

Solar System Scaling

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Mission Scenario: All Missions - Primarily "Return to the Moon" or "Voyage to Mars"

Application to Mission Preparation: This lesson will help students better understand and conceptualize the scale of the Solar System, and may inspire them to continue their studies in STEM-related fields.

Whole Group/Small Group/Individual: Small Group or Individual

Team (if applicable):

Summary: In many reference resources relating to the Solar System planets and moons are not drawn to scale. Often the planets and their moons are not depicted correctly as to both their relative sizes and in their average distances from each other. In this lesson students will gain a better understanding of the sizes of some of the objects that comprise the Solar System as well as the size and scope of the Solar System itself.

LESSON AT A GLANCE

Subject(s): Science

Grade/Level: 5-8

Objective: By building scale models of the Earth, Moon, and Mars, and calculating their relative distances from each other students will gain a better understanding of the sizes of some of the objects that comprise the Solar System as well as the size and scope of the Solar System itself.

Standards:

USA- National Science Education Standards

- **Chapter Chapter 6:** Science Content Standards
 - **Grade Level :** 5-8
 - **Content Standard A:** Science as Inquiry: As a result of activities in grades 5-8, all students should develop
 - **Ability/ Concept :** Abilities necessary to do scientific inquiry
 - **Detail :** DEVELOP DESCRIPTIONS, EXPLANATIONS, PREDICTIONS, AND MODELS USING EVIDENCE. Students should base their explanation on what they observed, and as they develop cognitive skills, they should be able to differentiate explanation from description--providing causes for effects and establishing relationships based on evidence and logical argument. This standard requires a subject matter knowledge base so the students can effectively conduct investigations, because developing explanations establishes connections between the content of science and the contexts within which students develop new knowledge.

■ **Detail** : USE MATHEMATICS IN ALL ASPECTS OF SCIENTIFIC INQUIRY. Mathematics is essential to asking and answering questions about the natural world. Mathematics can be used to ask questions; to gather, organize, and present data; and to structure convincing explanations.

- **Ability/ Concept** : Understandings about scientific inquiry

■ **Detail** : Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models.

• **Content Standard D:** Earth and Space Science: As a result of their activities in grades 5-8, all students should develop an understanding of

- **Ability/ Concept** : Earth in the solar system

■ **Detail** : The earth is the third planet from the sun in a system that includes the moon, the sun, eight other planets and their moons, and smaller objects, such as asteroids and comets. The sun, an average star, is the central and largest body in the solar system

• **Content Standard E:** Science and Technology: As a result of activities in grades 5-8, all students should develop

- **Ability/ Concept** : Abilities of technological design

■ **Detail** : IMPLEMENT A PROPOSED DESIGN. Students should organize materials and other resources, plan their work, make good use of group collaboration where appropriate, choose suitable tools and techniques, and work with appropriate measurement methods to ensure adequate accuracy

■ **Detail** : COMMUNICATE THE PROCESS OF TECHNOLOGICAL DESIGN. Students should review and describe any completed piece of work and identify the stages of problem identification, solution design, implementation, and evaluation

Time Required: 1 class period. 1 Hr per class.

Essential Question: How accurate must a scientific model be?

Can scientific models or representations be both good and bad?

Lesson Overview: In many reference materials the objects in our Solar System are often not represented accurately in terms of their sizes relative to each other and in their relative distances from each other. These inaccuracies often add to the misconceptions students have about the objects in our Solar System as well as the Universe as a whole. In this lesson students will build scale models of the Earth, Moon, and Mars, and will calculate and then model their relative distances from each other. Students will gain a better understanding of the sizes of some of the objects that comprise the Solar System as well as the size and scope of the Solar System itself.

TEACHER PREPARATION

Subject Matter Overview: It is assumed that the instructor has a basic knowledge of the Solar System and related space science.

Materials:

Balloons - Specific colors can represent specific Solar System objects, e.g., Earth=Blue, Mars=Red, Moon=White

Measuring tapes (measure circumference of balloon)

Calculators

Attachments

1. [Solar System Tables](#) The Solar System Objects Table and the Solar System Distances Table contain reference material and will hold information calculated by the students.

Preparation: See "Resources" section

Differentiated Instruction: The instructor can have model diameters and circumferences already calculated and entered into the Solar System table for at-risk students. Advanced learners can have additional objects added into the Solar System table, and/or have to derive the scaling factor through independent reasoning.

TEACHING THE LESSON

Lesson Management:

- 1) Students may be divided into small groups. Each individual/group should have access to the materials.
- 2) The instructor may want to assess the students as to their knowledge regarding the relative sizes of the Solar System objects (For example have the students list from biggest to smallest the relative sizes of the Earth, Moon, and Mars.)
- 3) The instructor should show the students how to determine the "scaling factor" that will be used to create the models representing the Solar System objects. (Assuming a diameter of 20 centimeters (cm) for the Earth, have the students determine the "scaling factor" ratio by using the actual diameter of the Earth to the model diameter. For example, the "scaling factor" of the Earth $\sim 12756 / 20 \sim 738$. The "scaling factor" can then be used to determine the diameters/circumferences for the other objects to be modeled.)
- 4) The students, using the "scaling factor", should calculate the remaining diameters/circumferences and fill in the appropriate fields in the Solar System Objects Table.
- 5) The students can then use the information in the table to inflate the balloons to the proper size to model the Solar System objects.
- 6) The students can revise any misconceptions they may have had previously in the relative sizes of the Solar System objects.
- 7) The students can then use the "scaling factor" to calculate the average distances between pairs of Solar System objects, and can enter their calculated distances into the Solar System Distances Table. The students can then model the distance between the

Earth and the Moon by placing the balloons representing these objects the calculated distance apart from each other. (With a "scaling factor" of 738 the Earth and Moon will be roughly 542 cm (5.42 meters) apart. Obviously, some Solar System distances will not be easily modeled within the typical classroom and school yard.)

8) The students can discuss all or any of the following questions:

Using the calculated scaling factor how large would a balloon have to be to model Jupiter?

Using the calculated scaling factor how large would a balloon have to be to model the Sun?

Using the calculated scaling factor how far would a balloon representing the Sun have to be from a balloon representing the Earth?

Using the calculated scaling factor how far would a balloon representing the Sun have to be from a balloon representing Pluto?

If it took astronauts about three to four days to travel from the Earth to Moon how long would it take astronauts traveling at the same speed to go from Earth to Jupiter? ... to Pluto?

Teaching Tips:

Student Instructions:

Student Worksheets: See "Materials" section

Resources: Materials and resources:

http://www.northern-stars.com/solar_system_distance_scal.htm

<http://www.solarviews.com/eng/solarsys.htm>

<http://www.nineplanets.org/overview.html>

ASSESSMENT AND EXTENSIONS

Assessment/Rubrics: **Rubrics**

1. [Problem Solving](#)
2. [Science Experiment](#)
3. [Scientific Explanation](#)

Extension Activities: Additional Solar System objects (sizes and relative distances) could be calculated by students and modeled (depending upon balloon size and spatial area required.) Students could also model the orbital motions of Solar System objects and discuss/determine optimal positions/times to send spacecraft between or among Solar System objects.

Solar System Objects Table

Object	Actual Diameter (km)	Model Diameter (cm)	Model Circumference (cm)
Earth	12,756	20	
Moon	3,476		
Mars	6,794		
Phobos	22		

Scaling Factor: _____

Solar System Distances Table

Pair of Objects	Average Distance (km)	Model Distance (cm)
Earth - Moon	385,000	
Earth - Mars	228,000,000 *	

* The Earth-Mars distance can be as small as 54,500,000 km or as great as 401,300,000 depending upon their orbital positions.

Problem Solving Rubric

Levels:

	1	2	3	4	Score
<i>Criteria:</i>					
Reflective Habits	Student does not carry knowledge over from one problem to the next. Does not look back over work when finished with a problem.	Student occasionally transfers knowledge from one problem to the next. Sometimes looks back over work.	Student often transfers knowledge from one problem to the next. Usually looks back over work.	Builds on prior knowledge and experience. Goes over work thoughtfully to make sure solution makes sense.	
Strategies and Representations	Student does not make use of problem solving strategies, models, or mathematical representations.	Student makes use of a single problem solving strategy, model, or mathematics representation.	Student uses a clear strategy to solve the problem and an appropriate model or representation to explain or enhance the solution.	Student uses multiple strategies and representations that clearly explain and enhance the solution.	
Attitudes	Student avoids problem solving, has little confidence, gives up easily.	Student does not approach unfamiliar problems with confidence, but feels comfortable solving problems with assistance. Student gives up when assistance is not provided.	Student approaches almost all familiar and unfamiliar problems with confidence. Can overcome frustration and persist with minor support.	Approaches familiar and unfamiliar problems with confidence. Persists despite difficulty. Does not give up or become overly frustrated. Asks for assistance occasionally.	
Explanation	Explanation is unclear, confusing, and/or incomplete. No	Explanation is incomplete. Alludes to underlying mathematics,	Explanation is clear and complete. Alludes to underlying	Explanation is clear and complete. Student evidences	

	reference is made to underlying mathematics.	but does not evidence full understanding.	mathematics, but does not evidence full understanding.	understanding of mathematics behind problem.
Planning	Student does not do any planning before starting the problem.	Student makes some cursory attempts at planning before beginning the problem. Student does not refer back to plan or make any revisions after the initial planning stage.	Student outlines a plan for problem solving, but is not able to revise plans that are not working.	Student makes a clear plan for solving problem before he/she begins. Demonstrates ability to revise plans that are not working.

Science Experiment Rubric

Levels:

	1	2	3	4	Score
<i>Criteria:</i>					
Data and Observations	Data and observations are incorrect or missing entirely. Relevant units or labels are missing.	Data and observations are incomplete or do not include sufficient details. Relevant units or labels may be missing.	Data and observations are complete and correct.	Data and observations are complete and correct, with all relevant units and labels included. Student provides a level of detail and organization that goes above and beyond requirements.	
Conclusions and Explanations	Conclusions and explanations are missing or do not make sense given student's data and observations.	Conclusions and explanations are incomplete not supported by sufficient details. Relevant data and observations are not referenced.	Conclusions and explanations are complete and supported by student's data. Relevant data and observations and referenced where appropriate.	Conclusions and explanations are complete and supported by student's data. Student provides a level of detail and depth that goes above and beyond requirements.	
Understanding of Science Context	Little to no understanding of science context is evidenced from student's writing.	Some understanding of science context is evidenced from student's writing, but student does not always reason scientifically.	Firm understanding of science context is evidenced from student's writing.	Complete understanding of science context is evidenced from student's writing. Student provides a level of detail and depth that exceeds requirements.	
Materials and Tools	Student is unable to identify many tools and materials.	Student is able to identify nearly all tools and materials.	Student is able to identify all tools and materials. Student usually	Student is able to identify all tools and materials. Student uses	

	Student does not use materials and tools appropriately or responsibly.	Student does not use all tools and materials appropriately or responsibly.	uses tools and materials appropriately and responsibly.	tools and materials appropriately and responsibly.
Procedure	Student does not correctly follow many aspects of the procedure.	Student correctly follows some aspects of procedure, but makes crucial mistakes or skips some important steps.	Student follows critical aspects or procedure, but has difficulty responding effectively to problems.	Student correctly follows every aspect of the procedure and supplements procedure with effective and inventive additions.
Collaboration	Student is unable to work cooperatively with lab partners to complete the activity. Requires continual intervention by teacher.	Student simply follows directions of partner(s) and makes little effort to actively contribute.	Student is able to work cooperatively with lab partners to complete the activity, but may not be receptive to partners' ideas.	Student works cooperatively with lab partners to complete the activity, emerging as an effective collaborator who supports the ideas and suggestions of his/her peers.

Scientific Explanation Rubric

Levels:

	1	2	3	4	Score
<i>Criteria:</i>					
Considers Methodology	Does not include reference to how observations or measurements were made and when queried, cannot speculate and cite possible ways.	Does not include reference to how observations or measurements were made and when queried, can speculate, but has little knowledge of the process.	Shows knowledge of reference to how observations or measurements were made when queried, but does not include and does not offer ways to test results.	As a matter of course, includes reference to how observations or measurements were made to validate or question data cited. Proposes ways to test or predicts results.	
Logical Consistency	Right or wrong, the explanation shows poor understanding of the process or issue and has misapplication of principles and evidence.	Right or wrong, the explanation is not well supported by principles, evidence and/or these may be applied without complete understanding	Right or wrong, the explanation integrates most principles, evidence, known to author(s), but has omissions and inconsistencies.	Right or wrong, the explanation integrates all principles, evidence, known to author(s) in a logically consistent way.	
Generalizes Explanation	No extension beyond specific explanation or extension is out side of the boundaries of science.	Little extension of explanation to other situations or phenomena or speculation is inappropriate, and or unsupported.	Speculates on a wider application of explanation, but does not apply to specific situations or phenomena.	Attempts to use explanation to make predictions in different situations. E.G., "If this is right, then maybe its how ... works."	
Scientific Method	Is unsure of the question and the answer.	Starts with a question, proposes the	Starts with a question, proposes the	Starts with the question, proposes	

	Recites an answer with little understanding of its meaning or need for supporting evidence.	answer, but is unable to support the answer and cannot cite valid evidence.	answer supported by valid scientific evidence, but does not consider multiple answers or tests.	multiple answers, confirms or denies each with valid evidence, proposes tests for remaining potential answers.
Scientific Principles	No citation of scientific principles or cites wrong ones. Explanation is largely recitation of text or source material. Non-science processes included	Cites some relevant scientific principles, but misuses some. Understanding of cited principles incomplete. Non-science processes included.	Cites and accurately uses an array of relevant scientific principles from text or source material. May include irrelevant principles.	Cites and accurately uses an integrated array of relevant scientific principles, including ones not in text or other source materials.
Use of Numerical Data	Relevant data not cited or cited erroneously. Units are not accurate and values are not consistent with general explanation.	Some data cited are inaccurate or have inappropriate units. No attention to size of values. Important omissions.	Data cited are accurate and have appropriate units. For some data the citation shows poor understanding of size of values. Minor omissions.	Data cited are always accurate and always have appropriate units. The citation indicates understanding of size of values.
