Experiment: Scale model 2, the Solar System

Names: ____

Group: _______________________

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Objective

Develop intuition for the large scales and distances found in astronomy. Gain working understanding for creating scale models of physical systems.

Equipment

Measuring tape, meter sticks. Cones, flags. Balls, marbles, pinheads, etc for planets. Calculator. Pen-lights. Student's Textbook (NO google, phones or internet). Whiteboards.

Theory and background (pre-lab preparation)

This section should be read before lab, as part of your preparation. This includes working out any examples or calculations you are asked to do in this section.

Consult lectures and textbook readings. Specifically, your Textbook's Appendices with tables of astronomical data for the solar system (so you can look up planet sizes, orbital distances from Sun, etc.).

Note: NO google, phones or internet can be used in this lab, only your textbook and calculator (so bring these with you to lab).

Scale model 1: the Earth-Moon system.

Recall our first Scale Model in the course, based upon the work of Hipparchus (born 190 BC): If Earth is taken as 1.0 foot in diameter (size of a basketball) then the Moon is about 4 inches in diameter (size of a tennis ball) and orbits Earth at a distance of about 30 feet (size of classroom).

Scale model 2: the Solar System.

The scale model constructed in this lab is based upon modeling the Earth as a blue marble, approximately 1 cm in diameter. Since the diameter of the Earth is 12,800 km (twice the radius 6,400 km), this defines the ratio,

$$\frac{\text{Diameter Earth model}}{\text{Diameter Earth actual}} = \frac{1 \text{ cm}}{12{,}800 \text{ km}}$$

This ratio is key to our scale model, and will be used for this entire lab. The whole point of a scale model is that *every* body in the solar system is placed on the same scale. The ratio (1 cm / 12,800 km) can be used to calculate the model diameters and model distances of any other body in the solar system. For instance, the Sun's size in our scale model must also follow this ratio:

$$\frac{\text{Diameter Sun model}}{\text{Diameter Sun actual}} = \frac{1 \text{ cm}}{12{,}800 \text{ km}}$$

which allows us to solve for "Diameter Sun model." Study this example before lab:

Example: size of a body in our scale model. The actual radius of the Sun is 7×10^5 km, or 700,000 km (see your Textbook's Appendix). Therefore, Sun has an *actual* diameter of 2*700,000 = 1,400,000 km. Thus, the *model* diameter can be found using the ratio above:

$$\frac{\text{Diameter Sun model}}{\text{Diameter Sun actual}} = \frac{1 \text{ cm}}{12{,}800 \text{ km}}$$

$$\frac{\text{Diameter Sun model}}{1{,}400{,}000 \text{ km}} = \frac{1 \text{ cm}}{12{,}800 \text{ km}}$$

and using algebra and calculator to solve the equation for "Diameter Sun model." Solve for this value now. Record your result below:

Diameter Sun model = ____________________ cm

Note on units: the resulting model size of Sun will have units of cm (or "blue marbles" since that's the basis for our scale model: Earth as one marble)

Note on precision: all scale models are approximate, so we will not use many digits (significant figures) in our calculations. Use 2 or 3 digits in your results. The purpose is intuition, not precision.

Procedure (executed during lab)

Your professor will briefly show you the equipment. Your instructor will assign each group several solar system bodies for this lab (referred to as “bodies” from now on). There is a table provided to record your results.

1) Diameters for objects in Solar system.

- Using your Textbook’s Appendix (not Google or internet), look up the actual diameter for each of your bodies. Record the values in the table.

- Whiteboard: Using our scale model ratio (Theory and Background section) determine the scale model diameter for each body. Show your work *on a whiteboard*, clearly numbering and following these steps: 1) setup the scale model ratio (see example for Sun), 2) Solve for unknown “Diameter Body model” where “Body” is the name of your assigned body, 3) box your final results.

🌜 CHECK YOUR WORK BEFORE CONTINUING 🌛

- Record your results in the data table, as well as on the classroom’s whiteboard grid so all groups can share.

- Record other groups’ results in your data table also, so you have a complete dataset for all planets by the end of this lab.

- Find something (e.g., ball, etc.) which matches the size of your solar system bodies in this scale model. [Dr. Clarage can help]

2) Orbital distances for objects in Solar system.

Now that you know the relative *sizes* of the objects in our model of the solar system, we will find the *distances* at which these objects orbit the Sun in our model. Follow these steps:

- Using your Textbook’s Appendix, look up the *actual* orbital distances for each of your bodies. Record the values in the table.

- Before using these actual distances to calculate your scale model distances, read this example for how the calculation would go for Mercury:

Example: orbital distance of a body in our scale model. Like all bodies in our model, Mercury must obey the scale model ratio:

$$\frac{\text{Distance Mercury model}}{\text{Distance Mercury actual}} = \frac{1\ \text{cm}}{12{,}800\ \text{km}}$$

Mercury has an *actual* orbital distance (semi-major axis) from the Sun of 57.9 x 10^6 km = 57,900,000 km, so the above ratio can be written:

$$\frac{\text{Distance Mercury model}}{57{,}900{,}000\ \text{km}} = \frac{1\ \text{cm}}{12{,}800\ \text{km}}$$

This equation can be solved for “Distance Mercury model” to tell us how far away (how many “blue marbles” or cm) from the Sun to place Mercury in our scale model.

- Whiteboard: Following the example above, determine the scale *model* orbital distance for each of your bodies. Show your work on a whiteboard, clearly numbering and following these steps: 1) setup the scale model ratio (see example), 2) solve for unknown “Distance Body model” where “Body” is the name of your assigned body, 3) box your final results.

🌜 CHECK YOUR WORK BEFORE CONTINUING 🌛

- Record your results in the table, as well as on the classroom whiteboard grid so all groups can share.

- Record other groups results in your data table also, so you have a complete dataset for all planets assigned by the end of this lab.

3) Put it all together: Construct scale model of Solar system (UST academic mall)

When all groups are finished with the previous parts, the entire class will go outside and “walk-off” a model. Bring equipment listed on first page.

Measuring a meter: Approximately: one large step is approximately 1-meter. Find someone in your group whose step-size is close to one meter (using the meter sticks). Precisely: use a tape measure.

Note: As a helpful check on your distances: the distance between I-beams on the UST mall: 10' 6'' or 3.2 meters.

4) Conclusion

Write a brief (3-5 sentences) conclusion of what you learned in this lab. Comment on the role of mathematics and models in understanding the universe.

OPTIONAL 5) Construct scale model of outer Solar system (beyond UST academic mall)

Some objects may not fit on the campus. In this case, use Google maps and print out where the solar system objects would be on a map of the area around campus.

OPTIONAL 6) Speeds in our scale model

How fast do objects move in our scale model? One way to get feel for this is to calculate the "speed limit" in our model. The actual speed limit in our Solar system (and entire Universe) is the speed of light (look up in your brain, or textbook). Using our scale model ratio, convert the actual speed of light from units of [km/s] to model units of [cm/s] (i.e. number of blue marbles per second).

Speed of light actual = ____________________ km/s

Speed of light model = ____________________ cm/s