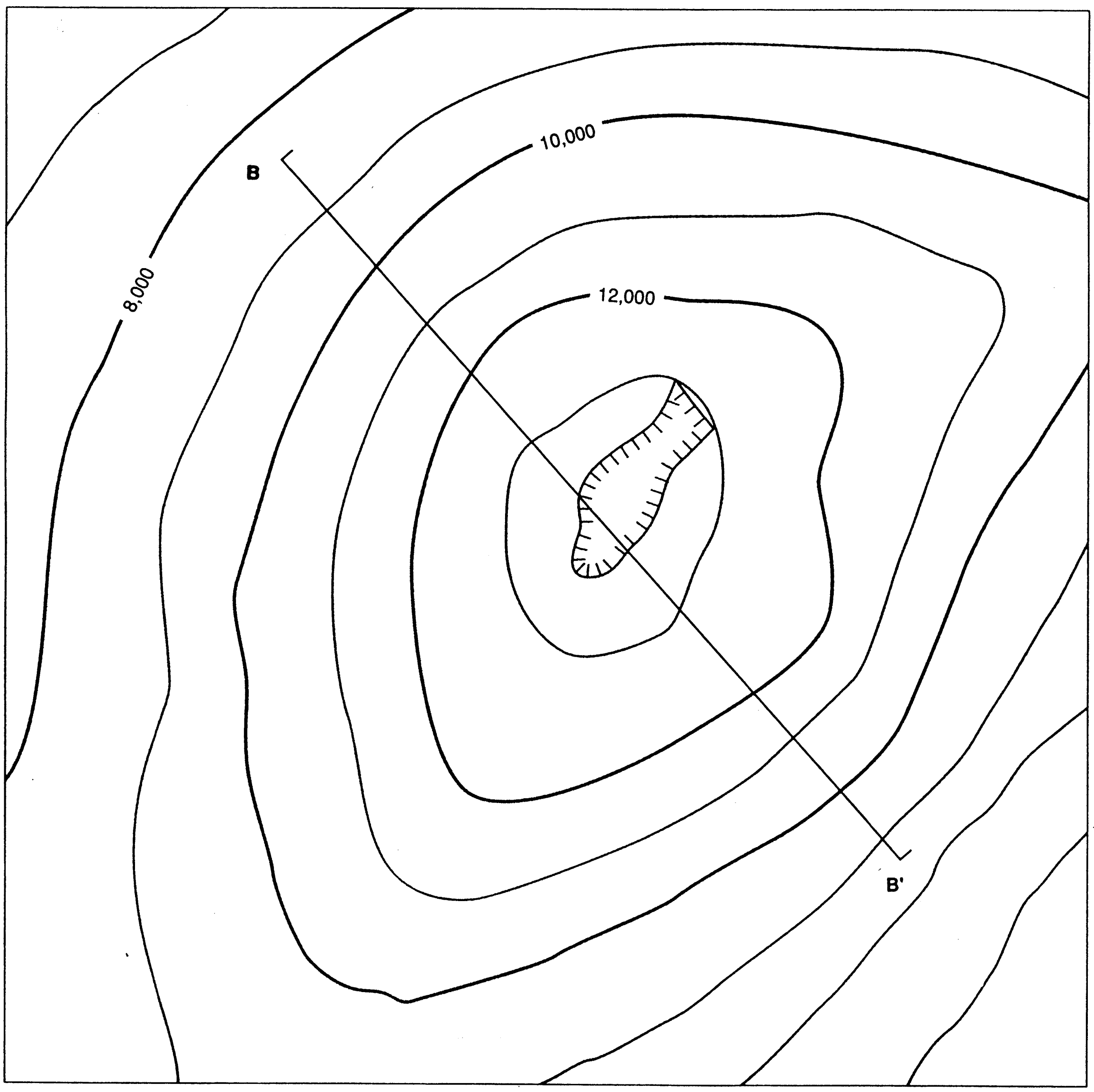


Figure 2: Topographic maps.
(A) Mount St. Helens, Washington. (B) Mauna Loa, Hawaii.

Study the topographic similarities and differences between shield and composite volcanoes. Consider the following information for each volcano and complete the comparison chart below.

a. Describe the morphology of the volcano (shield, composite cone, or cinder cone).
b. Measure the distance across the volcano shown map view (Fig. 2).
c. Determine and record the maximum elevation
d. Relief of volcanic peak above the surrounding topography
e. Calculate the slope of the volcano (vertical change in elevation/horizontal map distance). Use profile and map information.
f. Determine the area under each profile (Assume each block on the graph represents approximately 1 million ft^2)

Table 2: Topography comparison chart.

	Points of Comparison	**Hawaiian Volcanoes**	**Mt. St. Helens**
a.	**Morphology of Volcano**		
b.	**Distance across Volcano**		
c.	**Maximum Elevation**		
d.	**Relief of Volcano**		
e.	**Slope**		
f.	**Area under profile**		

Show calculations (or formulas) with units in chart or below...

Part C –Rock Types and Deposits

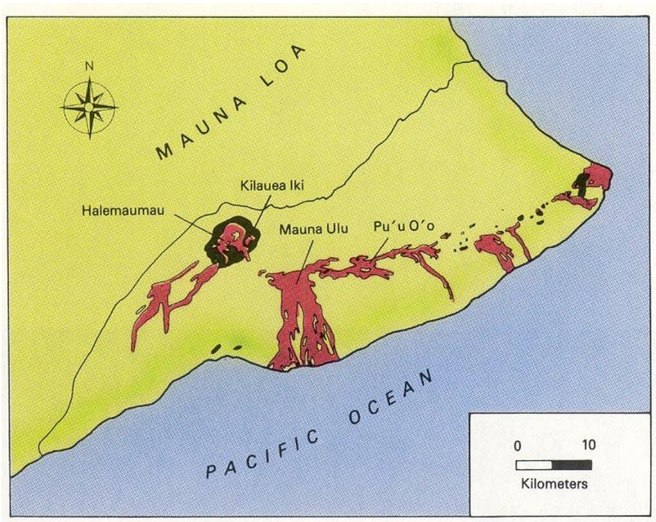
The different types of volcanoes produce different rock types and deposits. By studying the rock types and volcanic deposits, one can determine information about the volcano that produced them. Study examples of various samples from each type of volcano. Describe the samples in terms of texture and composition, provide the correct rock name, and interpret the origin of the samples.

Table 3: Sample comparison chart.

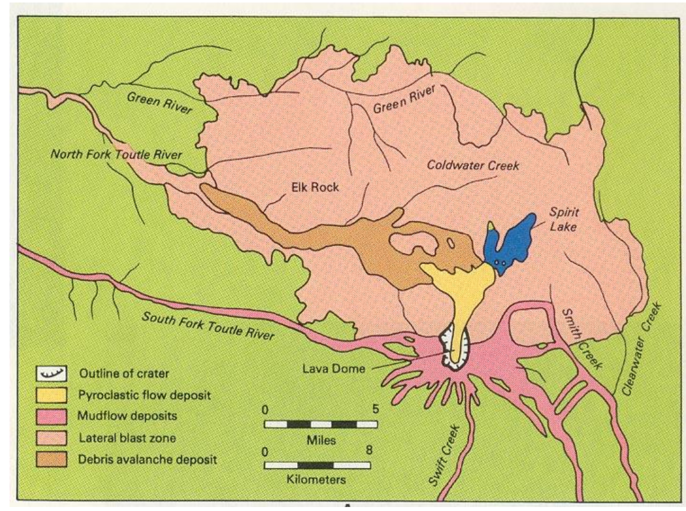
Sample	**Texture**	**Composition**	**Rock Name**	**Origin (volcano type)**
#5				
#6				
#7				
#9				

Study the geologic maps of Kilauea and Mount St. Helens on the next page (8.8). Compare the following attributes of the volcanic deposits of Kilauea and Mount St. Helens and complete the comparison table (Table 4) on page 8.8.

a. Observed composition or compositional range for each volcano.
b. Type and range of deposits produced.
c. Apparent lava viscosity.
d. Relative volume of deposits produced.
e. Surface area affected by primary volcanic deposits.
f. Inferred plumbing system (single conduit, fissures, or both)



Geologic map of Kilauea: Brown areas are lava flows formed since 1900. Black areas are pyroclastic deposits.



Geologic map of Mt. St Helens
Deposits formed from 1980 eruption.

Figure 3: Simplified geologic maps showing volcanic deposits formed around Kilauea and Mount St. Helens since 1900.

Table 4: Volcanic rock types and deposits comparison chart.

Points of	**Hawaiian Volcanoes**	**Mt. St. Helens**
Observed Compositions		
Type and Range of Deposits		
Apparent Lava Viscosity		
Relative volume of deposits		
Surface area affected		
Plumbing system (see 'f', pg. 8.7)		

Name______________________________________

Lab day ______Lab Time_____________________

POST LAB ASSESSMENT

1. Using differences in lava viscosity, explain why the diameter of Mauna Loa is much larger than the diameter of Mount Saint Helens.

2. Explain the relationships of lava viscosity, lava composition, and volcano morphology relative to one another.

3. Suppose 200 million years in the future, that the solidified magma chambers beneath Mauna Loa and Mount Saint Helens became exposed at the surface by erosion. What rock(s) would most likely make up the Mauna Loa magma chamber? What rocks would the Mount Saint Helens magma chamber contain?

ES106 Lab Exercise # 9
Introduction to Scientific Inquiry and Data Analysis

Introduction

Name: ____________
Lab day/time ______

Earth Science employs the scientific method via qualitative and quantitative observation, the collection of data, hypothesis formulation / testing, and hypothesis modification. This lab exercise provides a basic introduction to quantitative observation and analysis.

Part 1 - Unit Conversion: Using the attached metric and English measurement unit conversion tables, complete the following conversions. SHOW YOUR FORMULA WITH UNITS IN THE SPACE PROVIDED, or you will NOT receive full credit for this assignment.

2.05 m = ________ cm

1.50 m = ________ mm

5.4 g = ________ mg

6.8 m = ________ km

4214.6 cm = ________ m

321.5 g = ________ kg

1 in = ________ cm

1 m = ________ ft

1 mi = ________ km

123.4 mi = ________ km

1234 km = ________ mi

1054 lb = ________ kg

2×10^5 in = ________ mi

2×10^9 ft = ________ mi

126,765,000 ft = ________ km

72^o C = ________ ^{o} F

8^o F = ________ ^{o} C

0^oC = ________ ^oF

212^oF = ________ ^oC

5.7×10^{45} sec = ________ years

9.8×10^{20} days = ________ years

2.0×10^{31} in = ________ km

If 1 inch equals 2000 ft on a map; points A and B are 7.8 inches apart on the map. How far apart are points A and B on the ground in feet? in miles?

Part 2. Solving Equations

For Part 2, you must SHOW THE FORMULA AND ALL OF YOUR MATH WORK WITH UNITS!

A. The density of a substance is defined by it's mass divided by it's volume. The equation has the following form:

$$D = M / V$$

where D is density in gm/cm^3, M = mass in grams, and V is volume in cm^3

1. You measure the mass of a substance as 2356 gm. Its volume is 534 cm^3, calculate it's density in gm/cm^3.

2. The density of a substance is 9.8 gm/cm^3. If you had a volume of 3.8 cm^3 of the substance, what would be the corresponding mass in grams? Hint: Use the units to properly set up the equation.

3. The density of a substance is 2.5 gm/cm^3 and you possess 15.3 grams of that material. What will be its corresponding volume in cm^3. Hint: Rearrange the density equation by solving for mass. Then calculate the volume.

B. The velocity of moving objects (for example your car while driving) is measure as a rate of motion, according to the following equation:

$$V = d / t$$

where V is velocity (m/sec), d is distance (m), and t is time (sec).

4. You drive your car between two cities that are 123 miles apart. It takes you 4 hours to get there. Calculate your average velocity in mi/hr.

5. Using the velocity you calculated in 4 above, what was your velocity in m/sec? Hint: you will have to use a distance and a time conversion factor.

6. You are driving a car at a velocity of 10 m/sec for a distance of 12 km. How long did it take you to get there? Answer in hours.

Part 3. Introduction to Hypothesis Testing, Data Collection, and Analysis

The scientific method involves observation, hypothesis formulation, data collection/analysis, and hypothesis testing. Let's use your lab class to introduce the basic concepts.

A. **Observation** - Make a qualitative (non-numeric) observation by examining all the individuals in your lab class and pay attention to their relative height and shoe size. Based on your observations, write a hypothesis that relates a person's height to their shoe size (i.e. how do you think they relate to one another, if at all?).

B. **Data Collection** - Now let's collect some data to test your hypothesis from "A" above. Using the meter sticks and other tools available in the lab, measure the height of 15 class mates (to the nearest hundredth of a meter) and their shoe length (to the nearest whole millimeter). Randomly select your subjects from the group. Fill in the data table below.

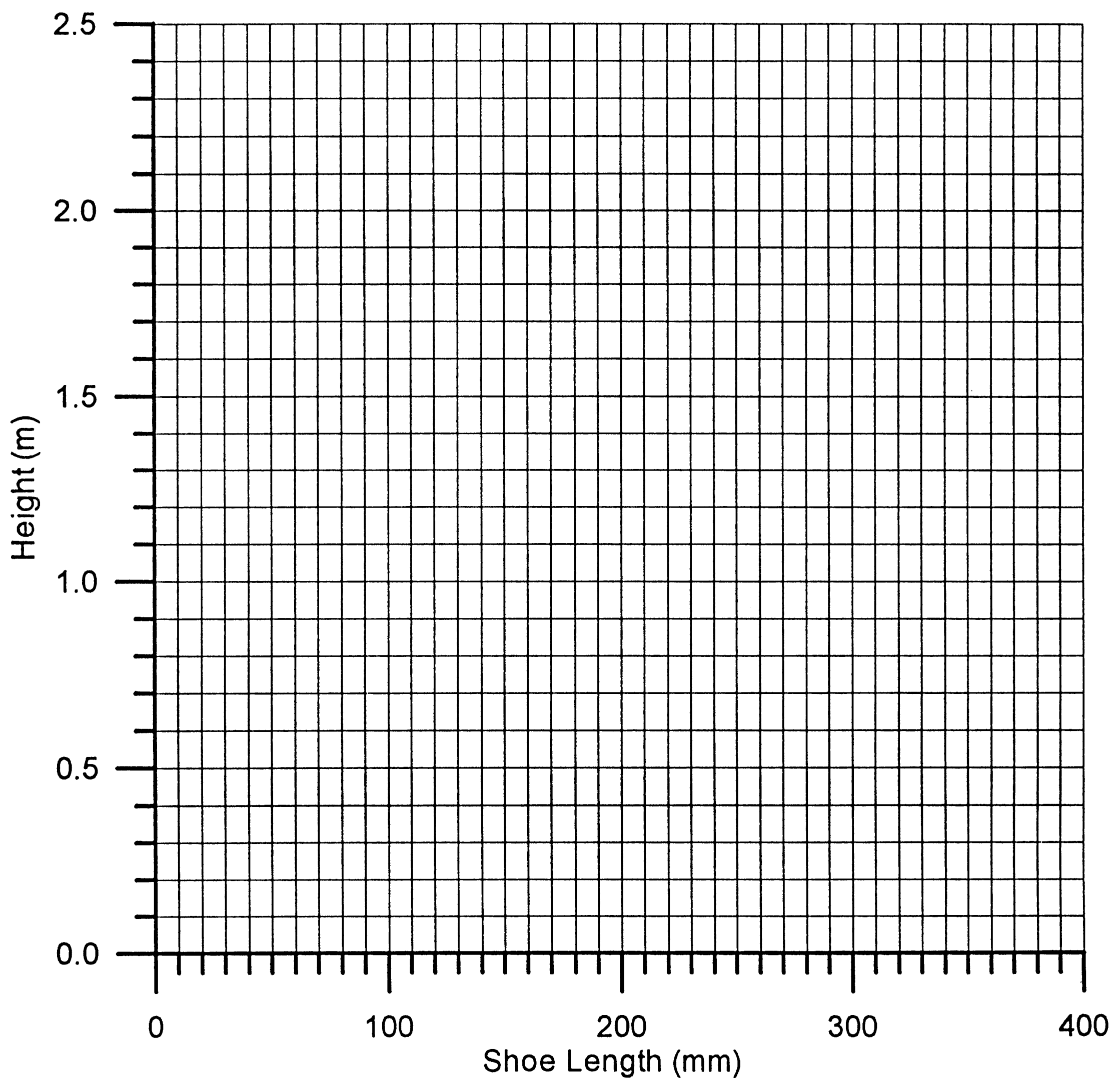
Person ID	Height (nearest hundredth of meter)	Shoe Length (nearest millimeter)
1	______________ m	____________________ mm
2	______________ m	____________________ mm
3	______________ m	____________________ mm
4	______________ m	____________________ mm
5	______________ m	____________________ mm
6	______________ m	____________________ mm
7	______________ m	____________________ mm
8	______________ m	____________________ mm
9	______________ m	____________________ mm
10	______________ m	____________________ mm
11	______________ m	____________________ mm
12	______________ m	____________________ mm
13	______________ m	____________________ mm
14	______________ m	____________________ mm
15	______________ m	____________________ mm

C. **Graphical Analysis** - Plot a "scatter graph" of the data collected on the graph below. Use Shoe Length (mm) on the X-axis, and Height (m) on the Y-axis. Once you plot the points, do the following, and answer the questions at the end.

(i) Describe the overall shape or trend of the data points on the graph (for e.g. straight line pattern, curved line pattern, "shot gun" scatter pattern, etc.).

(ii) If there is a linear trend to the data, draw a "best-fit" line on the graph that appears to average the pattern of the data points.

Plot of Student Height vs. Shoe Length

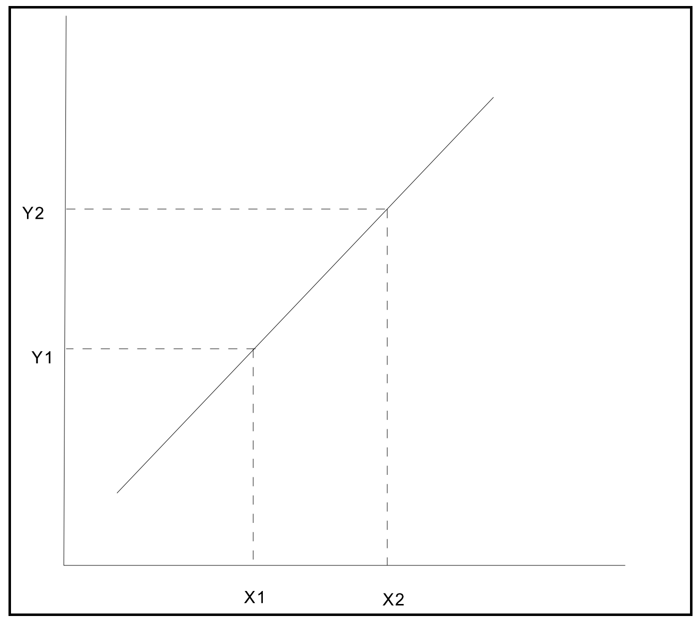


Analytical Questions / Summary

The general equation of a line has the form: Y = mX + B

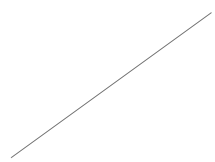
Where Y is the predicted value on the Y axis, X is the observed value on the X axis, B is the Y-intercept or the Y value at the point where the line intersects the Y axis. and m is the slope of the line.

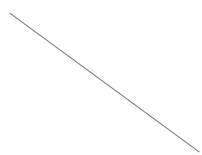
Determining Slopes of Lines—
Slope of any line on a graph = rise / run = $(Y_2 - Y_1) / (X_2 - X_1)$ See diagram to right.



Specifically, lines that are oriented like those shown below can be described as indicated.

Positive Slope





Negative Slope

Zero Slope

Undefined Slope

1. Use your data plotted on the 'Height vs. Shoe Length' graph to determine the equation of the line that best fits your data. The Y value is height; the X value is shoe length.

Your line equation will have the form:

Height = m(Shoe Length) + B where
Height = predicted height of individual,
Shoe Length = measured shoe length,
m = slope of line on the graph, page 9.4
B = y intercept (where line crosses vertical axis) of line on your graph, page 9.4.

Step 1: Determine B--the Height value where your best fit line intersects the Y axis

Step 2: Calculate m--the slope of the line using the rise/run formula on pg. 9.5

Step 3: Plug your B and m values from your graph on page 9.4 into the blanks of the equation below:

Height = ___ (Shoe Length) + ____

There! You have determined the equation of the linear relationship between height and shoe size for your class mates!

2. Ask several friends (that were not included in your data to make the graph) their shoe length in millimeters. Plug this data into your equation above and calculate their predicted height. See if their height is predicted accurately. How well does your equation predict the shoe size of your unknown participants?

3. Using your graph's ability to predict height from shoe length, comment on the viability of your original hypothesis (Part 3A Observation on page 9.4). Does the data support it or reject it? Explain your answer.

4. What would you do to further test the validity of your hypothesis? What would happen if you collected height and shoe data from Brazilian class mates? Would the Brazilian data likely fall in the same data set or not? Discuss the strengths and limitations of your analytical ability to predict height and shoe size.

ES 104 Laboratory # 10
LENSES AND TELESCOPES

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.

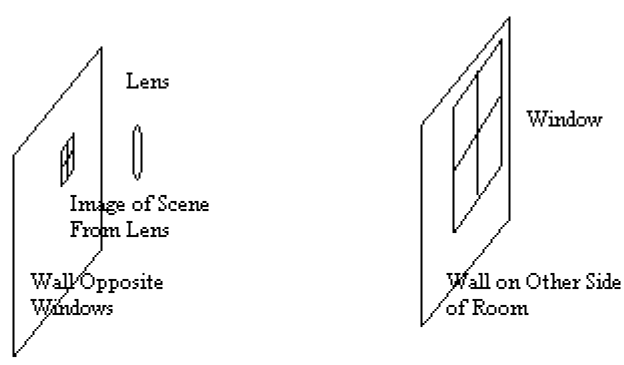


Figure 2: Lens-room configuration

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?

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 image 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.

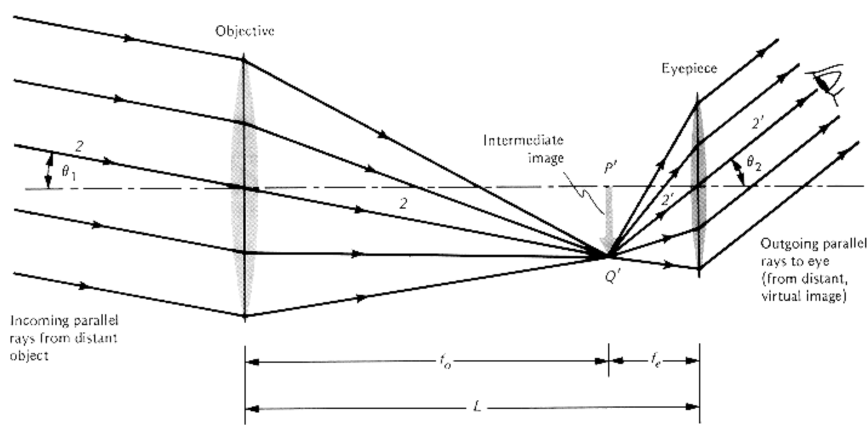


Figure 3: Diagram of a refracting astronomical telescope.

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

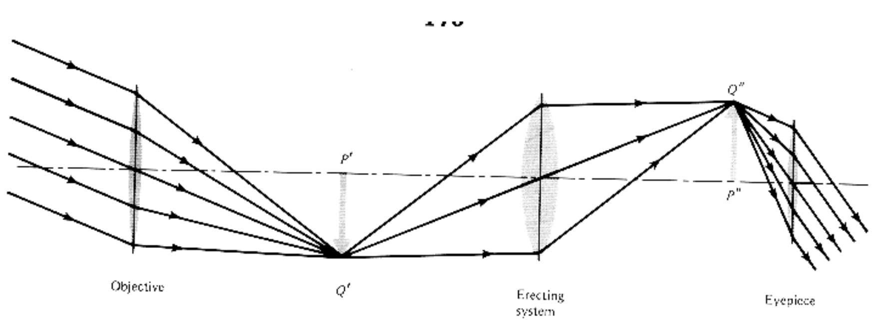


Figure 4: Diagram of a refracting terrestrial telescope.

telescope becomes rather long (of the type favored by pirates). An 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. 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).

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 getting 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.

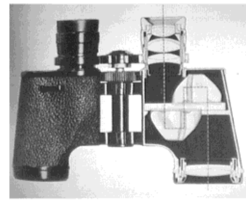


Figure 5: A cut away view of binoculars.

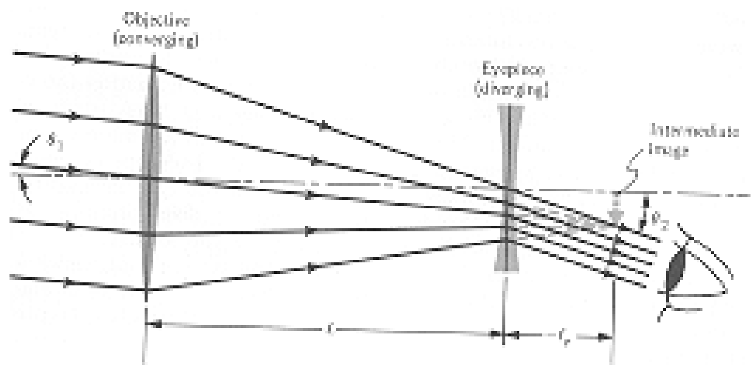


Figure 6: Diagram of a Galilean telescope.

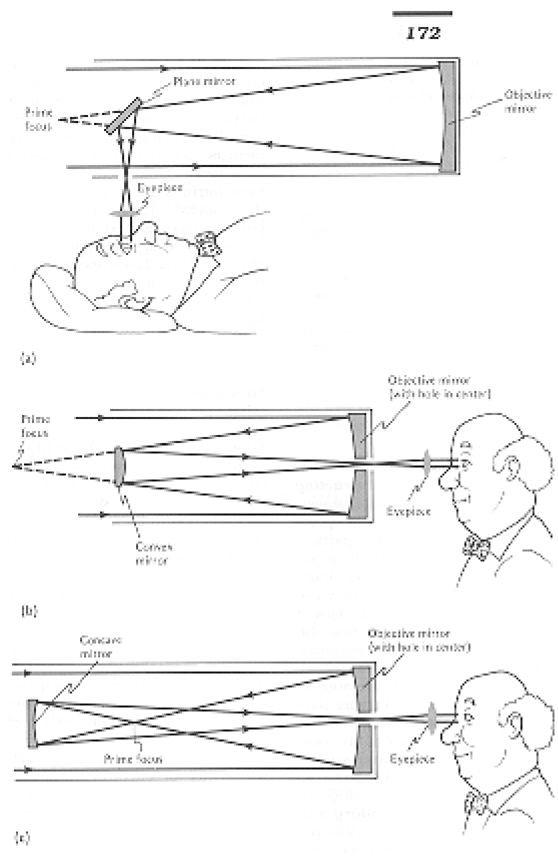


Figure 7: Diagrams of reflecting telescopes.

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.

<u>The Refracting Astronomical Telescope</u>: 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.

<u>The Galilean Telescope</u>: 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.

APPENDIX –Unit Conversions

Multiply units in left column by number in table to obtain units at top of table column

Table 1: Length conversion to metric units

Unit	mm	cm	m	km
1 millimeter	1	0.1	0.001	10^{-6}
1 centimeter	10	1	0.01	0.0001
1 meter	1000	100	1	0.001
1 kilometer	10^{6}	10^{5}	1000	1
1 inch	25.4	2.54	0.0254	2.54×10^{-5}
1 foot	304.8	30.48	0.3048	3.05×10^{-4}
1 yard	914.4	91.44	0.9144	9.14×10^{-4}
1 mile	1.61×10^{6}	1.61×10^{5}	1.61×10^{3}	1.6093

Table 2: Length conversion to English units

Unit	in	ft	yd	mi
1 millimeter	0.0397	0.00328	0.00109	6.21×10^{-7}
1 centimeter	0.3937	0.0328	0.0109	6.21×10^{-6}
1 meter	39.37	3.281	1.094	6.21×10^{-4}
1 kilometer	39,370	3281	1093.6	0.621
1 inch	1	0.0833	0.0278	1.58×10^{-5}
1 foot	12	1	0.333	1.89×10^{-4}
1 yard	36	3	1	5.68×10^{-4}
1 mile	63,360	5280	1760	1

Table 3: Area conversion to metric area units

Unit	cm^2	m^2	km^2	ha
1 sq. centimeter	1	0.0001	10^{-10}	10^{-8}
1 sq. meter	10^{4}	1	10^{-6}	10^{-4}
1 sq. kilometer	10^{10}	10^{6}	1	100
1 hectare	10^{8}	10^{4}	0.01	1
1 sq. inch	6.452	6.45×10^{-4}	6.45×10^{-10}	6.45×10^{-8}
1 sq. foot	929	0.0929	9.29×10^{-8}	9.29×10^{-6}
1 sq. yard	8361	0.8361	8.36×10^{-7}	8.36×10^{-5}
1 sq. mile	1.59×10^{10}	2.59×10^{6}	2.59	259
1 acre	4.04×10^{7}	4047	4.047×10^{-3}	0.4047

Temperature Conversions : $F^0 = \left(\frac{9}{5} \times C^0\right) + 32$ $\qquad C^0 = \frac{5}{9}\left(F^0 - 32\right)$

Table 4: Area conversion to English area units

Unit	in^2	ft^2	yd^2	mi^2	ac
1 sq. cm	0.155	1.08x10^{-3}	1.2x10^{-4}	3.86x10^{-11}	2.47x10^{-8}
1 sq. meter	1550	10.76	1.196	3.861x10^{-7}	2.47x10^{-4}
1 sq. km	1.55x10^{9}	1.076x10^{7}	1.196x10^{6}	0.3861	247.1
1 hectare	1.55x10^{7}	1.076x10^{5}	1.196x10^{4}	3.861x10^{-3}	2.471
1 sq. inch	1	6.94x10^{-3}	7.7x10^{-4}	2.49x10^{-10}	1.574x10^{-7}
1 sq. foot	144	1	0.111	3.587x10^{-8}	2.3x10^{-5}
1 sq. yard	1296	9	1	3.23x10^{-7}	2.07x10^{-4}
1 sq. mile	4.01x10^{9}	2.79x10^{7}	3.098x10^{6}	1	640
1 acre	6.27x10^{6}	43560	4840	1.562x10^{-3}	1

Table 5: Volume conversion to metric volume units

Unit	mL	liters	m^3
1 milliliter	1	0.001	10^{-6}
1 liter	10^{3}	1	0.001
1 cu. meter	10^{6}	1000	1
1 cu. inch	16.39	1.64x10^{-2}	1.64x10^{-5}
1 cu. foot	28,317	28.317	0.02832
1 U.S. gallon	3785.4	3.785	3.78x10^{-3}
1 acre-foot	1.233x10^{9}	1.233x10^{6}	1233.5
1 million gallons	3.785x10^{9}	3.785x10^{6}	3785

Table 6: Volume conversion to English volume units

Unit	in^3	ft^3	gal	ac-ft	million gal
1 milliliter	0.06102	3.53x10^{-5}	2.64.10^{4}	8.1x10^{-10}	2.64x10^{-10}
1 liter	61.02	0.0353	0.264	8.1x10^{-7}	2.64x10^{-7}
1 cu. meter	61,023	35.31	264.17	8.1x10^{-4}	2.64x10^{-4}
1 cu. inch	1	5.79x10^{-4}	4.33x10^{-3}	1.218x10^{-8}	4.329x10^{-9}
1 cu. foot	1728	1	7.48	2.296x10^{-5}	7.48x10^{6}
1 U.S. gallon	231	0.134	1	3.069x10^{-6}	10^{6}
1 acre-foot	75.27x10^{6}	43,560	3.26x10^{5}	1	0.3260
1 million gal.	2.31x10$_{8}$	1.338x10^{5}	10^{6}	3.0684	1

Table 7: Time conversion

Unit	sec	min	hours	days	years
1 second	1	1.67x10^{-2}	2.77x10^{-4}	1.57x10^{-5}	3.17x10^{-8}
1 minute	60	1	1.67x10^{-2}	6.94x10^{-4}	1.90x10^{-6}
1 hour	3600	60	1	4.17x10^{-2}	1.14x10^{-4}
1 day	8.64x10^{4}	1440	24	1	2.74x10^{-3}
1 year	3.15x10^{7}	5.256x10^{5}	8760	365	1