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Tool Kit: Solar System overview

*WP 2: STAND TOOLKITS

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Introduction:

In this document, we will outline the structure of Solar System tool kit that can be used for the Stand project. This tool kit encompasses a variety of resources related to the solar system, including online resources, virtual labs and visualization tools. The best way to appreciate the size of our solar system and the size of the planets is by creating a scaled model of them that shows how far from the sun the eight planets are located (scaled distance). Students will have the opportunity to make these estimates and attribute their findings inside (using digital mapping tools) and outside the classroom (experimentation). Thus, if the sun has the size of your school, where is the earth placed inside your city? Or maybe outside?

Solar System Toolkit:

Physics, Mathematics, Geoscience classes
Ages: 9-15.
Topic: Solar system, Size, Scale, Distances

The Micrometeorite Toolkit is designed to guide users in understanding the scale and kinematics of the solar system. It provides online tools and educational materials to facilitate a hands-on learning experience.

Purpose:

1. To compare the size of the objects (Sun, planets, moons) of our Solar System (see teachers manual), and,
2. comparing the distances between the objects in our Solar System at different scales inside and outside classroom

Components of the Solar System Kit:

Material: Search Engines
Software: Spreadsheet app., FreeMapTools
Through this toolkit, students will gain an understanding of the comparative size of the objects in our Solar System and the great distances between them.

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ONLINE RESOURCES

Scale of the Solar System
NASA's eyes:
Eyes on the Solar System

Solar system scale:
https://joshworth.com/dev/pixelspace/pixelspace_solarsystem.html

Solar system scale video:
https://www.youtube.com/watch?v=DMZ5WFRbSTc&ab_channel=NASAJPLEdu

Scale of the Universe
https://htwins.net/scale2/

Excel Worksheet
https://docs.google.com/spreadsheets/d/19zjr7QB7hx_oJ03y7nYyeTbs93owcfB2/edit?gid=611232705#gid=611232705

Map tool
https://www.freemaptools.com/radius-around-point.htm

PROCEDURE

Provoke curiosity

Our solar system is the Sun and everything that travels around it. Traveling around the Sun are eight official planets, at least five dwarf planets, nearly 200 moons (or natural satellites of the planets), and a large number of comets and asteroids.

Our solar system is so big it is almost impossible to imagine its size if you use ordinary units like kilometers or miles. The distance from Earth to the Sun is 149 million kilometers (93 million miles), but the distance to the farthest planet Neptune is nearly 4.5 billion kilometers (3 billion miles). Compare this to the farthest distance you can walk in one day, the distance covered by a vehicle in his entire life-cycle (approx. 300000 km.) or that the International Space Station (ISS) travels in 24 hours 643720 kilometers (400000 miles).

To trigger student's interest, you can show the following video or you can visit the following online games explaining the solar system distances and planets' size.

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Scale of the Solar System

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Solar system scale video:
https://www.youtube.com/watch?v=DMZ5WFRbSTc&ab_channel=NASAJPLEdu

Propose preliminary explanations or hypotheses

It is best to ask these questions in the context of a relative discussion.

- Can you imagine these vast distances and sizes scaled on the Earth's surface?
- If the Sun has a size of 1 meter and is located at the center of your school, how far are located from your school the other planets orbit?

Active investigation

Students should be familiar with the names of all the planets in the solar system and the order in which they appear. To succeed this, students can copy of the radius (or diameter) and distance from the Sun for each planet and the Sun. You can make this into a worksheet for each student or in groups of 2 students.

See Figure 1

	A	B	C	D
1				
2		Solar System objects	Distance from the Sun (Km.)	Planets' radius in Km.
3		Mercury	57000000	2439
4		Venus	108000000	6051
5		Earth	149000000	6371
6		Mars	228000000	3389
7		Jupiter	780000000	69911
8		Saturn	1437000000	58232
9		Uranus	2871000000	25362
10		Neptune	4530000000	24662
11				
12		Moon	150000000	1737
13		Sun	0	696340

Figure 1: Solar System objects' distance from the sun (ascending order) and their radius in Km.

Moreover, students have to be familiar with the terms of "scale" and "scaled model". They must further investigate how they can scale the size of an object or/and the distances among objects or even the geographical scaling (in a map).

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https://en.wikipedia.org/wiki/Scaling_(geometry) (Scaling - Geometry)

https://en.wikipedia.org/wiki/Scale_(map) (Scaling - Map)

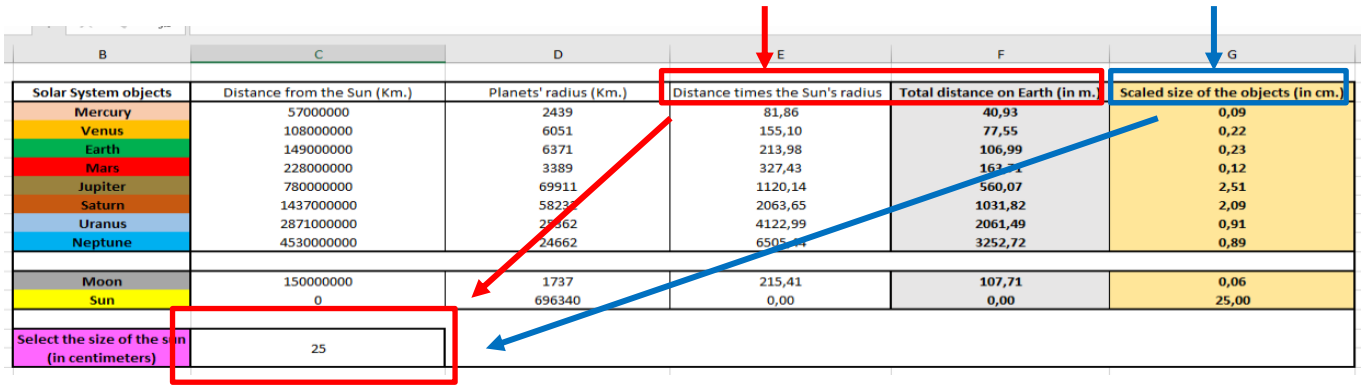
https://www.mathsteacher.com.au/year8/ch06_ratios/06_scale/draw.htm (Scaling examples)

Remind students of the model idea if they don't mention it? "Let's make a model that accurately represents the size and distance from the Sun and of all planets. This model will give us a better idea of the sizes and distances in our solar system."

Show them a basketball and ask them how big each of the planets would be if the Sun was the size of the basketball.

You can draw a basketball on the board. Ask from students if they can imagine how can we estimate the size of each planet compared to the Sun (actually, the basketball)?
When this drawing of the solar system is complete, ask students how far apart each of these planets would be if the sun were a basketball. Would they fit in this room? Would they fit in the school? In their city/village?

To answer these questions, we have to make some calculations first! Open the excel worksheet.



Solar System objects	Distance from the Sun (Km.)	Planets' radius (Km.)	Distance times the Sun's radius	Total distance on Earth (in m.)	Scaled size of the objects (in cm.)
Mercury	57000000	2439	81,86	40,93	0,09
Venus	108000000	6051	155,10	77,55	0,22
Earth	149000000	6371	213,98	106,99	0,23
Mars	228000000	3389	327,43	163,71	0,12
Jupiter	780000000	69911	1120,14	560,07	2,51
Saturn	1437000000	58232	2063,65	1031,82	2,09
Uranus	2871000000	25362	4122,99	2061,49	0,91
Neptune	4530000000	24662	6505,44	3252,72	0,89
Moon	150000000	1737	215,41	107,71	0,06
Sun	0	696340	0,00	0,00	25,00
Select the size of the sun (in centimeters)	25				

Figure 2: The fields that the students have to set-up and fill, including the scaled distances and sizes of each planet compared to the Sun's radius

Focus on columns E, F and G. In order to scale the size of each object, students must focus on each planet's radius compared to the radius of the Sun (blue box). Moreover, for estimating the total scaled distance on Earth (in centimeters or meters, Column F), students must consider how many times the Sun's radius fits on the distance of each planet (column E).

In order to estimate the aforementioned

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scaled values, you will need the following formulas (embedded at an excel file, estimate by hand or even by using a programming language).

$$\boldsymbol{Size_{scaled}} = Sun_{cm}(Planet_{radius}/Sun_{radius})$$

$$\boldsymbol{Distance_{scaled}} = ((Planet_{dist}/Planet_{radius})Sun_{cm})/100)$$

$$\boldsymbol{Time_{light}} = (Planet_{dist}/Speed_{light})/60$$

where Sun_{cm} is the scaled size of the Sun on Earth, $Planet_{dist}$ is the distance of each object from the Sun, $Speed_{light}$ is the speed of light and finally, $Planet_{radius}$ and Sun_{radius} are the radius of each solar object and the Sun's radius respectively.

Solar System objects	Distance from the Sun (Km.)	Planets' radius (Km.)	Distance times the Sun's radius	Total distance on Earth (in m.)	Scaled size of the objects (in cm.)
Mercury	57000000	2439	81,86	40,93	0,09
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Neptune	4530000000	24662	6505,44	3252,72	0,89
Moon	150000000	1737	215,41	107,71	0,06
Sun	0	696340	0,00	0,00	25,00
Select the size of the sun (in centimeters)	25				

Figure 3: Scaled distances and objects' size based on the Sun's radius and the scaled size of the Sun

Finally, to draw our scaled model on the Earth's surface, we have to select a central point (as the Sun) and then we can add all of the remaining circles (orbits) for each planet or the moon using a different color (see **Figure 4**).

In order to select the position of the Sun, we can either type the name of a country, city or region or we can insert the exact coordinates (in lat-lon) of our school etc.

Note: During this step you can introduce to the classroom the geographic coordinates concept. For instance, you can ask from them to explain *"The **latitude** of The Eiffel Tower in* Paris*, France is 48.858093, and the **longitude** is 2.294694."* What does it mean and how Lat-Lon is estimated?

Lat-Lon explanation:
https://gsp.humboldt.edu/olm/Lessons/GIS/01%20SphericalCoordinates/Latitude_and_Longitude.html

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Follow the Steps described in **Figure 4** in order to draw your scaled Sun and planets using FreeMapTool! Draw each orbit on different color!

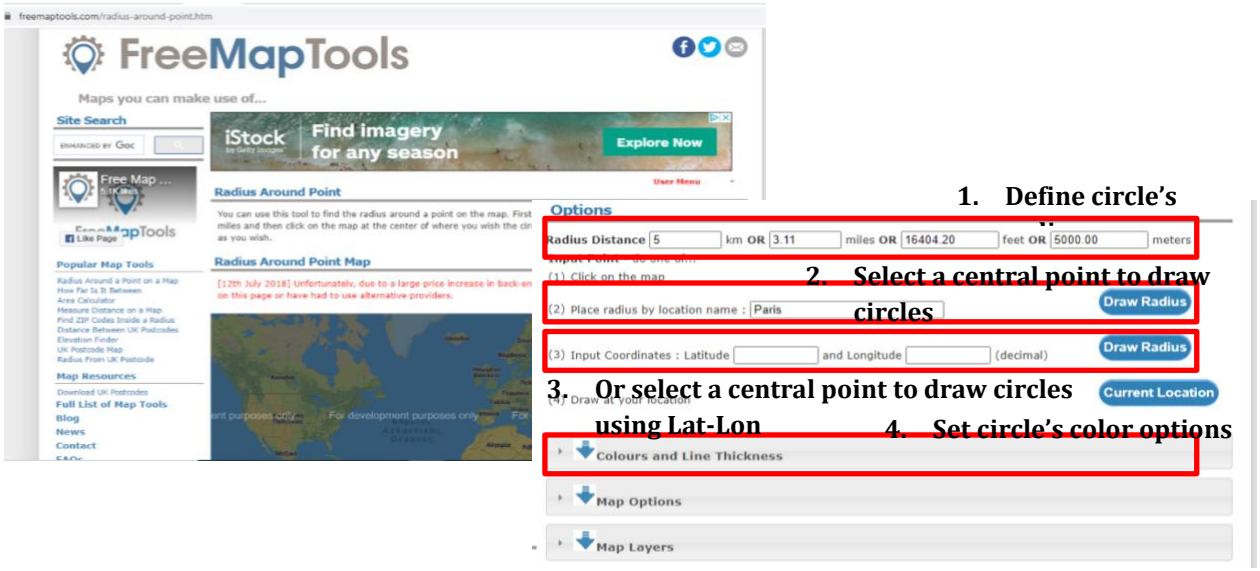

Figure 4: FreeMapTool to draw planets' orbits with different colors and size
https://www.freemaptools.com/radius-around-point.htm

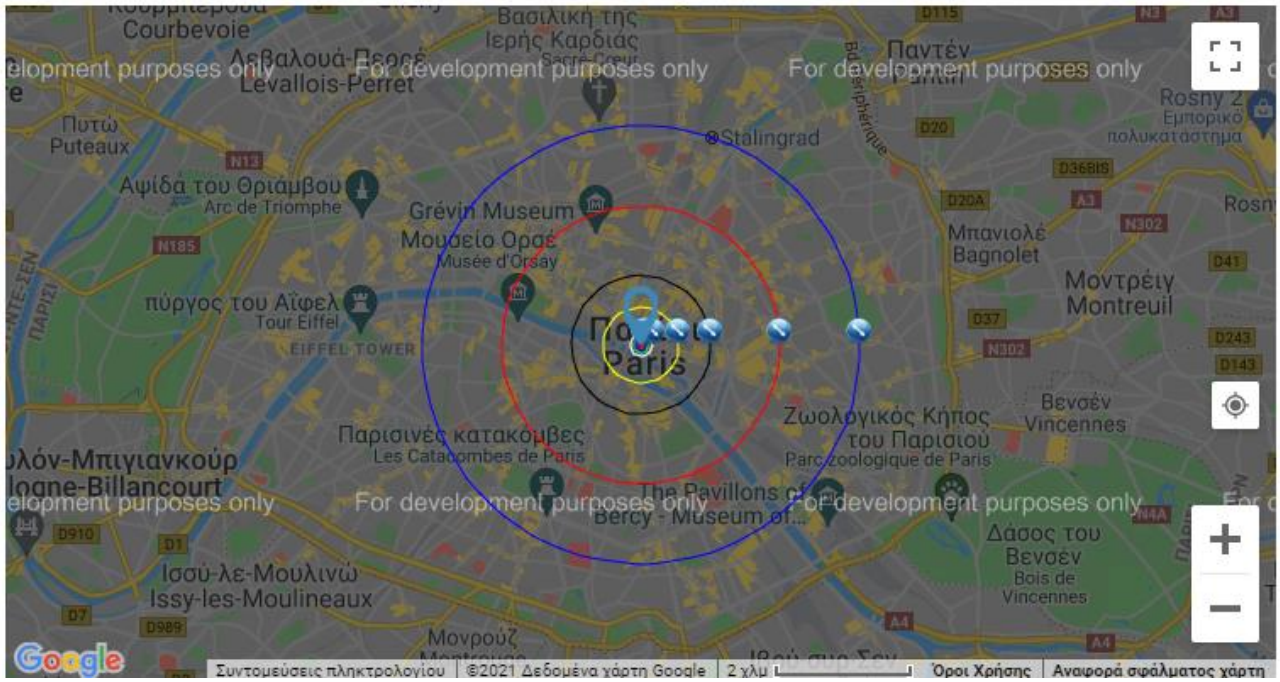

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Figure 5: The scaled planets' orbits considering that the Sun's position is located on the center of Paris

You can also draw the Sun (i.e 25-centimeter radius) for realizing the vast differences considering the size of the Sun and the distance of each planet (covering the entire Paris center)!

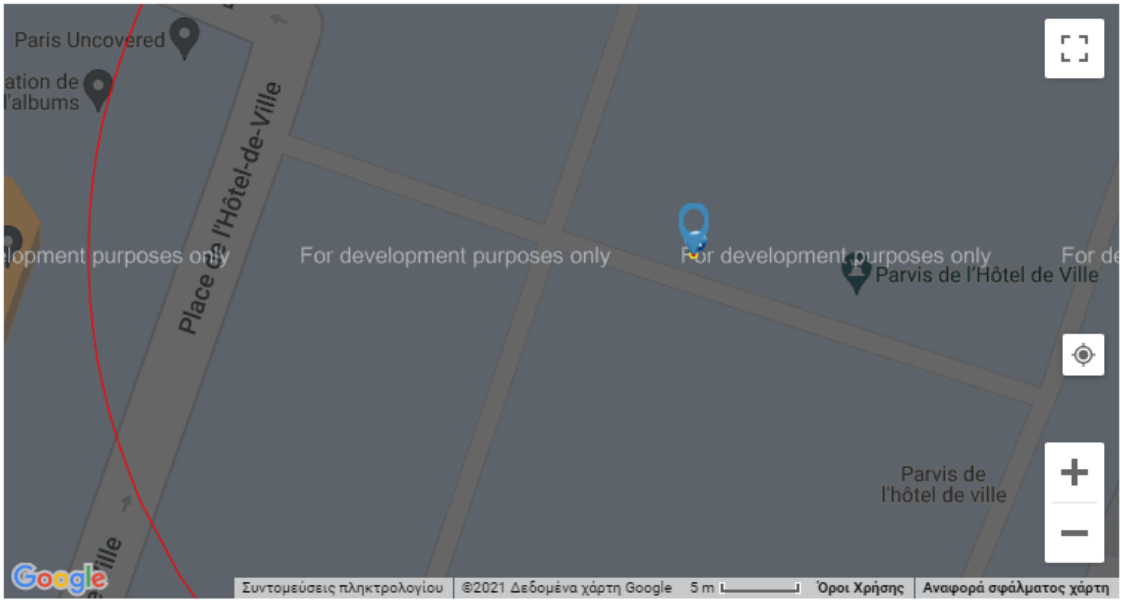

Figure 6: The Sun is merely illustrated at a building block level

Of course, you can force students to test this experiment for different Sun radius, for example, what if the size of the Sun was 50 meters?

Solar System objects	Distance from the Sun (Km.)	Planets' radius (Km.)	Distance times the Sun's radius	Total distance on Earth (in m.)	Scaled size of the objects (in cm.)
Mercury	57000000	2439	81,86	8185,66	17,51
Venus	108000000	6051	155,10	15509,66	43,45
Earth	149000000	6371	213,98	21397,59	45,75
Mars	228000000	3389	327,43	32742,63	24,33
Jupiter	780000000	69911	1120,14	112014,25	501,99
Saturn	1437000000	58232	2063,65	206364,71	418,13
Uranus	2871000000	25362	4122,99	412298,59	182,11
Neptune	4530000000	24662	6505,44	650544,27	177,08
Moon	150000000	1737	215,41	21541,20	12,47
Sun	0	696340	0,00	0,00	5000,00
Select the size of the sun (in centimeters)	5000				

Figure 7: Scaled distances and objects' size based on the Sun's radius of 50 meters (5000 cm.)

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Discussion

Discuss the difficulties you encountered during your investigation.
Did you understand the method of scaling?

Why scaling is important and where can we use it?

Estimate the one-way travel time from the Sun to each of the solar system planets. Use that fact that the travel time from the Sun to Earth is 8 ½ minutes to validate their results. They can fill their answers in the excel form, in units of seconds, minutes or hours depending on the adjustment that the teacher wants for the students to learn (i.e. how to estimate arrival time in seconds, minutes or hours).

Explain the formula: Time = distance/speed (in minutes)

Some further explanations and examples related to the light travelling around the universe:

https://www.pbs.org/seeinginthedark/astronomy-topics/light-as-a-cosmic-time-machine.html (Time for the light to reach different planets, stars or galaxies)

You can conclude with the following question:

"What do you think aliens could see right now from the Orion Nebula if they looked towards Earth?"

Think about how we could use the method of scaling objects or distances in other aspects of everyday life.

You can ask from students to write a short report with the results occurred during this activity (including tables, images from the FreeMapTool etc.). Also, students can provide some relevant examples and why is important to scale down some physical entities or to think of an example of scaling up! (for example, scale up the size of ants, humans and mammals).

If you have ever wondered where we fit in the universe, then this interactive is for you. The Scale of the Universe takes you on a ride down to the smallest thing theorized by scientists and then out to the vastness of the universe. The interactive opens with a variety of objects shown on the screen, from a Giant Earthworm to a hummingbird.

Try the following game

https://htwins.net/scale2/

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