LAB 2. SOLAR SYSTEM WALK

Introduction

Your task is to make a scale model of the Solar System with a basketball representing the Sun. You will select tokens to represent the Moon and planets, and place them at the correct distance from the basketball/Sun.

Supplies

Computer running a spreadsheet, basketball, assorted spheres to represent the Moon and planets, ruler, Vernier calipers, trundle wheel, chalk

Scaling the Model

The first part of making the model is to calculate the scaled sizes and distances of the model. You will create a spreadsheet to carry out the calculations.

The diameters and orbital distances (semi-major axes) of the objects are as follows.

Object	Diameter (km)	Distance (km)
Sun	1.40×10^6	N/A
Mercury	4,879	5.80×10^7
Venus	1,2104	1.08×10^8
Earth	12,756	1.50×10^8
Moon	3,475	384,400
Mars	6,779	2.28×10^8
Jupiter	139,820	7.78×10^8
Saturn	120,000	1.43×10^9
Saturn's rings	270,000	N/A
Uranus	50,724	2.88×10^9
Neptune	49,244	4.51×10^9

The diameter of the basketball that will represent the Sun is 23.8 cm.

Computing the scale dimensions

Finding the dimensions in the model is a matter of carrying out conversion. IN conversions, a value expressed in one unit is converted to an equivalent value in another unit. The conversion is carried out by multiplying the first number by a "conversion factor" that is equal to 1, which maintains its equivalence.

For this model, the conversion factor is derived from the equivalence

$$1.40 \times 10^6 \text{ actual km} = 23.8 \text{ model cm.}$$

To convert the other actual dimensions in km to model dimensions in cm, you will multiply the actual dimensions by the conversion factor

$$\frac{23.8\text{ cm}}{1.40 \times 10^6\text{ km}} = 1$$

Since the numerator and denominator of this fraction are equal to each other, the conversion factor is equal to 1.

Making the spreadsheet

Conversion factor

Framework

Open MS Excel. Create a new spreadsheet. Set up the framework for the conversions.

In one cell, type "Actual diameter of the Sun."

In the cell to its right, type "1.40e6."

In the cell to the right of that, type "km."

In a cell in the next row, type "Model diameter of the Sun."

In the cell to its right, type the diameter of the basketball, in cm.

In the cell to the right of that, type "cm."

Formula

In a cell in the next row, type "conversion factor."

In the cell to its right, type "=" (an equal sign) to indicate that you are entering a formula. After the equal sign, click on the cell containing the value of the diameter of the basketball. The formula cell will populate with the address of that cell, with a letter for the column and a number for the row. After the address, type "/" to code for a division operation, then click in the cell containing the actual diameter of the Sun in km. Then type a Return to finish the formula.

In the cell to its right, type "cm/km."

Diameters

Framework

Now you are ready to code the conversions. In a new row, type "Object" in the first cell, "Actual diameter (km) in the next, and "model diameter (cm)" in the next. In the first column in succeeding rows, type the names of the Solar system objects ("Sun," "Mercury," etc.). In the second column, enter the numbers for the diameters in km from the table above. (Enter just the numbers; don't include the unit symbols.) Excel supports "e" notation for scientific notation: to enter, say, 6.02×10^{23}, type "6.02e23."

Formulas

The third column is where the magic will happen. In the first row, type an equal sign to begin a formula. Then click on the cell to the immediate left (containing the object's actual diameter in km). Then type "*" to code for multiplication, then click in the call containing the numerical value of the conversion factor. Type Return to complete the formula. The cell should contain the diameter of the basketball, in cm. If it doesn't, consult your instructor.

To find the rest of the model diameters, "fill down" the cells. First, modify the formula you just created to always use the same conversion factor. Click on the formula you just created and find the address of the cell containing the conversion factor. To immobilize the cell reference in your formula, type "$" character before the letter (column) in the conversion factor cell address, then type another "$" character before the number (row) in the cell address. Type Return; the cell should still display the same value.

After that preparation, the formula is ready to populate the calculations for all the other diameters. Click on the lower right corner of the cell that calculates the model diameter of the Sun; it should display a small square in that corner. Click on the square, and drag down the column through the rows of the list. Release the mouse button, and the cells you just filled should show the model diameters of all the objects. Click into any of the cells to see its formula. The first cell address in the formula should be the address of that object's actual diameter; the next address should be the unchanging (with the "$" signs) address of the conversion factor.

Distances

In centimeters

To calculate the model distances of the objects, make another table in the spreadsheet. Type a heading like "Model Distances from the Sun." In the next row, type the column headings: "Object," "Distance(cm)." Then select the list of names of objects (not the Sun), CTRL-C to copy the names, then click in the cell below the heading to paste the copied names. To calculate the distances, make conversion formulas as you did for the diameters, using the same conversion factor that you used before. Fill down in the same manner to create the table.

In useful units

Now that your tables are finished, you will find that all of the sizes are in inconvenient units. Object diameters in cm are often too small, while distances in cm are too large. To convert these to more convenient units, create conversion factors using the equivalencies

10 mm = 1 cm
1 ft = 30.48 cm

(Why feet? Because the trundle wheel you will use to find where to place the planets reads in feet.) I recommend putting the converted diameters and distances in new columns, to supplement, rather than override, your previous calculations.

Choosing the tokens

Now that you have calculated the sizes of the Moon and planets in the model, select items to represent them to scale. You may not be able to find objects that are exactly the right size, so find the closest object that you can. The class should agree on the representative tokens.

Walking the Model

Bring the chalk, the trundle wheel, and the tokens, including the basketball, outside. Set the Sun/basketball at the starting point, and mark it ("SUN") on the sidewalk with chalk. Use the trundle wheel to find the locations of the remaining objects. Set them where they belong in the model, and see just how far apart they are.

Questions

1. How large does the basketball appear from “Earth” in the model? Is it about the same angular size as the Sun in the sky?

2. How large do the tokens for Uranus and Neptune appear from “Earth”? Does it make sense that you can’t normally see them without a telescope?

3. Why aren’t pictures of the Solar system in books shown to the correct scale?