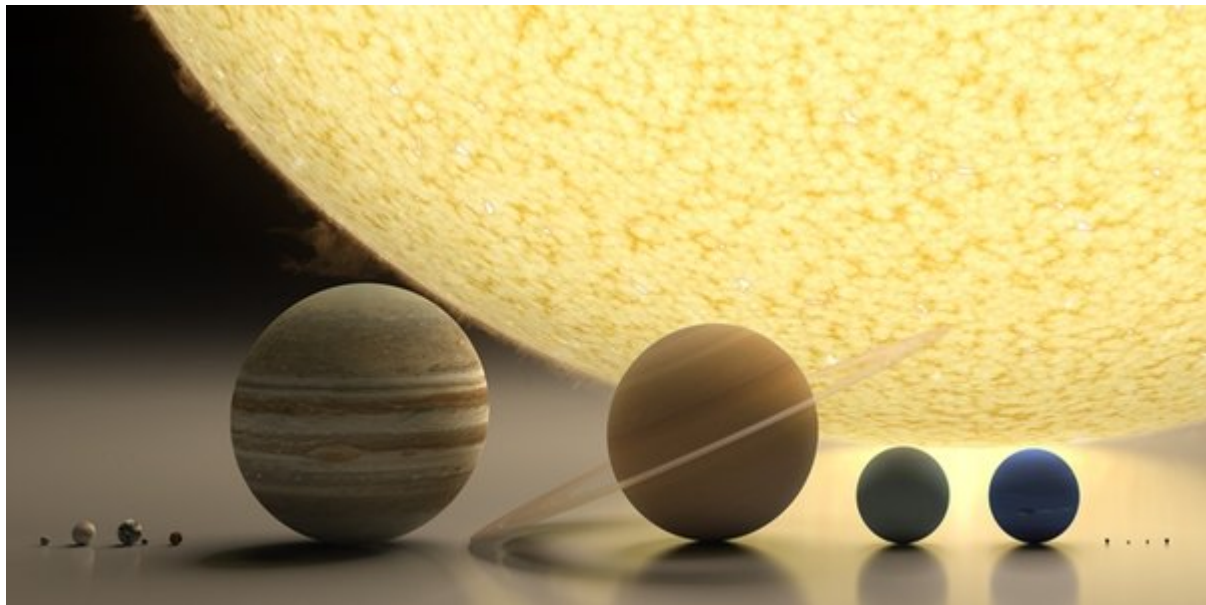




Solar System Model on a City Map

Build a scale model of the Solar System on a city map.

Author: Mayte Vasquez



KEYWORDS

Solar System, city map, scale model



CATEGORY

Planetary systems



LOCATION

Small Indoor Setting (e.g. classroom)



AGE

12 - 16



LEVEL

Middle School



TIME

2h



GROUP

Group



SUPERVISED

No



COST

Low Cost



SKILLS

Asking questions, Developing and using models, Analysing and interpreting data, Communicating information



TYPE OF LEARNING

Modelling, Fun activity



GOALS

Students will understand the scale of Solar System in terms of relatively well-known sizes and distances on Earth.

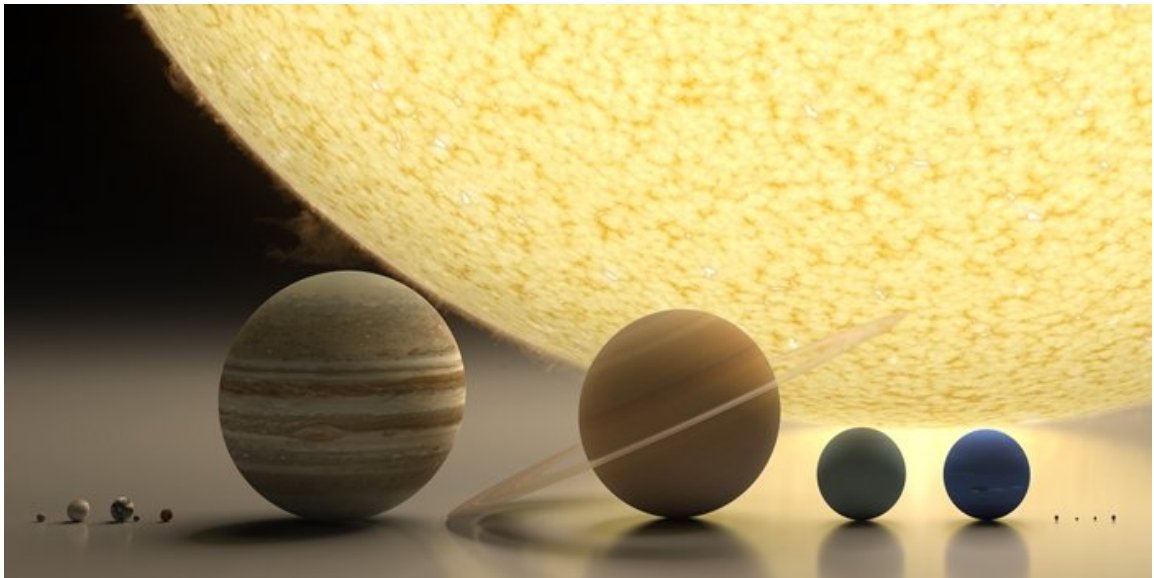


LEARNING OBJECTIVES

- Students will be able to identify which quantities are required to build a scale model.
- Students will be able to demonstrate a scale model of solar system on a city map.
- Students will be able to apply a conversion factor from true units to model units.
- Students will be able to identify contributing factors to the inaccuracy of a model.
- Students will be able to recognise the relative smallness of Solar System objects compared to the astronomical distances between them.



BACKGROUND



The Solar System is home to a star located at its center and to eight planets including Earth. These planets orbit around the Sun and present variations in size and composition. The Solar System is located in the Milky Way galaxy along with a vast number of stars. The great distances between the stars are almost unimaginable along with the location of the Solar System in the Universe. Compared to these distances, the planets of the Solar System are close, but compared to distances on Earth, it becomes difficult to visualize them. The distance between Pluto and the Sun is about 5.9 billion kilometers!

Sun and planets in the solar system: (teachers are encouraged to share these information while conducting the activity)

- The Sun is the closest star to Earth consisting of electrically charged particles and mostly composed of hydrogen and helium. More than one million Earths could fit into it. The Sun is a middle sized star powered by nuclear fusion. It takes about 8 minutes for the sunlight to reach Earth after being emitted from its surface.
- Mercury is the nearest planet to the Sun and also the smallest in size. Since the planet lacks of an atmosphere, it experiences both hot and cold extreme temperatures. Out of all the terrestrial planets in the Solar System, Mercury is the densest planet.
- Venus is the hottest planet of the Solar System and is very close in size to Earth. The planet possesses a very dense atmosphere of mainly carbon dioxide that causes it to reach the highest temperatures of all the planets (740 Kelvins at the surface while Earth is about 290 Kelvins!). Venus is nearly covered by a thick layer of sulphuric acid clouds that prevent the solar rays to penetrate in the atmosphere below.
- Earth is the only planet known so far to support life. It has a magnetic field that extends thousands of kilometers into space and protects the planet from harmful incoming solar radiation. The planet is located at the center of what astronomers call the habitable zone, where temperatures are suitable enough for water to exist in its liquid state.

- Mars presents frozen water in its polar caps. Several flybys, landers, orbiters, and rovers have been sent to Mars to study the planet. However, one of the biggest questions about the planet still remains open: did water ever exist on Mars?
- Jupiter is the largest planet of the Solar System and is the first among the gaseous planets. It contains more than twice the mass of all the planets of the Solar System together. The planet is so large enough that 1400 Earths can fit into it.
- Saturn is well known for its bright rings. Saturn needs about 30 Earth years to orbit the Sun but only about 11 hours to rotate around its axis. Its rings are composed of billions of icy and rocky materials.
- Uranus is known as an ice giant planet since it is composed of relatively great amounts of icy methane and water. Uranus' rotation axis is tilted almost parallel to its orbital plane while the rest of the planets spin more or less perpendicular to the plane of the Solar System.
- Neptune is the most distant planet of the Solar System. It is roughly half as far from Uranus as Uranus is from the Sun. Like Uranus, Neptune has rings that are thin and which consequently appear very dim when observed.

Other bodies: * The Moon is Earth's only natural satellite and it was visited for the first time by the Apollo 11 landing mission in 1969. The dark and relatively featureless lunar areas that can be clearly seen with the naked eye are called maria, which are known to be the result of ancient basaltic lava.

- The asteroid belt is a region of the Solar System found between the orbits of Mars and Jupiter and it is occupied by asteroids of different shapes and sizes. Asteroids are rocky-metallic objects which are also called planetoids or minor planets because they are too small (they can range from the size of pebbles to ~ 1000 km).
- Comets are icy small bodies that have a wide range of orbital periods. When passing close to the Sun, comets heat up and outgas material giving it the shape of a snowball with a tail. They are known to have a wide range of orbital periods.
- Pluto is a dwarf planet found in the Solar System. Since its discovery in 1930, Pluto remained classified as a planet until the detection of the more massive body Eris put it in question. In 2006, the definition of a planet stated by the International Astronomical Union excluded Pluto since it failed to clear out the neighbourhood objects from its orbit.

Astronomical unit (au): Is a unit of length, approximately the distance between the Earth and the Sun, astronomers use to describe the great distances in the Solar System.

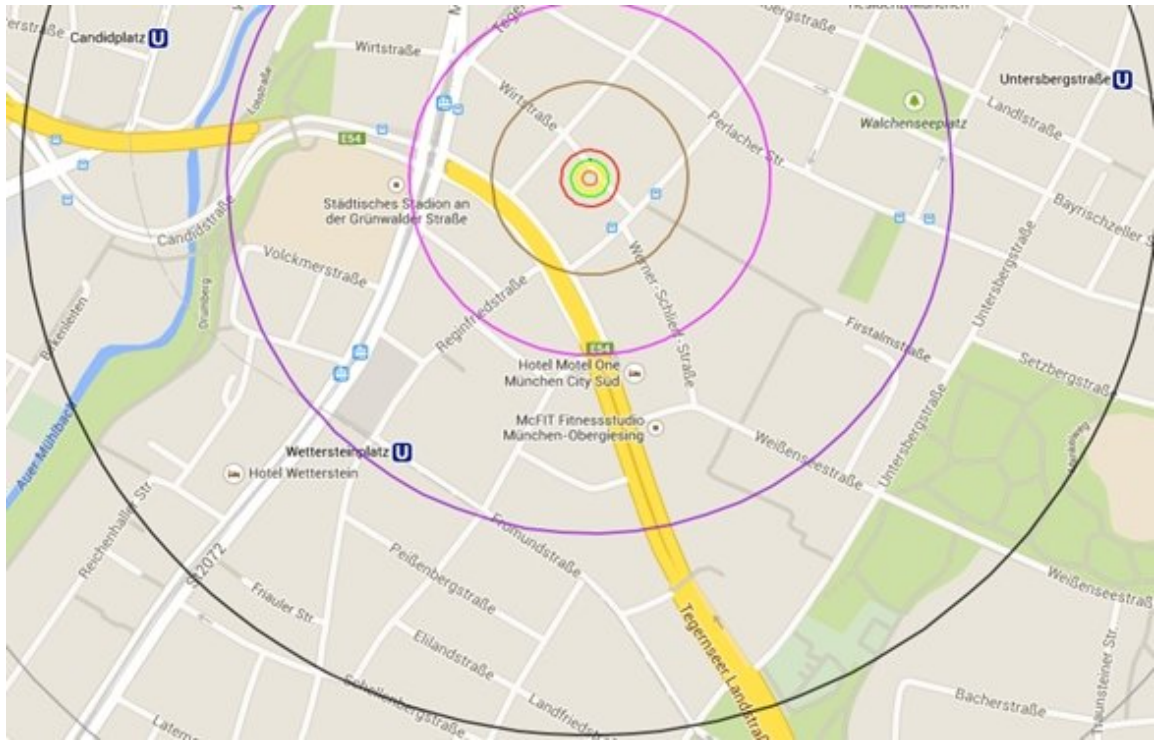
The scale factor:

In a scale model, all linear distances and sizes are enlarged or reduced by a scaling factor. The scale factor is given by; $\text{scale factor} = \frac{\text{true value}}{\text{reference value}}$

For example, when scaling the Solar System, the diameter of Earth and the reference size (in this case is a peppercorn of 2 mm) could be used as the true and reference values, respectively. In order to scale the rest of the planets, their true sizes and the scale factor calculated above are used:

$\text{scale model} = \text{true value} / \text{scale factor}$

Example of a scaled model of the Solar System on the city map of Munich showing the orbits of Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune around the Sun (located at the city center in Marienplatz, Munich, Germany).



FULL DESCRIPTION

The activity consists of engaging students to build a reduced-scale model of the Solar System. It is very difficult to visualize the great empty space that exists between the planets and the Sun and to realize how big or small these are relative to each other. The following steps may help in the realization of the scale model:

Step 1:

Involve students in an introductory discussion about the Solar System:

- Ask students where in the Milky Way galaxy is the Sun located (this can be done by showing an image of the Milky Way galaxy).
- Which star is the closest to Earth?
- How close is the next nearest star to Earth? Nearest planet to Earth?
- Which other bodies can be found in the Solar System?
- How big are the Solar System bodies relative to each other? How far apart are they? Are there other differences between them? In which two big categories are the planets divided?
- How could we represent these values on Earth? Have students bring any suggestions on how to represent such distances and sizes at a lower scale.
- Ask students to list characteristics of scale models, write responses on the board and discuss until having the correct answer. The list should have all linear dimensions (e.g. width, height, length, ...) This discussion may help bringing students to realize the difficulties of understanding the large numerical values of the Solar System bodies and drive them to intuitively think about a scale model.

Step 2:

Engage students in predicting the model:

- Divide students into different groups.
- Ask students which parameters are required to scale the Solar System.

- Have students make predictions without using calculations about the scale model by positioning their estimated scaled model on the map (taking into account the distances shown on the map) and creating or identifying a size for each Solar System body.
- What could be done to have a more accurate representation of the Solar System?
- Discuss about their predicted model and any misconceptions found.

By the end of this step, students should be able to understand that both distance and size are required to build a scale model.

Step 3:

Have students build a scale model based on calculations

- Provide a worksheet containing the distances between Solar System bodies and their sizes to each group of students.
- Challenge students to brainstorm on how these data could be combined to build a model.
- Give examples by scaling objects found in the classroom and using simple calculations (this could be done by re-sizing a pen to twice its size or reducing the distance between two students by twice) to show how to use a scaling factor.
- Provide a peppercorn (or any round object of 2 mm) to each group to be used as the representation of Earth.
- Let students determine what calculations are involved in order to construct the scale model. What is the new size of Venus given that Earth is scaled to 2 mm? How can we use this information to also scale the distances between the objects and the Sun?
- Have students complete the Student Worksheet. For the scale size, students also identify the rest of the planets using the common objects provided or create them using the play dough or aluminum foil based on their calculations.
- Have students compare the relative sizes and distances of the different planets from their predicted model and the actual model (students should see that science is not about knowing the right answer at first).
- Optionally, mention the definition of astronomical units and the reason astronomers make use of them. Write the distances between the Sun and some of the planets for students to convert them to kilometers.

Step 4:

Let students build a scale model on a city map and extend to other scenarios

- Have students position the planets and the Sun on a city map. A map containing a scale indicating the actual distances may be used along with a metric ruler to place the planets.
- If possible, ask students to look for the actual position of the planets relative to each other. This information can be obtained, for example, from: <http://www.theplanetstoday.com> A compass may be used to draw the orbits.
- Discuss results with students and ask for or provide specific facts about the Sun and planets.
- Ask students what characteristics of the planets are not taken into account in the model and how would the model be impacted if only distances are scaled. What factors can contribute to the inaccuracy of the model? How can this be corrected?
- Engage students thinking about other kinds of scale models (for example, used in other disciplines) and how could they apply the same procedure to build a model.

Step 5:

Organize a walk with students to the different locations of the Solar System bodies on a city map * Motivate students to go on a journey through the Solar System. * Hand the Sun and the planets to students before starting the walk. * Make sure most students are more or less familiarized with the locations placed on the map. * Feel free to separate students into different groups to represent each body and stand on their location while the rest reach the next. This step depends on the city type you are located and it is more suitable on a long straight street. * When reaching to the different locations, ask students facts and characteristics about each of the bodies. Relate the planets' orbital periods to their distances to the Sun (the further away they are, the larger the orbital period).



EVALUATION

Questions for the instructor to ask themselves to evaluate the student learning:

- How well students are able to understand how relatively small are the planets as compared to the Sun?
 - How well students are able to understand how great are the distances between the different bodies of the Solar System?
 - How well students are able to distinguish the different types of bodies of the Solar System from the great difference in size?
 - How well students are able to gather the information required to build the model?
 - How well students are able to calculate scale factors?
 - How well students are able to determine what parameters of the planets are scaled properly?
 - How well students are able to understand how incomplete would the model be if only one of the parameters (either size or distance) is scaled?
 - How well students are able to apply a mathematical thinking to build a more accurate scale model?
 - How well students are able to identify the factors contributing to the inaccuracy of the model?
 - How well students are able to identify what is gained from a scale model?
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CURRICULUM

Country | Level | Subject | Exam Board | Section --- | --- | --- | --- UK | KS3 | Maths | - | Ratio, proportion and rates of change: scale factors UK | GCSE | Maths | AQA | 3.3 Ratio, proportion and rates of change: R2, R12 scale factors UK | GCSE | Maths | Edexcel | 3.3 Ratio, proportion and rates of change: R2 scale factors UK | GCSE | Maths | OCR | 10. Mensuration .01c) Maps and scale drawings UK | GCSE | Maths and Numeracy | WJEC | All tiers: Geometry and Measure: scale drawings UK | GCSE | Physics | Edexcel | 3. Waves and the Universe .4 Sizes and Distances UK | GCSE | Physics | OCR A | P1 The Earth in the Universe P1.1.6. UK | GCSE | Physics | OCR B | P2f) Exploring our solar system UK | GCSE | Physics | WJEC | Physics 1.7 The Solar System and its Place in an Evolving Universe a) UK | GCSE | Astronomy | Edexcel | 2.1 Our Solar System c



ADDITIONAL INFORMATION

- Grounded solar system in Zagreb <http://astrogeo.geoinfo.geof.hr/prizsunce/eng-home.html>
 - To Scale, The Solar System <https://www.youtube.com/watch?v=zR3lgc3Rhfg>
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CONCLUSION

The activity should help students understanding the great distances between Solar System bodies and their relative size. It should provide a sense on how a scale model is built and its relevance to visualize the Solar System around their city. Students should reflect on how the model changes if only a single characteristic of the celestial body is taken into account in the calculations.

CITATION

Vasquez, M., , *Solar System Model on a City Map*, [astroEDU, 1512](#) [doi:10.14586/astroedu/1512](https://doi.org/10.14586/astroedu/1512)
