Introduction to the Solar System

A: What is the Solar System?

Among otherwise well-educated people, it is common to hear the terms Solar System, Galaxy, and Universe interchanged. For instance, you might hear "Jupiter is the biggest planet in the Galaxy," or the question, "How many stars are there in our solar system?" These may seem silly to those who know a bit about the subject, but even knowledgeable people are not really sure what constitutes the solar system, what objects are part of it and what objects are not--in short, what constitutes the boundary between our solar system and the rest of the galaxy. This lecture will hopefully give you a feeling for what is part of the solar system and what is not, and will also give you some idea of the size scale of the solar system.

As the name implies, the *solar system* has something to do with the Sun, or Sol. (Incidentally, the words Sun, Moon, Earth, Mars, etc., should be capitalized since they are proper names.) The Sun dominates and controls the solar system, mainly by its gravitational influence (keeping the planets in their orbits), but of course its light, heat, and other forms of energy are important also. We will learn of another important way that the Sun dominates its surroundings--through its magnetic field.

Most people would agree that the solar system is made up of

- the Sun
- the planets

and probably would include

- the asteroid belt.

However, there are also

- other asteroids
- comets
- meteoroids
- dust
- even elementary particles (protons and electrons of the solar wind).

The subjects of this course will include all of these things, and we will learn about them from the point of view of *physics*. The language of physics is *mathematics*. To quote from Galileo:

> Philosophy is written in this grand book, the universe, which stands continually open to our gaze. But the book cannot be understood unless one first learns to comprehend the language and to read the alphabet in which it is composed. It is written in the language of mathematics, and its characters are triangles, circles, and other geometric figures, without which it is humanly impossible to understand a single word of it; without these, one wanders about in a dark labyrinth. **Galileo in *The Assayer.***

We will be using the somewhat more advanced language of algebra, trigonometry, calculus, and even a bit of simple differential equations. I hope and expect that you have learned this language well, although we will go over some of it in review as we go along. If you find yourself in a "dark labyrinth," come and see me for help.

B: The Sun and Planets

Let us list the major components of the solar system, the Sun and planets, in order of their distance from the Sun.

- Sun
- Mercury
- Venus
- Earth
- Mars
- Jupiter
- Saturn | S
- Uranus | U -- Spells SUN (helps to remember the order)
- Neptune | N
- Pluto (dwarf planet)

1. Scaling the Solar System

We want to get a feeling for the immense size of the solar system. To do that, we will look at distances and sizes of the planets, and try to put them into a scale that we can understand.

There are important tables in Appendix C of the text (Solar System Data, page A-1). We will be referring to these tables often during the course of the semester, and in homework problems you may be asked a question that requires information from these tables, *without the problem telling you where to find the information*. You should get familiar with what is in these tables. Another great place to find this and more information is at the Calsky web page . For now, we are especially interested in two of the tables in the text--Planetary

Physical Data and Planetary Orbital Data--in particular, in the second table we want the semi-major axis of the orbits, and in the first table we want the equatorial radius of each planet. We will also need the radius of the Sun, from Appendix A (front cover of the book). The semi-major axes are given in AU (astronomical unit), which is the distance from Sun to Earth, given in Appendix A as 1.496 x 10^{11} m, but just think of it as 150 million km. The equatorial radii are given in Earth radii, given in Appendix A as 6378 km. Let's make our own table:

Object	**Orbital Radius** *D* **(x 10^6 km)**	**Equatorial Radius** *R* **(km)**	D/R_o	R/R_o
Sun	---	696,000	---	1.0
Mercury	57.9	2,439	83.2	0.0035
Venus	108.2	6,052	155.5	0.0087
Earth --Moon	149.6	6,387 1,738	215	0.0092 0.0025
Mars	228.0	3,393	327.6	0.0049
Jupiter	779.3	71,398	1118	0.1026
Saturn	1427	60,000	2050	0.0862
Uranus	2871	25,559	4125	0.0367
Neptune	4497	24,800	6461	0.0356
Pluto	5913	1,140	8496	0.0016

Now, looking at these numbers, we get a really good notion of the vast scale of the solar system, right? ...No! It is not possible to comprehend the scale by looking at numbers alone.

2. The Thousand-Yard Model

Let's build a scale model of the solar system, right here in this room. First we need to choose a convenient scale. Note that the whole purpose of this exercise is to allow you to get a "gut-feeling" for the size and scale of the solar system, and since for better or worse, we use inches, yards, and miles in the U.S., it is better to use those units here. This is the *only* time we will do so. Elsewhere in this course, we will use MKS (meter-kilogram-second) units.

Since the Sun is 696,000 km in radius, its diameter in miles is about 860,000 miles. Let us choose 1" = 100,000 miles, so that our Sun will be about 8.6 inches in diameter. This same scale gives the radius of the Sun in yards as 4.3 inches/36 inches/yd = 0.12 yd. So let's make a new table using this scale:

Object	Distance *D* (yards)	Diameter *R* (inches)	Model Object
Sun	---	8.6	Melon
Mercury	10	0.03	Mustard seed
Venus	19	0.08	Peppercorn
Earth --Moon	26	0.08 0.02	Peppercorn
Mars	39	0.04	Mustard seed
Jupiter	134	0.88	Walnut
Saturn	246	0.74	Acorn
Uranus	495	0.32	Peanut
Neptune	775	0.31	Peanut
Pluto	1020	0.01	Mustard seed

We will now take volunteers to "be" the planets, hold the object, and pace off the distance. Since each step is about 1 yd, we can pace off the distance easily. The rest of this lecture takes place outside. See The Thousand-Yard Model for a description and more information.

C. What we have Learned

As a result of this lecture, you should have a much better idea of the scale and size of the solar system. For the next few weeks we will be discussing the motions of planets and other solar system bodies, both as seen from our vantage point on the Earth and as would be seen from a fixed point in space. When we discuss planetary orbits, we will get into some rather heavy mathematics and physics, but keep in mind that we are talking about something really very simple--the motions of these little "seeds and nuts" in a vast volume of empty space, under the influence of a far-reaching, but rather weak central force, the force of gravity.