Scale in the Solar System

SIXTH GRADE SCIENCE STANDARDS:

STANDARD FOUR

Students will understand the scale of size, distance between objects, movement, and apparent motion (due to Earth's rotation) of objects in the universe and how cultures have understood, related to and used these objects in the night sky.

OBJECTIVE 1

Compare the size and distance of objects within the systems in the universe.

ACTIVITY DESCRIPTIONS:

- **Activity One**: Activate Prior Knowledge: "Powers of Ten Video" and Explore the sizes of various objects in the solar system
- **Activity Two**: 2D Comparison and Investigation of the size of the sun, earth and moon
- **Activity Three**: 3D Comparison and Investigation of the size and volume of Earth and the Moon
- **Activity Four**: Construct a 2D Scale Model of the Solar System: There are two versions: easy and advanced.
- **Activity Five**: Examine the Scale of Solar System on a Meter Stick
- **Activity Six**: Construct an Outdoor Scale Model of the Solar System: 3 Different Versions: Meters, Paces, or Toilet Paper Squares
- **Activity Seven:** Investigate the Apparent Sizes of Objects in the Solar System
- **Activity Eight:** Investigate the Expanding Universe using a Balloon
- **Activity Nine:** Use Math to Scale down the Solar System by diameter and distance using astronomical units

THE IMPORTANT POINTS

- The Solar System is an enormous empty space. Even our closest neighbors in space are very large distances away.
- Space is mainly nothingness.
- A scale model is one way of looking at distances that are too large to visualize
- The planets are RARELY lined up on one side of the sun.
- As long as the scaling factor is known, true measurements can be determined from scale measurements and vice-versa.

VOCABULARY:

Scale Model: a model that is proportional in all respects to the object being modeled.

Scaling Factor: The factor or proportion which, when multiplied by measurements of a scale model, gives measurements of the object.

Astronomical Unit: The basic unit of length to measure distances in the Solar System. It is the distance from the center of the mass of the sun to the center of the mass of the Earth-Moon System (149,600,000 km).

BACKGROUND INFORMATION:

Space is HUGE. Even planets that are relatively close to Earth on a cosmic scale are still far, far away. In 2003, when Mars was as close to Earth as it had been in 60,000 years, the Mars was still 35 million miles away. That's more distance than it would be to fly to the Moon and back 75 times. You could fly from Los Angeles to New York and back every day and it would still take you 20 years to travel that far. Jupiter is ten times farther away.

Students have a hard time dealing with such huge numbers. We need a simpler way to think about the solar system. It involves reducing the sizes and/or distances by the same amount. For example, divide all the distances by ten. These new values can be used to make a scale model.

It get an idea of the tremendous size of space, imagine for a moment that our Earth is just one millimeter across, a little smaller than a head of a pin. At this scale, the moon is half the size of the period at the end of this sentence and the distance from Earth to the moon would be 3 cm. At this scale, the huge planet of Saturn is about a centimeter across. The sun would be about 10 centimeters. At this scale, the sun is on the goal line of a football field, the Earth is a pinhead at the 10-yard line and Saturn is at the other end of the field. Pluto would be about four football fields away. The nearest star is almost 8000 football fields away (500 miles).

ACTIVITY #1 PREASSESSMENT- ACTIVATING PRIOR KNOWLEDGE

MATERIALS

- "Powers of Ten" Video " "
- Powers of Ten Book (optional)
- Science Journal
- How Big? Size Comparison Worksheet
- Hang Ten? Powers of Ten Worksheet
- Powers of Ten Worksheet

1. Assess student's background knowledge. Have the students do a QUICK WRITE.
   - Have the students name the top ten largest and top ten smallest objects on Earth.
   - List the largest and smallest objects in the universe.

2. Watch the video Powers of Ten video by Charles and Ray Earnes. (Available through ASP catalog)

> **EXTENSION**: Use the book Powers of Ten. Scientific American Library and W.H. Freeman Co. publish it.

3. Students attempt to match the measurements sheet adapted from the lesson: How Big is the Universe? Produced by the Astronomy Education program of the Lawrence Hall of Science, University of California, Berkeley Copyright 1992.

Answers:

1 cm	width of a light switch lever (about 1 cm)
10 cm	softball (about 10 cm)
1 meter	width of a door (about 1 meter)
10 meters	the classroom (about 8 meters)
100 meters	the school (about 100 meters)
1 kilometer	depth of the Grand Canyon (over 1 km)
10 kilometers	deepest depth of Pacific Ocean (about 11 km)
1000 kilometers	length of California
10,000 kilometers	diameter of the Earth (12,756 km)
100,000 kilometers	diameter of Jupiter (142,800 km)
1,000,000 kilometers	diameter of the sun (1.4 million km)
100,000,000 kilometers	distance to the sun (152 million km)
1,000,000,000 kilometers	distance from Sun to Saturn
Off the chart	
38 million million kilometers	nearest star (other than the sun)
100,000 Light Years or a million billion km	Milky Way Galaxy

HOW BIG?

Distance from Sun to Saturn	Depth of Grand Canyon	Distance of Sun from Earth
Classroom	Earth to Moon Distance	Width of a light switch lever
Deepest depth of Pacific Ocean	Softball	Distance to the sun
Width of the door	Diameter of the sun	School
Diameter of Jupiter	Diameter of Jupiter	Length of California
Diameter of Earth	Milky Way Galaxy	Nearest sun (other than the sun)

MATCH THE APPROXIMATE SIZE OF OBJECTS:

1 cm	
10 cm	
1 meter	
10 meters	
100 meters	
1 kilometer	
10 kilometers	
1,000 kilometers	
10,000 kilometers	
100,000 kilometers	
1,000,000 kilometers	
10,000,000 kilometers	
100,000,000 kilometers	

HANG TEN!

Fill in the Powers of Ten and the approximate distances measured in Earth Diameters

STANDARD NOTATION (Earth Diameters)	POWER OF TEN	ASTRONOMICAL DISTANCE	APPROXIMATE DISTANCE	SCALED DISTANCE
1	10^0	Earth's diameter	12,000 km	1 mm
10	10^1	SATURN'S DIAMETER	120,000 km	10 mm (1 cm)
100		SUN'S DIAMETER		10 cm
1000		-----		100 cm
10,000		Distance from sun to Earth		10 m
100,000		DISTANCE from sun to Saturn		100 m
1,000,000		Distance light travel in 12 hours		1000 m
10,000,000		Distance light travels in 5 days		10 km
100,000,000		Distance light travels in 50 days		100 km

MATH IN THE SOLAR SYSTEM

Planet	Average Distance from the Sun (in Miles)	Write using exponents
Mercury	36,000,000	$3.6 * 10^7$
VENUS	67,000,000	
EARTH	93,000,000	
MARS	140,000,000	
JUPITER	480,000,000	
SATURN	890,000,000	
URANUS	1,800,000,000	
NEPTUNE	2,800,000,000	
PLUTO	3,700,000,000	

Planet	Average Distance from the Sun (in kilometers)	Write using exponents
Mercury	58,000,000	$5.8 * 10^7$
VENUS	110,000,000	
EARTH	150,000,000	
MARS	230,000,000	
JUPITER	780,000,000	
SATURN	1,400,000,000	
URANUS	2,900,000,000	
NEPTUNE	4,500,000,000	
PLUTO	5,900,000,000	$5.9 * 10^9$

ACTIVITY #2: SCALE OF SUN, EARTH, & MOON- 2D Size Comparison

MATERIALS

- Model of the Sun 55.4 cm diameter with 110 hole punched size earths glued across the diameter
- Full sheet of newspaper for each student
- Science Journal
- Four different sized poster board circles with diameters of 22in, 36in, 55in, and 70in

1. Begin the discussion with why the sun is important to us on earth: light, energy for green plants, part of the food chain, helps drive the water cycle, and heat.

2. Begin with a large sheet of newspaper for each student. Have the student draw how big they think the sun; earth and moon are if it was scaled down to this size of paper.

3. Students share ideas with other students and discuss their thinking.

4. Show the students that the earth would be the same size as a hole punch (.5 cm) and the sun would be 55 cm in diameter. The moon would be a quarter of the size of a paper punch. Share with the students that the sun is 110 times bigger than the earth. Have students explain why it seems so small if it really is so much larger. (it is due to the distance away it is)

5. Give the students four different size circles cut out of poster board (22-inch diameter, 36-inch diameter, 55-inch diameter and 70-inch diameter. Have the students measure the diameter and figure out which one is the correct sun to match with our hole-punched earth. MODIFY FOR STUDENTS THAT ARE MORE ABLE: Have students measure and cut out a 55-inch diameter circle. The best way to make a circle this large is to have the students hook paper clips large and small together until it is the predetermined length.

6. Discuss how far apart you would have to place this model to make it accurate. The earth is 93,000,000 miles from the sun. Start at the earth and walk the model 100 suns away.

7. Take the students outside and have them measure 100 suns away from a predetermined point.

EXTENSION

1. Have the students cut out a new earth and moon out of newspaper and justify their scale.
2. Have them correct it by seeing if the moon is 1/4 the diameter of the earth, so that four moons could fit across each earth.

ACTIVITY #3: SCALE OF SUN, EARTH, & MOON- 3D Size and Volume Comparison

COMPARING SIZE

1. We are going to discuss scale again, but with three-dimensional objects. Show a basketball labeled as the earth and four other different varied size balls (tennis ball, red playground ball, softball, ping-pong ball). Have the student think about if you shrunk the earth down to this size how big would the moon be compared to the earth. Have the students discuss their ideas in small groups. Have the groups prepared to justify their answers.

2. Tally the thinking of the groups. If the earth was a basketball (30 inch), then the tennis ball would be the moon because it is ¼ the size. On the board, write that the distance from the earth to the moon is 380,000 km. Write the circumference of the earth is 40,000 km. How many times would they go around the earth to equal the distance of the moon to earth? (divide 380,000 by 40,000, which equals about 9.5 5 times) 4. Use a string to model the circumference of the earth, and then walk out 9 1/2 lengths of the string.

3. How far would you have to place the earth from the moon? Would the earth be two feet, ten feet, twenty miles? Have a short discussion.

ANSWER: The Earth is 12,756 miles in diameter and the moon is 3,476 miles in diameter. The distance from the earth to the moon is 384,400 kilometers on average. The earth would have to be placed 24 feet (7.3 meters) from the tennis ball. If the earth were a 20 cm ball in diameter, then a 5 inch in diameter ball would represent the moon.

COMPARING VOLUME

1. Ask the students if they could pull the moon out of the sky and place it on the earth, how big would it be: the school, Utah, United States, or North America?

2. Give each group (4 students) a different sized ball of clay. Have the students divide it into 50 equal sized balls.

3. Discuss how it takes 49 moons to fill one earth. Chart this on the board.

4. Discuss how the groups have a different sized Earth and moon, but the scale remains the same.

5. Have students predict the ratio of the Earth's diameter to that of the moon. Push a toothpick through the center of the clay balls and measure the diameter on the ruler. The answers should be around 3.7. Discuss why everyone had the same ratio.

6. Finally, have the students place how far apart the earth and the moon should be from each other. The correct answer is that the Earth/Moon is almost 30 times the Earth's diameter. Have students compare their estimate the actual answer.

INTERESTING NOTE

*The next closest object in Space is Venus. Its orbit is 41 million kilometers away. This is 3000 Earth diameters. One hundred times, further away than the moon.

ACTIVITY #4: SCALE OF SOLAR SYSTEM-
2D Size and Distance Comparison
There are 2 versions: Easy and Advanced

MATERIALS

Easy Version
- Adding machine tape (about 2 ½ feet per student)

Advance Version
- 6 pages of typing paper taped together
- Ruler
- Sharp pencil
- Compass

EASY
Show the relative distance from the sun to planets using adding machine strips. Give each student a strip of adding machine tape about 2 ½ to 3 feet long. Work together as a class to fold and label the various distances.

1. Label one end of the tape "sun" and at the other end write "Pluto."
2. Fold the tape in half and label the fold Uranus.
3. Fold each half in half again. The fold between Uranus and the sun is labeled Saturn and the fold between Uranus and Pluto is labeled Neptune.
4. Fold the remaining paper in half between Saturn and the sun and label this fold Jupiter.
5. Fold the remaining paper in half between Jupiter and the sun and label this fold Mars.
6. Fold the remaining paper in half between Mars and the sun and label this fold Earth.
7. Fold the remaining paper in half between Earth and the sun and label this fold Venus.
8. Fold the remaining paper in half between Venus and the sun and label this fold Mercury.

ADVANCED VERSION

1. Have the student picture in their minds what a scale model of the solar system would look like on the six pages. Do a quick sketch in your science journal.

2. Discuss the scale model of the Solar System that they are going to do. Show how big a worksheet it will take for them to do it.

3. Have students hold up left had. Start with only one sheet on the left side.

4. Put up transparency showing first page of solar system chart. Show how to mark top and bottom of page, and then draw a straight line.

   - Put dots at 1 cm, 2 cm, 3 cm, 5 cm, 7 cm, 9.5 cm, 10.5 cm, and 21 cm.

5. Also, after drawing line, put a dot at 10.5 cm up the middle of the line, at about the center of the page. This will mark where the middle of the planets goes.

6. Show how to use a compass, and how to draw circles. Use the center dot to mark the middle of each planet.

   These are the measurements of the planets using the Safe-T compasses:
   Mercury 2 cm 1/2 cm circle (smallest circle)
   Venus 3 cm 1.5 cm circle (largest circle)
   Earth 5 cm 1.5 cm circle (largest circle)
   Mars 7 cm .75 cm circle (middle circle)
   Asteroid belt is drawn between 9.5 and 10.5 cm
   Jupiter 21 cm Use dot at 6.5 cm
   Saturn 10.5 cm (from 2nd page) Use dot at 4 cm
   Uranus 22 cm on 3rd page Use dot at 0 mm
   Skip a page. Be sure that everyone skips a page
   Neptune 20 cm on 5th page Use dot at 0 mm
   Pluto 20 1/2 cm on 6th page. Use smallest circle (1/2 cm)

7. Describe what your model looks like. Is this different from what you sketched in your science journal? Discuss it with your group.
8. Discuss what are some advantages and disadvantages that you seen using a scale model? Be specific and use examples from this activity (alignment of the planets and size of the planets).

ACTIVITY 5: SCALE OF SOLAR SYSTEM- On a Meter Stick

Materials

- Meter Stick

If the size of the solar system were reduced about six trillion times, Pluto on average would be about one meter from the sun. On this scale, the Sun itself will be about 0.2 millimeters (1/100 inch) in diameter. This is about the size on a pin.

Place a mark on the meter stick at the distance of each planet. Place the mark for Pluto at the end of the stick

Mercury	3/8
Venus	¾
Earth	1
Mars	1 ½
Jupiter	5 ¼
Saturn	9 5/8
Uranus	19 ¼
Neptune	30 1/8
Pluto	39 1/2

INTERESTING: In this model, one light-year is a mile.

Alpha Centuri is the closest star to the sun. It is about 26,395,632,000,000 miles away. It would have to be placed 4.5 miles from the end of the ruler.

ACTIVITY 6: SCALE OF SOLAR SYSTEM- 3 Different Outside Models

Materials
- 20 rolls of 500 sheet toilet paper
- Planet Marker Signs
- Meter Sticks

Have the students work in groups of three. Each group is to double check their measurements and display a sign at the correct location for the planet. This leads to greats discussions.

Measure the distance. There are three different methods. Choose your favorite or use all three and discuss the differences.

Planet	Meters	Paces
Mercury	1	2
Venus	2	4
Earth	3	6
Mars	5	10
Jupiter	16	32
Saturn	29	58
Uranus	58	116
Neptune	90	180
Pluto	118	236

Toilet Paper Sheets- THIS REQUIRES A VAST AMOUNT OF SPACE,
Yet, this can easily scaled down by dividing all the numbers by ten.
In this model, each square of toilet paper represents 1 million (1,000,000) miles.

Note: The distances are from the sun NOT from each planet the next.

Planet	Distance from the Sun
Mercury	36 sheets of TP (3.6 meters)
Venus	57 (5.7 meters)
Earth	93 (9.3 meters)
Mars	141 (14.1 meters)
Jupiter	483 (48.3 meters)
Saturn	886 (88.6 meters) football field
Uranus	1,783 (178.3 m.) 2 football fields
Neptune	2,793 (279.3 m.) 3 football fields
Pluto	3,675 (367.5 m.) 4 football fields

ACTIVITY #7: APPARENT SIZES OF OJBECTS IN THE SOLAR SYSTEM

Adapted from Out Of this World, 2005 AIMS Education Foundation

MATERIALS

- Empty toilet paper rolls
- Four round objects of different sizes
  - (marble, soccer ball, tennis ball, ping pong ball)
- Black paper
- Paper Punch

BACKGROUND KNOWLEDGE:

There are many misconceptions about the size of objects in Outer Space. This lesson focuses on why different objects may appear to the same size. The main idea is that the further something is from the viewer, the smaller it will appear.

The moon is 3476 km in diameter, while the sun is approximately 400 times that diameter- 1,400,000 km. In addition, the sun is 400 times as far away as the moon. The distance of the sun from the Earth is approximately 150,000,000 km and the distance of the moon from the Earth is 384,000 km.

1. Introduce the topic by talking about a full moon at night. How does the size of the full moon compare to the size of the sun. Discuss in small groups.

2. Have the student construct the viewing eyepieces. Cut a piece of black construction paper large enough to cover one end of the tube. Using a paper punch put a hole in the middle of the paper. Secure the paper to the tube using tape or a rubber band. Make certain the hole is centered on the end of the table.

3. Place the four ball objects on a table. Demonstrate the proper way to use a tube. Tell the students to put the open end to their eye, resting it on their cheekbone. Ask the students to predict whether they think they will be able to see all the objects even the small and the large objects through the hole.

4. After some exploration time, ask the students where they think they would have to stand to make one of the objects appear to be the same size as the hole. Ask if you would be able to see all four objects by standing in the one position. Let the students walk back and forth until the objects just fill the small hole in the paper. Encourage students to use the words appears. For example: From this position, the volleyball appears the same size as the marble appears from this other position.

5. Record in their journal:

 * What they had to do to see the objects
 * Explain why you think you had to do it

6. Have the students record their findings in their science journal. Answer the following questions: Is apparent size the same as actual size? How does distance affect apparent size? How does this activity explain the fact that the sun and the moon appear to be the same size?

ACTIVITY #8: Investigate Expanding Universe Using a Balloon

This is adapted from How Big is the Universe?
Produced by the Astronomy Education Program of the Lawrence Hall of Science

IMPORTANT NOTE: The universe can expanded infinitely in all directions and can still be expanding. It is important to stress that space itself is expanding, not galaxies, nor the matter they contain. The Milky Way does not seem to be getting bigger each year, nor is our solar system growing because the universe is expanding.

Materials:

- Video projector
- Computer
- 12 inch Balloon

1. Discuss with the students that the universe has a center. Scientists say that the universe is expanding. How do astronomers measure this expansion? Imagine a universe of many galaxies throughout space. We are going to make a 3-Dimensional model of the universe by drawing galaxies on the surface of the balloon.

2. Model for the students blow up a balloon partially and use a permanent marker to mark two different galaxies. Measure the distance from between these two galaxies. If you blow it up to twice it size, have the students predict how far apart the galaxies will be from each other. Then, have blown it up to twice its size and check the prediction.

3. Discuss the following questions:
* Are all the galaxies moving away from each other? (yes)
* In what ways might our balloon universe model be different from the real universe? (The real universe is not like the surface of a balloon; (The universe is expanding in Einsteinium "space-time," a four-dimensional space. In the real universe, evidence shows that all galaxies are moving away from each other.)
* Will our universe expand forever or will it stop expanding and start collapsing? (No one knows. Scientist today are carefully measuring the rate of expansion and may be able to determine the fate of the universe soon.)

4. We are going to look at some the technology used to find out the answers. What discovery did Galileo make to help with our knowledge of the stars? Since the telescope, we have gotten better and better at using telescopes. In addition, scientists are using the complete electromagnetic spectrum to help see what is out there.

5. Turn on projector, and then go to http://spaceplace.nasa.gov/en/kids/cosmic/index.shtml (Space Place, Cosmic Colors). Review the elect. Spectrum, then click on Cosmic colors. Look at the different constellations, and then choose different telescopes to look at. (This is incredible!)

6. Next go to JPL website http://www.jpl.nasa.gov/index.cfm to look at the Solar System missions, planets, etc.

ACTIVITY 9: Using Math to Scale Down the Universe

MATERIALS
* scaled down model car
* "SCALE DOWN" worksheet
* Calculators (optional)

1. Ask the students how do scientist know the correct way to scale down something as large as the planets?

2. Show the students a scaled down model car. Discuss how knowing mathematics is essential for scientists. We are going to explore two different aspects: how to scale down the diameter and the distance between planets.

3. Pass out "SCALE DOWN PART 1" activity sheet. Discuss the diameters of the different planets given. Make comparisons. Notice how the sun is 1,380,000 km in diameter. We will assign the sun a diameter value of one.

4. To get the diameter of Mercury, divide 1,380,000 km by 4989. The answer is 277. Do this same activity with all the planets and fill in the chart in the "# times smaller than the sun" section.

5. For the last column, you will need a scaled down value for each of the planets. The sun will be 1 meter (1000 mm). Calculate the value of the planets by dividing 1000 by the number of times smaller we calculated that planet to be than the sun.

FOR EXAMPLE: Divide 1000 by 277. The answer is 3.6 mm. Repeat for all the planets.

6. Now, move to part two. This chart tells the distance of the planets from the sun in millions of miles. We want to convert these distances to astronomical units (AU). AU is the distance of the earth from the sun. This means that 93 million miles is equilvant to one AU. Notice how the chart lists it as 1 by Earth. Now, we need to figure out the other objects in the solar system. To find the astronomical unit, you should divide each planet's distance from the sun by 93 million. For example, Venus is 0.7 AU, that is 67.27 divided by 93 million miles. Finish the chart.

7. In the last column, we once again need to calculate the relative distance from the sun by assigning a value of 1000 mm (1 meter) for the distance of the earth from the sun- 1 AU. The distance from Venus to the sun will be 700 mm.

8. Now, divide the class into small groups. Students will use the information on the charts to create their own scaled down solar system model. Students may use objects of approximate size to represent the planets. Stress creativity, measuring, and re-measuring.

SCALE DOWN DIAMETER- PART ONE

OBJECT	DIAMETER	# TIMES SMALLER THAN SUN	SCALED DOWN DIAMETER (mm)
SUN	1,380,000	1	1000 mm
MERCURY	4989	277	3.6 mm
VENUS	12,392		
EARTH	12,757		
MARS	6759		
JUPITER	142,749		
SATURN	120,862		
URANUS	51,499		
NEPTUNE	44,759		
PLUTO	2,414		

SCALE DOWN DISTANCE - PART TWO

OBJECT	DISTANCE FROM THE SUN (MILLIONS OF MILES)	Astronomical Unit EQUILVENT	SCALED DOWN DISTANCE (mm)
SUN	0	0	0
MERCURY	36		
VENUS	67.27	0.7	700
EARTH	93	1	1000
MARS	141.7		
JUPITER	483.9		
SATURN	887.1		
URANUS	1783.98		
NEPTUNE	2795.5		
PLUTO	3675.3		

Resources:

Out of this World, AIMS, 1994
This has some cool activities that involve math and science.
Available from AIMS Education Foundation PO Box 8120, Fresno, CA 93747
1-888-733-2467
http://www.AIMSedu.org

Solar System Scale Model Kit by Learning Technologies, Inc.
This is an inexpensive kit to make models of the solar system.