ES 104 Laboratory # 2
INVESTIGATING THE SOLAR SYSTEM

Introduction

We have sent unmanned spacecraft through the solar system, landed robot space probes on Mars, Venus, and the Moon, have landed people on the Moon, and have sophisticated telescopes to obtain data. We know that each planet and satellite (moon) has unique physical characteristics that set them apart from one another. We also know our solar system exhibits some regular patterns. During this laboratory you will try to discover some of these patterns. Much of the numerical data about our solar system, such as planetary size or distance from Sun, is so large that you will need to work with scale models. By studying planetary data we can compare and contrast conditions on other planets and their satellites (moons) to those of Earth.

Goals and Objectives

- Describe similarities and differences among planets of our solar system
- Create scale models and make sketches that reasonably portray observations of components of the solar system
- Create graphs to communicate and interpret data from a variety of sources
- Use internet resources which contain current information on the solar system and cosmos

Useful Websites

- http://www.nineplanets.org
- http://pds.jpl.nasa.gov/planets
- http://photojournal.jpl.nasa.gov/index.html
- http://www.noao.edu/

Name_________KEY_________________________

Lab day _______Lab Time_______________________

Pre-lab Questions – Complete these questions before coming to lab.

1. Define the Astronomical Unit (AU).

Distance from Earth to Sun 1 AU = 9.3×10^7 miles = 1.5×10^8 km

2. If the distance from Monmouth to Washington D.C. is 2870 miles, convert this distance to units of AUs. (Show calculations with units.)

$$\boxed{\frac{2870\ mi.}{1} \times \frac{1\ \text{AU}}{93000000\ mi} = 3.086 \times 10^{-5}\ \text{AU}}$$

3. List the planets in order of increasing distance from the sun.

Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, (Pluto)

4. What are the three types of materials that make up the planets?

Gases,
Ices (water, carbon dioxide, methane, ammonia),
Rocky material (including metal)

5. Which planet is the largest in the solar system?

Jupiter

6. Which planet is covered in liquid water?

Earth

7. Which planet is the hottest planet?

Venus

Part A – Scale Model of The Solar System

An *astronomical unit*, AU, is the average distance Earth is from Sun. That distance is 93,000,000 miles, 8.3 light-minutes, or 150,000,000 kilometers. It is convenient to work with AUs because the real distances are in numbers that can be cumbersome to deal with. Table 1 below shows the mean distance of the planets from Sun (orbital distance) in AUs. Alternatively, you might find the orbital distances in terms of light-minutes more illuminating (pun intended). Choose which system of units you feel more comfortable with.

Your group will construct a scale model of the solar system based on average distance to Sun. Your model must fit in the hallway (54 meters long), the classroom, or outside (weather permitting). You must decide the scale you will use for your model. Additionally, place the satellites of each planet alongside their appropriate "host" planet.

Table 1: Solar System Data

Planet	**Radius of Planet** (Kilometers)	**Mean Distance from Sun** (AU)	**Radius of Planet** (millionths of AU)	**Mean Distance from Sun** (Light-Minutes)
Mercury	2439	0.39	16	3.25
Venus	6052	0.72	40	6.00
Earth	6378	1.00	42	8.33
Mars	3393	1.52	23	12.6
Jupiter	71,492	5.20	477	43.3
Saturn	60,268	9.54	402	79.5
Uranus	25,559	19.20	170	160
Neptune	24,766	30.10	165	250
Pluto *	1137	39.40	8	328
Sun	696,000	N/A	4,640	N/A

*The IAU has changed the definition of "planet" so that Pluto no longer qualifies. There are now officially only eight planets in our solar system. Of course this change in terminology does not affect what's actually out there. It is much smaller than any of the official planets and now classified as a "dwarf planet". Pluto is smaller than seven of the solar system's moons (the Moon, Io, Europa, Ganymede, Callisto, Titan and Triton). http://www.nineplanets.org/ 9-7-2006

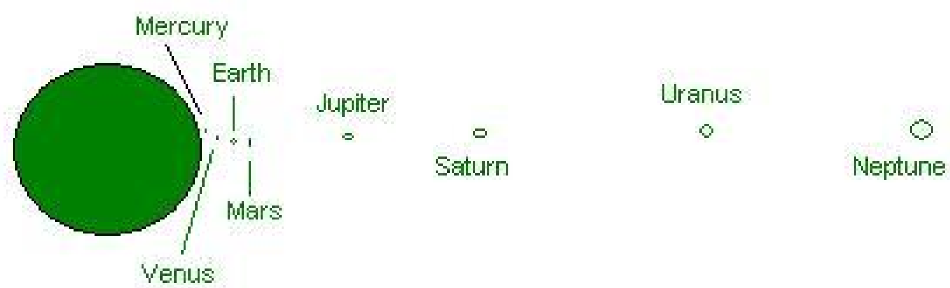
Questions:

1. What scale did you use for your distance?

2. What pattern did you notice about the spacing of the planets from Sun?

Inner planets very close to one another and to Sun
Outer planets much further apart

3. Draw a sketch of your model (with spacing **generally to scale**) below. (sizes of planets not to scale, distance estimated to scale)



4. What general pattern did you notice about the relative sizes of the planets?

Small close to Sun, Large very far away

5. Which planets have the greatest number of satellites (moons)? Note that not all of the satellites in our solar system are shown. In fact new satellites are being discovered every few years.

Jupiter, as of 2007, has 63. Saturn has 60, not counting ring debris.

Table 2: Planet Data

	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto*
Mass ($x10^{24}$ kg)	0.3302	4.869	5.975	0.6419	1,898.6	568.46	86.83	102.43	0.0125
Radius (km)	2439	6052	6378	3393	71,492	60,268	25,559	24,766	1137
Mean Density (kg/m^3)	5,427	5,204	5,520	3,933	1,326	687	1,318	1,638	2,050
Orbital Distance (10^6 km)	57.9	108.2	149.6	227.9	778.3	1427.0	2869.6	4496.6	5913.5
Orbital Period (in Earthdays)	87.969	224.7	365.25	686.98	4330.6	10,747	30,588	59,800	90,591
Rotational Period (in hours)	1407.6	5832.5	23.934	24.62	9.92	10.5	17.24	16.11	153.3
Ave. Surface Temperature (Kelvin)	440	737	288	210	165	134	76	72	50
Surface Pressure	10^{-15} bars	92 bars	1.014 bars	0.008 bars	>>100 bars	>>100 bars	>>100 bars	>>100 bars	3 micro-bars
Atmospheric Composition	98% He 2% H2	96.5% CO_2, 3.5% N_2	78% N_2, 21% O_2, 1% H_2O	95.32% CO_2, 2.7% N_2	90% H_2, 10% He	96% H_2, 3% He	83% H_2, 15% He 2% CH_4	80% H_2, 19% He 1% CH_4	methane & N2

Table 3: Density of Common Materials.

Material	Density
Air	1.2 kg/m^3
Water or Water-Ice	1000 kg/m^3
Typical Rocks	3000 kg/m^3
Metal at High Pressure	10,000 kg/m^3

*see footnote page 2-3

Part B – Classifying the Planets

Study the solar system information in Table 2. The table provides information scientists believe to be true about the planets in the solar system based on the latest technology to help them. **By looking carefully at the data in this table you should be able to find some patterns, similarities, and differences among the planets in our solar system.** The following questions will assist you in thinking about what is considered a pattern, similarity, and difference. You should also look over Table 3 which contains density information and investigate densities of the air, water, rock, and lead ore samples (lead ore approximates the density metal at high pressure). Because all of the samples have the same volume, you can investigate the effect of density directly by picking each one up and comparing their masses.

On the back of this sheet, make four tables: each table should contain all of the planets, and be based on a different property of the planets. Use the properties of the planets (in table 2) to group them into general categories. For example, using the property of density, you could place the planets into two groups, high density planets and low density planets. Or perhaps the density data suggests that low, medium and high density groupings are more appropriate. Let the data be your guide to the number and types of groups. (The tables should not be lists in an order, but divisions into groups of similar characteristics, based on the properties of the planets.)

Label each table with the title of the property used to construct it, and include column headings showing your method of grouping the planets. In the space below, write any general statements you can draw from your study of properties that could be cited as patterns in the solar system.

Orbital distance and orbital period proportional

Examples of classifications. You may have used three divisions of the group of planet for one or another parameter.

Small Mass	Large Mass
Mercury	Jupiter
Venus	Saturn
Earth	Uranus
Mars	Neptune
(Pluto)	

Small radius	Large radius
Mercury	Jupiter
Venus	Saturn
Earth	Uranus
Mars	Neptune
(Pluto)	

Low density	High density
Jupiter	Mercury
Saturn	Venus
Uranus	Earth
Neptune	Mars
	(Pluto)

Short rotation	Long rotation
Earth	Mercury
Mars	Venus
Jupiter	(Pluto)
Saturn	
Uranus	
Neptune	

Cold temperature	Hot temperature
Jupiter	Mercury
Saturn	Venus
Uranus	Earth
Neptune	Mars
Jupiter	
(Pluto)	

Low pressure	High pressure
Mercury	Venus
Earth	Jupiter
Mars	Saturn
(Pluto)	Uranus
	Neptune

Questions:

1. Which planet would float in water? ______**Saturn**___________
   (HINT: Less dense objects float in denser fluids.)

2. How long is a day on Jupiter? _9.92 hours , (answer in Earth hours)

   on Venus? ___5832 hours .   on Mars? 24 hours, 37 minutes _

3. How many Earth years go by before one Mars year has passed?1.88
   Show work here.

   $$\boxed{\frac{687}{365} = 1.8821918...}$$

4. Which two planets account for 90% of the total mass of all of the planets?

   Saturn and Jupiter

5. Which planet seems unusually hot, considering its distance from

Sun? ___________Venus __________________________________

6. By looking at the data in Table 2, suggest a reason for this extreme high temperature. Carbon Dioxide atmosphere
7. Estimate the relative densities (from the mass) of the four samples by picking them up. (Density = Mass/Volume and the samples chosen all have similar volumes). For each sample, note in the spaces below how many times larger or smaller the density is compared to water.
   a. Air seems to be ______1000___________ times **less dense** than water.
   b. Rock seems to be _____3-5________________ times **more dense** than water.
   c. Metal at high pressure seems to be ___5-10______________ times **more dense** than water.

8. How do your guesses compare to Table 3?

9. What estimates can you make about the bulk composition of each planet **based upon its density**? Table 3 provides information about the density of common materials found on Earth. Compare the **density** of metal, rock, water ice, and gas (in Table 3) to the *mean density* of each planet **from Table 2**. ***Rely on Tables 2 and 3****; not other information.*

(HINT: You can answer in terms of *mostly* metal, rock, ice, or gas; or *combinations* of these.)

Table 4:

Planet	Deduced Composition
Mercury	.Rock and metal
Venus	.rock and metal
Earth	.rock and metal
Mars	.mostly rock
Jupiter	.mostly water, a little rock
Saturn	.water and air
Uranus	..mostly water, a little rock
Neptune	..mostly water, a little rock

Part C – Graphing Planetary Data

Sometimes graphs can give you a different perspective about data that reading a table cannot. In this activity you will graph selected data. You will graph one set from the list below. Graph paper is provided at the end of this lab, on pages 2-11 and 2-12.

Activity:

Each person in your group should make a different graph of one of the sets of data listed below. When you are completed, present your graph and your conclusions about your graph to the rest of the members of your group.

- Mean Density vs. Orbital Distance from Sun
- Surface Temperature vs. Orbital Distance from Sun
- Orbital Period vs. Orbital Distance from Sun
- Rotational Period vs. Orbital Distance from Sun
- Mass vs. Orbital Distance from Sun

In the space below, report the title, presenter and results of **each** graph (the conclusions presented by your group member). Consider the following questions: What does each graph tell you? Is there a relationship between the two quantities being graphed? If a relationship exists, try to construct an explanation for the relationship. (These questions will require a long answer so feel free to use the back of the page, if you use all the space below.) Also, be sure to include **your graph** with your report.

Graphs for key are after the postlab.

1. Title: ____________________ Presenter: ___________________

2. Title: ____________________ Presenter: ___________________

3. Title: ____________________ Presenter: ___________________

4. Title: ____________________ Presenter: ___________________

Some general trends noted from graphs

- Density in greater closer to Sun, but increases slightly after Saturn
- Temperature decreases with distance from Sun, except for Venus
- Period increases with distance from Sun—Kepler's Law!
- Inner planets are small, outer planets are huge

Name_____**KEY**_________________________

Lab day ______Lab Time_____________________

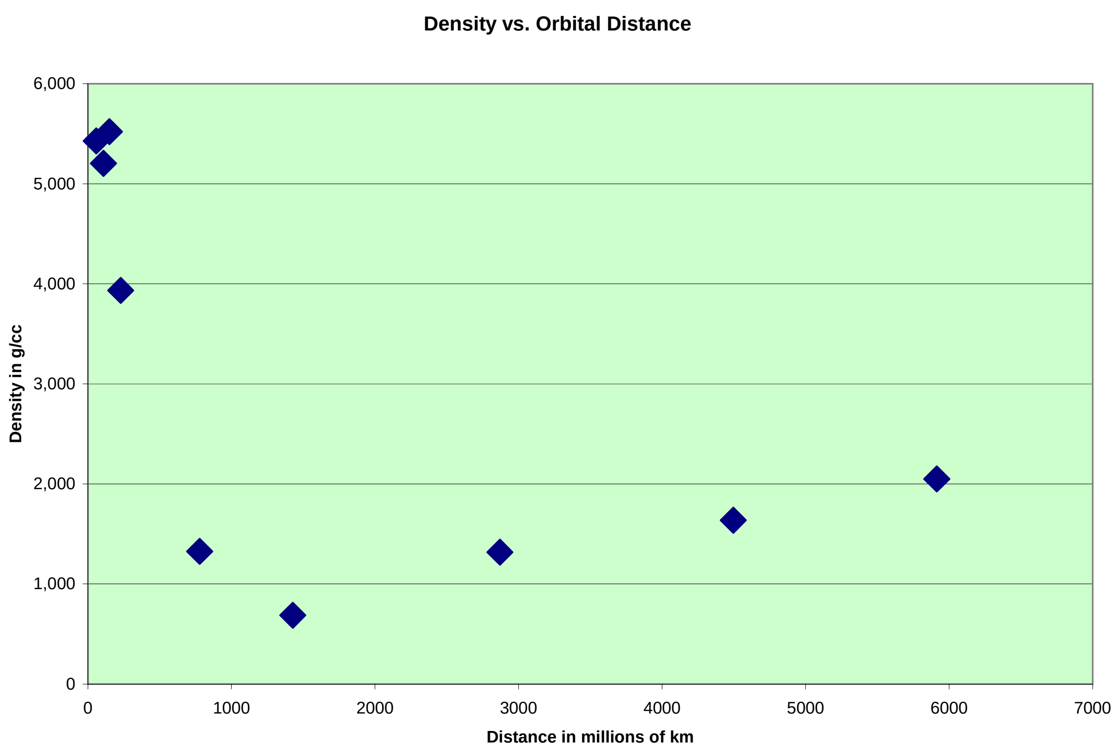
POST LAB ASSESSMENT

1. Consider the uniqueness of Earth compared to the other planets in our solar system. Make a table that identifies the characteristics Earth shares with other planets and characteristics that are unique to Earth.

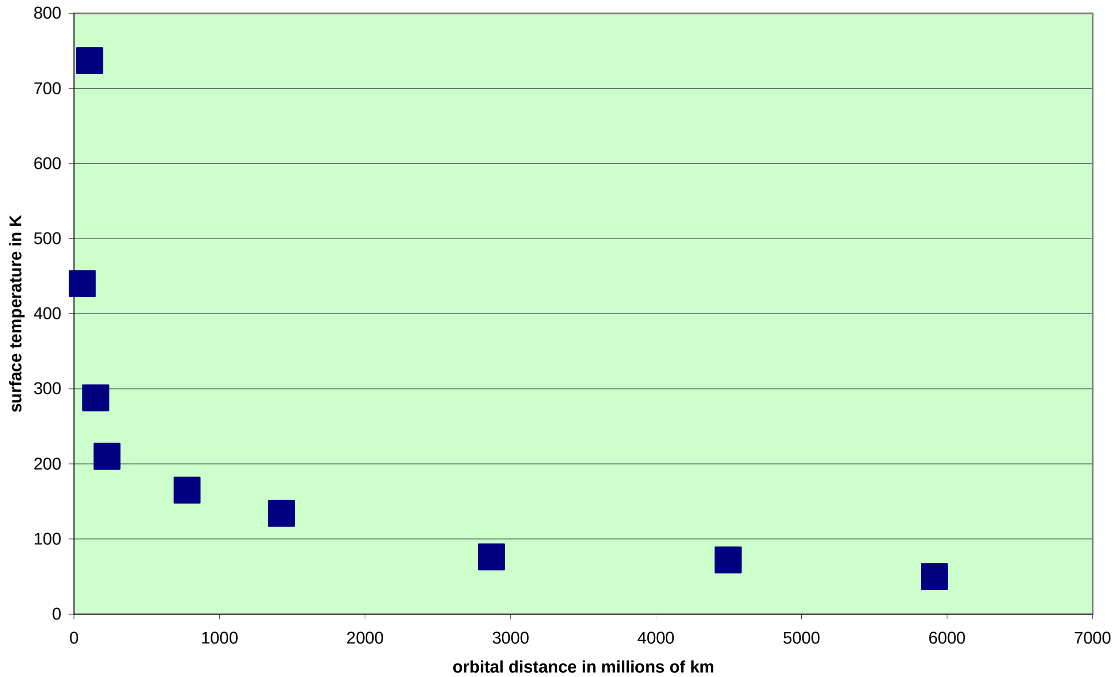
Earth Characteristic	Planets that share this characteristic	Planets that are different in this characteristic
Mass	Venus, (Mars, Mercury)	Jupiter, Saturn, Uranus, Neptune
Density	Mercury, Venus, (Mars)	Jupiter, Saturn, Uranus, Neptune
Atmospheric composition	None	All
Another characteristic of your choice Radius:	Venus, (Mars, Mercury)	Jupiter, Saturn, Uranus, Neptune
Orbital distance	Venus, Mars, (Mercury)	Jupiter, Saturn, Uranus, Neptune
Rotational Period	Mars, (Jupiter, Saturn, Uranus, Neptune)	Venus, Mercury
Surface Temperature	Mars	All others but Mars
Surface Pressure	Not any	All others

2. In the past two labs, you have explored information in a number of ways: physical models, pictorial models (sketches/diagrams), data tables and graphs. Which did you find most useful in your investigations, and why do you think it was useful for you?

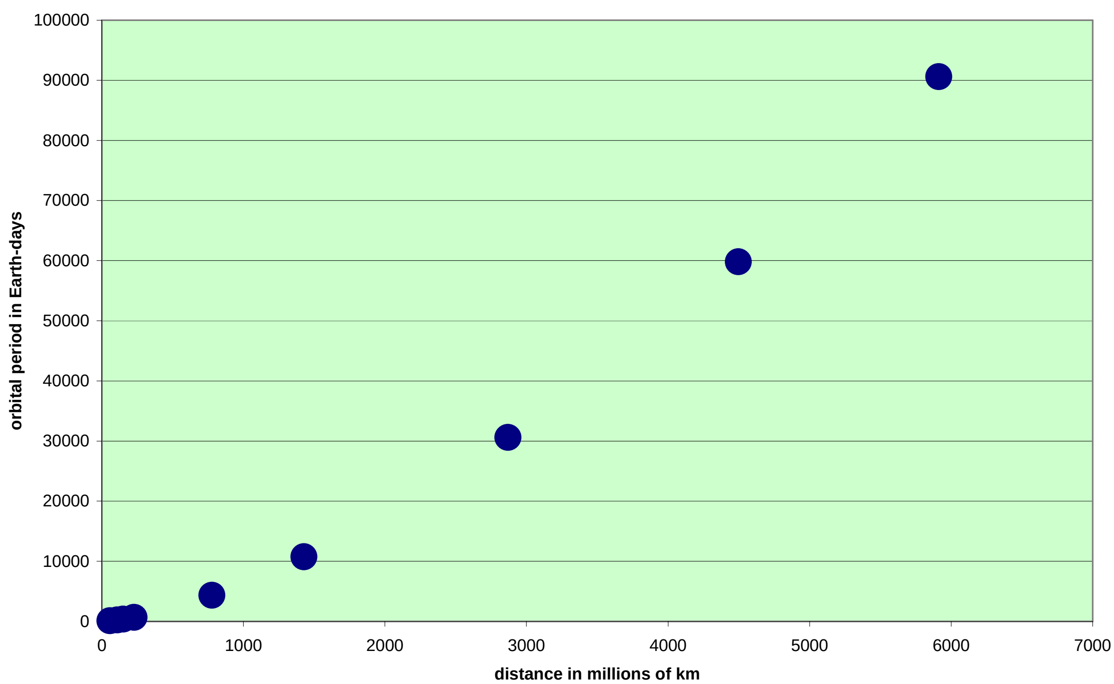
Here are examples of how your graphs may look. They were constructed as 'scatter plots' in Excel. Blank graphs follow these. Notice that the planets are not labeled, as their distance from Sun indicates which planet is which. Observe how the vertical axis is linear—each increment represents an equal quantity of the parameter graphed compared to the distance from Sun.

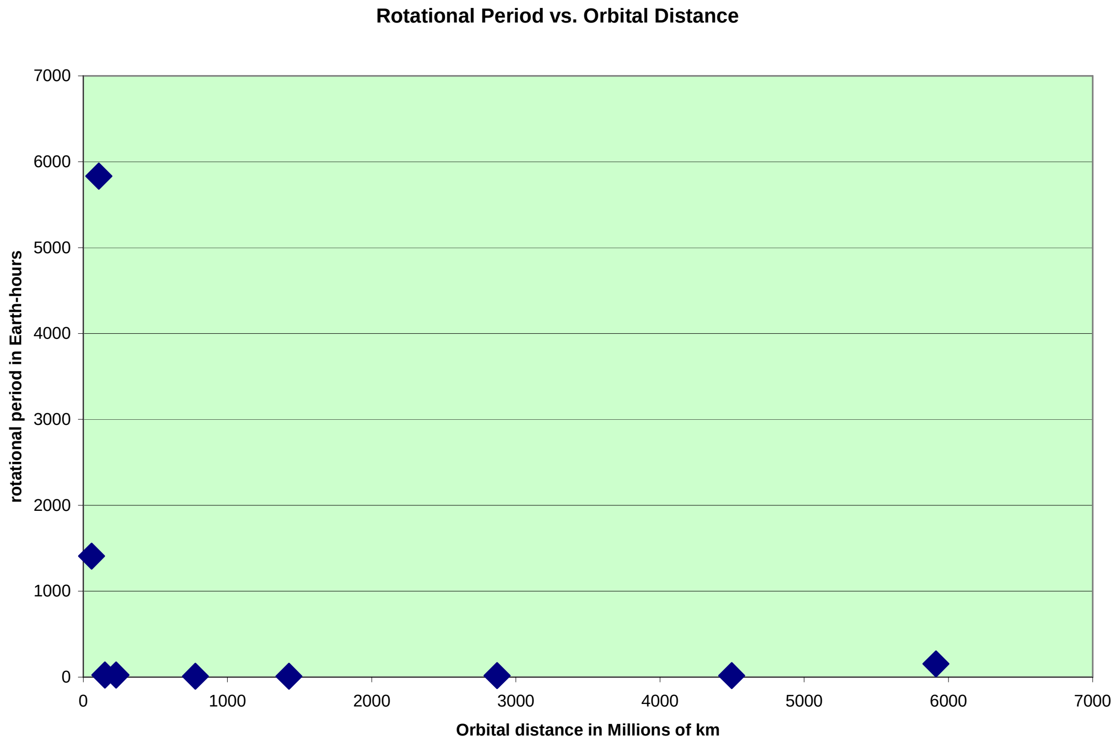


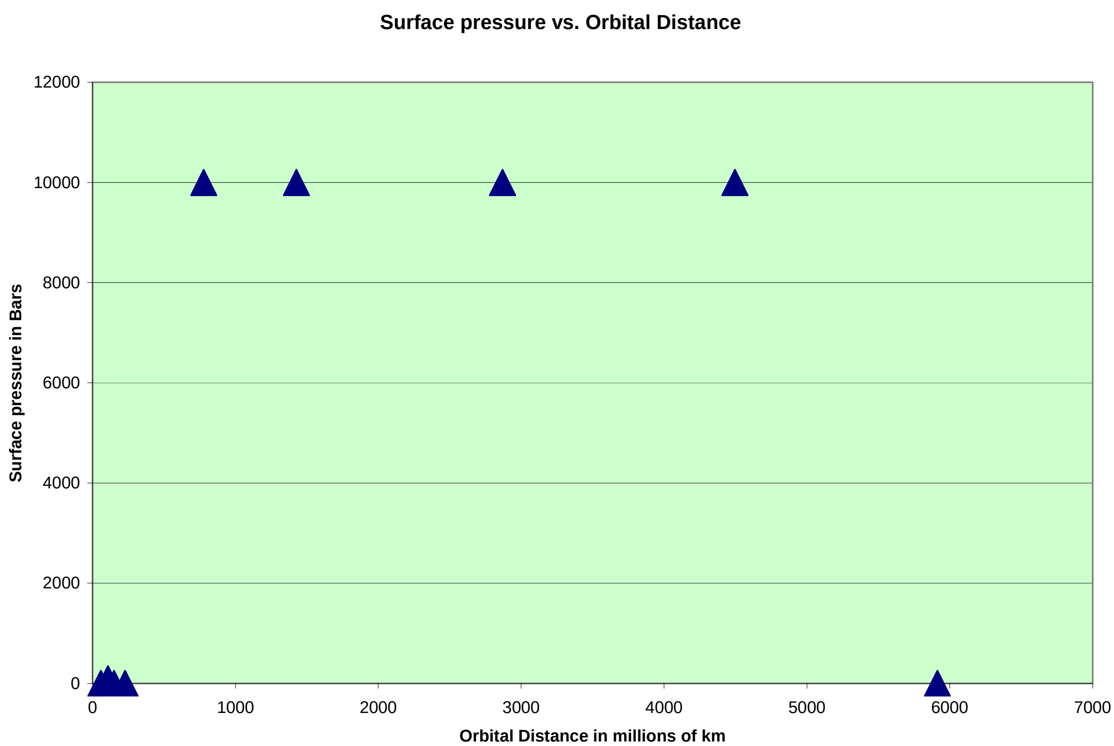
Surface temperature vs. orbital distance

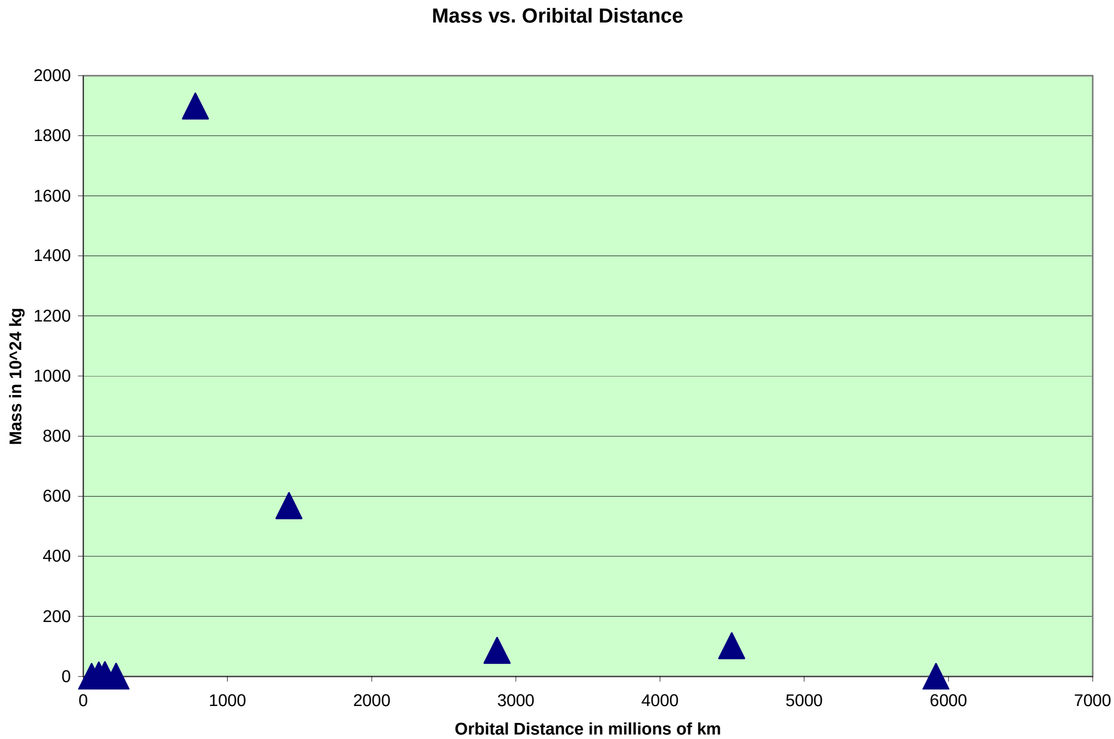


Orbital Period vs. Orbital Distance

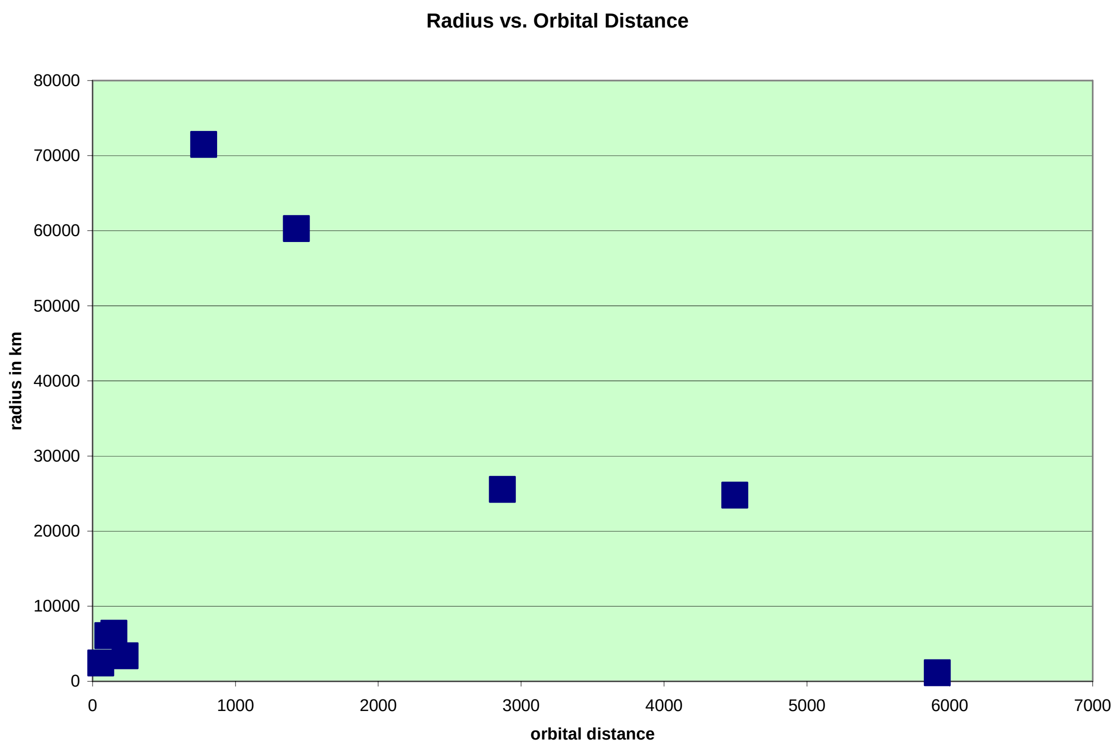



Rotational Period vs. Orbital Distance
rotational period in Earth-hours
Orbital distance in Millions of km
0
1000
2000
3000
4000
5000
6000
7000


Surface pressure vs. Orbital Distance
Surface pressure in Bars
Orbital Distance in millions of km
0
2000
4000
6000
8000
10000
12000
1000
3000
5000
7000



Mass vs. Oribital Distance
Mass in 10^24 kg
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
1000
2000
3000
4000
5000
6000
7000
Orbital Distance in millions of km



Radius vs. Orbital Distance
radius in km
80000
70000
60000
50000
40000
30000
20000
10000
0
0
1000
2000
3000
4000
5000
6000
7000
orbital distance