

Astronomy

AST 101 Lab Book



York Technical College

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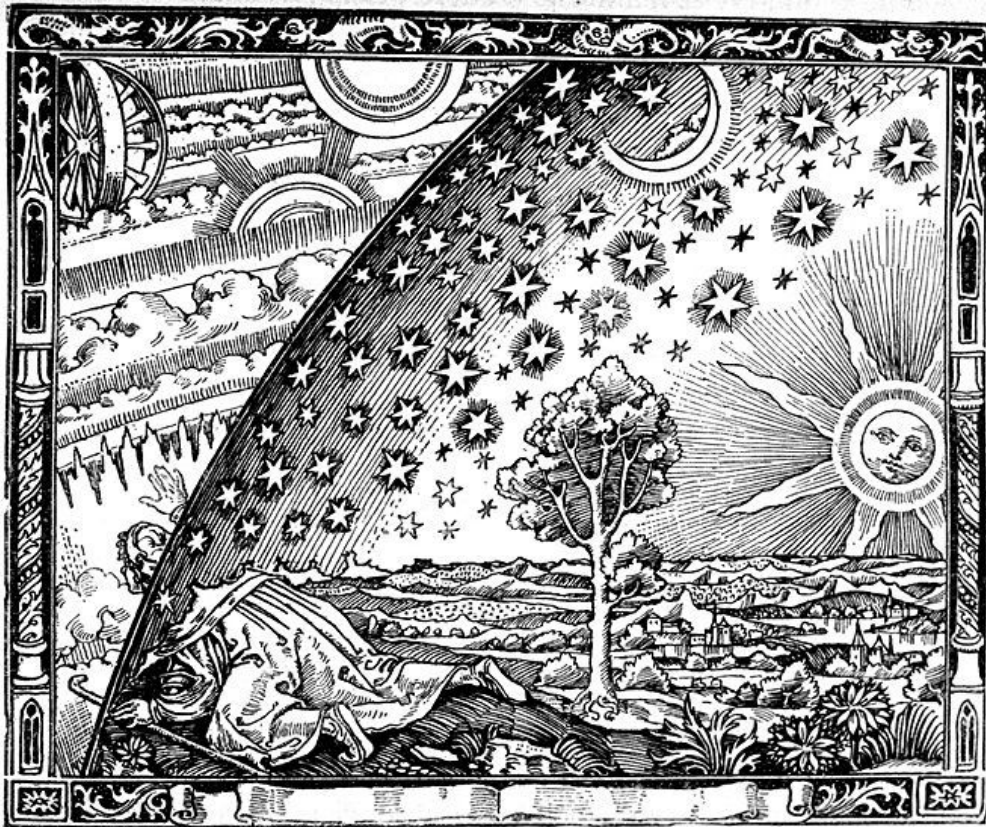
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Welcome to AST 101

Welcome to AST 101 at York Technical College. This class is being taught as a “hybrid” class, which means that sometimes we will meet and work in class/lab on campus and sometimes you be working on your own at home. This really offers the best of both worlds as you get the help you need, and the freedom and convenience of working according to your schedule.

At home you will login to D2L and receive reading and activity assignments and submit your work to be graded. We will also meet roughly once a week in room ST 210. During this time we will discuss the main ideas of the current material, work problems, answer any questions and perform lab experiments and activities to make the material clear. The labs will be turned in through D2L.

My main webpage is at <http://www.yorktech.com/science/craig/>
To contact me come by ST227, call (803)981-7342 or write lcraig@yorktech.com



Un missionnaire du moyen âge raconte qu'il avait trouvé le point
où le ciel et la Terre se touchent...

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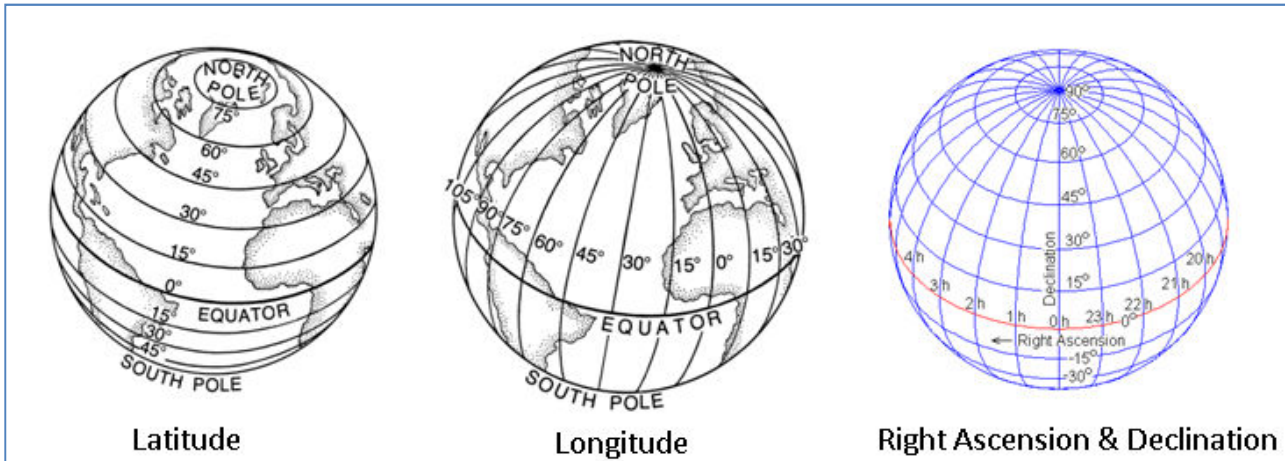
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Lab 1: Coordinate Systems & Star Charts

To find our way around, we develop systems that map significant places. Here on Earth we call these imaginary lines Latitude and Longitude. In space we extend these lines out into space and call the lines Declination and Right Ascension.

The picture on the left shows the Earth's lines of Latitude, which measure the angle above or below the equator. The picture in the middle shows the lines of Longitude, which measure the angle east or west of the "Prime Meridian" which runs through Greenwich England. By using both sets of lines we can pinpoint any spot on Earth. For example Rock Hill SC is roughly 35° north of the equator and 81° west of the prime meridian.

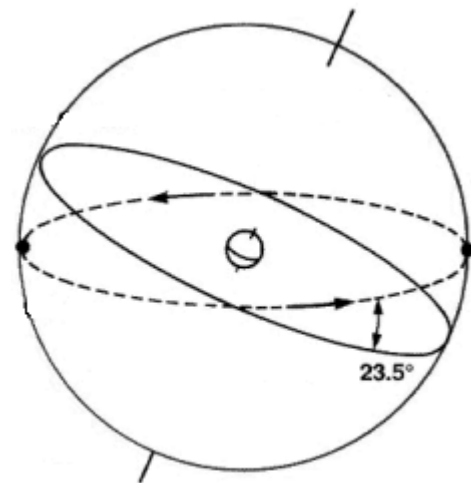
The picture on the right shows the lines of Latitude and Longitude extended out into space. What were the lines of Longitude are marked off every 15° and labeled as hours of Right Ascension. The old lines of latitude are the same, but are called Declination.



Procedure 1 - Coordinates – Some terms you need to know:

- The **Celestial North Pole (CNP)** is above Earth's North Pole.
- The **Celestial South Pole (CSP)** is above Earth's South Pole.
- The **Celestial Equator** is directly above Earth's equator.
- The **Ecliptic** is the path the Sun and planets appear to follow.
- The **Equinoxes** (spring and fall) occur when the Ecliptic crosses the Celestial Equator.
- The **Solstices** occur when the Ecliptic is at its highest (summer) or lowest (winter) point.

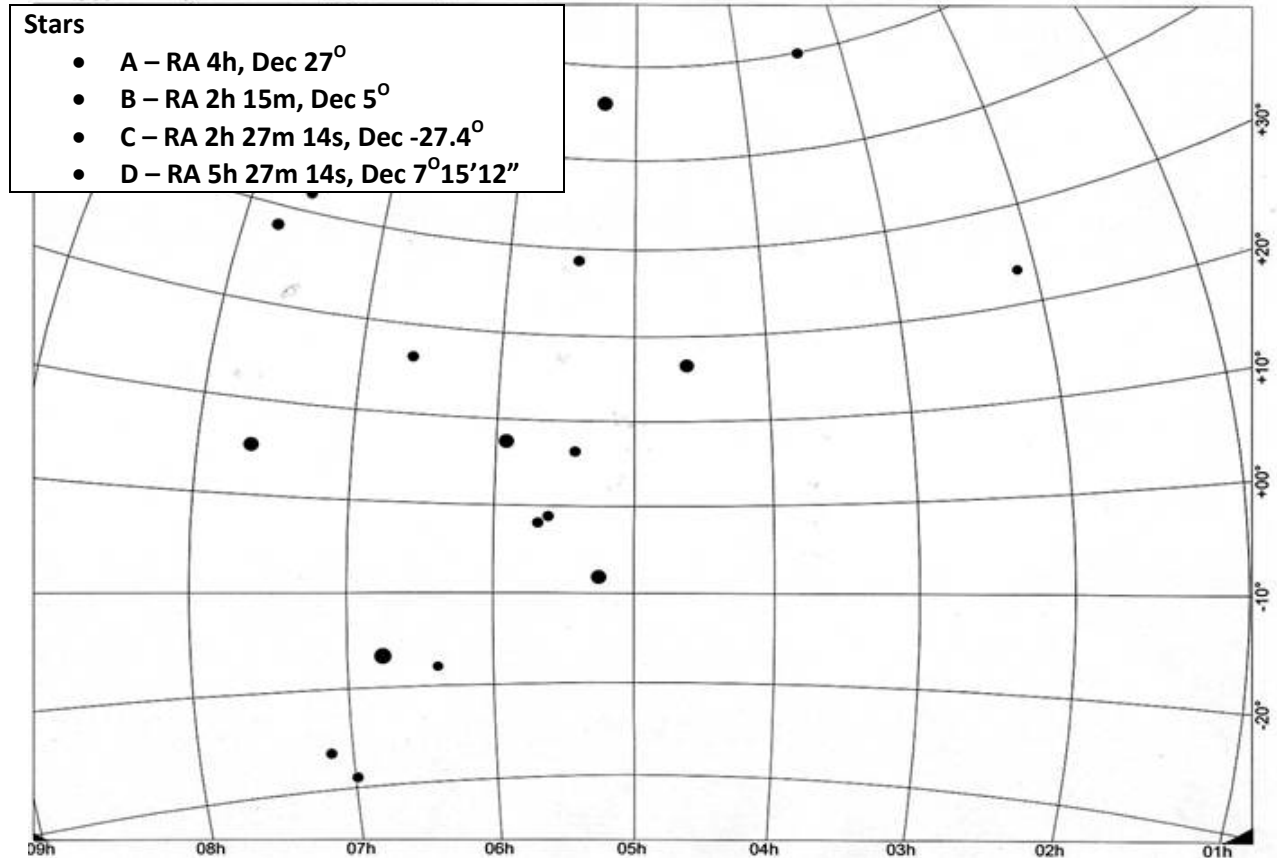
Map these points or lines on the figure at the right. The Earth is the small circle inside the larger "Celestial Sphere".



Procedure 2 - Coordinates – Map the following points using the lines of longitude and latitude and identify the city at that point . The cities are London, Moscow, Paris, New York & Dallas



Procedure 3 – Space Coordinates - Plot the stars using hours of Right Ascension and degrees of Declination.



Procedure 4 – Planisphere - A “Planisphere” is a star chart capable of showing the positions of the stars at any date and time. Two disks are pinned together and will rotate to show the movement of the night sky. All you have to do is match the date on the dark blue disk with the time on the light blue outer cover.



Using the Planisphere, answer these questions:

- 1) At what time will the constellation Leo rise above the Eastern horizon on January 15?
 9 pm 11 pm 1 am 3 am

- 2) At what time will the constellation Leo rise above the Eastern horizon on April 15?
 9 am 11 am 1 pm 3 pm

- 3) On Mar 15 at 2 am, which of the following constellations would be near the southern horizon?
 Cygnus Centaurus Canis Minor Cassiopeia

- 4) At what time do the constellations Ursa Minor and Cassiopeia go below the horizon today? (These are called “circumpolar” constellations)
 4 am 6 am 8 am They don’t

- 5) Mar 21 at noon, the two lines representing the Ecliptic and the Celestial Equator cross. What does this mean? Check all that apply.
 The end of the world Vernal Equinox 1st day of spring Christmas

- 6) Is the sun higher in the sky in the Winter or in the Summer. (Hint: hold the planisphere by the point marked south, turn the wheel and watch the dotted ecliptic line. Closer to you is closer to the ground. Check the date closest to south)
 Higher in winter Higher in summer Same Neither

Lab 2: Planetarium

The planetarium at The Museum of York County offers an excellent opportunity to view the stars without the hazards of inclement weather, light pollution and sleepless nights. It is also very easy to view the stars as they would appear at other places or times, and to add lines representing the ecliptic, Right Ascension and Declination and other coordinate markers.

Questions

1. In the course of one day which star doesn't appear to move? _____
2. What are "circumpolar constellations"? _____
3. The Celestial Equator runs through which of these constellations?
Orion Cephus Leo Cassiopeia
4. The Ecliptic runs through which of these constellations?
Orion Cephus Leo Cassiopeia
5. The Celestial Equator and the Ecliptic cross how many times _____ in the constellations

6. How do the lines of Right Ascension move relative to the stars? _____
7. Declination measures _____
8. Why is Orion a "winter constellation"? _____
9. The "great square" is a part of what constellation? _____
10. In the planetarium, the Milky Way appears as a _____
11. Why can't we see this in Rock Hill? _____
12. What company made the planetarium projector? _____
13. When was it made? _____

Lab 3: Optics

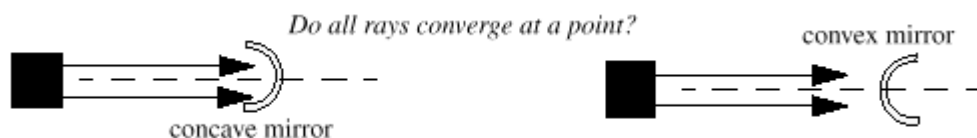
Optics is the study of light and how light interacts with matter and itself. In this experiment we will observe three main topics of optics; reflection, refraction and color mixing.

Equipment	Vocabulary
Light box and optics set	Reflection – “bouncing” a ray of light
Power supply	Refraction – bending of a ray of light as it passes through different materials
Protractor	Plane - flat
Ruler	Concave – curved inward
Paper	Convex – curved outward
Sharp Pencil	Normal – a line drawn at a right angle
	Converge – come together
	Diverge – move apart

Setup - Connect the electrical plugs for the light box into the DC outputs of the power supply. Plug the power supply in and adjust the voltage with the knob on the front of the power supply to NO MORE THAN 10 VOLTS DC. Supplying more than 10 V will cause the very expensive light bulb to burn out.

Place the light box on a blank sheet of paper. Insert the "four slit mask" in the end of the light box farthest from the light source. Adjust the lens with the black knob on the top of the light box, until the four light rays viewed on the sheet of paper are parallel.

Procedure 1 - Reflection - With the lights dimmed, observe the light paths for both sides of all of the different kinds of mirrors in the light box kit. Sketch the position of the mirror. Then, sketch the rays of light before and after they strike the mirror. Answer the questions on the datasheet.



1) What type of mirrors cause all rays to converge at a point?

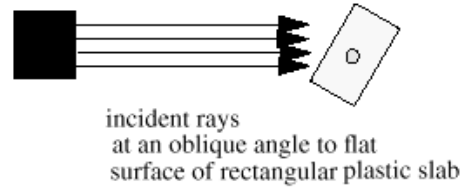
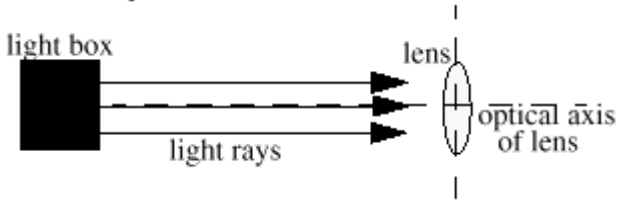
2) Pick one ray in your diagram of reflection with a plane mirror. Draw a normal to the line representing the mirror at the point where the ray strikes the mirror. Measure the angle between the “mirror” and incoming ray. This is called the angle of incidence. Now measure the angle between the mirror and the outgoing ray. This is the angle of reflection. What happened?

3) What is true about the angle of incidence and angle of reflection for the curved mirrors?

4) In your diagram of the semicircular concave mirror, measure the distance from the mirror to the point where the rays converge. This is called the focal length. The point where the rays converge is called the focal point.

5) In your diagram of the semicircular convex mirror, continue the lines representing the reflected rays back through the “mirror”. Do they cross at a point? What is the focal length?

Procedure 2 – Refraction - With the lights dimmed, observe the light paths for both sides of all of the different kinds of lenses in the light box kit. Sketch the position of the lens. Then, sketch the rays of light before and after they strike the lens. Answer the questions on the datasheet.



Include the rectangular prism with the prism rotated as shown above.

- 1) What type of lenses or prisms cause all rays to converge at a point?

- 2) Pick one ray in your diagram of refraction with the rectangular prism. Measure the small angle between the “prism” and incoming ray. Now measure the small angle between the “prism” and the outgoing ray. What happened?

- 3) In your diagram of the convex lens, measure the distance from the lens to the point where the rays converge. This is called the focal length. The point where the rays converge is called the focal point.

- 4) In your diagram of the concave lens, continue the lines representing the refracted rays back through the “lens”. Do they cross at a point? Measure the focal length?

Procedure 3 – Lens Equation & Magnification – The formulas below govern optics and relate the following variables:

- f is the focal length of the lens,
- p is the “object distance” – the distance from the object to the lens
- q is the “image distance” or distance from the lens to the image.
- m is the magnification, how many times larger the image is than the original object. Negative magnification means the image is upside down.

$$q = \frac{pf}{p - f} \quad \text{and} \quad m = -\frac{q}{p}$$

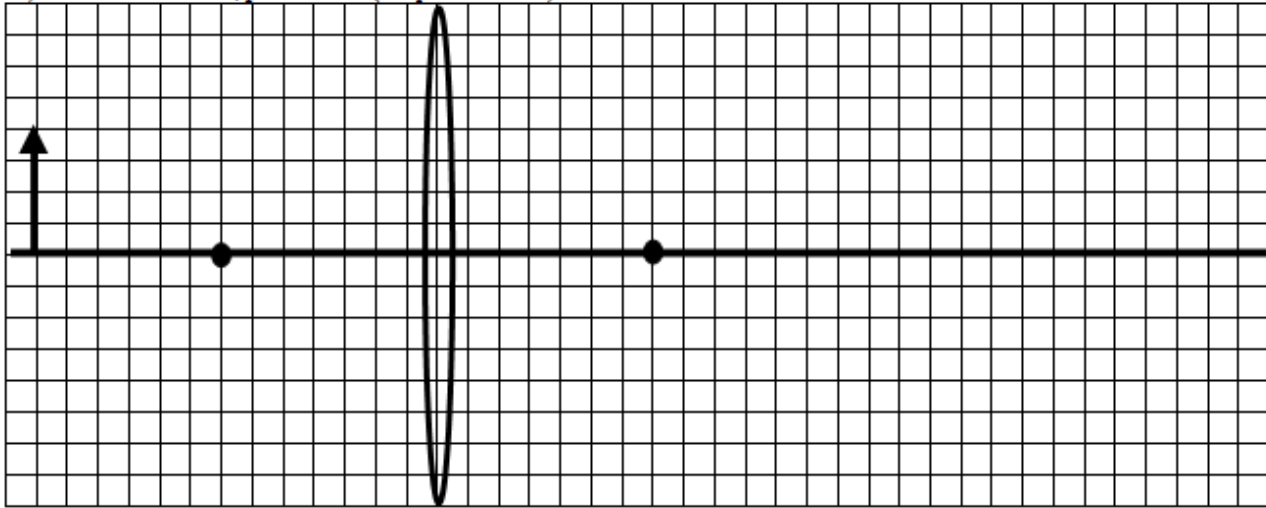
- 1) A tree is 15 m from a lens with a focal length of 3 m. Find the image distance and the magnification.

- 2) A tree is 3 m from a lens with a focal length of 2 m. Find the image distance and the magnification.

Procedure 4 – Ray Diagrams – Ray diagrams show what happens with the light beams.

- 1st Ray - Draw from the top of the arrow straight across to the middle of the lens, pass through the far focal point and keep going.
- 2nd Ray - Draw from the top of the arrow through the center of the lens and keep going.
- 3rd Ray - Draw from the top of the arrow through the close focal point until you reach the middle of the lens, and then go straight across and keep going.
- The three rays should all cross at the same point, which is where the image will appear, and the height of the image.

1) LENS: $f = 35 \text{ cm}$, $p = 65 \text{ cm}$ (1 square = 5 cm)



$q =$ _____ Image height _____ Magnification from height _____

Use the equations from procedure 3 to find:

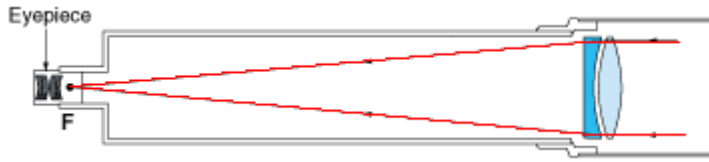
$q =$ _____ Magnification from height _____ Image height _____

Procedure 5 – Optics Bench – An optics bench uses a lens in a sliding frame to study optics.

- Place a lens in the frame & turn on the light box.
- Slide the lens until a clear image is formed on the screen.
- Measure the distance from the object to the lens. $p =$ _____
- Measure the distance from the lens to the image. $q =$ _____
- Calculate the focal length of the lens $f = \frac{pq}{p + q} =$ _____
- Is the image right side up or upside down? _____
- Is the image left-right reversed? _____

Lab 4: Telescopes & Spectroscopy

Procedure 1 – Refracting Telescopes – When a telescope is made using lenses, it refracts the light to focus the light for your eye.



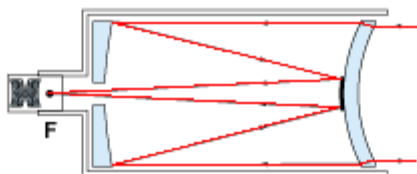
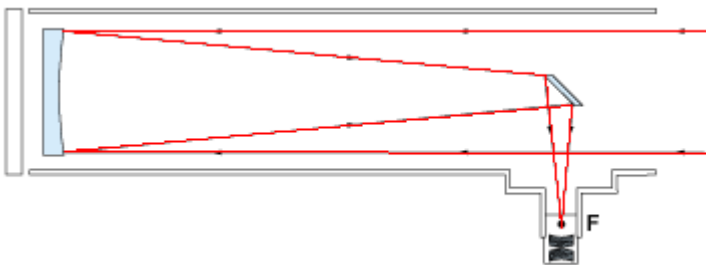
- The bigger the diameter of the opening of the telescope, the more it gathers and the better the image is. Measure (or read) the aperture of the objective lens

50 mm 60 mm 80 mm 100 mm

- Using the refracting telescope in lab, observe the satellite tower on the north side of campus. Describe the red shape on the white dish at the top.

Star Comet Lightning Bolt Raccoon

Procedure 2 – Reflecting Telescopes -



- Using the reflecting telescope in lab, observe the cellphone tower on the south side of campus. At the very top there are some black wires going to the vertical transmitters. What two colors of electrical tape are wrapped around these black wires?

Green and blue Red and green Red and blue Yellow and blue

- Try both eyepieces. Do you get higher magnification with the 25 mm or the 40 mm eyepiece

25 mm 40 mm neither the same

- Do you see more area with the 25 mm or the 40 mm eyepiece

25 mm 40 mm neither the same

Procedure 3 – Spectroscopy – We also look at the light from stars through a “spectrometer”. This breaks white light into the spectrum (or rainbow). Light from Each gases give off distinctive patterns and can identify

What color is “bent” the most? _____

Mystery Gas 1 light: Draw the spectrograph.



What is it?

Mystery Gas 2 light: Draw the spectrograph.



What is it?

Mystery Gas 3 light: Draw the spectrograph.



What is it?

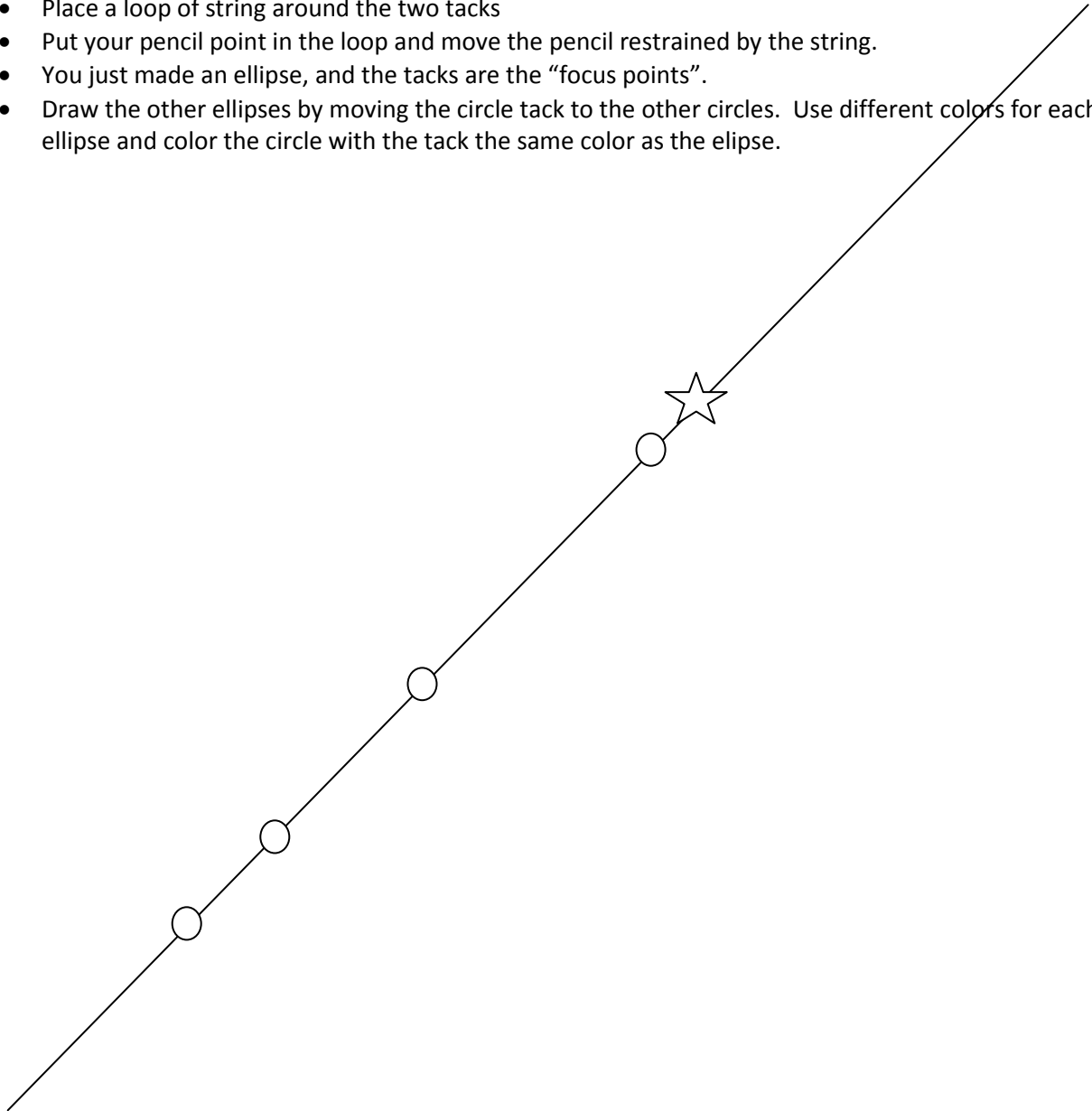
Lab 5: Kepler's Laws

Around 1605, three mathematical laws were discovered by German mathematician and astronomer Johannes Kepler (1571–1630), and used by him to describe the motion of planets in the Solar System.

- The orbit of every planet is an ellipse with the sun at a focus.
- A line joining a planet and the sun sweeps out equal areas during equal intervals of time.
- The square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit.

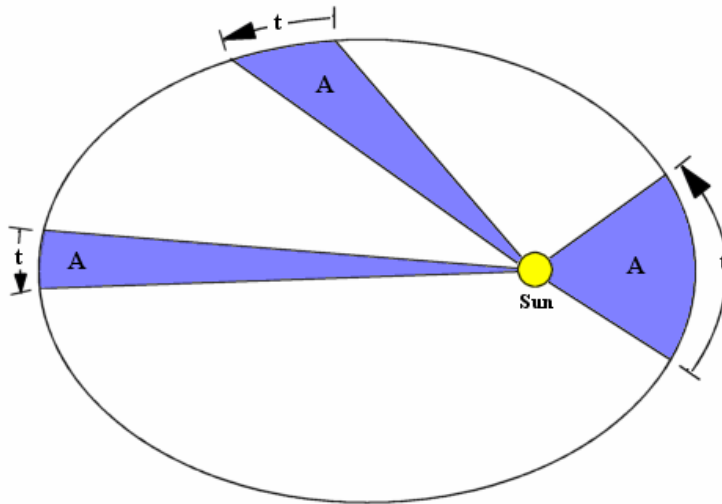
Procedure 1 – Drawing Ellipses - Ellipses can be thought of as a “flattened circles”. Draw a couple of ellipses below.

- Push a thumbtack through the star on the line below into a surface.
- Push another tack into one of the circles.
- Place a loop of string around the two tacks
- Put your pencil point in the loop and move the pencil restrained by the string.
- You just made an ellipse, and the tacks are the “focus points”.
- Draw the other ellipses by moving the circle tack to the other circles. Use different colors for each ellipse and color the circle with the tack the same color as the ellipse.



Procedure 2 – 2nd Law - Planets sweep out equal areas in equal times. Three areas are shaded, but each was made in the same amount of time. When the object is closest to the Sun it moves faster. When the planet moves farther out, it slows down.

- The plexiglass ellipse representing the orbit of Halley’s comet and Pluto’s comet is cut into sections that would be swept out in equal times.
- Get the mass of each wedge by placing it on a scale and record it in the table below. If the wedges have equal masses, they have equal areas.



Pluto	
Section #	Mass (g)
1	
2	
3	
4	
5	
6	

Halley’s Comet	
Section #	Mass (g)
1	
2	
3	
4	
5	
6	

Procedure 3 – 3rd Law - Everything moving around an object orbits such that the square of the orbit time divided by the cube of the average distance to the central object is a constant. Close to home that means that for everything that orbits the Sun, P^2/R^3 is the same number. Finish the table by calculating this constant for the known planets. Also, calculate the average distance and orbital period for imaginary planets X & Y using the proportion

Object	P (Period)	R (AV Distance from Sun)	P^2/R^3
Mercury	.241 yr	0.39 AU	
Venus	.615 yr	0.72 AU	
Earth	1.00 yr	1.00 AU	
Mars	1.88 yr	1.52 AU	
Jupiter	11.9 yr	5.20 AU	
Saturn	29.5 yr	9.54 AU	
Uranus	84.0 yr	19.2 AU	
Neptune	165 yr	30.1 AU	
Pluto	248 yr	39.4 AU	
Halley’s Comet	76 yr	17.8 AU	
Planet X		52 AU	1.00
Planet Y	315 yr		1.00

proportion

$$1 = \frac{P^2}{R^3}$$

which can be written as

$$P = \sqrt{R^3} \quad \text{or} \quad R = \sqrt[3]{P^2}$$

Lab 6: Rock Lab

Rocks are made of minerals, like quartz, calcite, feldspars, and micas. The crust of the earth is made of rocks, but is often buried under soil. There are three different types of rock:

- **Igneous Rock** is formed when molten rock, called magma, cools either underground or on the surface, and crystallizes. When magma cools slowly underground the crystals are large enough to see. If it cools quickly on the surface, the crystals are very small and you need a magnifier or a microscope to see them. Sometimes, when the magma cools very quickly, it forms a kind of black glass called obsidian.
- **Sedimentary Rock** forms from particles, called sediment, that are worn off other rocks. The particles are sand, silt, and clay. Sand has the largest particles while clay has the smallest. The sediment gets turned into rock by being buried and compacted by pressure from the weight above it and cemented together by material that has been dissolved in water.
- **Metamorphic Rock** is formed by great heat and/or pressure. The pressure can come from being buried very deep in the earth's crust, or from the huge plates of the earth's crust pushing against each other. Deep burial also means high temperatures. Magma rising through the earth's upper crust also causes high temperatures.

There are six rock samples at different places in the room, each accompanied with a laptop that has a rock key. The rock key asks questions to help you identify the rocks. Answer the questions and the rock key will take you to the next question and finally will identify your rock - if you answer the questions correctly.

Moh's scale of hardness is another tool to aid in the identification of minerals. Sometimes geologists carry a couple of common items with them to check the hardness of a minerals.

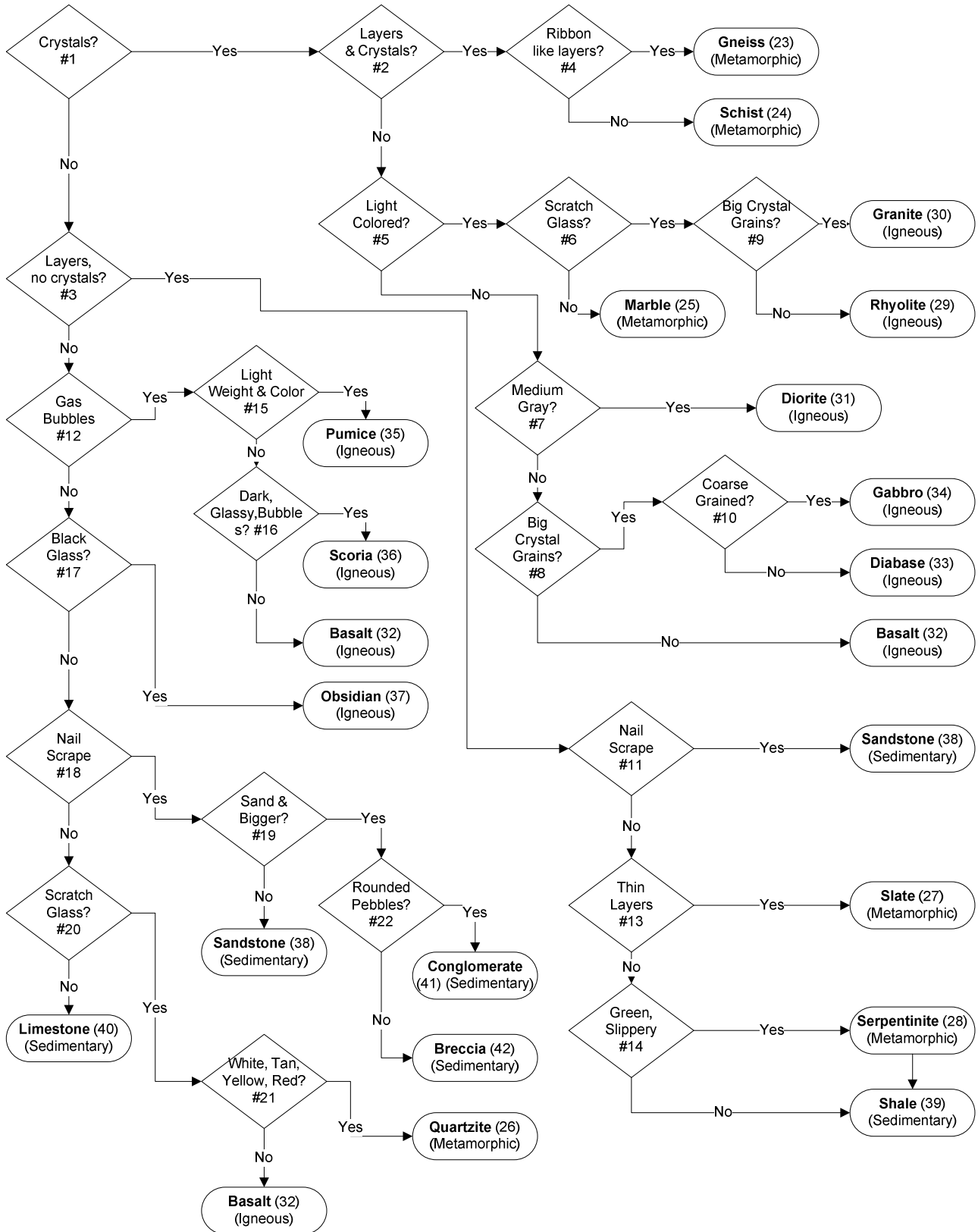
- a pencil "lead" (graphite) has a hardness of 1;
- a fingernail, 2.5;
- a copper penny, about 3.5;
- a nail, 5.5;
- window glass, 6;
- and a steel file, 6.5.

Assignment: Go to the six samples, identify them with the rock key, and record your identifications.

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

Sample #	Identification	Moh's Hardness

The Rock Key



The Rock Key - <http://www.rockhounds.com/rockshop/rockkey/index.html#Key>

1. Is the rock made of crystal grains? (Does it have a lot of flat, shiny faces - maybe tiny to small - that reflect light like little mirrors? You may need to use a magnifier.)

Yes - The rock is made of crystal grains with flat shiny surfaces. . . Go to 2

No - There are no (or not many) shiny, flat, crystal grains. . . Go to 3

2. Does the rock have both layers and crystal grains? (Look carefully for layers , especially along the edges of the rock. You may need a magnifier.)

Yes - The rock has both layers and crystals. . . Go to 4

No - The rock has crystals, but it has no layers. . . Go to 5

3. Does the rock have layers but not crystal grains? (Look carefully for layers, especially along the edges of the rock. You may need a magnifier.)

Yes - The rock has layers, and crystal grains are not visible. . . Go to 11

No - The rock has no layers, and crystal grains are not visible. . . Go to 12

4. Do the layers look like ribbons or bands of minerals running through the rock; and is the rock kind of blocky? (The bands of minerals may be straight or wavy. The rock breaks into blocky chunks, not along its layers.)

Yes - The rock has crystals, layers that look like ribbons or bands of minerals running through it, and is kind of blocky . It is. . . Go to 23

No - The rock has crystals and layers that are thin and do not look like ribbons of minerals. It breaks along the layers. It is. . . Go to 24

5. Is the entire rock mostly light colored, compared to other rocks? (Look at the whole rock, not just mineral grains in the rock.)

Yes - The rock is mostly light colored or light gray minerals grains. . . Go to 6

No - The rock is mostly medium gray to very dark colored minerals. . . Go to 7

6. Can you scratch glass with the rock? (If it does, the rock is hard. If it doesn't, the rock is soft.) (Safety note: keep the glass flat on your desk, not in your hand. Carefully press a point of the rock against the glass and pull it about 2cm. Look to see if it scratched the glass. Do not hit the glass with the rock.)

Yes - The rock scratches glass. It has crystals, but has no layers. . . Go to 9

No - The rock does not scratch glass. It has crystals, but has no layers. It is. . . Go to 25

7. Is the rock mostly light or medium gray, not very dark gray or black?

Yes - The rock is mostly light to medium gray, has crystal grains, and is not layered. It is. . . Go to 31

No - The rock is mostly very dark gray or black. . . Go to 8

8. Can you see crystal grains in most or all of the rock without using a magnifier?

Yes - The rock is coarse or medium grained, has crystals, and no layers. . . Go to 10

No - The rock is fine grained, has crystals, and no layers. It is. . . Go to 32

9. Can you see crystal grains in most or all of the rock without using a magnifier?

Yes - The rock is mostly crystal grains. It is medium or coarse grained, has no layers, and is light colored. It is. . . Go to 30

No - The rock is mostly fine grained, it has crystal grains, has no layers, and is light colored. It is. . . Go to 29

10. Is the rock coarse grained? (If the rock is coarse grained, most of the rock mostly is made of crystals that are as large, or larger, than rice. If you can see the crystals without a magnifier, but they are smaller than rice, the rock is medium grained.)

Yes - The rock is made of coarse crystal grains. It has no layers, and is dark colored. It is. . . Go to 34

No - The rock is made of medium crystal grains. It has no layers, and is dark colored. It is. . . Go to 33

11. Using the point of a steel nail, can you scrape grains of sand off the rock? (Hold the rock over a clean sheet of paper and scrape it hard with the point of the nail. Rub your finger over the paper. Can you feel grains of sand?)

Yes - The rock has layers. It is made of grains of sand. The rock is. . . Go to 38

No - The rock has layers and is not made of grains of sand. . . Go to 13

12. Does the rock have gas bubbles in it? (It may look something like a sponge. Look for rounded holes, or glassy bubbles in the rock. They may be tiny {like a pinhead}, small, or large {like a pea})

Yes - The rock has gas bubbles. . .Go to 15

No - The rock has no gas bubbles. . .Go to 17

13. Does the rock look like it is composed of mostly only one mineral and has many thin flat layers? (The layers are less than 2mm thick, mostly thinner. not thick layers)

Yes - The rock has many thin flat layers, seems to have only one mineral, and usually no visible crystals. The rock is. . . Go to 27

No - The rock is mostly one mineral, but the layers are thicker (usually more than 4mm). . .Go to 14

14. Is the rock definitely green in color, and does it feel slippery?

Yes - The rock is mostly green and slippery. The rock is. . . Go to 28

No - The rock is not green and slippery. The rock is. . . Go to 39

15. Is the rock light in weight and mostly light colored (probably gray)?

Yes - The rock is full of gas bubbles, is light in weight, and is light colored. The rock is. . . Go to 35

No - The rock is heavy, dark colored, and has some gas bubbles, but the bubbles are mostly larger. . . Go to 16

16. Is the rock dark colored, glassy, with gas bubbles in it? (Does it have some jagged or sharp points?)

Yes - The rock is dark colored, glassy, with gas bubbles in it. The rock is. . . Go to 36

No - The rock is gray or black, has a few gas pockets in it, and has no layers. It is not glassy. The rock is. . . Go to 32

17. Does the rock look like black glass with no bubbles in it? (It may have some white "snowflakes" in it ,or some reddish bands in it)

Yes - The rock looks like black glass. The rock is . . Go to 37

No - The rock does not look like a black glass. . . Go to 18

18. Using the point of a steel nail, sand can be scraped off the rock. (Use the point of a steel nail to scrape the rock over a sheet of clean paper. Can you feel sand on the paper?)

Yes - Sand can be scraped off the rock. . . Go to 19

No - Sand cannot be scraped off the rock. . . Go to 20

19. Does the rock contain sand and larger pieces of rock or pebbles?

Yes - The rock is composed of sand and pebbles or other larger pieces of rock. . . Go to 22

No - The rock is made of sand, but not pebbles or other larger pieces of rock. The rock is. . . Go to 38

20. Can the rock scratch glass? (Safety note: keep the glass flat on your desk, not in your hand. Carefully press a point of the rock against the glass and pull it about 2cm. Look to see if it scratched the glass)

Yes - The rock scratches glass, but it is not made of sand. . . Go to 21

No - The rock does not scratch glass. It is not composed of visible crystals. It is. . . Go to 40

21. Is the rock white, yellowish, tan, or reddish?

Yes - The rock is. . . Go to 26

No - The rock is either black or gray. The rock is. . . Go to 32

22. Are the larger pieces of rock (that are mixed with the sand) rounded pebbles, not blocky or jagged?

Yes - The larger pieces are rounded pebbles. The rock is. . . Go to 41

No - The larger pieces are jagged and blocky. The rock is. . . Go to 42

Metamorphic Rocks

23. **GNEISS** (nice) - Metamorphic - Gneiss is usually light in color, but it can be quite dark. It looks like it has ribbons or stripes of minerals running through the rock. The grain size is usually fairly coarse. Gneiss usually breaks into blocky pieces, not along the layers. Unlike granite, in which the crystals are randomly arranged, the crystals in gneiss are lined up and in layers. Gneiss is a tough and hard rock. Minerals?: Almost always: feldspars, quartz, and mica. Sometimes: kyanite, garnet, hornblende, tourmaline, magnetite, and many others. Formed?: Gneiss is formed from another metamorphic rock, called schist. The schist formed from fine grained sedimentary rock (often a shale). Gneiss can be formed also from some igneous rocks, especially granite. It is usually formed under great pressure from moving plates of the earth's crust. Compare To: schist, granite

24. **SCHIST** (sh-ist) - Metamorphic - Top and bottom layers are usually a silvery, to green, to brown, to black mica, or a green to very dark green chlorite. The micas are often in small flaky crystals. Layers are usually thin, often with lens like layers of quartz between the mica layers. Layers may be somewhat wavy. Grain size varies from medium to coarse. Schist usually splits easily along the layers of mica, unlike gneiss. Minerals?: quartz, feldspar, mica (muscovite, biotite). Sometimes: chlorite, garnet, hornblende, actinolite, kyanite, magnetite, pyrite, staurolite, tourmaline, and many others. Formed? Schists are usually formed from shales that were formed from clay or sandy clay, sometimes with a little lime, sometimes from rocks and sediments from volcanoes. Schists are most often formed when plates of the ocean floor push under, into, or up onto a continent. It is the sea floor rocks that get crunched to form schists. Compare To: gneiss, shale, slate, serpentinite

25. **MARBLE** (mar^l-bul) - Metamorphic - Often pure white. It may be streaked or patchy gray, green, tan, or red. Marble is fine grained to very coarse grained and crystals are usually easy to see. The rock is soft; it will not scratch glass (quartzite may look like a fine grained marble, but easily scratches glass). The powdered marble will often fizz with white vinegar. If it does not fizz, it may be dolomitic marble. Minerals?: calcite, or dolomite (dolomitic marble); Sometimes: graphite, pyrite, mica, tremolite, and a few others. Formed? Marble forms from the metamorphism of limestones. Compare To: quartzite , limestone

26. **QUARTZITE** (kwart^l-zite) - Metamorphic - If the quartzite is pure quartz it is white. It may have a yellowish to reddish color if it contains iron minerals. Rarely, it is black if it contains a lot of magnetite. Sometimes, using a magnifier, the grains of sand from which it formed can be seen. The rock breaks through the grains, not around them (sandstone breaks around the grains). Quartzite often shows lighter colored flakes on a broken surface, where air is behind a very thin chip. Unlike marble, quartzite is very hard and easily scratches glass. Minerals?: quartz; Sometimes, a little: mica, feldspar, magnetite, pyrite, ilmenite, garnet, and any of a few others. Formed? Most quartzite is metamorphosed sandstone. Compare To:

marble, sandstone

27. **SLATE** (sl-ate) - Metamorphic - Slate can be black, gray, brownish red, bluish gray, or greenish gray. It is very fine grained and has thin, quite smooth, flat layers. Unlike shale, slate easily splits into thin flat pieces. It often will scratch glass, with a little difficulty.

Minerals?: micas, feldspars, quartz (but they can not be recognized because the grains are so small you would need a microscope to see them); Sometimes contain: pyrite

Formed? Slate is usually formed from clay sediments or shale that has been heated and put under pressure by plate collisions. The pressures and temperatures that form slate are lower than those that form schist.

Compare To: shale, schist, serpentinite

28. **SERPENTINITE** (Sir'-pen-tin-ite) - Metamorphic -Serpentinite feels very slippery. It is more a broken rock than it is a layered rock. The "layers" are sort of flat plates of green rock. They may be thin or more than 2cm thick. Serpentinite is usually green to grayish-green. The flat plates may have long scratch like grooves in them. It may be dull or nearly glassy looking. When serpentine is dull it may be fine to coarse grained. When it is glassy it looks very smooth and has no visible grains. Minerals?: Mostly antigorite, amesite, and lizardite. Sometimes: chrysotile (a type of asbestos), brucite, magnesite, chromite, magnetite and garnets.

Talc is often found because serpentine alters to talc.

Formed? When an ocean floor plate collides with a continental plate, giant slices of the oceanic crust are pushed up into the rocks of the continent. A rock, called peridotite, at the bottom of the oceanic plate is changed to serpentinite because there is less weight on it, the temperature is lower, and water circulates through it. Serpentinite is usually found in mountains that were once at the edge of a continent. Another way serpentinite can form is from peridotites that crystallize deep in the earth's crust from magma. The peridotites are gradually uncovered by erosion, and as they get close to the surface, they alter to serpentinite. Compare To: diabase, gabbro, slate, schist

Igneous Rocks

29. **RHYOLITE** (rye'-o-lite) - Igneous - Usually light colored; light gray, tan, reddish, greenish, brown. Fine grained, but often contains scattered larger crystals. May contain small pockets that were gas bubbles. Sometimes shows flow lines or bands. Minerals?: quartz, feldspars; Sometimes contain: biotite, diopside, hornblende, zircon. Formed? Rhyolite is a volcanic rock. It forms from the rapid cooling of a magma or lava that contains a lot of silica (quartz). The molten material often contains gas bubbles which freeze into the rock. Pumice is a kind of rhyolite that has really a lot of tiny gas bubbles in it. Compare To: pumice, basalt

30. **GRANITE** (gran'-it) - Igneous - The feldspars give granite most of its color, which may be white to light gray, yellowish, or pink. The quartz is usually smoky gray or white. Black specks of biotite, or sometimes hornblende, are common. So is silvery to brownish muscovite. Granite is coarse grained to very coarse grained. The crystals are randomly arranged (unlike gneiss where they are in lines or layers). Minerals?: quartz, feldspars (microcline, orthoclase, albite), biotite, muscovite; Sometimes contain: hornblende, augite, magnetite, zircon. Formed? Granite forms deep in the earth's crust from cooling magma. The magma contains a lot of silica (quartz). Slow cooling produces the large crystals in granite. Compare To: gneiss diorite

31. **DIORITE** (die'-or-ite) - Igneous - May contain: light colored plagioclase feldspars, but only a little. Mostly it looks like a dark colored granite. The dark colored plagioclase feldspars and pyroxenes give it a darker color. It is usually medium to dark gray. Unlike granite, diorite has no mica, or very little, and those are dark colored. It is coarse grained (larger than rice). Minerals?: Dark colored plagioclase, hornblende, pyroxene, and sometimes a little quartz. Formed? Diorite forms deep in the earth's crust from cooling magma - just

like granite. But, the magma does not contain a lot of quartz or the light colored minerals that make up the granite. Instead it contains only dark colored minerals.

Compare To: granite, diabase

32. **BASALT** (buh-salt') - Igneous - Basalt is dark gray to black. When exposed to the weather, it may turn yellow or brown on its surface. Basalt is fine grained rock You may or may not be able to see crystals with a hand magnifier. The crystals are often microscopic. Basalt is a hard, tough rock. It is difficult to break. Sometimes, basalt contains gas bubbles. It is then called vesicular basalt. Minerals?: plagioclase feldspars, augite, hypersthene, olivine. Formed? Basalt is a volcanic rock. It is formed from a magma that is rich in iron and magnesium, and poor in silica (quartz). The magma erupts from a volcano or a fissure (a crack in the earth's surface) as lava. Because the lava cools rather quickly, basalt is fine grained. there is not time enough for the grains to become larger. Compare To: rhyolite, diabase, gabbro

33. **DIABASE** (die'-uh-base) - Igneous - Diabase is dark green to black, sometimes with some white crystals scattered through it. When exposed to the weather its surface often turns brown. It has a medium grain size (you can see them without a magnifier, but they are smaller than rice). It is a tough, hard rock. Minerals?: plagioclase feldspars, augite; Sometimes contains: hornblende, magnetite, olivine, glass. Formed? Diabase forms from a magma that is rich in iron and magnesium, and poor in silica (quartz). The magma is forced into cracks or between layers of rock near the earth's surface. Diabase is from the same kind of magma as basalt, but because it cools more slowly, it develops slightly larger crystals. Compare To: basalt, gabbro, diorite, serpentinite

34. **GABBRO** (gab'-row) - Igneous - Gabbro is dark green to black. When exposed to the weather its surface often turns brown. It has a large grain size (most of the rock is grains larger than rice). Minerals?: plagioclase feldspars, augite, hypersthene, olivine; Sometimes contains: magnetite, chromite, titanite, ilmenite. Formed? Gabbro forms from a magma that is rich in iron and magnesium, and poor in silica (quartz). The magma cools and crystallizes deep below the earth's surface. Gabbro is from the same kind of magma as basalt and diabase, but because it cools more slowly, it develops larger crystals. Compare To: basalt, diabase, serpentinite

35. **PUMICE** (pum'-iss) - Igneous - Pumice is very light gray to a medium gray in color. It contains a large number of gas bubbles, each surrounded by a thin layer of volcanic glass. Pumice looks something like a sponge. It is very light in weight. Most pieces of pumice will float on water. Flow lines or bands may show. Minerals?: glass, any mineral grains are unusual. Formed? Pumice is explosively blown out of volcanoes. It comes from a highly silicic magma that is thick and sticky. The gases that are trapped in the bubbles are the same that cause the explosive eruption. It is the same kind of magma which would form rhyolite or granite. Compare To: scoria, rhyolite

36. **SCORIA** (score'-ee-uh) - Igneous - The color is usually black, dark gray, brown, or dark green. Scoria is glassy, smooth to rough, and contains gas bubbles. Unlike pumice, it has many fewer, usually larger bubbles, and is moderately heavy. Minerals?: mainly a glass
Formed? Scoria usually is from the top of a lava flow, so it is volcanic. It forms from a somewhat sticky lava. Because it is on the top of the flow, it cools rather quickly, before many crystals start to form. Compare To: pumice, basalt

37. **OBSIDIAN** (obb-sid'-ee-an) - Igneous - Obsidian is a glass and is usually black, although sometimes it may be slightly grayish or greenish. It may include some white crystals that look like snowflakes (snowflake obsidian). It may include swirls of a red color. Obsidian breaks and chips like glass. The location where the chip came out is scoop shaped, like the inside of a clam shell. The chip often has ridges that that are semicircular. This kind of break is called a conchoidal fracture. Minerals?: black glass. Formed? Obsidian is

volcanic. It forms from rapid cooling lava that has a lot of silica. The lava cools so fast that crystals do not have time to form.

Sedimentary Rocks

38. **SANDSTONE** (sand'-stone) - Sedimentary - Sandstone is often red to brown, light gray to nearly white. Sometimes it is yellow or green. It usually is composed of rounded grains that are all of the same size; and it is usually medium grained. Some sandstones show slight color variations in layering. Minerals?: quartz; Sometimes contains: feldspars, mica, glauconite (in green colored sandstone), magnetite, garnet, rutile, ilmenite. Formed? quartz sand that is produced by the weathering of other rocks (such as granite, gneiss, and other sandstones) is deposited by rivers, waves, or wind. The sediment may have been a sand bar, an ocean beach, or desert sand dunes. The sand is buried under other sediments, compacted by the weight of those sediments, and cemented by material dissolved in water that seeps through it. Related Rocks: Arkose: Usually red or pink, may be gray. Grains are angular. Arkose contains more than 25% feldspar with quartz. Medium to coarse grained. Greywacke: Black or dark green. Usually contains coarse angular grains included with fine grains.

39. **SHALE** (sh-ale) - Sedimentary - Shale may be black, gray, red, brown, dark green, or blue. It is fine grained, so particles usually can not be seen. When moistened, shale usually smells like wet mud. Minerals?: clay minerals; Sometimes with some quartz sand, pyrite, gypsum. Formed? Clay sediments settle in quiet lakes, lagoons, bays, or off-shore areas. When buried and compacted the clays become shale. Iron oxides often help to cement the particles together. Compare To: slate schist

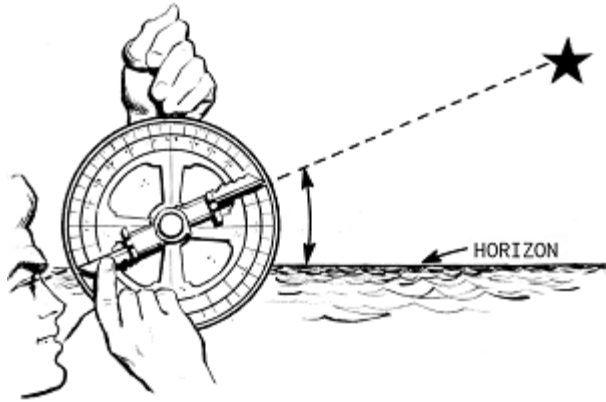
40. **LIMESTONE** (lime'-stone) - Sedimentary - Limestone is usually white, gray, tan, or yellow. It may contain impurities to make it red or black. Fossils are often found in limestone. It may be very smooth or even sugary, fine grained, or medium grained. The powdered rock will usually fizz in white vinegar. Unlike marble, limestone is not composed of visible crystals. Minerals?: mostly calcite
Formed? Most limestone is formed by a chemical reaction in sea water. The reaction makes a lime mud which sinks to the bottom to form the limestone. Some limestones are formed from buried coral reefs. Related Rocks: Dolostone (doe'-low-stone) looks like limestone, but is composed of the mineral, dolomite. Powdered dolostone does not fizz with white vinegar. Dolostone forms on the ocean floor. Compare To: marble

41. **CONGLOMERATE** (cun-glom'-er-at) - Sedimentary - Conglomerate looks like a mixture of sand and different sizes of rounded pebbles. The pebbles are the important observation. Minerals?: mostly quartz
Formed? Sand and pebbles collect along sea shores, lake shores, or river banks. They are compacted by the weight of sediments that collect above them and cemented by material dissolved in the water that seeps through them.
Related Rocks: Breccia (brech'-ee-uh) looks like conglomerate, but the "pebbles" in it are jagged and blocky, not rounded.

42. **BRECCIA** (brech'-ee-uh) - Sedimentary - Like conglomerate, but the "pebbles" in it are jagged and blocky, not rounded. Minerals?: The "cement" holding the rock together is mostly quartz, but the pebbles can be almost any kind of rock - often quartzite, granite, or another tough rock that does not easily erode into sand or silt. Formed? Where the environment is dry - like in deserts. When mountains erode broken pieces of rock don't get carried away by streams. They just pile up. When they get deep enough, the weight above compresses them and they get cemented together. Compare To: Conglomerate

Lab 7: Basic Celestial Navigation

The stars have been used for determining time and position since earliest antiquity. The oldest known sundial is over 7000 years old, in an Irish Neolithic grave complex. A device known as an "Astrolabe", used to sight off the stars to find position, goes back at least 2000 years.



Procedure 1: Build an Astrolabe

- Take a protractor and tie a string through the small hole. The string should swing from the small hole (or the straight edge of the protractor if there is no small hole) - not the big semi-circular hole. (If you don't have a protractor, see p.33.)
- Put some weight on the end of the string.
- You can tape a straw on top to serve as a sight.

Now that you have just constructed your sextants, it's time to put them to use! Back in the days before satellite navigation, seafarers used sextants to determine the angle of elevation of a celestial object in order to determine their

position at sea. This was done by using the sextant to find the elevation angle of a celestial object (the north star, sun, or constellation) above the horizon.

Procedure 2: Using an astrolabe to determine latitude (do this part at home)

- Go out on a clear night and face north.
- Find the North Star, aka Polaris - remember it's the tip of the handle of the Little Dipper, and the two last stars in the bucket of the Big Dipper point directly at the North Star.
- Sight along the top of your protractor to the North Star, letting the string hang straight down.
- Pinch the string against the protractor so that the angle doesn't get lost when you move the protractor away from your eye.
- Read the angle (you want the number that is between 0° and 90°).
- Subtract your angle from 90° to get the angle of inclination.
- The angle of inclination should be the same as the Latitude.

Procedure 3: Determine longitude - This has been one of the great challenges of history, to accurately find the longitude. It's easier now since we have decent clocks, but up to the late 1700's this was a big problem. Here, we'll do a rather simple and crude version of finding our longitude.

- The 24 time zones start at a line that runs through Greenwich England.
- The time there is called GMT or Greenwich Mean Time.
- We are five hours behind GMT.
- Dividing the world into 24 hrs means each time zone covers $360^{\circ}/24 \text{ hr} = 15^{\circ}$.
- The map below shows the approximate location of Rock Hill SC.
- The lines show where the Eastern Time Zone starts and ends.

You need to:

- Measure and record the distance in cm from Rock Hill's dot to the line where the Eastern Time Zone begins.
- Measure and record the distance in cm between the lines where the Eastern Time Zone begins and ends. (I would use the dotted line on the left)
- Divide the first number by the second number. This gives an estimate of our fractional distance into the time zone.
- Add five to the fractional distance (to account for the five full time zones between us and Greenwich England.)
- Multiply by 15° .

- Look up the longitude of Rock Hill and see how close we came. (It's gonna be off a little...)



Angle in degrees	Multiply distance by
0	0.0
5	0.1
10	0.2
15	0.3
20	0.4
25	0.5
30	0.6
35	0.7
40	0.8
45	1.0
50	1.2
55	1.4
60	1.7
65	2.1
70	2.7
75	3.7

Procedure 4: Measure height - Using an astrolabe to determine the heights of objects. You can also measure things here on Earth with your astrolabe.

- Pick an object with some height to it - for example your house or a tree.
- Pace off the distance to the object. My pace when walking (distance between right foot footprints) is about five feet. Use that or a little less - or you walk a known distance, counting every time your right foot hits the ground. Divide the distance by #paces.
- Use your astrolabe to record the angle of inclination.
- Use the table at the right and multiply the distance along the ground by the amount in the second column to get the height of the object above your eye.
- Add the height of your eye to the height from the last step.

Procedure 5: Sextants The best device to do celestial navigation is a sextant. The animated gif (from Wikipedia) shows the basic steps to using a sextant. There are also lots of tables to use and calculations to perform to accurately find your latitude and longitude. You can see though that your astrolabe has the same basic function of a swinging arm (or string) that measures the angle of inclination.

see: http://en.wikipedia.org/wiki/Celestial_navigation

- What angle did you measure for the inclination of the North Star?
35° 45° 55° 25°
- What is the actual latitude of Rock Hill SC
25° 35° 45° 55°
- Which of these is closest to what you measured as the longitude of Rock Hill SC
8° 70° 85° 75°
- Which of these is closest to the actual longitude of Rock Hill SC?
70° 85° 8° 75°

Lab 8: Measuring Distances

There are several ways to measure distances in space.

Procedure 1 – Radio Bounce If the object is pretty close, say in the solar system. We can bounce radio signals off the object. If a radio signal takes 600 seconds to go from Earth to Mars and back, then it only took 300 seconds to go one way. Radio signals travel at the speed of light, 3×10^8 m/s. Since $s = vt$, by multiplying the 300s times the speed of light, it's pretty easy to get a distance from Earth to Mars at that time as 9×10^{10} m.

Try it: If I send a radio signal from Earth to Jupiter and back and it takes 3100 seconds to return, how far away is Jupiter?

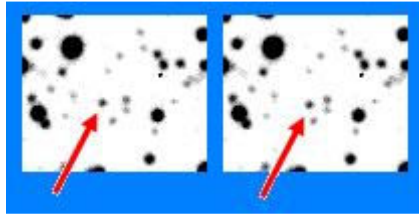
$$4.65 \times 10^{11} \text{ m}$$

$$1.86 \times 10^{12} \text{ m}$$

$$3 \times 10^8 \text{ m}$$

$$1.3 \times 10^{16} \text{ m}$$

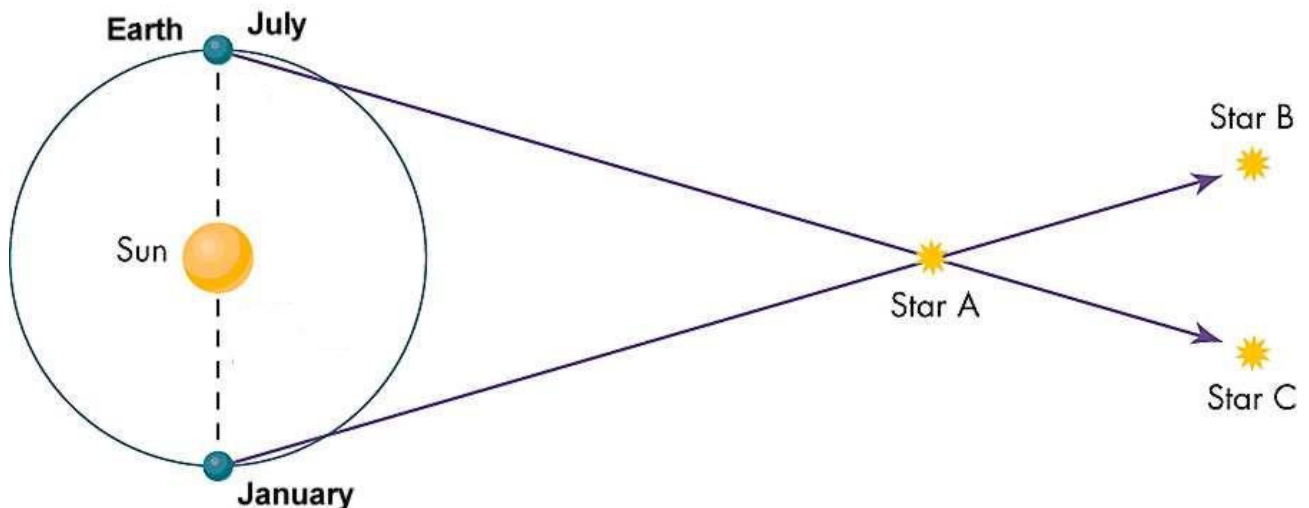
Procedure 2 –Parallax If the object is farther away, we have to work a little harder. These two pictures were taken six months apart. They are negatives - that is bright stars show up dark, and the black space shows up white. As the Earth moves around the Sun every year, six months would put us on the opposite side of the Sun, or 186 million miles from where we took the first picture. Notice how the small star with the arrow has appeared to **slightly** move towards the stars to the right.



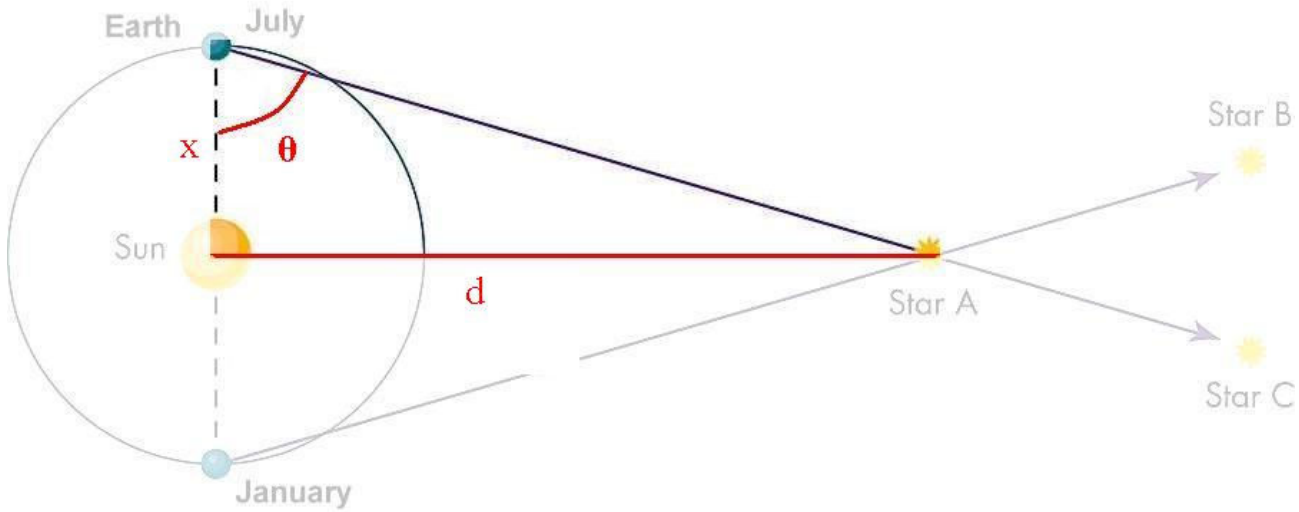
This effect is called parallax and can be seen very easily, wherever you are.

- Pick an object you can see - a clock on the wall, a light switch, your dog, whatever.
- Close one eye and cover the object with a finger held at arm's length.
- Now close that eye and open the other. Notice how the object is no longer covered.

Because of the distance between your two eyes, there is a different angle to the object. In the picture below, we would like to know the distance to "Star A". Stars B and C are much farther away, and serve as a background for Star A as our vantage point changes. In January Star A would appear close to Star B. After six months, and a displacement of 186 million miles, Star A would appear close to Star C.



The simplest way to measure stellar distances is to focus on the right triangle formed by the Sun, Star A, and the Earth's position in July. By measuring the angle θ , we can find the distance d from the Sun to Star A using trigonometry.



The formula we need is $d = x \tan \theta$. $\tan \theta$ is a function from trigonometry that relates the length of the two sides x and d to the angle θ . If you haven't seen it before, don't worry about it too much. Here's an example, though:

If $x = 200$ ft and $\theta = 80^\circ$ find the distance d

- $d = x \tan \theta$
- $d = (200 \text{ ft})(\tan 80^\circ) = 1134.3$ ft
- $d = 1134$ ft

Here's a couple of tips about doing the calculation on a calculator:

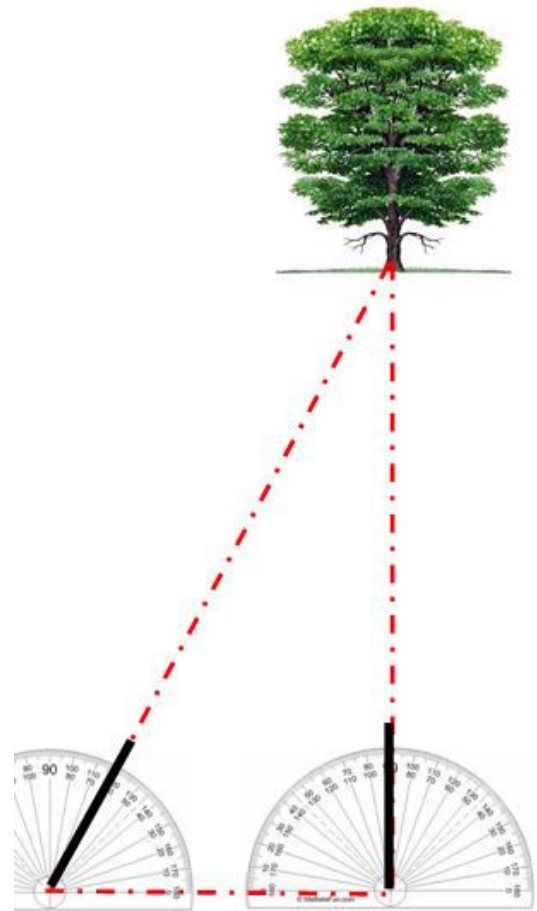
- make sure your calculator is set to degrees
- put in x by hitting 200
- push the TAN button (on all scientific calculators - if you don't have one try the Windows calculator and set the view option to scientific)
- put in 80
- hit enter. You should get 1134.3.
- **IF THAT DIDN'T WORK** - some calculators require you to put in the angle first then TAN - try this: put 80, hit TAN, hit times button, push 200, hit enter.

Try it - If a star measures at an angle of 89.99° when we are a distance $x = 9.3 \times 10^7$ miles from the Sun, find the distance to the star.

- | | |
|----------------------------|-------------------------|
| -2.4×10^8 miles | 2.4×10^8 miles |
| 5.3×10^{10} miles | 162,315.8 miles |

Let's try it

- Get a protractor and a paper clip. ([Print a Protractor](#))
- Bend the paper clip straight except for one side of - it should look like a long, skinny letter "j"
- Slip the paper clip through the vertex hole in the protractor so that the the paperclip can swing through angles
- Go out in the yard and stand a good distance facing some object like a tree.
- Hold your protractor up to your eye and sight along the paper clip to the tree. You may need to tip the protractor slightly up to see the paperclip, but keep it perpendicular to the line to the tree.
- Look at the angle marked on the protractor - it should read 90°
- Pace off some distance (either right or left) perpendicular to the line to the tree. Write down how many paces you took - that will be x.
- Face straight ahead again (not towards the tree) and measure the angle again with the protractor. You want the smaller angle between 0 and 90°
- Calculate the distance to the tree using the formula $d = x \tan \theta$
- Pace the actual distance off (from the first measuring point) and see how close you came.



Space is so vast that measuring the distance to a star in miles just doesn't make any sense - so we use light-years (the distance light moves in a year) and parsecs (the distance that will cause a parallax angle of 1 second, or a 3600th of a degree). The unit conversion here is $1 \text{ parsec} = 3.26 \text{ light-years} = 3.08568025 \times 10^{16} \text{ meters} = 19.174 \times 10^{12} \text{ miles}$.

Betelgeuse, a star in Orion, is around 600 lightyears away. Use the conversion factor to find the distance in parsecs.

1956 parsecs 184 parsecs 2000 parsecs 200 parsecs

Do some research to find out what the nearest star to the Earth (other than the Sun) and how long does light take to reach us from that star.

Procyon A Sirius B Rigel Kentaurus Proxima Centauri

Give <http://www.spitzer.caltech.edu/features/articles/20070103.shtml> a quick read over. What is the closest galaxy to the Milky Way galaxy (that we know about so far)

Andromeda Galaxy Pikachu Galaxy Euripides Galaxy Canis Major Dwarf Galaxy

Lab 9: Stars and the HR Diagram

Luminosity – actual amount of light put out by star

Apparent Magnitude – brightness from Earth

Absolute Magnitude – brightness from 10 parsecs (~ 32.6 light years or 3.1×10^{14} km)

Spectral Class - a division of stars by temperature/color. Stars decrease in temp OBAFGKM and then 0 to 9 for every letter. The sun is a G2 star which would be warmer than a G3 or K6 for example.

In the early 1900's two astronomers, Hertzsprung and Russell, studied the stars by making a graph of apparent magnitude vs. color and absolute magnitude vs. spectral class. This diagram is called an HR Diagram and is shown on the back of this page.

Procedures

- 1) Plot the stars on the HR diagram using Abs.Mag. and Spec.Type.
- 2) Plot the stars on the sky map using RA and Dec.

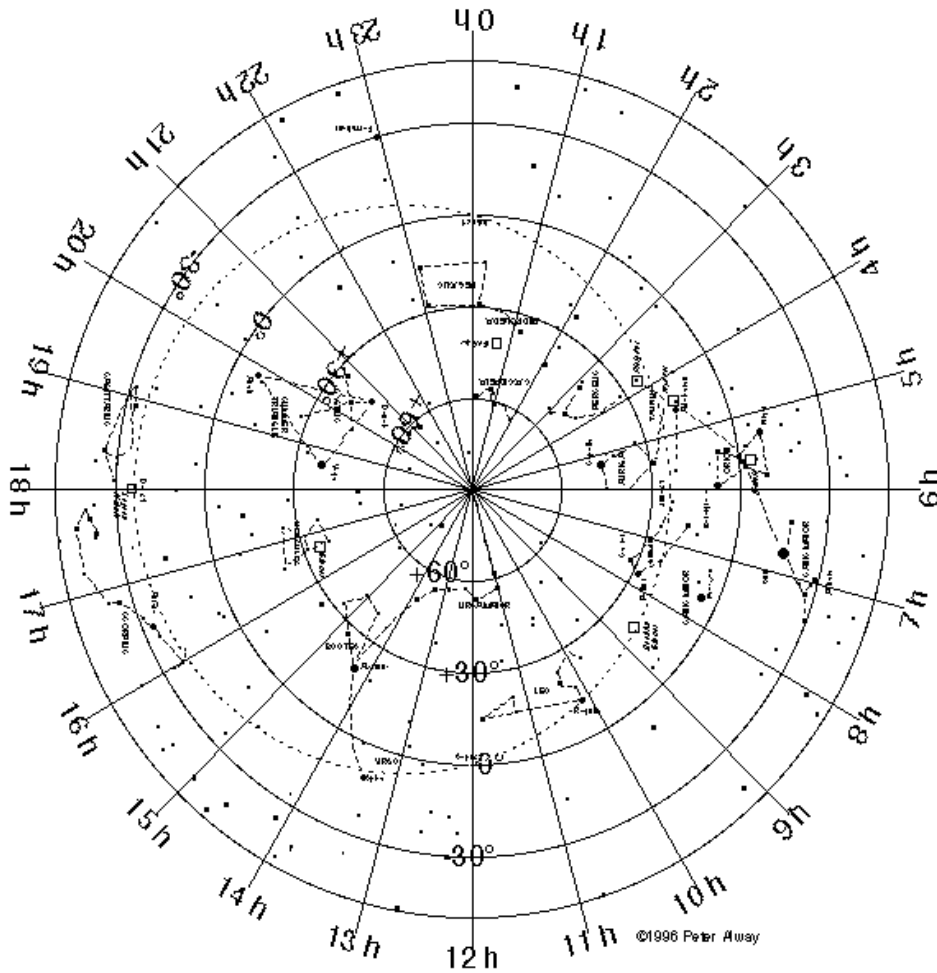
11 Closest Stars									
#	Name / Ident.	Dist.pc	Dist. ly	App Mag	Abs Mag	Spec Type	Const	RA	Dec
	Sun	-	-		4.8	G2	-	-	-
1	Proxima Centauri	1.30	4.24	11.10	15.53	M5.5	Cen	14 22	-62 15
2	Alpha Centauri A	1.33	4.35	-0.01	4.37	G2	Cen	14 32	-60 25
3	Alpha Centauri B	1.33	4.35	1.34	5.72	K0	Cen	14 32	-60 25
4	Barnard's Star	1.83	5.98	9.54	13.23	M5	Oph	17 52	+04 25
5	Wolf 359	2.39	7.78	13.46	16.57	M6.5	Leo	10 51	+07 37
6	Lalande 21185	2.53	8.26	7.48	10.46	M2	UMa	10 57	+36 38
7	Sirius A	2.62	8.55	-1.46	1.45	A1	CMa	06 40	-16 34
8	Sirius B	2.62	8.55	8.44	11.34	A2	CMa	06 40	-16 34
9	Luyten 726-8A	2.68	8.73	12.56	15.42	M5.5	Cet	01 33	-18 28
10	Luyten 726-8B	2.68	8.73	12.52	15.38	M6	Cet	01 33	-18 28

Questions

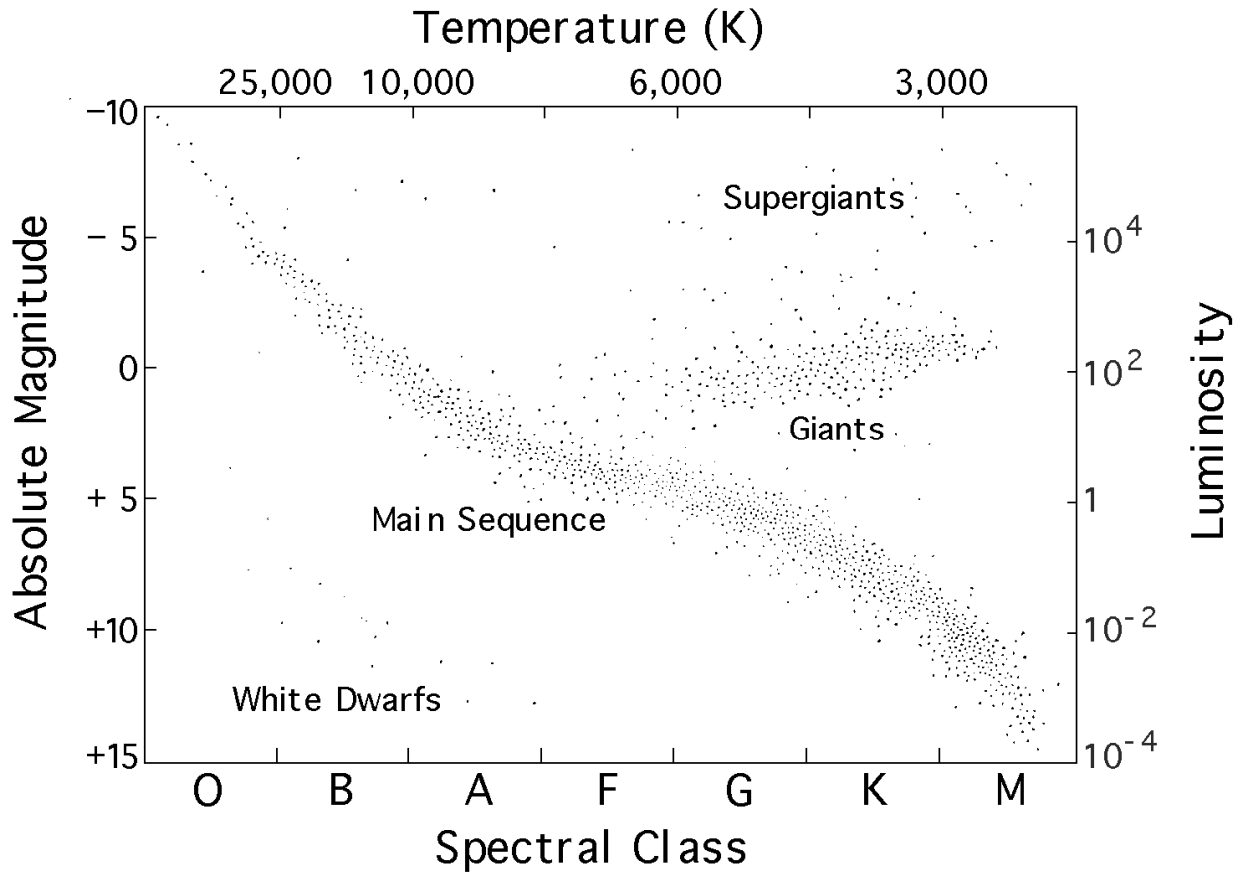
1) The sun has an absolute magnitude of 4.8. What percent of the listed stars have a magnitude greater than the Sun?. Do you think this is true for all stars?

2) What spectral class (OBAFGKM) dominates in the listed stars? Do you think this is true for all stars?

Bright Stars Visible from Michigan, Plotted by Right Ascension and Declination



Positions of these stars are plotted accurately to within a degree. Note that this chart covers more than half the sky, so that not all of these stars can be seen at once.



EXERCISE 1: NAVIGATING IN STELLARIUM



Stellarium: Stellarium is a FREE computer program that shows the sky at any time/place that we will use this semester to simulate the night sky.

- **To Install at home:** goto Stellarium.org and download the file, doubleclick the downloaded file
- **To run:** doubleclick the desktop icon.















Fill in the function and the keyboard shortcut command of each of the following commands.








Fill in what these do	Mouse	Keyboard
	click and drag the hand icon across the screen	←→
	click and drag the hand up/down the screen	↑↓
		Page Up/Down








Bottom Tool Bar Controls



Explain the purposes and shortcuts of these buttons

		
		
		
		
		
		
		
		
		
		
		
	 (must have a selected object)	
		none
		

<p>Side Tool Bar Controls</p>  <p>BRIEFLY explain the purposes and shortcuts of these buttons</p>		
		
		
		
		
		
		

Hints:

- If Stellarium seems to lock up, or won't let you get to other programs you are running, its probably the full screen mode – hit the full screen button on the bottom toolbar.
- If Stellarium “flashes” it’s probably a memory thing – a) try taking it out of full screen mode, b) turn off other programs that may be running or c) reboot the computer.
- Remember to check your viewing location and date/time settings each time you start Stellarium.



EXERCISE 2: LINES & POINTS



Definitions:

- **North Celestial Pole (NCP)** - directly over the North Pole. Marked by Polaris, the North or pole star
- **South Celestial Pole (SCP)** - directly over the South Pole. No South pole star exists.
- **Celestial Equator** - The Earth's equator extended out into space
- **Equatorial Grid** - A grid based on CE, NCP & SCP
- **Azimuthal Grid** - A grid based on your viewing dome
- **Ecliptic** - the line that the Sun and the planets seem to follow through the sky
- **Meridian** - a line directly over YOUR head from north to south
- **Right Ascension** - lines to measure East or West - similar to longitude
- **Declination** - lines to measure North or South - similar to latitude

Stellarium: All of the lines and markings can be turned on and off by going to the “Sky and Viewing Options Window” which is activated on the left side menu, or by pressing F4. There are also keyboard shortcuts to all these markings as well. Try the following exercises:

North Celestial Pole (NCP)

- Set your viewing location to Rock Hill SC
- Face North and turn on the equatorial grid coordinates (press E)
- The NCP is where all the lines come together.
- Click on Polaris. The Information on Polaris should appear upper left.
- Look in the information to find the distance to Polaris in light years _____
- Center on Polaris (Press Space bar)
- Zoom in (press Page Up)
- Are there any stars closer to NCP than Polaris _____
- If these are closer, then why don't we use those for the “North Star” _____

South Celestial Pole (SCP)

- Face South. Why can't you see where the equatorial grid lines come together. _____
- Press G to turn off the ground and press ↓ until you can.
- Zoom in to see if there is a star at or close to SCP? _____
- With several stars closer to SCP than Polaris is to NCP, why do we say there is no star at SCP? _____
- Click on those three closest stars and record the smallest number listed as “Magnitude” in the info box _____
- The typical unaided human eye can see anything below a magnitude of 6. Are these stars visible? _____
- What is the star closest to SCP we can see? _____
- Do we in Rock Hill SC ever see this or any of the constellations around SCP? _____

Celestial Equator (CE)

- Turn the ground back on (press G)
- Zoom back to normal view (press \)
- Turn on the CE (press .)
- Pan up until you can just see the Line labeled Equator at the top and the ground at the bottom.
- What color is the CE _____

Ecliptic

- Turn on the Ecliptic (press ,)
- Turn the ground off (press G)
- Search (F3) for the following, fill in if they lie on or close to the Ecliptic

Sun	Mercury	Venus	Moon	Ceres	Mars	Jupiter	Saturn	Neptune	Uranus	Pluto	Eris

- If all of the planets and the Sun follow the same line, our Solar System must be _____ like a _____
- Measure the tilt of the Earth’s axis by measuring the angle between the Ecliptic and the CE (need CE, Ecliptic and Equatorial grid on) _____

Meridian

- Face South
- Turn the ground back on (press G)
- Turn off the Ecliptic (press ,)
- Turn on the Meridian (press ;)
- Where’s the Meridian line run _____
- Pull up the DateTime control box (press F5)
- Set a couple of different times, maybe 8 am, 10 am, 2 pm, 4pm
- Any time marked a.m. (*ante meridiem*) is when the Sun is _____ the meridian
- Any time marked p.m. (*post meridiem*) is when the Sun is _____ the meridian

Right Ascension and Declination

- Search (F3) for Mintaka, a star in the belt of Orion
- Record the RA and DEC in the table below
- Speed time WAY up (Press L a bunch)
- What happens to the RA/DEC
- Repeat for Polaris and for Mars
- Circle truth – The RA/DEC of stars **changes/stays the same** while the RA/DEC of planets **changes/stays the same**

Object	Initial RA/DEC	RA/DEC Much Later
Mintaka		
Polaris		
Mars		

EXERCISE 3: EARTH'S MOTION



Definitions:

- **Rotation** - directly over the North Pole. Marked by Polaris, the North or pole star
- **Revolution** - directly over the South Pole. No South pole star
- **Precession** - The Earth's equator extended out into space
- **Geocentric Model** - The Earth's equator extended out into space
- **Heliocentric Model** - The Earth's equator extended out into space

Stellarium: Fill in the function and the keyboard shortcut command of each of the following commands.

Earth's Rotation –fill in the following with descriptive terms like clockwise, up, sideways

- Face East. Speed up time and note how the stars move _____
- Face South. Speed up time and note how the stars move _____
- Face West. Speed up time and note how the stars move _____
- Face North and find the North Star. Speed up time and note how the stars move _____

Earth's Revolution

- Face South and turn on the ecliptic
- Speed up time (L several times) to watch the Sun appear to move around the Earth
- Stop time (K)
- Open the Location window (F6) and change the planet to “Sun”
- Open the Viewing Options window (F4) and on the Landscape tab change to “Saturn”
- Face South
- Turn on the ecliptic
- Speed up time (L several times) to watch the Earth actually move around the Sun.
- Do all the planets of our Solar System mostly follow the ecliptic when observed from the Sun? _____
- Does the Sun spin _____. If so, find the number of hours it takes to spin _____
- Do the stars seem to move from East to West like Earth of West to East? _____
- Search for Earth and turn the ground off
- Speed time up. Against the backdrop of stars, which way does Earth seem to move? _____

Earth's Precession

- Open the Location window (F6) and change the planet to “Earth” Rock Hill
- Turn on the Equatorial Grid (E)
- Face North and click on the North Star to select it
- Open the Date/Time window (F2) and change the year by thousands (2012, 3000, 4000, 5000...)
- Does Polaris remain the Pole Star? _____
- In the year 14,000 AD what star will be basically where Polaris is now? _____
- In the year 28,000 AD what star will be basically where Polaris is now? _____

EXERCISE 4: TRANSIT OF VENUS

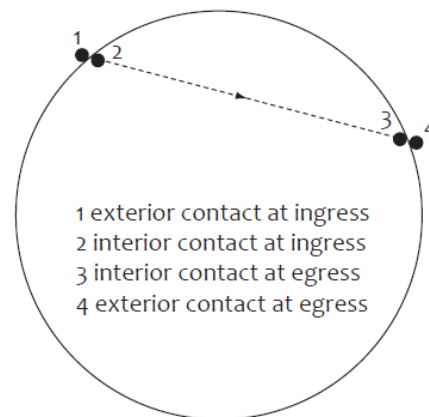


Definitions:

- **Transit** – when something, from our point of view crosses something, here Venus passes in front of/ across the Sun
- **Ingress** – when Venus begins to cross the face of the Sun
- **Egress** – when Venus finishes its crossing

Stellarium:

- Set the Stellarium date to June 5, 2012 around 2pm.
- Search for Venus
- Press Page Up until Venus and the Sun cover most of the screen
- Record the times in the table below at which Venus completes the following. Press L to speed time up, K to stop time and J to run time backwards
- What happens between 19:00 and 19:30? _____
- Press G to turn off the ground to finish getting the times
- Switch the location to Tokyo and Paris to find the times the transit will be visible from those cities



Fill in the times for the following points. Place an X by those that cannot be seen from that location.

	Rock Hill SC	Tokyo Japan	Paris France
1. Ext. ingress			
2. Int. Ingress			
3. Int. Egress			
4. Ext. Egress			

Observed Transits of Venus	# of years since the previous transit
1639	X
1761	
1769	
1874	
1882	
2004	
2012	
2117	
2125	

EXERCISE 5: MOONS OF JUPITER



400 years ago the common belief was that everything went around the Earth. Many problems arose from misplacing the center of the solar system, and 50 years earlier Copernicus had correctly predicted the Sun should belong at the center. Galileo watched Jupiter for three months and charted some “stars” which he realized were really moons of Jupiter, giving the first experimental data that not everything goes around the Earth. Kepler’s mathematics finally proved the case.

Stellarium:

- Turn off ground, atmosphere, fog (Press g, a, f)
- Search for Jupiter (Press F3)
- Center Jupiter in the screen (Press space)
- Either use Ocular View (Press CTRL O) or zoom in (Press page up)
- Speed time up to see the moons dance (Press = to advance one day, L repeatedly to speed up, k to stop, j to go backwards)

*Observations Jupiter
1610*

2. J. Jovis marc H. 12	○ **
3. J. Jovis	** ○ *
2. J. Jovis	○ ** *
3. J. Jovis	○ * *
3. H. J.	* ○ *
4. J. Jovis	* ○ **
6. J. Jovis	** ○ *
8. J. Jovis H. 13.	* * * ○
10. J. Jovis	* * * ○ *
11.	* * ○ *
12. H. J. Jovis	* ○ *
13. J. Jovis	* ** ○ *
14. J. Jovis	* * * ○ *

Appendices

Planetary Data

	Mercury	Venus	Earth	Mars	Ceres	Jupiter	Saturn	Uranus	Neptune	Pluto	Eris
Distance Sun (AU)	0.39	0.72	1.00	1.52	2.8	5.20	9.54	19.2	30.1	39.4	67.7
Diameter 1000 km	4.9	12.1	12.7	6.8	.95	143	120	51	50	2.4	1.3
Mass, Earth = 1	0.055	0.82	1.00	0.11	0.0002	318	95	15	17	0.03	0.003
Density, Water = 1	5.4	5.25	5.52	3.93	2.1	1.33	0.71	1.27	1.70	1.99	
Surface Gravity, Earth = 1	0.38	0.90	1.00	0.38	0.028	2.6	1.2	1.1	1.2	0.43	0.08
Escape Speed, km/s	4.3	10.4	11.2	5.0	0.51	60	36	22	24	3.2	
Rotation on axis	59 days	243 days	25 hrs	24.5 hrs	.38 days	10 hrs	10 hrs	16 hrs	16 hrs	6 days	8 Hrs ?
Revolution around Sun	88 days	225 days	365 days	687 days	4.6 yr	11.9 yr	29.5 yr	84 yr	165 yr	248 yr	557 yr
Eccentricity of Orbit	0.21	0.01	0.02	0.09	.08	0.05	0.06	0.05	0.01	0.25	0.44
Inclination of Orbit to Ecliptic	7°00'	3°34'	-	1°51'	10°35'	1°18'	2°29'	0°46'	1°46'	17°12'	44°12'
Moons	0	0	1	2	0	63	61	27	13	3	1
High Temp °F	800	847	120	100		-244	-301	-354	-375	-400	
Low Temp °F	-280		-40	-190							
Atmosphere	none	CO ₂	N ₂ ,O ₂	CO ₂		H ₂ ,He	H ₂ ,He	H ₂ ,He	H ₂ ,He	none	

- The mean earth-sun distance is called the astronomical unit where 1 AU = 1.496 x 10⁸ km.
- The Earth's mass is 5.98 x 10²⁴ kg.
- The density of water is 1 g/cm³ = 1000 kg/m³.
- The acceleration of gravity at the Earth's surface is 9.8 m/s².
- Venus rotates in the opposite direction from the other planets.
- The axis of rotation of Uranus is only 8° from the plane of its orbit.
- Eccentricity is the difference between the minimum and maximum distances from the sun divided by the average distance.
- The ecliptic is the plane of the Earth's orbit.

Distances to Closest Stars

distance	star	magnitude	spectral class	RA	DEC
.000016 ly	The Sun	-26.9	G2	.	-23 to +23
4.2 ly	Proxima Centauri	11.3	M5e	14:30	-62:41
4.3 ly	Alpha Centauri A	.33	G0	14:40	-60:50
4.3 ly	Alpha Centauri B	1.70	K5	14:40	-60:50
5.96 ly	Barnard's Star	9.5	M5	17:58	+04:34
7.6 ly	Wolf 359	13.5	M6e	10:56	+07:01
8.11 ly	Lalande 21185	7.5	M2	11:03	+35:58
8.7 ly	Alpha Sirius	-1.47	A0	06:45	-16:43
8.7 ly	Beta Sirius	8.3	white dwarf	06:45	-16:43
8.93 ly	A Luyten 726-8	12.5	M6e	01:39	-17:57
8.93 ly	B Luyten 726-8	13	M6e	01:39	-17:57
9.4 ly	Ross 154	10.5	dM3.5 V	18:50	-23:50
10.3 ly	Ross 248	12.2	M6e	23:42	+44:10
10.7 ly	Epsilon Eridani	3.7	K2	03:33	-09:28
10.8 ly	Luyten 789-6	12.6	M6	22:38	-15:19
10.8 ly	Ross 128	11.1	M4	11:48	+00:48
11.1 ly	Alpha 61 Cygni	5.6	K5	21:07	+38:45
11.1 ly	Beta 61 Cygni	6.3	K6	21:07	+38:45
11.3 ly	Epsilon Indi	4.7	K5	22:03	-56:47
11.4 ly	Alpha Procyon	0.38	F5	07:39	+05:13
11.4 ly	Beta Procyon	10.7	white dwarf	07:39	+05:13
11.6 ly	Sigma 2398	9	m4	18:43	+59:38

Periodic Table

The Periodic Table of the Elements

1 H Hydrogen 1.00794																	2 He Helium 4.003										
3 Li Lithium 6.941	4 Be Beryllium 9.012182															9 F Fluorine 18.9984032	10 Ne Neon 20.1797										
11 Na Sodium 22.989770	12 Mg Magnesium 24.3050															17 Cl Chlorine 35.4527	18 Ar Argon 39.948										
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955910	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938049	26 Fe Iron 55.845	27 Co Cobalt 58.933200	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.61	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80										
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.29										
55 Cs Cesium 132.90545	56 Ba Barium 137.327	57 La Lanthanum 138.9055	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.078	79 Au Gold 196.96655	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98038	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)										
87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (262)	108 Hs Hassium (265)	109 Mt Meitnerium (266)	110 111 112	111 112	112 113	113 114	114														
58 Ce Cerium 140.116	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93032	68 Er Erbium 167.26	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967	90 Th Thorium 232.0381	91 Pa Protactinium 231.03588	92 U Uranium 238.0289	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

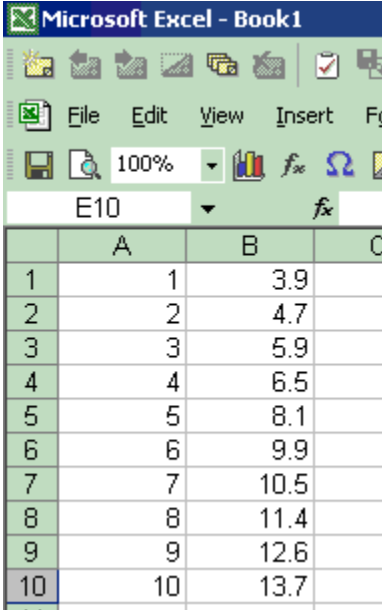
Excel 2003 Graphing

We will draw lots of graphs of the data we collect in lab this semester. Excel (or any other spreadsheet program) makes it very easy to graph and use that data. Some of the advantages to graphing in Excel rather than on paper by hand are the following:

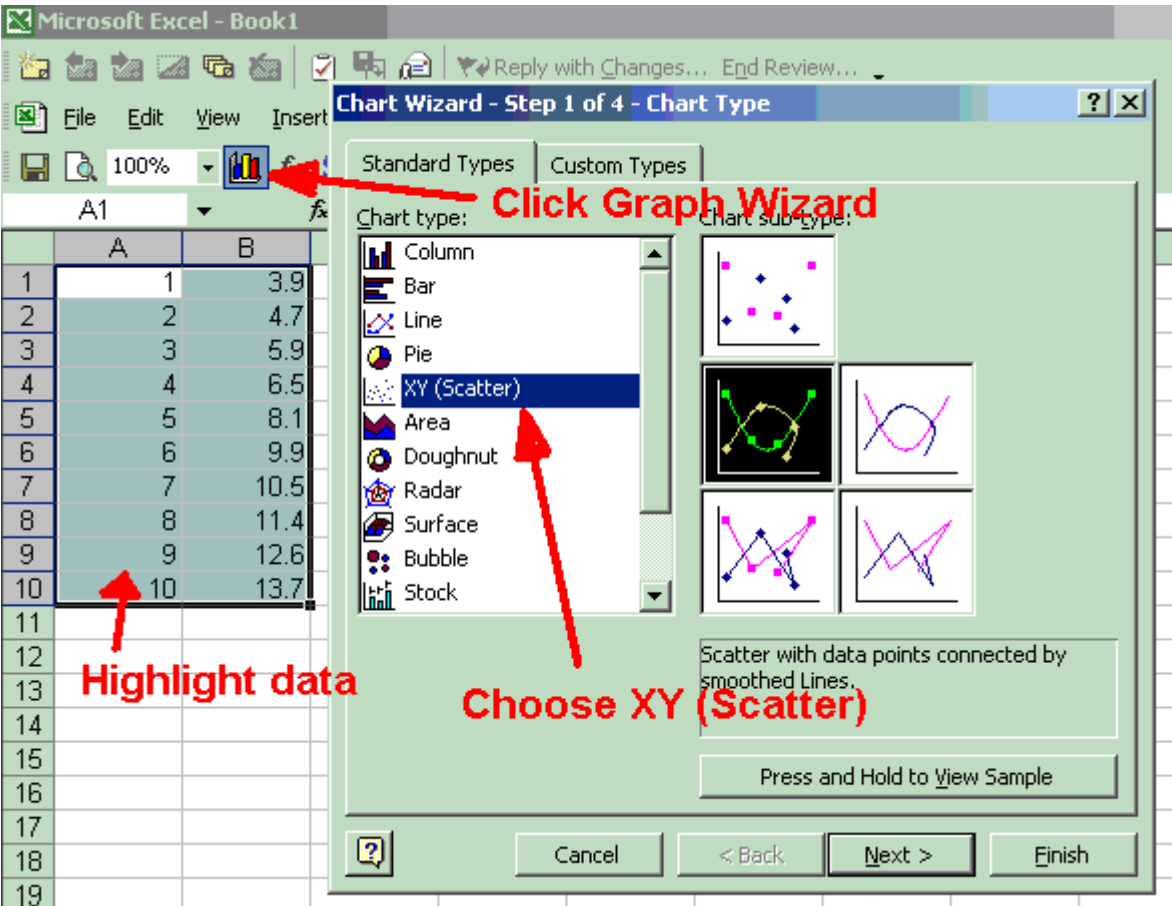
- easy and quick to do
- can print a nice looking graph with titles, units, labels
- can do linear regressions without knowing a ton of statistics
- can save, back-up, copy and email data to lab-partners or to me
- learn computer skills/valuable job skills

Step 1: Put the data into Excel: Place the data for the x-axis in column A (1,2,3...) and the data for the y-axis in column B (3.9, 4.7, ...)

Step 2: Using the mouse, highlight the entire data block, click the Graph Wizard button, choose XY (Scatter) for the chart type.



	A	B	C
1	1	3.9	
2	2	4.7	
3	3	5.9	
4	4	6.5	
5	5	8.1	
6	6	9.9	
7	7	10.5	
8	8	11.4	
9	9	12.6	
10	10	13.7	



Click Graph Wizard

Choose XY (Scatter)

Highlight data

Standard Types Custom Types

Chart type:

- Column
- Bar
- Line
- Pie
- XY (Scatter)
- Area
- Doughnut
- Radar
- Surface
- Bubble
- Stock

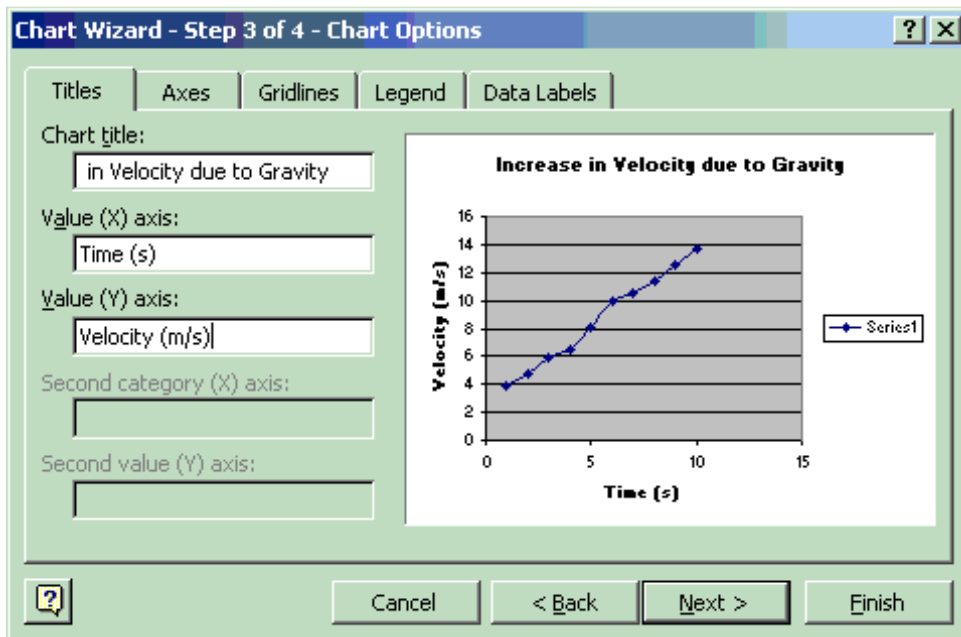
Chart sub-type:

Scatter with data points connected by smoothed Lines.

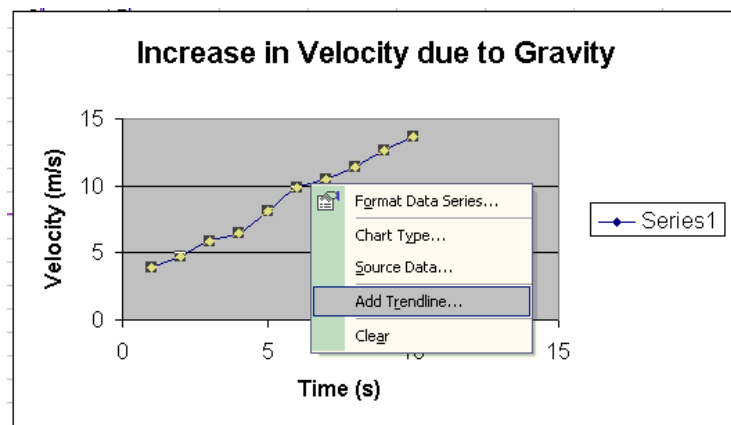
Press and Hold to View Sample

Cancel < Back Next > Finish

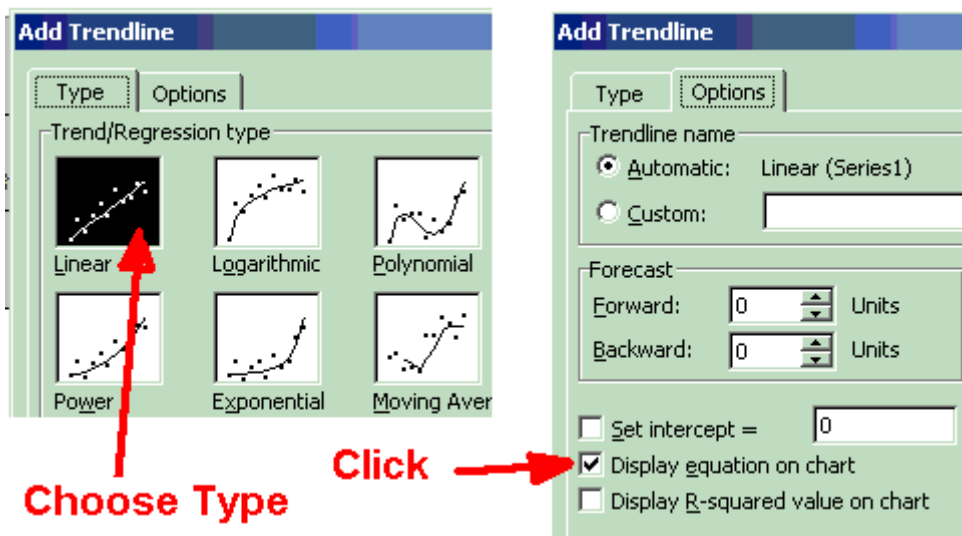
Step 3: Click next. Click next again. Enter Chart title, X axis label, Y axis label. Click Finish



Step 4: To add a trendline, click the line connecting the data points, right click to get the window options, select Add Trendline



Step 5: Select the type of Trendline - generally linear in these labs. On the options tab, select the "Display equation on chart" option.



Step 6: To print, click on graph and click Print.

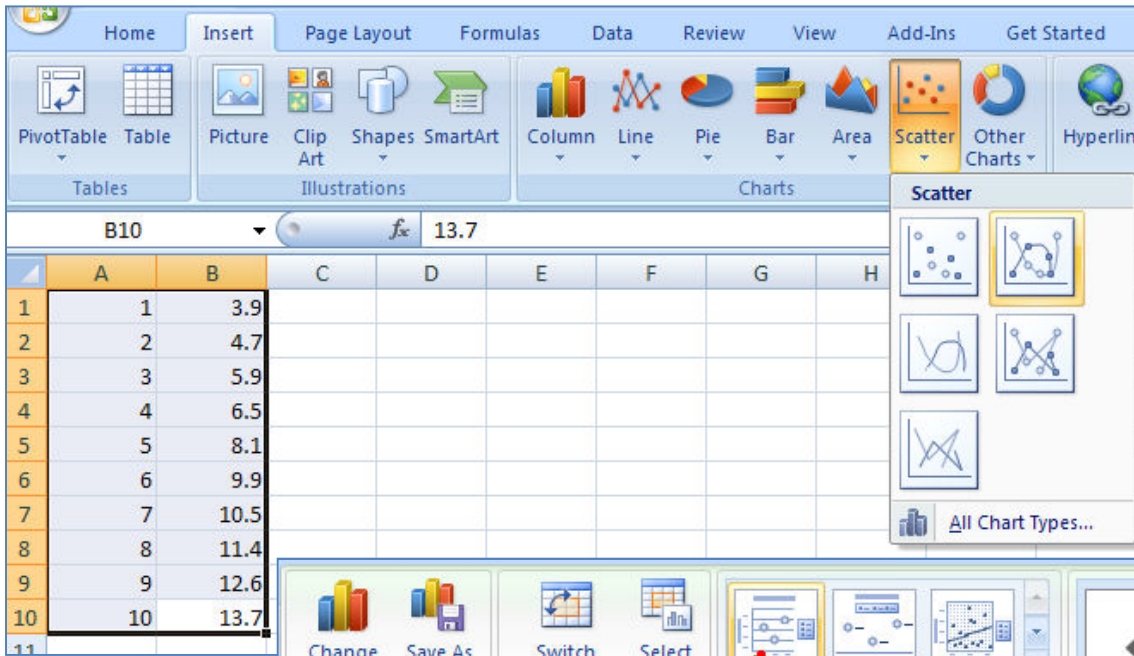
Excel 2007 Graphing

We will draw lots of graphs of the data we collect in lab this semester. Excel (or any other spreadsheet program) makes it very easy to graph and use that data. Some of the advantages to graphing in Excel rather than on paper by hand are the following:

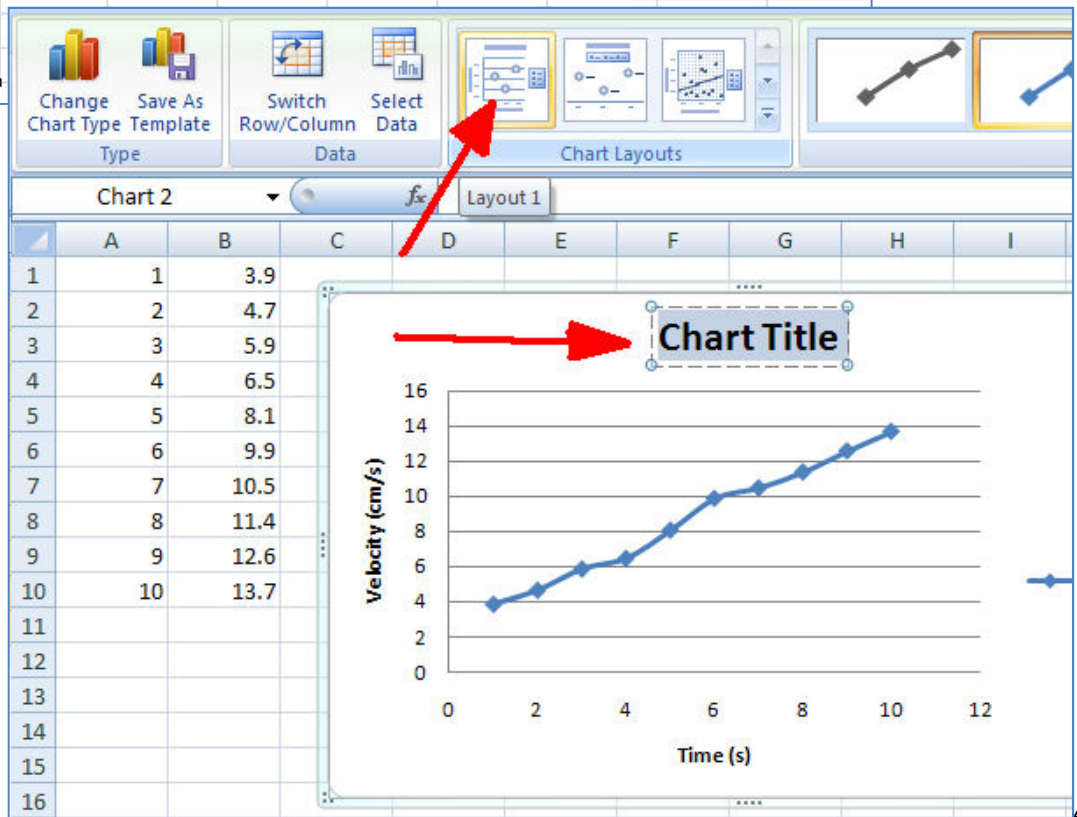
- easy and quick to do
- can print a nice looking graph with titles, units, labels
- can do linear regressions without knowing a ton of statistics
- can save, back-up, copy and email data to lab-partners or to me
- learn computer skills/valuable job skills

	A	B
1	1	3.9
2	2	4.7
3	3	5.9
4	4	6.5
5	5	8.1
6	6	9.9
7	7	10.5
8	8	11.4
9	9	12.6
10	10	13.7
11		

Step 1: Put the data into Excel: Place the data for the x-axis in column A (1,2,3...) and the data for the y-axis in column B (3.9, 4.7, ...)

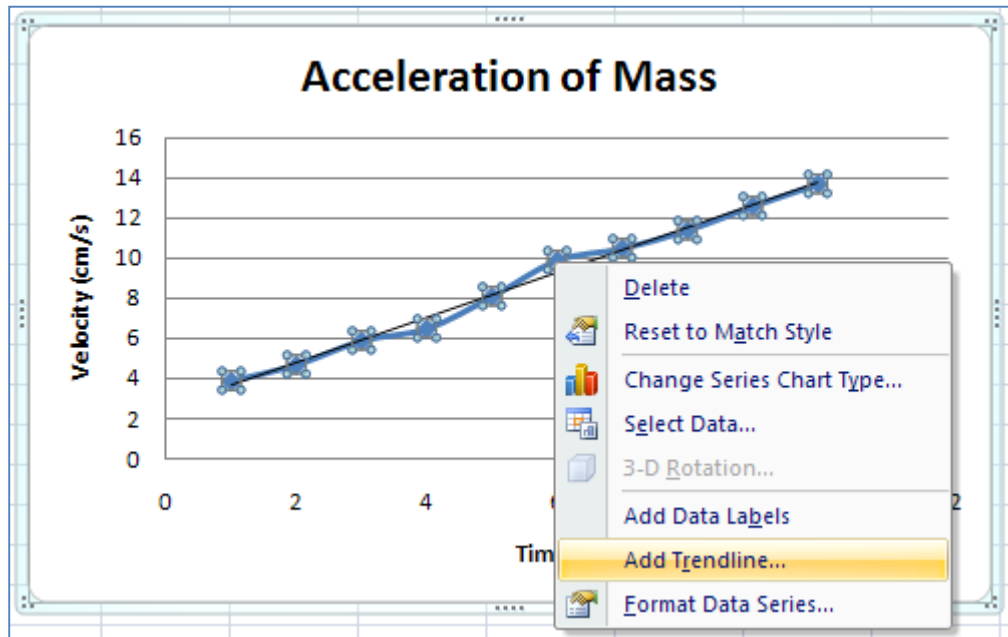


Step 2: Using the mouse, highlight the entire data block, click the Insert Tab, choose Scatter for the chart type and pick one of the Scatter types.

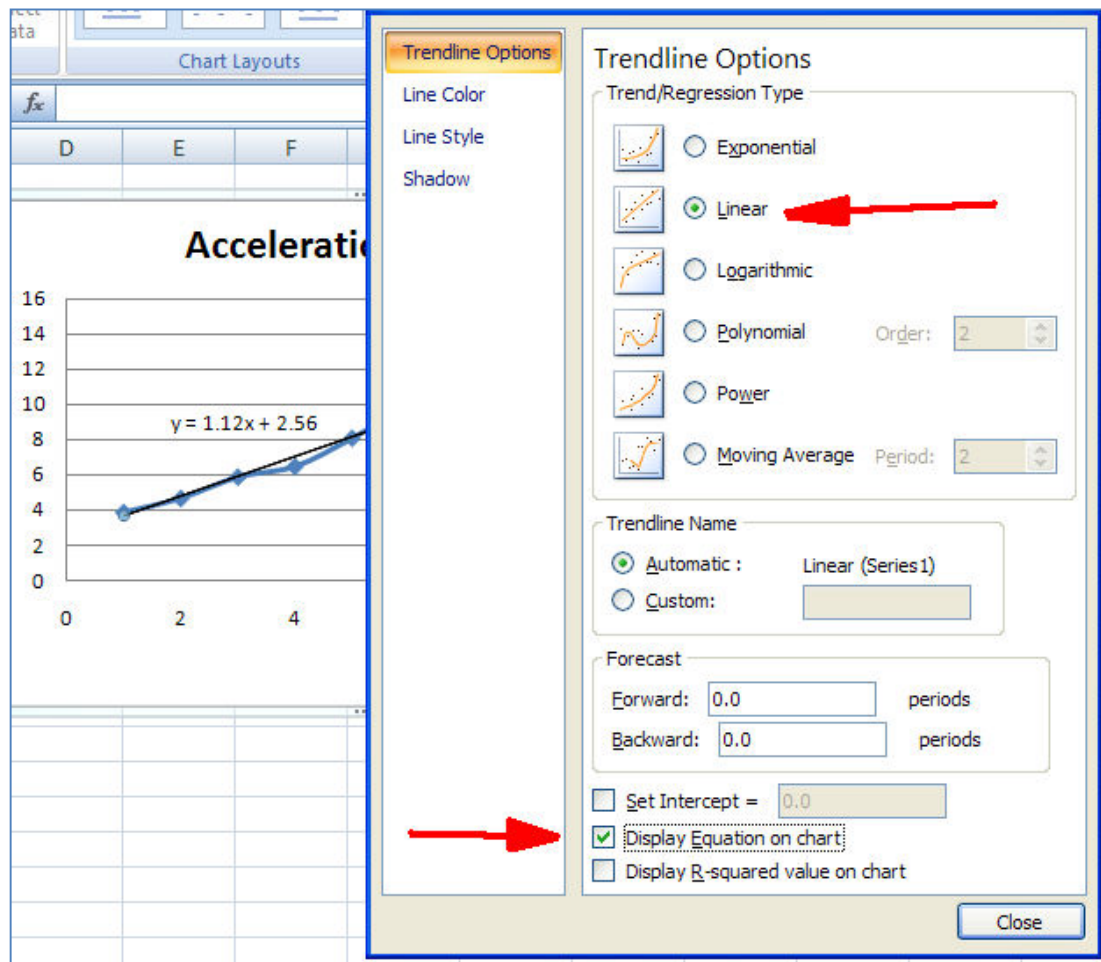


Step 3: Click the first Chart Layout to get titles. Enter Chart title, X axis label, Y axis label by clicking each label and editing.

Step 4: To add a trendline, click the line connecting the data points, right click to get the window options, select Add Trendline



Step 5: Select the type of Trendline - generally linear in these labs. Select the "Display equation on chart" option.



Step 6: To print, click on graph and click Print.

Protractor

