Scale Sizes of the Solar System
ASTR 1010

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Overview
In this activity you will compare the physical properties of objects within the Solar System to better understand relative scale and distances. You will also explore the scale of planetary orbits in relation to each other.

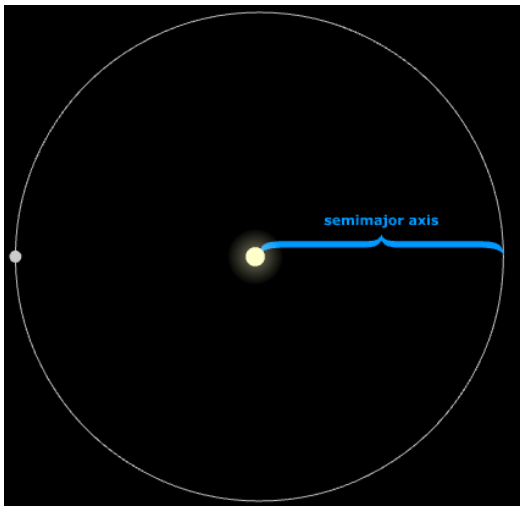
Objectives
After completing this activity students will be able to:
• Calculate spherical volume and density.
• Calculate travel time.
• Interpret given data and perform unit conversions.
• Understand the relative sizes of objects within our Solar System.
• Understand the relative distances of objects within our Solar System.

Definitions
Here are some terms that we will be using today in lab:

• **Spherical Volume**:

$$V = \frac{4}{3}\pi R^3$$

where **R** is the radius of the sphere and **V** is the volume of the sphere.
• **Density**: D = Mass/Volume = M/V
• **Astronomical Unit (AU):** the average distance between the Earth and Sun -- 1 AU = 1.5×10^{11} meters.
• **Semi-major Axis (a):** half of the major-axis or the longest radius of an ellipse. For the planets this is approximately the same as the distance to the Sun. The figure on the right shows the orbit of the Earth and the semimajor axis which is approximately 1 AU in length.



Part 1. Relative Sizes within the Solar System

1) Fill in the table below by calculating the diameter of each object relative to the Earth -- divide the diameter of the object by the diameter of the Earth.

Object	Mass (kg)	Diameter (km)	D_{Object}/D_{Earth}	Semi-major Axis
Sun	2×10^{30}	1.38×10^{6}	108.66	0.00
Mercury	3.3×10^{23}	4.84×10^{3}	0.38	0.39
Venus	4.87×10^{24}	1.21×10^{4}	0.95	0.72
Earth	5.97×10^{24}	1.27×10^{4}	1.00	1.00
Moon	7.35×10^{22}	3.47×10^{3}	0.27	1.003
Mars	6.42×10^{23}	6.78×10^{3}	0.53	1.52
Jupiter	1.9×10^{27}	1.41×10^{5}	11.10	5.20
Saturn	5.68×10^{26}	1.2×10^{5}	9.45	9.54
Uranus	8.68×10^{25}	5.1×10^{4}	4.02	19.18
Neptune	1.02×10^{26}	4.94×10^{4}	3.89	30.06

2) List the objects from the table above in order of decreasing size.

Sun, Jupiter, Saturn, Uranus, Neptune, Earth, Venus, Mars, Mercury, Moon

3) Based upon mass and diameter, which object is most similar to the Earth?

Venus

4) What is more massive – Jupiter OR Saturn, Uranus, and Neptune combined? Show your work.

Saturn, Uranus, and Neptune combined is 1.2 x 10^5 + 5.1 x 10^4 km + 4.94 x 10^4 km = 220,400 km. 220,400 km is about 1.56~ times larger than Jupiter ’ s diameter of 1.41 x 10^5 km

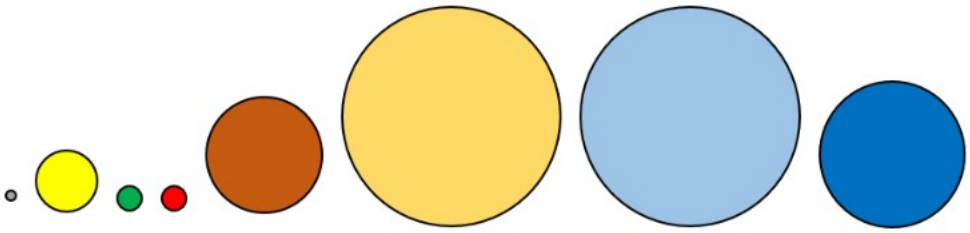
5) How many Earths could fit end-to-end from one side of the Sun to the other side? Show your work.

(1.38 x 10^6 km)/(1.27 x 10^4 km) = 108.66~. The Sun could fit about 108 Earths end-to-end.

6) Each diagram below represents the planets in order of increasing distance from the Sun. Which diagram is most accurate?

B

A)



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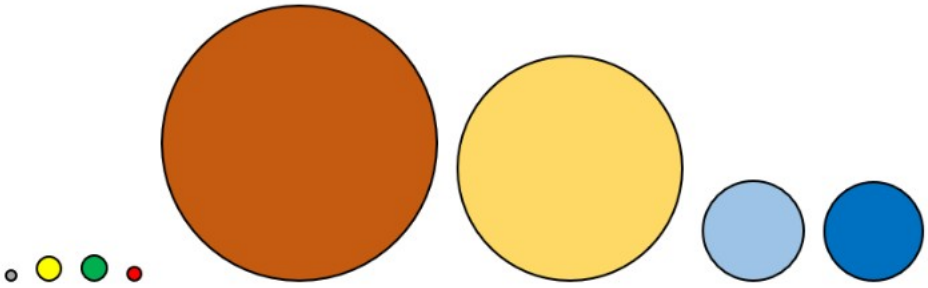

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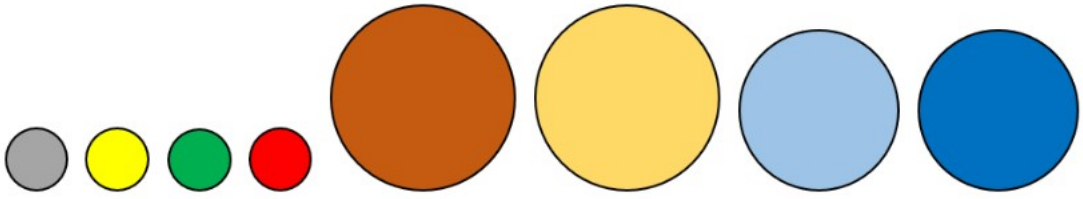

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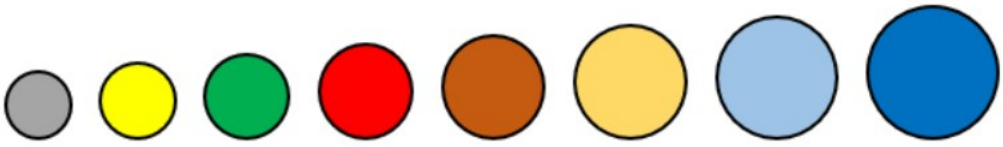


7) Calculate the volume of Jupiter and the volume of Earth. Use the equation for volume provided on page 1. Remember that the radius (R) is half the diameter. Don't forget units! Show your work.

(4/3) x pi x ((1.41 x 10^5 km)/2)^3 = 1.47 x 10^15 m^3 = V

8) How many Earths could fit inside Jupiter? Show your work.

(1.41 x 10^5 km)/(1.27 x 10^4 km) = 11.10 km

9) Calculate the density of Jupiter. Use the equation for density provided on page 1. Don't forget units. Show your work.

(1.9 x 10^27 km) / (1.47 x 10^15 m^3) = 1.29 x10^12 kg/km^3

10) The density of Earth is about 5.5 x 10^{12} kg/km^3. Is Jupiter more or less dense and by how many times? Show your work.

Earth is more dense than Jupiter because 5.5 x 10^12 kg/km^3 > 1.29 x10^12 kg/km^3.

Part 2. Relative Masses

11) Add up the masses of the planets and Moon.

2.67 x 10^27 kg

12) How many times more massive is the Sun than all the planets (and Moon) combined? Show your work.

(2 x 10^30 kg)/(2.67 x 10^27 kg) = 749.06

13) What percentage of the mass you calculated in Q11 is Jupiter?
Show your work.

(1.41x10^5kg)/(2.67x10^27kg) = 5.28x10^-23 kg

Part 3. Relative Sizes of the Planetary Orbits

14) If a spaceship takes 1 month to travel from the Sun to Earth (a distance of 1 AU), how long would it take to travel from the Sun to Saturn? Show your work.

The distance from Sun to Saturn is 9.5 AU. If one AU is equal to 1 month, it would take 9.5 months to travel from Sun to Saturn.

15) The nearest star system to ours is Alpha Centauri, which is 4.16×10^{13} km away. Calculate how far away this is in AU. Show your work.

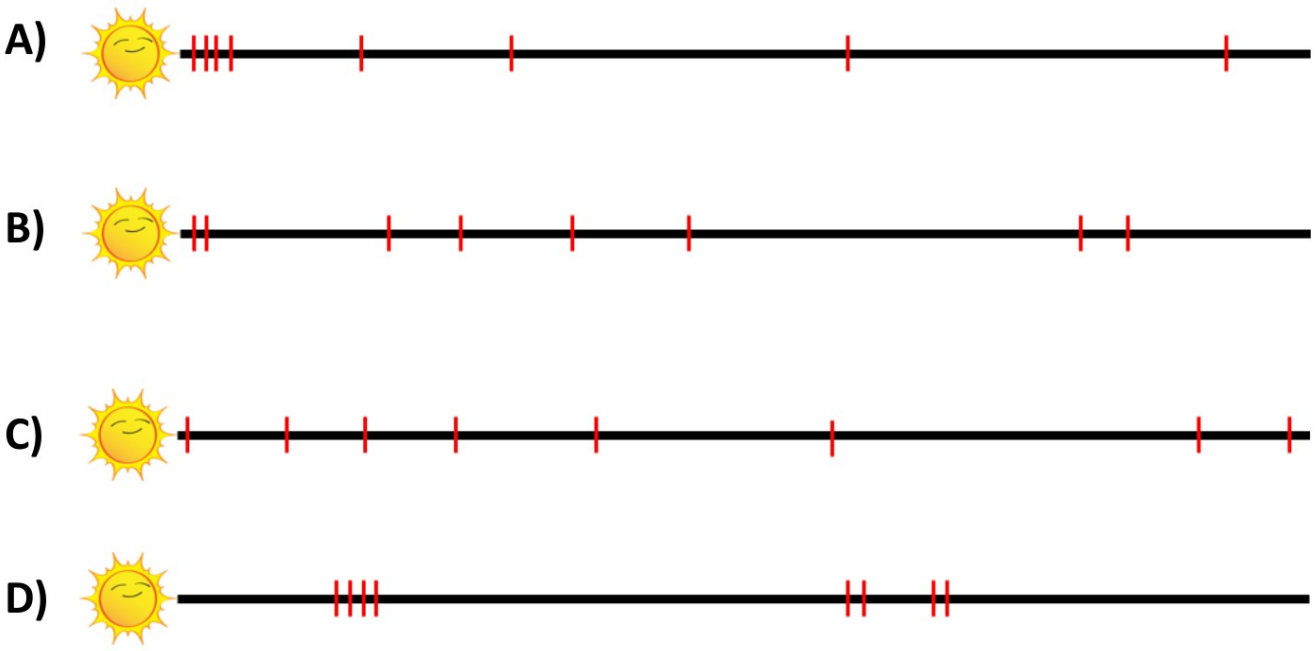
The distance to Alpha Centauri is 4.16x10^13 km, 1 AU is 1.5x10^8 km. The distance in AU is 4.16x10^13 km / 1.5x10^8 km = 2.77x10^5 AU.

16) How long would it take for the spaceship in Q14 to travel from the Sun to Alpha Centauri? Give your answer in years.

The Sun to Alpha Centauri is 2.77x10^5 AU, divided by 12 gives 23,111 years.

17) Each diagram below represents the relative distance of the planets from the Sun. Which diagram is most accurate?

A



18) Add up the diameters of the planets (in km), to determine how far they would extend if put side-by-side.

401,290

19) The largest orbital distance between the Moon and Earth is 4.06×10^5 km. How many planets from our Solar System fit side-by-side in this distance?

8

20) What did you find most surprising or interesting in this lab and why?

I didn’t expect the Sun to be larger than all the planets combined. I knew the Sun is large but this took me by surprise.