Great Explorations in Math and Science (GEMS)

A Human Orrery

A 3-Dimensional Kinesthetic Model
of the Solar System:
2 Dimensions of Space and 1 of Time

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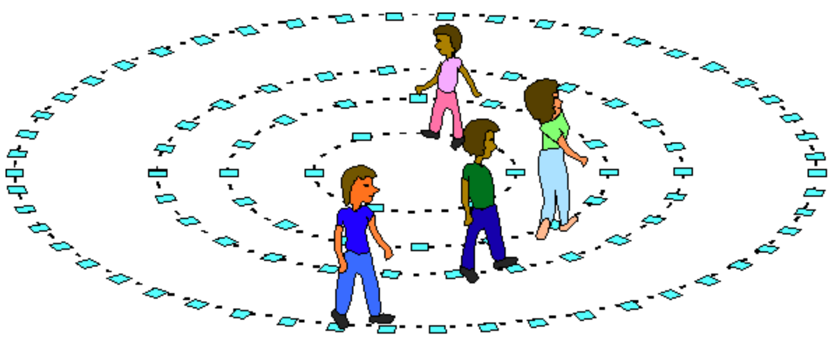
Most models of the solar system are one dimensional in terms of distances between objects in the solar system. Most 3-D models have spherical planets made to a scale correct for the size of the planets, but not for distances between planets.

This "human orrery" is a model of the solar system in which students act out the model and set it in motion. Students measure out orbits for the inner solar system (Sun, Mercury, Venus, Earth, and Mars), and place "footstep" markers along the orbits, to indicate position of each planet in 2-week intervals. Students take turns in teams of 4 to "walk the model, " setting the planets in motion, and seeing vividly how the speeds of the planets in their orbits depend on distance from the Sun.

To lay out the model, students work in teams of four also, so for a large class (32 students), it is ideal to have the class set up two orreries. This can be done in a multipurpose room or outdoor area that is not in use. It is also possible to set up a single model right in the classroom, depending on what types of desk arrangement you have. The preparation section gives hints on how this can be done.



Materials

For the whole class, for *one model:**

2 or 3 push pins and

1 piece of triwall cardboard, about 10 cm x 30 cm; or regular cardboard folded or stacked to 4 times thickness. Alternative: broomstick or pole to tie strings to—add about 10 cm to string lengths below if you use this alternative.

6 Post-it™ pads (any size) or rolls of masking tape for marking "footsteps" on the floor. You can have a different color for each planet's orbit.

6 strings (or twine) with minimum "stretchiness", lengths: 58 cm (for Mercury), 109 cm (for Venus), 150 cm (for Earth—2 of these), and 229 cm (for Mars—2 of these). It's handy to have 4 scrap pieces of cardboard, about 10 cm x 10 cm, to wrap the string around for storage and ease of handling. [Lengths are for 14 mm scale Sun.]

6 strips of card stock, these lengths: 58 cm (for Mercury), 42 cm (for Venus), 36 cm (for Earth—2 of these), 29 cm (for Mars—2 of these).

* If you plan to have your class make 2 models, you need double the number of each item.

Preparation

Gather the materials and cut the string and card-stock to the specified lengths. You'll need a large clear area for this activity, so determine if it's possible for you to use a large room or outdoor area. If you need to make the model smaller to fit into your classroom, do calculations to determine new lengths of strings, as described in Figure 3. If you are absolutely limited to use of your classroom only, see hints in Figures 1 and 2 for strategies on how to manage desks and tables.

The origin of the word "orrery" is from the Duke of Orrery who, in the 17th Century, built a clock device that showed the motion of planets around the Sun.

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Figure 1. Classroom with tables.

All tables can be moved to the end(s) of the room. If space is tight, angle four of the tables to fill the "corner spots" around the solar system model area.

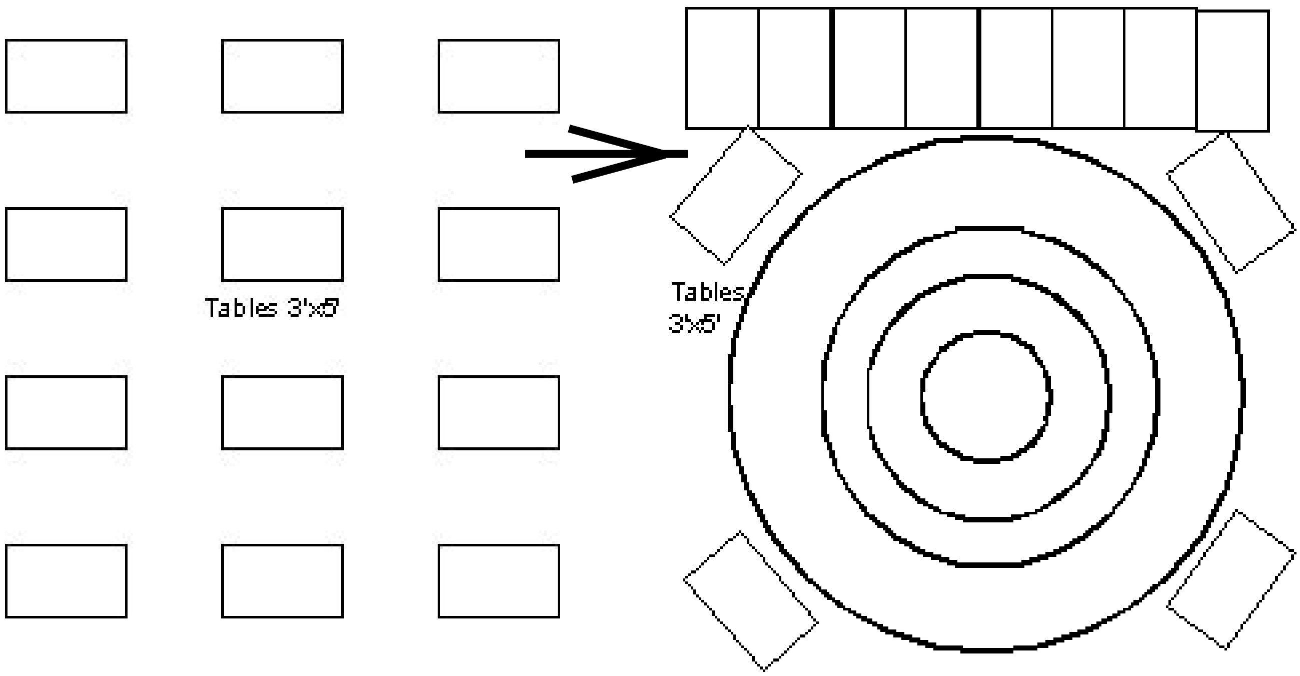
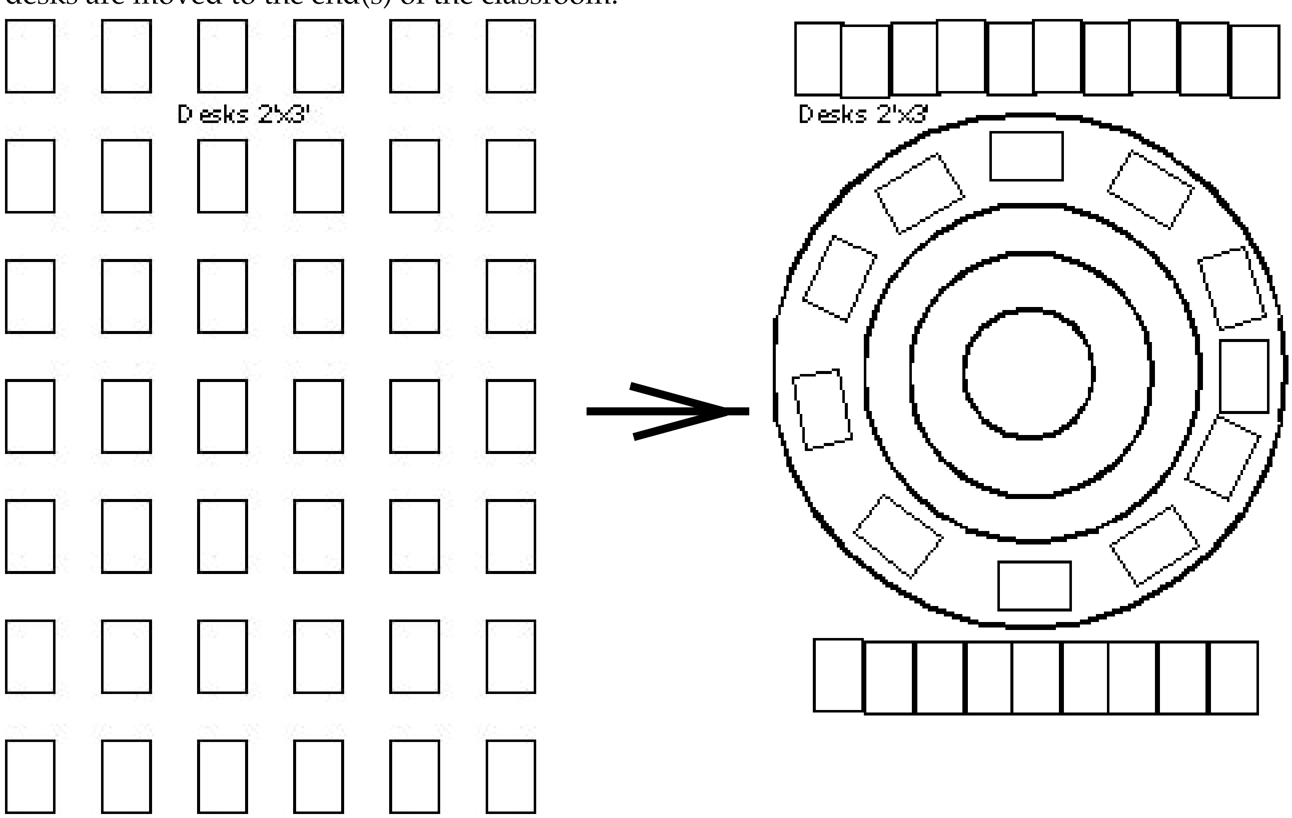


Figure 2. Classroom with individual desks.

It's possible to place about a dozen of the desks in a circular arrangement between the outer two orbits (Earth and Mars). The rest of the desks are moved to the end(s) of the classroom.



⇨Go

1. Ask the class, "Have you ever made a model of the solar system?" [Many students have. Ask them to explain what kind of model they made.] Explain that they will make a 3-D model of the inner solar system with whole orbit circles (2-D) and planets moving. Time is the 3rd dimension in this model.

2. Ask, "What would be in the inner solar system?" [Sun, Mercury, Venus, Earth, Mars.]

3. Determine the scale of the model. Have students determine the distances from the Sun to each of the inner planets, with the stipulation the Sun is to be only 14 mm in diameter.
[1 m = 100,000,000 km] They can use one of the methods in Figure 3, or develop their own.

Figure 3. Methods of determining model solar system distances.

- Use the Exploratorium "Build a Solar System" website at http://www.exploratorium.edu/ronh/solar_system/
- Use proportions to calculate, with the following actual data:

	Size (km)	Orbit Radius (km)
Sun	1,391,900	
Mercury	4,866	57,950,000
Venus	12,106	108,110,000
Earth	12,742	149,570,000
Mars	6,760	227,840,000

- Set up a spread sheet (e.g. Microsoft Excel) with the proper formulae to do the proportion computations

4. Form teams of 3 to 5 students. Explain how the model is to be made:

a. There are four strings with lengths corresponding to the model orbit radii of the planets. These are used to place the planets at the proper distances from the Sun in their orbits.

b. There are four cardboard strips that will be used to measure out footsteps in the orbits, each footstep being the distance the planet travels in two weeks.

c. Post-its will be stuck to the floor for the footsteps.

d. Team roles will be:

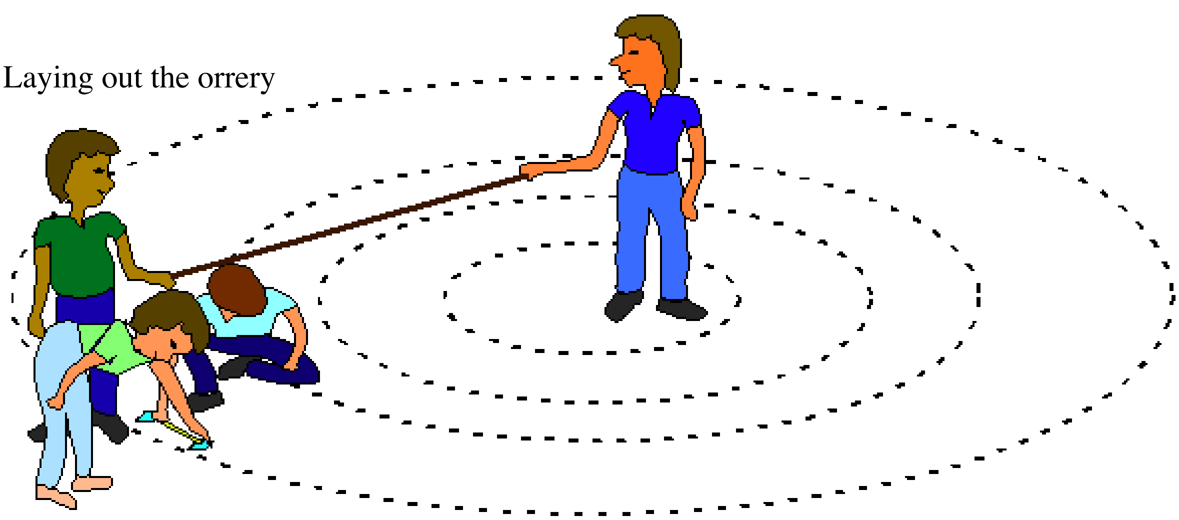
(1) Orbit radius person, to hold the orbit radius string to measure the proper distance—Sun to-planet, for each footstep.

(2) Footstep measuring person, to operate the cardboard strip footstep measurer

(3) Post-it placer, to place post-its at the right spot on the floor, as given by the Orbit radius person and Footstep measuring person.

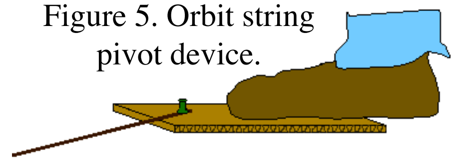
(4) (Optional) Post-it dispenser, to hand post-its to the Post-it placer person as needed.

Figure 4. Laying out the orrery



If you need to have 5 students in a team, have them take turns doing different roles, with everyone checking to make sure it's being done right.

Figure 5. Orbit string pivot device.

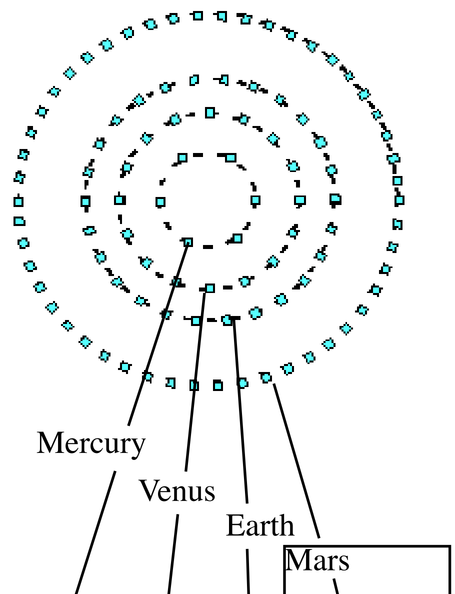


Note: if you use the "broomstick" method of pivot for the strings, you must add roughly 10 cm to the radius string lengths, to allow for tying the strings around the stick.

The orbit measuring strings can be fastened to a piece of triwall cardboard (or quadruple thickness cardboard) with a pushpin. The cardboard can be either taped to the floor, or there can be a student or even the teacher who takes on the role of making sure that the "Sun-end" of the orbits strings all stay properly pinned. Alternatively, tie the strings to a broomstick or pole.

There are 5 or 6 teams needed for each orrery: Mars has the most footsteps in its orbit and 2 teams can work on that orbit, one team starting out clockwise in the orbit, and the other team counter-clockwise. The same can be done for the Earth's orbit. Depending on whether you want 5 or 6 teams working at once, you can have one team lay footprints for both Mercury and Venus orbits, or keep those planets as separate teams. The Mercury team will be done in a very short time, since it has the fewest footsteps to lay out.

Figure 6. Layout of footsteps.



5. Lay out the Human Orrery model. Have students layout the model. You can have each team start one at a time. The Sun end of the orbit radius string needs to be secure for each group and other groups must stop and allow slack in their orbit strings, while the new one is secured. Another way is to secure all the orbit radius strings first and have all the groups start in measuring at different points around the circle. The two teams that work on the Mars orbit need to start at the same point in the orbit and work in opposite directions until they meet. The same goes for the two teams working on the Earth orbit.

6. Run the Human Orrery. Once it's all laid out, have the teams take turns "running" the orrery, four or five students at a time—one Mercury, one Venus, one Earth, one Mars, and one "clock." The clock keeps time by simply counting: 1, 2, 3, 4. Since each step is actually two weeks, an alternate way of counting would be by actual weeks: 2, 4, 6, 8.... The way to "run" the orrery is for each planet take a position on one of the footsteps on his or her orbit, and for the clock to start counting. On each count, the planets take a step along the orbit line.

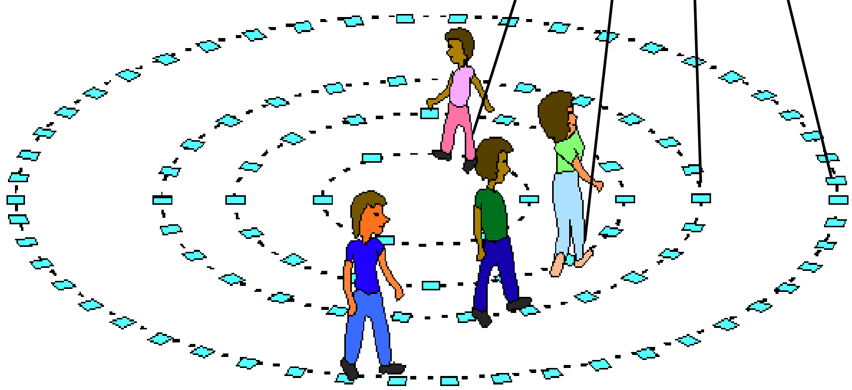


Figure 7. Running the human orrery

7. Ask, "How big are the planets on this scale?" If students have not already done so, have them find out how big the planets are on this scale, where the Sun is 12 mm in diameter. Students can use one of the techniques mentioned in step 3. Ask the class, how the sizes of the planets at this scale might be represented? [A pinhole in a card, made with a small straight pin, is probably somewhat bigger than Earth should be on this scale. Pencil dots may work, with sharp pencil!]

8. Ask, "What is the time scale we are using? [If the counting is one count per second, and each count is 2 weeks, then the "time scale" is 1 sec = 1 week.]

