Name: ____________________________ TA: ______________________________

Physics 10263 Lab #1: Scale Models

Introduction

The Universe is a big place. But what does that statement really tell you? One of the goals of this course is to have each of you develop some sense for the size of the Universe and the objects in it (such as our own solar system). To do that requires more than just comparing numbers...it helps to actually design your own scale model of the solar system and demonstrate it to someone else.

You are already familiar with scale models. Perhaps you built models or played with toy cars or people when you were younger. Both of these are examples of scale models. In the case of model cars, they are usually 1/24th scale (or 1 inch = 2 feet). That means every dimension in the model is 24 times smaller than the real car. If the car is 12 feet long, the model car will be:

12 feet * (1 inch/2 feet) = 6 inches long.

The scale factor to convert from real units to model units would be 1 inch/2 feet.

If we asked you to make a scale model of TCU, you might choose to make 1000 feet equal to one step. Then the distance across the entire campus would be about ten steps and the model might fit inside SWR 360. The scale factor in this case would be 1 step/1000 feet. Thus, a real distance of 5000 feet would be equivalent to a model distance of:

5000 feet * (1 step/1000 feet) = 5 steps.

Our own campus map (at http://maps.tcu.edu) is an example of a scaled picture of TCU in which the scale factor is about 1 inch/1000 feet.

The solar system is very large compared with anything you have probably dealt with before (even though it is tiny compared to the size of our galaxy, the Milky Way, which is in turn very tiny compared to the size of the visible Universe). So to fit the scale model within a realistic area, like this building, the TCU campus or the city of Fort Worth, we will require a tiny scale factor. Fortunately, when constructing a scale model of the solar system, we can treat it as a two-dimensional map like the map of TCU. That's because all the planets in the solar system lie roughly in the same plane, so we won't have to worry about climbing buildings or renting balloons to walk through our scale model.

Example: Suppose your scale factor is 1 meter / 7.5 x 10^7 km...

Step 1:
$$1 \text{ parsec} * \frac{3.1 \times 10^{13} \text{ km}}{1 \text{ pc}} = 3.1 \times 10^{13} \text{ km}$$

Step 2:
$$3.1 \times 10^{13} \text{ km} * \frac{1 \text{ m}}{7.5 \times 10^{7} \text{ km}} = 4.1 \times 10^{5} \text{ m, so } 1 \text{ pc} = 413{,}000 \text{ m}$$

... so, on this scale, 1 parsec is about 400 km, which is about 260 miles, the distance from Fort Worth to Houston. So you can see that even with this tiny scale factor ("1 m / 7.5 x 10^7 km" is the equivalent of "1 inch / 10 million miles"), the galaxy is an enormous place!

Part 1

Let's begin by filling out the data table for objects and distances within our solar system. First, copy down the true values for each quantity from the reference sheet of Astronomical constants at the end of the lab. Now let's try two different scale factors and see which one is more appropriate.

Scale Factor #1 : 1 meter / 32,000 km

Scale Factor #2 : 1 meter / 2,000,000 km

The first scale factor shrinks down the Universe by a factor of 32 million, making the Earth about the size of a standard map globe like you can see in the classroom. Using this scale factor examples above and the values on the reference sheet to guide you, fill in the 3rd column (scaled value #1) on your table (next page). Throughout this lab, all of your answers should have two significant figures.

The second scale factor shrinks down the Universe by a factor of 2 billion, making the Earth about the size of a green pea. Again, use this new scale factor to fill in the 4th column (scaled value #2) on your table.

Quantity	True Value (km)	Scaled Value #1 (m)	Scaled Value #2 (m)
Size of Sun			
Size of Earth			
Size of Jupiter			
Average Distance of Mercury			
Average Distance of Venus			
Average Distance of Earth			
Average Distance of Mars			
Average Distance of Jupiter			
Average Distance of Saturn			
Average Distance of Uranus			
Average Distance of Neptune			
Average Distance of Pluto			

Part 2

Now let's consider which scale factor is more appropriate. Our goal here is to create a scale model of the solar system that is relatively easy to grasp, so the objects in it must have scaled sizes that we can relate to (scaling the Sun down to a radius of, say, 1000 km or 0.0000001 m doesn't make any sense). Also, the model itself must be small enough that we can walk through and explore it. It is easier to walk a distance of 1 mile but much harder to walk 1,000 miles.

Answer the following questions about **scale model #1** below:

(2a) - Which is an example of an object (it doesn't have to be spherical, just roughly the same size) that has a size close to that of your scaled-down Sun. Remember, in this model, the Earth is about the size of a standard map globe.

a) Basketball b) House

c) City d) Continent

(2b) - Give an example of an object that has a size close to that of your scaled-down Jupiter.

a) Basketball b) Van

c) Fruit Fly d) Skyscraper

(2c) - Suppose you could walk with a speed of 3600 meters per hour (about 1 meter per second). Use d = vt to determine how much time it would take you to cover the following distances in **scale model #1** (in hours):

- Sun-Earth scaled distance #1
Travel time = ____________ hours

- Sun-Jupiter scaled distance #1
Travel time = ____________ hours

- Sun-Pluto scaled distance #1
Travel time = ____________ hours

(2d) - Based on your answers to question (2c), do you think you can easily walk through this scaled-down solar system and show it to someone else? Explain below

Part 3

Answer these questions about **scale model #2** below:

(3a) - Give an example of an object that has a size close to that of your scaled-down Sun. Remember, in this model, the Earth is about the size of a green pea.

a) Basketball b) Fruit Fly

c) House d) City

(3b) - Give an example of an object that has a size close to that of your scaled-down Jupiter.

a) House b) Grape

c) Fruit Fly d) Van

(3c) - Suppose you could walk with a speed of 60 meters per minute (about 1 meter per second). Use d = vt to determine how much time it would take for you to cover the following distances in your **scale model #2** (in minutes).

- Sun-Earth scaled distance #2
  Travel time = __________________ minutes

- Sun-Jupiter scaled distance #2
  Travel time = __________________ minutes

- Sun-Pluto scaled distance #2
  Travel time = __________________ minutes

(3d) - Based on your answers to question (3c), do you think this scaled-down solar solar system would be easier or harder to show and explain to someone than scale model #1? Justify your answer.

Part 4

Ok, now let's have a look at the 2nd part of the table on the reference sheet, which focuses on objects and distances outside of our solar system. For each of our two scale models, fill out the table below. First, take the true value (in parsecs) from the data sheet, then convert it to kilometers as in the first part of the example in the Introduction. Write this value down in the 2nd column, then use your two scale factors (as in part 1) to find the scaled values in meters. Express your answers in scientific notation.

Quantity	True Value (pc)	True Value (km)	Scaled Value #1 (m)	Scaled Value #2 (m)
Distance to Nearest Star				
Distance to Center of Galaxy				
Distance to Andromeda Galaxy				

These are such large distances, so let's forget about walking and get in a car! On a long road trip, you can usually manage to drive about 800 km (500 miles) per day, or 800,000 meters per day (assuming you stop for gas, food and sleep). Since we decided above (I hope!) that scale model #2 was more appropriate, let's use those scaled distances. Figure out how long it would take to drive (in your scaled down model!)…

- How many **days** to the nearest star? _________ days

- How many **years** to the center of the galaxy?

_________ years

(800,000 meters per day = 292,000,000 meters per year)

- How many **years** to the Andromeda galaxy

_________ years

Essay

The essay portion was incorporated into the parts above as the answers to various questions, so there will be no formal essay at the end of this lab.

Astronomical Constants

Object	Size (radius) in km	Average distance from Sun in km
Sun	7.0×10^5	--
Mercury	2,400	5.8×10^7
Venus	6,100	1.1×10^8
Earth	6,400	1.5×10^8
Mars	3,400	2.3×10^8
Jupiter	71,000	7.8×10^8
Saturn	60,000	1.4×10^9
Uranus	26,000	2.9×10^9
Neptune	25,000	4.5×10^9
Pluto	1,200	5.9×10^9

1 parsec (pc) = 3.1×10^{13} km

Distance to nearest star (alpha Centauri) = 1.3 pc

Distance to center of Milky Way Galaxy = 12,000 pc

Distance to Andromeda Galaxy = 750,000 pc

Distance to limit of observable Universe = 3.5×10^9 pc