ES 104 Laboratory # 2 (Summer 2022)
INVESTIGATING THE SOLAR SYSTEM

Introduction

TASK 1 – before you begin this lab, watch a short 14-minute YouTube video tour of our solar system at the following URL: https://www.youtube.com/watch?v=evWeRHMwSu0

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 the 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_______________________________________

Lab day ______Lab Time______________________

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

1. Define the Astronomical Unit (AU).

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

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

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

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

6. Which planet is covered in liquid water?

7. Which planet is the hottest planet?

Part A – Scale Model of The Solar System

An *astronomical unit*, AU, is the average distance the Earth is from the 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 the 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 the 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. (HINT: a good scale to start with is 1 AU = 3 floor tiles)~~

Table 1: Solar System Data

Planet	**Radius of Planet** (Kilometers)	**Mean Distance from the Sun** (AU)	**Radius of Planet** (millionths of AU)	**Mean Distance from the 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), is composed of about 1/3 ice, and has a highly eccentric orbit. 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 the Sun?

3. Draw a sketch of your model (with spacing **generally to scale**) below.

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

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.

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 (days)	87.969	224.7	365.25	686.98	4330.6	10,747	30,588	59,800	90,591
Rotational Period (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.**

Questions:

1. Which planet would float in water? _________________________
   (***Hint***: Less dense objects float in denser fluids.)

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

   on Venus? _________________, on Mars? _________________

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

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

_________________________ and _____________________________

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

____

By looking at the data in table 2, suggest a reason for this extreme high temperature.

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.

6. Compare the density of materials to the density of water. (Density = Mass/Volume and the samples chosen all have similar volumes). Pick up each sample and guess how its density compares to water. For each sample, note in the spaces below how many times larger or smaller you think the density is compared to water.
   a. Air seems to be _____________________ times **less dense** than water.
   b. Rock seems to be _____________________ times **more dense** than water.
   c. Metal at high pressure seems to be _____________________ times **more dense** than water.

7. How do your guesses compare to Table 3?

8. 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**.

(HINT: You can answer in terms of *mostly* metal, rock, ice, or gas; or *combinations* of these.) ***Rely on tables 2 and 3****; not other information.*

Table 4:

Planet	Deduced Composition
Mercury	.
Venus	.
Earth	.
Mars	.
Jupiter	.
Saturn	.
Uranus	.
Neptune	.

On page 1.9, make four tables: each table should contain all of the planets, and be based on a different property of the planets. Use properties of the planets (in Table 2) to group them into general categories. Write the property used for the classification in each table, and column headings for how you divided the planets using that property. 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 that a particular property requires. (*The tables are not lists in an order, but divisions into groups of similar characteristics, based on the properties of the planets.*)
Write any general statements you can draw from your study of properties that could be cited as patterns in the solar system.

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 from Table 2 (page 1.5). Graph paper is provided at the end of this lab (on pages 1.11 and 1.12), or you can use a spreadsheet to make a chart.
Activity: Graph the data sets below from Table 2

- _______________Mean Density vs. Orbital Distance from Sun
- _______________Surface Temp. vs. Orbital Distance from Sun
- _______________Orbital Period vs. Orbital Distance from Sun
- _______________Rotational Period vs. Orbital Distance from Sun
- _______________Mass vs. Orbital Distance from the Sun

Consider the following questions:

What does each graph tell you?

Is there a relationship between the two quantities being graphed?

If a relationship exists, provide an explanation for the relationship.

Write the name of the property used to categorize the planets.
Subdivide each area to categorize the planets based on properties

Table A: ___________________	**Table B:** ___________________
Table C: ___________________	**Table D:** ___________________

General Statements about categories:

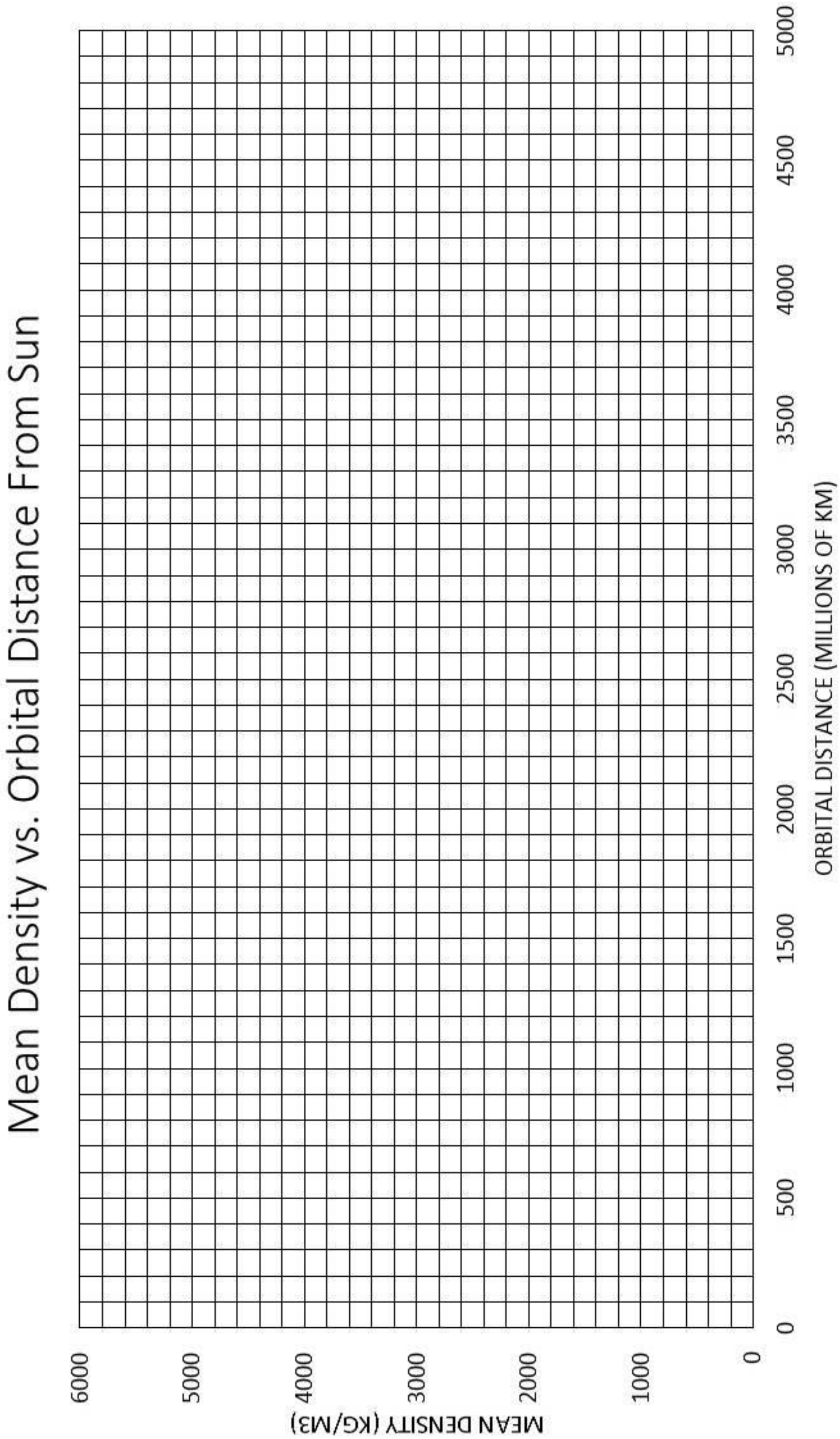
Name______________________________________
Lab day ______Lab Time______________________

POST LAB ASSESSMENT

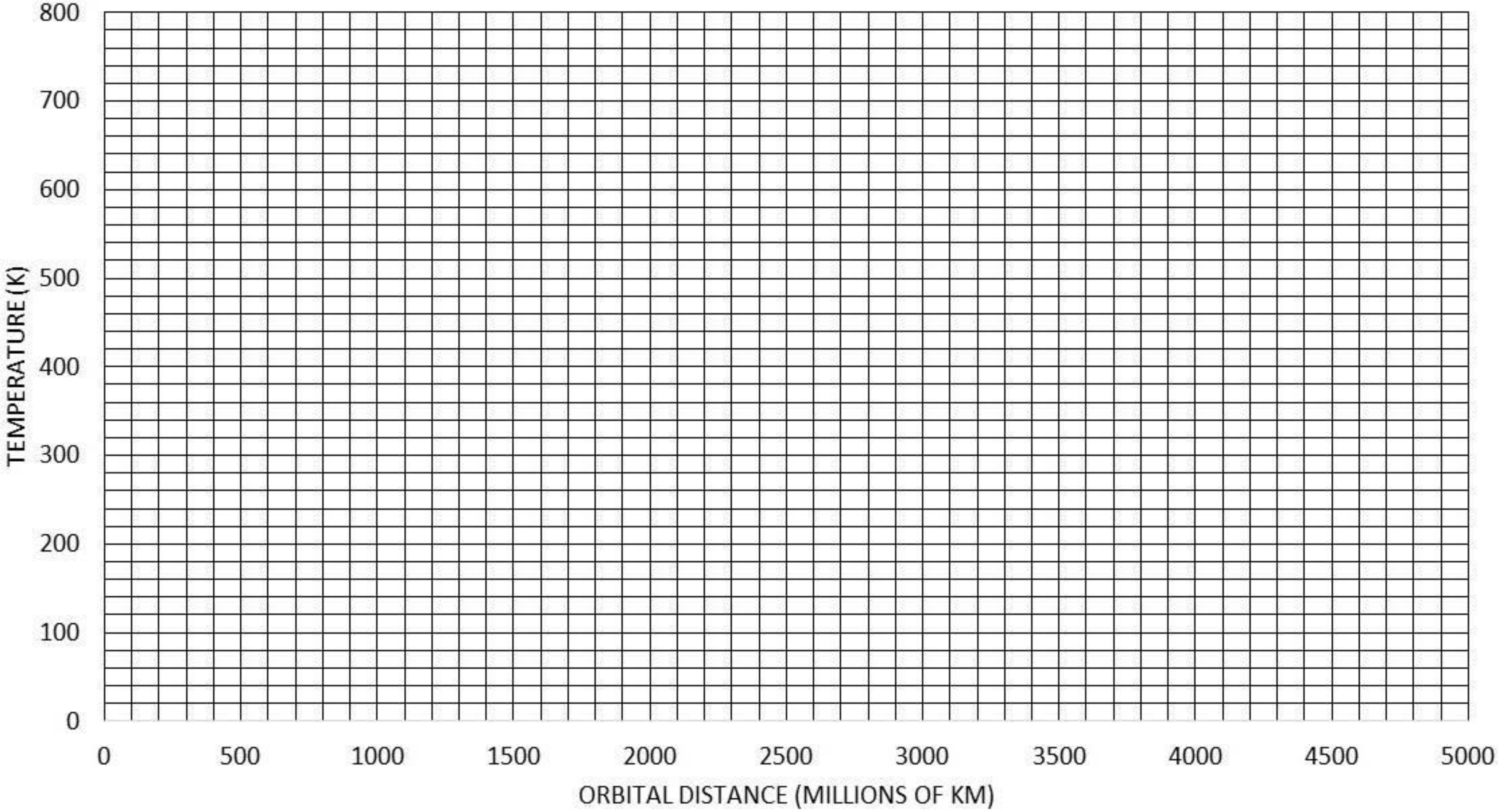
1. Consider the uniqueness of Earth compared to the other planets in our solar system. Make a table that identifies the characteristics Earth shares with other planets and characteristics that are unique to Earth.

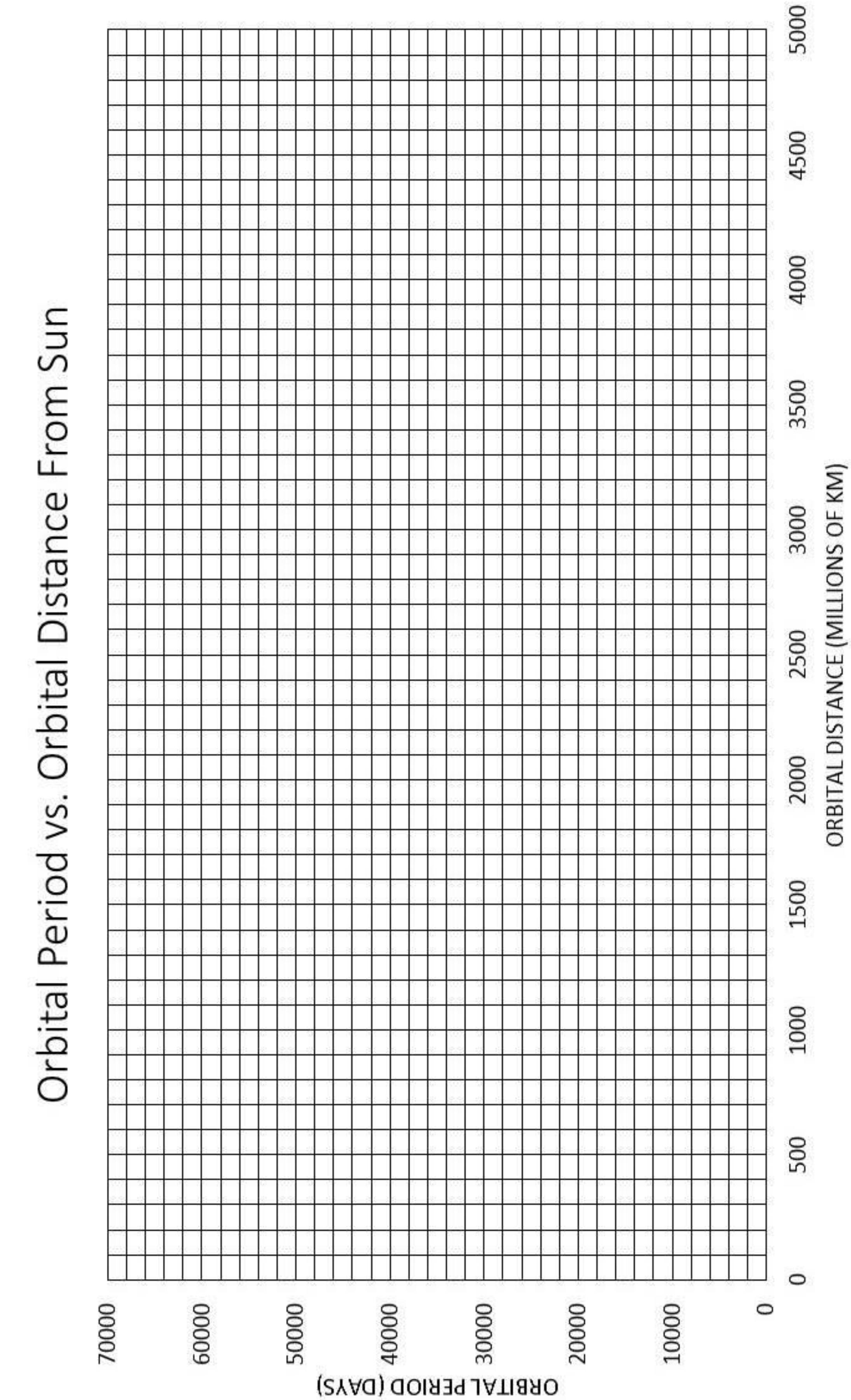
Earth Characteristic	Planets that share this characteristic with Earth	Planets that are different in this characteristic
Mass		
Density		
Atmospheric composition		
Another characteristic (write your choice)		

1. 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?

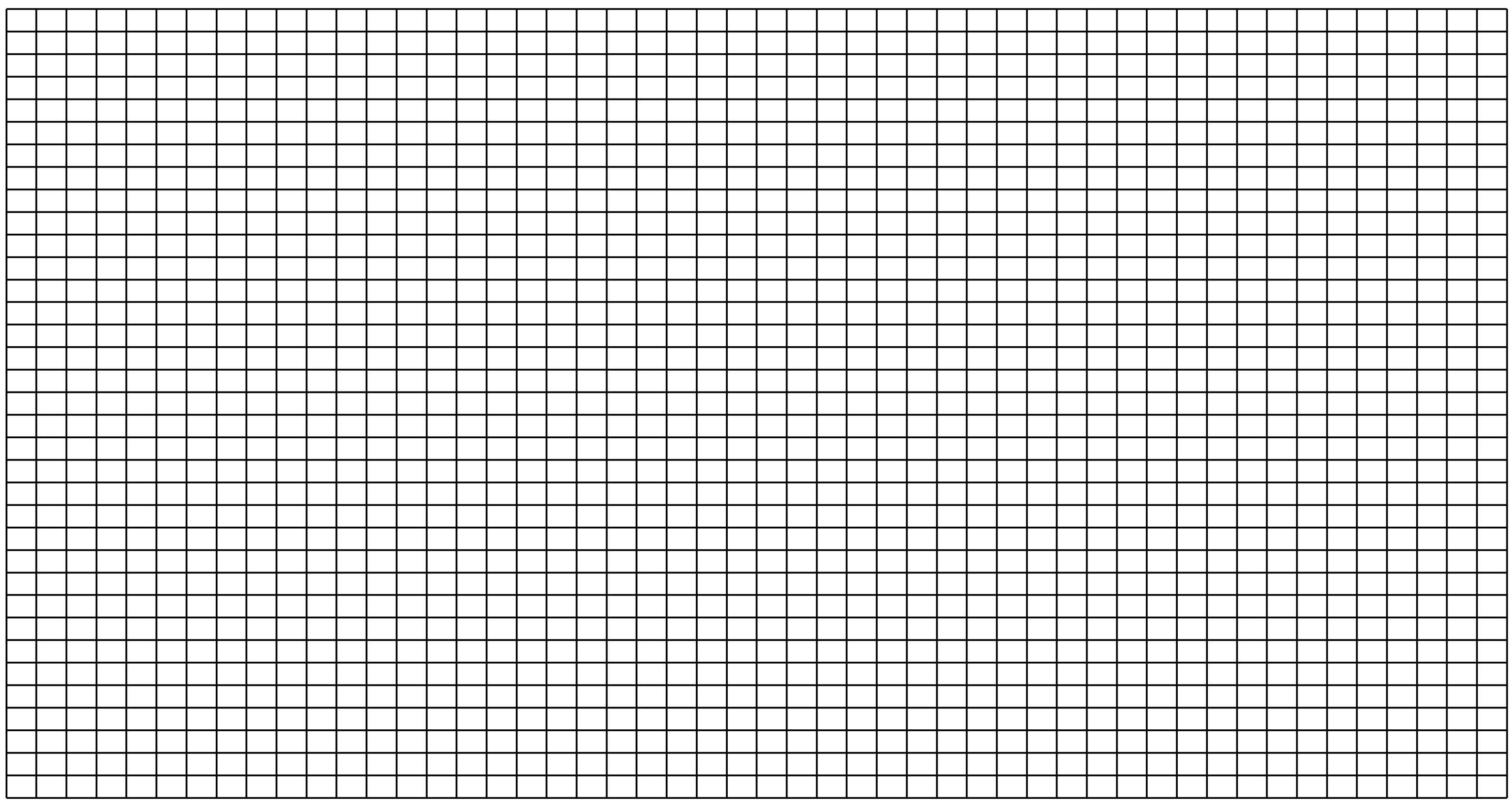

Mean Density vs. Orbital Distance From Sun
MEAN DENSITY (KG/M3)
6000
5000
4000
3000
2000
1000
0
ORBITAL DISTANCE (MILLIONS OF KM)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

Temperature vs. Orbital Distance From Sun




Orbital Period vs. Orbital Distance From Sun
ORBITAL PERIOD (DAYS)
70000
60000
50000
40000
30000
20000
10000
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
ORBITAL DISTANCE (MILLIONS OF KM)

______________ vs. Orbital Distance From Sun



0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000

ORBITAL DISTANCE (MILLIONS OF KM)