Our View of the Solar System

Version 1.2, 3/20/02

Student Name: ______________________________

Background

When we learn about things that are difficult to imagine, we use models. As we learn about the Solar System and learn the planet names in order, we imagine a model of the Solar System in which the planets are arranged in a straight line. Actually this never happens. But the Solar System is SO huge and complex, that most people find it difficult to imagine the Solar System any other way.

Our view of the Solar System from Earth changes over time. This makes it even more difficult to imagine. Throughout a single night, the Earth rotates—constantly changing the direction we are facing out in space. When our part of the Earth is facing toward the Sun, it's daytime, and the Sun and the Moon are the only objects which are bright enough for us to see. But when our part of the Earth is facing in a direction where we can't see the Sun, it's nighttime, and we can see stars and planets.

Only five of the planets are ever visible in the sky to the unaided eye: Mercury, Venus, Mars, Jupiter, and Saturn. Uranus, Neptune, and Pluto are too far away, and the Earth is below your feet (try not to trip over it).

Our view of the Solar System also changes over weeks, months, and years as the planets move in their orbits around the Sun. This activity will provide an opportunity for you to build and explore a model of the current positions of the planets in their orbits around the Sun. You will look for connections between your model and where we see the planets in our current sky.

For this model, you will be shrinking the visible part of our Solar System down to fit into an open space that you have inside or outside your school. Your model will be so small that you will not be able to show the sizes of the planets. You will use colored plastic balls, all of the same size, to represent each of the planets.

Objective

The objective of this activity is to use a model to explore the current positions of the visible planets, and find connections to our view of the planets in the current sky.

Materials

- string (length will be determined later)
- tape measure or meter stick
- 1 ball
- "planet holder": type will vary

Procedure

Part A: Preparations

1. Answer the pre-activity questions in the **Questions and Conclusions** section.
2. Observe the planets in the sky, if possible, or visit the planetarium. Or find an illustration in an astronomy magazine which shows the appearance of the planets in the sky.
3. Think of some questions about why the planets appear the way they do in the sky.
4. Calculate the scaled distance to each of the planets. Your teacher will tell you the maximum distance possible for Saturn. Divide all of the planets by the same number so that the distance to Saturn is less than that maximum. Record your answers.
5. Form pairs or groups of students as your teacher directs you to do. Your teacher will also assign your group a planet. Cut a piece of string to match the length of your planet's scaled distance.
6. Someone in the class must tape the 360° protractor in position on the floor (as directed by the teacher).

Information about your planet

Your Planet: ______________________

Scaled Distance: ___________________

Direction: ___________ °

Part B: Straight Line Model

(Alert! This alignment never actually happens in the real Solar System.)

7. Use your string to measure the distance from the center of the protractor to where your planet should be located in a straight line model of the Solar System. You will need to place the planets in a line toward the direction of the longest dimension so that you will have room to place Saturn.

Madison Metropolitan School District Planetarium and Observatory
201 South Gammon Road, Madison, Wisconsin 53717-1499
Telephone: (608)663-6102 FAX: (608)662-9850 WWW: http://www.mmsd.org/planetarium/

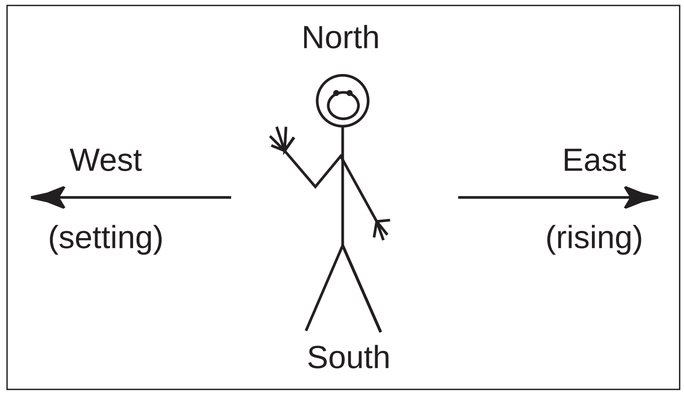
8. Place your planet ball in position using your planet holder (labeled cone and/or flashlight as directed by your teacher).
9. Stand back and observe your model. Answer the questions for the **Straight Line Model**.

Part C: Current Positions Model

10. Your planet's "direction" (obtained from your teacher; recorded on page 1) tells where your planet is located in its orbit around the Sun. Find the zero on the protractor. Moving from the zero in a **counterclockwise** direction, find the direction in which your planet would currently be located.
11. In that direction, use your string to place your planet at the proper scaled distance from the center of the protractor. When you place the planet holder, turn the cone so that the label is facing toward the Earth.
12. Stand back and observe the model of the current positions of the planets. Answer the questions for the **Current Position Model**. **<u>Note</u>:** each group will need to take turns doing the **Viewing from Earth** questions.

Part D: Current Positions Model (viewing from Earth)

13. (Exploring the Earth model) Go to Earth in your model. You should find a card attached to the "Earth" ball. On the card you should find an observer (stick figure person), compass directions, and arrows pointing toward the East (rising) and toward the West (setting). The card represents our horizon. Imagine you are that person on the Earth for these exercises.
    a. **(Day)** Turn the Earth so that it's daytime for the observer (facing toward the Sun). If the observer can see the Sun, the sky is too bright for us to see any of the stars and planets (except the Sun and Earth of course).
    b. **(Night)** Now turn it so that it's nighttime for the observer (facing away from the Sun). Now the sky is dark and we can see the stars and planets.



14. **(Noon)** Turn the Earth so that it's noon for the observer (facing exactly toward the Sun). Imagine yourself as the observer on the Earth and look out into your model from that position. Answer the **Noon** questions on your answer sheet.
15. **(Sunset)** Turn the Earth so that it's sunset for the observer (the setting arrow should be pointing toward the Sun). Imagine yourself as the observer on the Earth and look out into your model from that position. Answer the **Sunset** questions on your answer sheet.
16. **(Midnight)** Turn the Earth so that it's midnight for the observer (facing exactly the opposite direction from the Sun). Answer the **Midnight** questions on your answer sheet.
17. **(Sunrise)** Turn the Earth so that it's sunrise for the observer (rising arrow pointing toward the Sun). Answer the **Sunrise** questions on your answer sheet.
18. (**Night**) Answer the question for **Night**.
19. (**Appearance of Mars**) Without moving the Mars cone, use the string for Mars to explore the different places that Mars could be as it orbits around the Sun. Compare the position in which Mars is closest to us, to the position in which Mars is farthest from us. Answer the **Appearance of Mars** question.

Data Table

Mnemonic	Planet/Sun	Distance from Sun (kilometers)	Scale Distance from Sun (meters)
	Sun	n.a.	n.a.
<u>M</u>y	**Mercury**	58,000,000	__________
<u>V</u>ery	**Venus**	108,000,000	__________
<u>E</u>ducated	**Earth**	150,000,000	__________
<u>M</u>other	**Mars**	228,000,000	__________
<u>J</u>ust	**Jupiter**	778,000,000	__________
<u>S</u>erved	**Saturn**	1,430,000,000	__________
<u>U</u>s	**Uranus**	2,870,000,000	__________
<u>N</u>ine	**Neptune**	4,500,000,000	__________
<u>P</u>izzas	**Pluto**	5,900,000,000	__________

Alert! Alert!
Remember that the planets never line up in a straight line, and are not all the same size!

Questions and Conclusions

Student Name: ______________________________

Pre-activity Questions

1. Could Mercury and Jupiter appear close to each other in the sky? (explain)

____

____

2. Does the appearance of a planet change over time, or does it always look the same in the sky? (explain your answer)

____

____

3. Can we see all of the planets in the sky tonight? (explain your answer)

____

____

Straight Line Model

4. Which 2 planets are closest to Earth? ____________________ , ____________________

5. Look at the Earth in the model. We have day time when we are on the side of the Earth facing toward the Sun. We have night when we on the side facing away from the Sun. We can only see the stars and planets at night.

Which planets WOULD NOT be visible from the Earth in this model?

____

Current Positions Model

6. Which planet is closest to the Earth? (Use string to measure if necessary.) _________________________

7. Which planet is farthest from the Earth? _________________________

8. Which 2 planets are closest to each other? _________________________ , _________________________

Viewing from Earth

9. (**Noon**) Which planet(s) would be in the daytime sky (but not visible)?

____

10. (**Sunset**) Which planet(s) would the observer be able to see in the sky?

____

11. (**Sunset and later**) Slowly turn the Earth toward midnight for the observer (facing exactly opposite of the Sun). Watch the setting arrow as you turn the Earth. Which planet will set first after sunset? _______________________________________

12. (**Midnight**) Which planet(s) would the observer be able to see in the sky?

____

13. (**Midnight and later**) Slowly turn the Earth toward sunrise for the observer (rising arrow pointing toward the Sun). Watch the rising arrow as you turn the Earth. Which planet will rise first after midnight? ______________________________

14. (**Sunrise**) Which planet(s) would the observer be able to see in the sky? ____

15. (**Night**) Remember that it's nighttime from sunset to sunrise. Any planets that we can see in our current sky must be visible at night. List all of the planets that we can currently see in the sky **at some point** throughout the night.

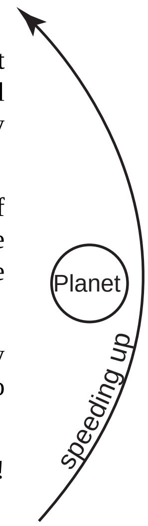
____

16. (**Appearance of Mars**) In which position would Mars appear larger and brighter in our sky? (circle) **closest** **farthest**

Conclusions

Review and discuss your answers to questions 1-3. Would your answers to those questions be different now?

Space Probe Flight Plan



Imagine that your group is a team of mission designers for a spacecraft which will be sent to Saturn. Your group must design a flight path for your spacecraft to follow to Saturn. However, we don't have enough money to pay for the fuel and spacecraft necessary to send the probe straight to Saturn. You'll need to design a flight path which uses the gravity of some of the other planets to speed the spacecraft up along way.

Mission designers use a series of "gravity assists" to make the spacecraft go faster, which is similar to the effect of firing rocket engines. They aim the spacecraft so that it just barely misses the planet. As the spacecraft approaches the planet, the gravity of the planet pulls on the spacecraft and speeds it up. The gravity of the planet also turns the spacecraft so that it's heading out in another direction, except that now it's moving faster.

Mission designers for the Cassini space probe sent it around Venus twice, then the Earth, and finally Jupiter on its way to Saturn. This series of gravity assists provided the amount of energy to accelerate (speed up) the spacecraft equal to 75 tons (68,040 kg) of rocket fuel.

Also, the real planets keep moving in their orbits around the Sun, so mission designers are aiming for a moving target! In this exercise, we will keep the planets in their current positions.

In the space provided below, draw a map of the current positions of the planets as you would see them from above. Use your map, or the model to plan the flight path for your space probe. Then, with a colored pencil, draw your flight path on your map. Then explain why you chose this route. (If you need more room, you could use a separate sheet of paper.)

Explain why you designed the flight path this way.

Background for Teachers

Very few students, and adults for that matter, have a good concept of where the planets would be found in the Solar System beyond a simple, straight-line model. They wrongly assume that Venus and Mars are always the closest planets to the Earth. Their misconceptions become obvious by their questions when they see something like Jupiter and Venus close together in the sky: "How can Venus and Jupiter be next to each other?"

This activity allows students to explore a model of the Solar System which shows the current positions of the planets, and compare this model to when and where we see the planets in our sky. This is not easy for everyone to do, but it is an excellent exercise in three-dimensional imagery. It also enhances their concept of the Solar System, and how NASA mission designers must take into account the positions of the planets in choosing a route for a space probe to follow, and in choosing a launch date.

Keep in mind that in most cases, you will not be creating a "scale model" of the Solar System. As students discover in the activity "Solar System Stroll" (important activity to do in the same unit as this activity), the Solar System is so vast, that in order to make a scale model in which the smallest planets would be visible, the scaled distance to Pluto must be about a kilometer. It's very difficult to find an area to accommodate a straight line model. Even if your straight line model is only for the planets we can see with the unaided eye, the minimum scaled distance to Saturn is 238 meters. Imagine how difficult it would be to make a scale model of the current positions of the planets!

An important prerequisite concept in which the students must have a firm foundation is the concept of day and night. It is recommended that students successfully complete "**Modeling Day and Night**" before attempting this activity.

Important Points for Students to Understand

- The planets never line up in a straight line.
- When it's night for us, we are somewhere on the side of the Earth where the Sun is not visible. When we experience day, we are somewhere on the side of the Earth that the sun is shining on.
- Planets which are actually very far away from each other can **seem** close to each other from the Earth's perspective.
- Models can be used to predict events such as when certain planets will be visible.
- Mission designers for a space probe use the gravity of planets to speed up the space probe and send it on its next leg of the journey. This is called a gravity assist.
- Mission designers for a space probe must plan their launch date and flight path according to where the planets are located in their orbits.

Time Management

This activity can be competed in 2 class sessions of about 50 minutes each. In the first session, introduce the activity, do the calculations (or provide the numbers for them), measure and cut the string, and discuss the procedures for the next session. The second session will consist of setting up the model, and answering the questions. While groups are taking turns doing the **Viewing from Earth** section, the other groups will be answering the other questions for the **Current Positions Model**, and completing the **Space Probe Flight Plan**.

If possible, schedule a nighttime observing session to see some of the planets in the current sky. If it's not possible to get together at night as a class, have the students look for the planets in the sky at home.

Materials: total for the class (assuming 1 model)

- string (1 ball of string which does not break easily, and does not stretch)
- tape measure (with metric), and/or meter sticks for measuring string.
- "playland" balls for the planets (6)
- larger orange or yellow ball (sun)
- "planet holders" (7): pylon-style cones
- (optional) flashlights (7): to place in the top of the cones, and to place the planet balls on for illumination
- 360° protractor (1) [large printable protractor available for download as a pdf file from the planetarium web site]
- masking tape (1 roll)
- planet position data from the office of the Planetarium & Observatory

Vocabulary

Model: a smaller representation of a large object or system.

Scale Model: a smaller representation of a large object or system in which all aspects are smaller to the same degree.

Rotate: to spin in place—on an axis.

Revolve: to orbit, or move around something.

Heliocentric Longitude: from the Sun's point of view, direction in the Solar System that an object is located. (counterclockwise as seen from above)

Mnemonic: a sentence or rhyme used as an aid in remembering.

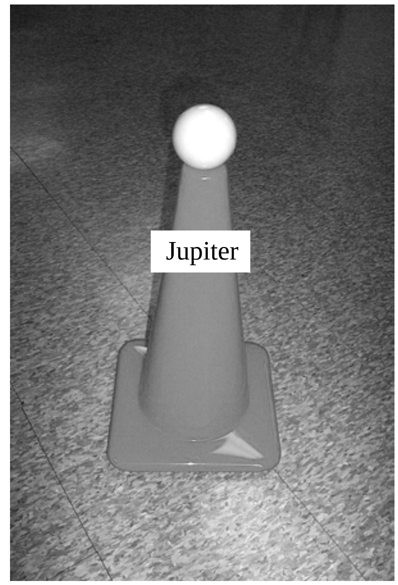
Accelerate: to increase the speed.

(Time Management, continued)

Alternative Plan if more "space" is available

If you have a large enough area to work with, you can set up 2 Solar Systems. There are 2 possible advantages to this: you could reduce the number of the people in the group to increase student involvement, or you can keep the group sizes the same and rotate groups through the **Viewing from Earth** section faster.

Preparation

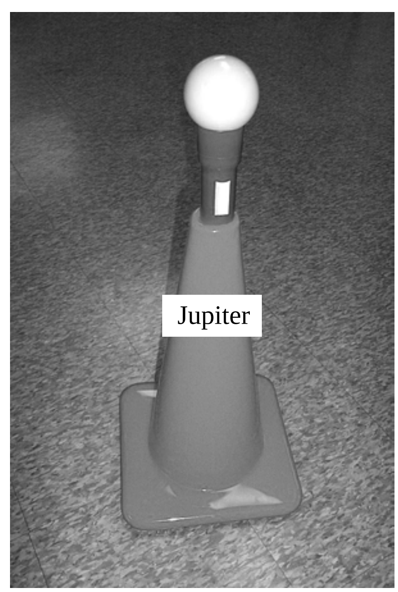


Simple "planet holder"

- Gather supplies: (some materials are provided in the kit available through the Science Materials Center)
- Assemble the 7 "planet holders" (6 planets and 1 sun). These can be as simple as a large cone used by the physical education classes with the balls place on top. Or you can illuminate the planets by placing a flashlight into the top hole of each cone and placing the ball on top of the flashlight. Using this "fancy" planet holder and turning off the lights can help students to imagine the planets appearing next to each other in the sky. See instructions for labels on page 8.
- Find a location in which you can set up the model. Usually a gym or multi-pupose room would work best for setting up themodel inside, but it could also be set up on the playground outside. In the Answers to Student Questions section, the scaled distances are provided in which the distance to Saturn is a little less than 15 meters. This usually requires a room which measures approximately 18 meters diagonally across the longest dimension. This size works well.
- Planet information: call the planetarium office (608-663-6102) to request the information about the location of the planets for the date(s) you'll be doing the activity. We can either e-mail, mail, or FAX you the information.

  If you have a computer program which displays the planet/stars positions for a given time, you can use it to gather the data. You'll be looking for something called the Heliocentric Longitude of each planet.

- If you want to help them with the math, you can provide them with the scaled distances (with the data below for example), or you and send them to the web site below where they could use trial and error to get Saturn's distance down to the length you need.
  Build a Solar System: http://www.exploratorium.edu/ronh/solar_system/
  Note: you can link to this site from the Astro Links page of our web site.



Fancy"planet holder"

Answers to Student Questions

<u>Data Table</u> (sample answers if your maximum distance for Saturn is 15 meters)

- To calculate this, multiply Saturn's distance (1,430,000,000 km) times 1000 to convert to meters. Then divide by 100,000,000,000 to get the answer of 14.3 meters for Saturn's scaled down distance.

Mercury = .58 meters (or 58 centimeters)
Venus = 1.08 meters (or 108 centimeters, or 1 meter and 8 centimeters)
Earth = 1.5 meters (or 150 centimeters, or 1 meter and 50 centimeters)
Mars = 2.28 meters (or 228 cm, or 2 meters and 28 cm)
Jupiter = 7.78 meters (or 7 meters and 78 cm)
Saturn = 14.3 meters (or 14 meters and 30 cm)

<u>Note</u>: To point out why we do NOT try to do the planet and sun SIZES on this scale, the sun would be 14 mm (or 0.5 inches) in diameter! And we can fit over 1000 earths inside the sun!

Questions

(**Note about questions #1-3:** we don't expect them to come up with the right answer here. The idea is just to get them thinking. But the "correct" answers are provided below for your information.)

1. Answers will vary, but the "correct" answer is: Yes, Mercury and Jupiter could appear close together in the sky if the appear to be out in the same direction from our point of view here on the Earth. However, Jupiter would actually be much farther away from us than Mercury.
2. Answers will vary, but the "correct" answer is: Yes, the appearance of a planet in the sky can change greatly over time due to changes in distance between the planet and us on the earth (affecting brightness), and changes in weather (affecting brightness, clarity, and twinkling).
3. Answers will vary, but the "correct" answer is: No, technically, we can't see all of the planets in the sky because 3 of the planets (Uranus, Neptune, and Pluto) are too dim to be seen with the unaided eye. But even out of the 5 other planets, sometimes we can't see all of them because they appear too close to the sun in our sky.
4. Venus and Mars.
5. Mercury and Venus.

6-15. Answers will vary depending on the date you are modeling and the position of the planets. Contact the planetarium if you would like help with this.

16. closest.

Variations

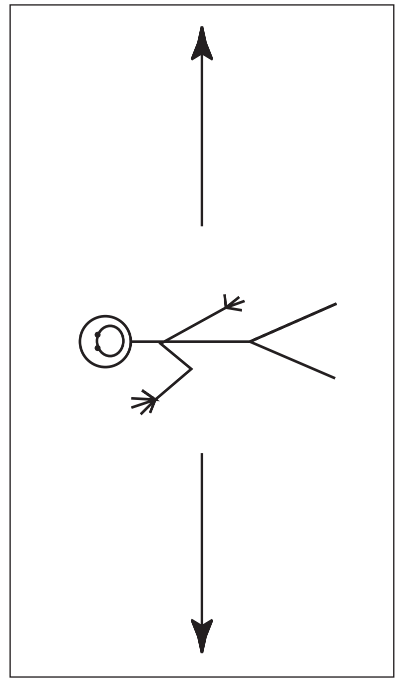
- **Two Models:** set up 2 Solar Systems (see Time Management)
- **Scale Model?** If you have plenty of "space" available, such as a football field, you **might** be able to set up an actual scale model out through Saturn. However, remember that you would be dividing the planet diameters by the same number that you used to scale down the distances: even the planets that are "visible" from Earth will appear very small! (In your model, they may be actually harder to see than in the sky. But you could use binoculars or a telescope to see them better. And they would appear the same size in the telescope, as seen from the Earth position, as they would with the telescope pointed at the real planets!) [**Notice safety note to the right.**] You can use the **Solar System Stroll** activity for a reference for how to create a scale model. You can use flags to call attention to the direction to look for a planet.
- **Do this more than once!** One or two months after the initial investigation, have the students set up the model using the same positions as last time. Have the students predict where the planets will be now. Then, have the students move the planets to their current positions, and ask the students to make observations about the differences, and conclusions about how fast the planets orbit around the Sun.

Safety Note:
Be sure that the telescope is supervised so that someone doesn't try to point the telescope or binoculars at the real Sun!

Suggestions for Further Study

- Visit the planetarium before or after doing this activity so that your entire class can see how the planets appear from Earth. And learn how to find them in the real sky.
- Learn more about the Cassini space probe, its flight path, and its mission to Saturn. (scheduled to arrive at Saturn in 2004) Web site: http://www.jpl.nasa.gov/cassini/
- Use the Office of Space Science (OSS) web site to learn about other space probe missions: http://spacescience.nasa.gov/missions/index.htm
- **Solar System Stroll**: an activity in which students calculate and walk through an actual scale model of the Solar System.

Instructions: Tape these labels to each "planet holder" so that they are facing toward the Earth.



Sun

Mercury

Venus

Earth

Mars

Jupiter