Name:________________________________

Date:___________________________________

2 Scale Model of the Solar System

SUPPLIES: a calculator, Appendix E in your textbook, the football field in Aggie Memorial Stadium, a collection of different sized spherical-shaped objects

The purpose of this lab is to allow us to develop an appreciation for the distances between objects (primarily planets) in our solar system and the sizes of these objects relative to each other and to the distances between them. To achieve this goal, we will use the length of the football field in Aggie Stadium as our distance 'tool' for developing a scale model of the Solar System. A Scale Model is simply a tool whereby we can use manageable distances to represent larger distances or sizes. We will properly distribute our planets on the football field (*the length of the football field will represent the distance between the Sun and the planet Pluto*, further described below) and then we will determine what the sizes of our planets should be to appropriately fit on the same scale.

2.1 Introduction

The Solar System is large, at least when compared to distances we are familiar with on a day-to-day basis. Consider that for those of you who live here in Las Cruces, you travel 2 kilometers (or 1.2 miles) on average to campus each day. If you go to Albuquerque on weekends, you travel about 375 kilometers (232.5 miles), and if you travel to Disney Land for Spring Break, you travel ∼ 1,300 kilometers (∼ 800 miles), where the '∼' symbol means "approximately." These are all distances we can mentally comprehend.

Now, how large is our sphere-shaped planet, Earth? If you wanted to take a trip to the center of the Earth (the 'core,' which we will discuss later in the semester), you would travel 6,378 kilometers (3954 miles) from Las Cruces down through the Earth to its center. If you then continued going another 6,378 kilometers you would 'pop out' on the other side of the Earth in the southern part of the Indian Ocean. Thus, the total distance through the Earth, or the **diameter** of the Earth, is 12,756 kilometers (∼ 7,900 miles), or 10 times the Las Cruces-to-Los Angeles distance. This is a large distance, but we'll go farther still.

Next, we'll travel to the Moon. The Moon, Earth's natural satellite, orbits the Earth at a distance of ∼ 400,000 kilometers (∼ 240,000 miles), or about 30 times the length of the Earth's diameter. This means that you could fit roughly 30 Earths end-to-end between here and the Moon. This Earth-Moon distance is ∼ 200,000 times the distance you travel to campus each day (if you live in Las Cruces). So you can see, even very near the Earth in our Solar System, it is a long way to Earth's nearest neighbor (the Moon).

Now let's travel from the Earth to the Sun. This *Earth-to-Sun average distance*, ∼ 150 million kilometers (∼ 93 million miles) is referred to as one **Astronomical Unit.** When we look at the planets in our Solar System, we can see that the planet Mercury, which orbits nearest to the Sun, has an average distance of 0.4 AU and Pluto, the planet almost always farthest from the Sun, has an average distance of 40 AU. Thus, Earth's distance from the Sun, which we think of as large (75 million times greater than the average distance you commute to campus!) is only 2.5 percent of the distance between the Sun and planet Pluto!! This is a tremendous distance indeed.

Now, how can we put all these distances into perspective on the field? For our Scale Model, the Sun will be located at the goal line of the North end zone.

Below you will proceed through a number of steps that will allow for the development of a scale-model of the solar system.

2.2 Distance From the Sun

Fill in the first and second columns of Table 2.1. In other words, list, in order of increasing distance from the Sun, the planets in our solar system and their average distances from the Sun in units of Astronomical Units (AU). You can find these numbers in Appendix E of your textbook. **(21 points)**

Table 2.1: Planets' average distances from Sun.

	Average Distance From Sun	
Planet	**AU**	**Yards**
Earth	1	2.5
Pluto	40	100

Determine the SCALED orbital semi-major axes of the planets, based upon the assumption that the Sun-to-Pluto average distance in Astronomical Units (which you have written down above) is represented by 100 yards, or goal-line to goal-line, on the football field. To determine similar scalings for each of the planets, use the following equation:

Distance of the planet from the Sun's goal line (in units of yards) = (Planet's average distance in AU) $\times$ (100 yards / 40 AU)

Write these values on the lines provided in Table 2.1 (fill in the third column).

2.3 Sizes of Planets

You have just determined where on the football field the planets are located (how far from the Sun they are located in our scale model). Now it is time to determine how large (or small) the planets themselves are on the **same** scale.

We have already indicated above that the diameter of the Earth is 12,756 kilometers, while the distance from the Sun to Earth (1 AU) is equal to 150,000,000 km. We already determined above that in our scale model, 1 AU is represented by 2.5 yards (90 inches).

We will start here by using the largest object in the solar system as our 'tool' for determining how large the objects will be in our scale model.

The *Sun* is the largest single object in the Solar System. It has a diameter of ~ 1,400,000 (1.4 million) kilometers. [Note that the Sun's diameter is ~100 times greater than the Earth's diameter!!] Since in our scaled model 150,000,000 kilometers (1 AU) is equivalent to 90 inches, how many inches will correspond to 1,4000,000 kilometers (the Sun's actual diameter)? This can be determined by the following calculation:

$$\textbf{Sun's scaled diameter (inches)} = \textbf{Sun's true diameter (km)} \times \frac{(90\ in.)}{(150{,}000{,}000\ km)}$$

Sun's scaled diameter = 0.84 inches

So, on the scale of our football field solar system, the *scaled Sun* has a diameter of only 0.84 inches!!

Now that we have established the scaled Sun's size (0.84 inch diameter), let's proceed through a similar exercise for each of the nine planets, and the Moon (diameter = 3476 kilometers), using the following formula:

$$\textbf{Scaled diameter (inches)} = \textbf{actual diameter (km)} \times \frac{(90\ in.)}{(150{,}000{,}000\ km)}$$

Fill in the values in Table 2.2 **(8 points)**.

Table 2.2: Planets' diameters in a football field scale model.

Object	Actual Diameter (km)	**Scaled Diameter (inches)**
Sun	∼ 1,400,000	0.84
Mercury	4,878	
Venus	12,104	
Earth	12,756	0.0075
Moon	3,476	
Mars	6,794	
Jupiter	142,800	
Saturn	120,540	
Uranus	51,200	
Neptune	49,500	
Pluto	2,200	0.0013

Now you have all the information required to create your scale model of the Solar System.

Use any of the items listed in Table 2.3 (spheres of different diameter) to select your scaled planets, Sun and Moon. NOTE: Some of the items are not the appropriate size for this scale model!!

Table 2.3: Everyday objects that could represent the planets.

Object	**Diameter (inches)**
Basketball	15
Tennis ball	2.5
Golf ball	1.625
Marble	0.5
Sesame seed	0.07
Poppy seed	0.04
Ground flour	0.001

Designate one person for each planet, one person for the Sun, and one person for the Earth's Moon. Each person should choose the model object which represents their solar system object, and then walk (or run) to that object's scaled orbital semi-major axis on the football field. The Sun will be on the goal line of the North end zone (towards the Pan Am Center) and Pluto will be on the south goal line.

2.4 Questions About the Football Field Model

When the planets/people are in place, pay attention to the relative spacing between the planets, and the size of the planets relative to these spacings.

1) Is this spacing and planet size distribution what you expected when you first began thinking about this lab today? Why or why not? **(10 points)**

Answer the following questions using the information you have gained from this lab and your own intuition **(20 points)**:

2) Which planet would you expect to have the warmest surface temperature? Why?

3) Which planet would you expect to have the coolest surface temperature? Why?

4) Which planet would you expect to have the greatest mass? Why?

5) Which planet would you expect to have the longest orbital period? Why?

6) Which planet would you expect to have the shortest orbital period? Why?

2.5 Take-Home Questions

Now you will work out the numbers for a scale model of the Solar System for which the size of New Mexico along Interstate Highway 25 will be the scale.

Interstate Highway 25 begins in Las Cruces, just southeast of campus, and continues north through Albuquerque, all the way to the border with Colorado. The total distance of I-25 in New Mexico is 455 miles. Using this distance to represent the Sun to Pluto distance (40 AU), and assuming that the Sun is located at the start of I-25 here in Las Cruces and Pluto is located along the Colorado-New Mexico border, you will determine:

- the scaled locations of each of the planets in the Solar System; that is, you will determine the city along the highway (I-25) each planet will be located nearest to, and how far north or south of this city the planet will be located. If more than one planet is located within a given city, identify which street or exit the city is nearest to.
- the size of the Solar system objects (the Sun, each of the planets) on this same scale, for which 455 miles ($\sim$ 730 kilometers) corresponds to 40 AU. Determine how large each of these scaled objects will be (probably best to use feet; there are 5280 feet per mile), and suggest a real object which well represents this size. Thus, if one of the scaled Solar System objects has a diameter of 1 foot, you could suggest a soccer ball as a representative object.

If you have questions, this is a good time to ask!!!!!!

1. List the planets in our solar system and their average distances from the Sun in units of Astronomical Units (AU). Then, using a scale of 40 AU = 455 miles (1 AU = 11.375 miles), determine the scaled planet-Sun distances and the city near the location of this planet's scaled average distance from the Sun. Insert these values into Table 2.4, and draw on your map of New Mexico (on the next page) the locations of the solar system objects. **(22 points)**

Table 2.4: Planets' average distances from Sun.

Planet	**Average Distance from Sun**		**City**
	in AU	**in Miles**	
Earth	1	11.375	
Pluto	40	455	3 miles north of Raton

2. Determine the scaled size (diameter) of objects in the Solar System for a scale in which 40 AU = 455 miles, or 1 AU = 11.375 miles). Insert these values into Table 2.5. **(19 points)**

$$\textbf{Scaled diameter (feet)} = \textbf{actual diameter (km)} \times \frac{(11.4 \ mi. \ \times \ 5280 \ ft/mile)}{150{,}000{,}000 \ km}$$

Table 2.5: Planets' diameters in a New Mexico scale model.

Object	**Actual Diameter (km)**	**Scaled Diameter (feet)**	**Object**
Sun	$\sim$ 1,400,000	561.7	
Mercury	4,878		
Venus	12,104		
Earth	12,756	5.1	height of 12 year old
Moon	3,476		
Mars	6,794		
Jupiter	142,800		
Saturn	120,540		
Uranus	51,200		
Neptune	49,500		
Pluto	2,200		


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