Patterns in the Solar System (Chapter 18)

For this assignment you will require: a calculator, colored pencils, a metric ruler, and meter stick. **Objectives:** you should be able to describe the appearance of the solar system when it is viewed along the plane of the ecliptic; summarize the distances and spacing of the planets in the Solar System; summarize and compare the physical characteristics of the terrestrial and Jovian planets; and describe the motions of the planets in the Solar System.

THE FOLLOWING QUESTIONS REFER TO CHAPTER 18 IN YOUR MANUAL

(Read the questions from your manual and place your answers in the following spaces provided.)

Table 18.1 Planetary Data: (Use this data to answer the following questions.) (I have included data for Pluto for comparison)

<table>
<thead>
<tr>
<th>Planet</th>
<th>Symbol</th>
<th>AU*</th>
<th>Millions of Miles</th>
<th>Millions of Kilometers</th>
<th>Period of Revolution</th>
<th>Inclination of Orbit</th>
<th>Orbital Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>☉</td>
<td>0.39</td>
<td>36</td>
<td>58</td>
<td>88°</td>
<td>7°00’</td>
<td>29.5</td>
</tr>
<tr>
<td>Venus</td>
<td>☉</td>
<td>0.72</td>
<td>67</td>
<td>108</td>
<td>225°</td>
<td>3°24’</td>
<td>21.8</td>
</tr>
<tr>
<td>Earth</td>
<td>☉</td>
<td>1.00</td>
<td>93</td>
<td>150</td>
<td>365.25°</td>
<td>0°00’</td>
<td>18.5</td>
</tr>
<tr>
<td>Mars</td>
<td>☉</td>
<td>1.52</td>
<td>142</td>
<td>228</td>
<td>687°</td>
<td>1°51’</td>
<td>14.9</td>
</tr>
<tr>
<td>Jupiter</td>
<td>☉</td>
<td>5.20</td>
<td>483</td>
<td>778</td>
<td>12”</td>
<td>1°18’</td>
<td>8.1</td>
</tr>
<tr>
<td>Saturn</td>
<td>☉</td>
<td>9.54</td>
<td>886</td>
<td>1427</td>
<td>30°</td>
<td>2°29’</td>
<td>6.0</td>
</tr>
<tr>
<td>Uranus</td>
<td>☉</td>
<td>19.18</td>
<td>1783</td>
<td>2870</td>
<td>84°</td>
<td>0°46’</td>
<td>4.2</td>
</tr>
<tr>
<td>Neptune</td>
<td>☉</td>
<td>30.06</td>
<td>2794</td>
<td>4497</td>
<td>165°</td>
<td>1°46’</td>
<td>3.3</td>
</tr>
<tr>
<td>Pluto</td>
<td>☉</td>
<td>39.44</td>
<td>3666</td>
<td>5900</td>
<td>248 yr</td>
<td>17°12’</td>
<td>2.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Planet</th>
<th>Mean Surface Temp. (°C)</th>
<th>Period of Rotation</th>
<th>Diameter</th>
<th>Relative Mass (Earth = 1)</th>
<th>Average Density (g/cm³)</th>
<th>Polar Flattening (%)</th>
<th>Eccentricity*</th>
<th>Number of Known Satellites**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>167</td>
<td>59°</td>
<td>3015</td>
<td>0.06</td>
<td>5.4</td>
<td>0.0</td>
<td>0.206</td>
<td>0</td>
</tr>
<tr>
<td>Venus</td>
<td>464</td>
<td>243°</td>
<td>7526</td>
<td>0.82</td>
<td>5.2</td>
<td>0.0</td>
<td>0.007</td>
<td>0</td>
</tr>
<tr>
<td>Earth</td>
<td>15</td>
<td>23°56’30”</td>
<td>7920</td>
<td>1.00</td>
<td>5.5</td>
<td>0.3</td>
<td>0.017</td>
<td>1</td>
</tr>
<tr>
<td>Mars</td>
<td>-65</td>
<td>24°37’23”</td>
<td>4216</td>
<td>0.11</td>
<td>3.9</td>
<td>0.5</td>
<td>0.093</td>
<td>2</td>
</tr>
<tr>
<td>Jupiter</td>
<td>-110</td>
<td>9°56”</td>
<td>88,700</td>
<td>317.87</td>
<td>1.3</td>
<td>6.7</td>
<td>0.048</td>
<td>67</td>
</tr>
<tr>
<td>Saturn</td>
<td>-140</td>
<td>10°30”</td>
<td>75,000</td>
<td>95.14</td>
<td>0.7</td>
<td>10.4</td>
<td>0.056</td>
<td>62</td>
</tr>
<tr>
<td>Uranus</td>
<td>-195</td>
<td>17°14”</td>
<td>29,000</td>
<td>14.56</td>
<td>1.2</td>
<td>2.3</td>
<td>0.047</td>
<td>27</td>
</tr>
<tr>
<td>Neptune</td>
<td>-200</td>
<td>16°07”</td>
<td>28,900</td>
<td>17.21</td>
<td>1.7</td>
<td>1.8</td>
<td>0.009</td>
<td>14</td>
</tr>
</tbody>
</table>

Pluto: 6.4° d - 1500 2445 0.002 1.8 0 0.250 1 - 4

* AU = astronomical unit, Earth’s mean distance from the sun
** Includes all satellites discovered as of December 2013
† Eccentricity is a measure of the amount an orbit deviates from a circular shape. The larger the number, the less circular the orbit.

1. Mercury’s orbit is inclined within (4, 7 or 10) degrees? (Pick one)__________ All of the other planets lie within (4, 7 or 10) degrees? (Pick one)__________

2. The orbit of the icy, dwarf planet Pluto is inclined 17° to the plane of the ecliptic. When compared to the eight major planets, Pluto’s orbit is more elliptical and tilted (very little, similar to the major planets, or very much) (Pick One):
3. Considering the nebular origin of the solar system, do you think that rotation and flattening of the nebular disk had anything to do with the alignment of the major planets in our solar system? Refer to your Geology 305 lecture notes and/or handouts if necessary.

4. Describe the overall composition of the inner and outer planets, i.e. what kind of materials make up these planets?
   A. Inner Planets:
   B. Outer Planets:

5. Use the space provided for you below for your scale model of the inner Solar System (see question 8 also). Use large points to represent the four terrestrial planets and place them at the appropriate distance from the Sun. Use the mean distance from the Sun in AUs listed in table 18.1 on the first page of this packet. Measure the scale below in either cm or mm to produce the scale of this model, for example if the scale measures 1.6 cm then: 1.6 cm = 0.22 AU or 1 cm = 0.1375 AU (for example only!). Once you have your scale calculated, you can use it as a conversion factor and convert the mean distance between the terrestrial planets and the Sun into cm and plot their location on the strip provided. Don’t forget to name each planet and to include arrows to represent the orbit and spin directions for each planet. Also, write the word “Asteroids” 258 million scale miles from the Sun, keeping in mind that 1AU =93 million miles.

6. What feature of the solar system separates and/or is located between the Terrestrial planets and the Jovian planets?
   •

7. Using the information from table 18.1 (planetary data) and describe the Spacing of the terrestrial planets, are the distances short or long? Are the distances relatively constant, variable, increasing, or decreasing?

Describe the spacing of the Jovian planets, are the distances short or long?

Are the distances relatively constant, variable, increasing, or decreasing?
8. Complete table 18.2 and use the space provided to produce a scale model of the different sizes of the planets and the sun using the planetary radii, which is half of the diameter. Follow the steps outlined in your manual and fill in your planetary radii and equivalent scale model radii in the following table, using the following scale instead! Scale: 1 centimeter = 3,600 km, 10 centimeters = 36,000 km. You will be using your model to answer some of the following questions.

<table>
<thead>
<tr>
<th>Planet</th>
<th>Radius (in kilometers) = ½ the diameter</th>
<th>Scale Model radius (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Venus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Earth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mars</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jupiter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saturn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uranus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neptune</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Sun</td>
<td>Radius = ½ (1,350,000 kilometers) =?</td>
<td>Radius of Sun is:</td>
</tr>
</tbody>
</table>

Use the data from the above scale model of the planetary radii to plot the sizes of the planets in the space below. You should have several lines at various distances depicting the planetary radii. Your lines should be parallel to the line already drawn, which will also act as your starting line. The distance between the starting line and your line will represent the radius of the planet in question. Be sure to label the line with the appropriate planet name and identify if the planet is Terrestrial or Jovian. Do not plot the radius of the Sun it is too large to fit on this model.
9. Which planet is the largest of the Jovian planets_____________________ and what is its radius?

10. Summarize the sizes (max vs. min) of the planets within each group, using MILES;

   A. **Radius** of the Terrestrial Planets:  Max: vs.  Min:

   B. **Radius** of the Jovian Planets:  Max: vs.  Min:

11. Write a general statement that compares the sizes of the terrestrial planets to those of the Jovian planets.

12. Complete the following statement: “The Sun is _____________ times larger than the Earth and _____________ times larger than Neptune. You can use radius or diameter, just be consistent.

13. The diameter of the icy, dwarf planet Pluto is approximately 1,500 miles, which is about (1/3, ½, or twice) the diameter of the smallest Terrestrial planet.  **(Pick one)_______________________

**Mass** is a measure of the quantity of matter an object contains. In table 18.1 the masses of the planets are given in relation to the mass of the Earth. For example, the mass of Mercury is given as 0.056, which means that it consists of only a small fraction of the quantity of matter that Earth contains. On the other hand, the Jovian planets all contain several times more matter than Earth.

**Density** is the mass per unit volume of a substance. In table 18.1 the average densities of the planets are expressed in grams per cubic centimeter (g/cm$^3$). As a reference, the density of water is approximately one gram per cubic centimeter.

**Using the relative masses, etc. of the planets given in table 18.1 answer the following questions.**

14. Complete the following statements:

   A. The planet _____________________ is the most massive planet in the Solar System. It is ___________________ times more massive than Earth.

   B. The least massive Jovian planet is ___________________ which and is _________ times more massive than Earth.

**The gravitational attraction of a planet is directly related to the mass of the planet**

15. Which planet exerts the greatest pull of gravity?_______________ Which planet exerts the least pull of gravity?

16. Name two planets there were massive enough to attract and retain large quantities of hydrogen and helium, the lightest elements.

   A. 

   B. 

17. Your weight is a function of the gravitational attraction of an object on your mass. The surface gravities of Mars and Jupiter respectively are about 0.4 and 2.5 that of Earth. What would be someone with a mass of 155 pounds weigh on Mars and Jupiter?

A. Mars  
B. Jupiter

18. Write a general statement comparing the masses and gravitational attractions of the Terrestrial planets to those of the Jovian planets.

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19. Use the graph in your manual or a separate sheet of graph paper and plot the Diameter vs. the Density for each of the major planets. Plot a point on the graph where the density and diameter of the planet intersect. Your data for the Diameter (km X 1000) will be your Y-axis and your data for Density (g/cm$^3$) will be the X-axis. You should have a point for every major planet and you should also specify if the point/planet is a Terrestrial or Jovian planet. **You will be using the graph to answer some of the following questions.** (optional)

20. What general relationship exists between a planet's size (e.g. Terrestrial vs. Jovian) and its density?

21. Consider the fact that the densities of the two rocks that form the majority of the Earth's surface, the igneous rocks granite and basalt, are each about 3.0 g/cm$^3$. Therefore the overall average density of the terrestrial planets is **(greater than or less than)** the density of the Earth's surface. **(Pick One)**

22. The term **(rock, ice, or gaseous)** (pick one) best describes the Terrestrial planets.

23. The term **(rock, ice, or gaseous)** (pick one) best describes the Jovian planets.

24. The average density of the Earth is about 5.5 g/cm$^3$. Considering that the densities of the surface rocks are much less than the average, what does this suggest about the density of the Earth’s interior?

25. Which of the planets has a density less than water (1g/cm$^3$) and therefore would “float”?

26. Explain why Jupiter can have such a **high mass** and yet have such a **low density**.
27. Write a general statement comparing the densities of the Terrestrial planets to the Jovian planets.

28. Why are the densities of the Terrestrial and the Jovian planets so different?

29. The terrestrial planets are all composed of the same types of materials, in various concentrations. What could explain the fact that Mars has a somewhat lower average density than the other terrestrial planets or that the Earth has a somewhat higher average density than the other terrestrial planets? Think about the materials that make up the terrestrial planets and the various planetary layers they contain.

30. The mass of Pluto, about 0.002 that of Earth’s, although Pluto is different than both the Terrestrial or Jovian planets it is somewhat similar to the masses of the (Terrestrial or Jovian) planets (pick one). __________________________ while its density of approximately 2.0 g/cm³ is somewhat similar to the (Terrestrial or Jovian) planets (pick one), __________________________. This suggests that this dwarf planet is made of (solid rock, a rock and ice mixture, or all gas) (Pick One)

31. Write a brief statement comparing the number of known moons of the Terrestrial planets to the number orbiting the Jovian Planets.

32. What is the general relationship between the numbers of moons orbiting a planet compared to the planets’ mass? Suggest a reason for the relationship.

The giant planet Jupiter rotates once on its axis approximately every 10 hours. If an object were on the equator of the planet and rotating with it, it would travel approximately 280,000 miles (the equatorial circumference or distance around the equator) in about 10 hours.

33. Using the above information, calculate the equatorial rotational velocity of Jupiter using the following formula:

\[
\text{Velocity} = \frac{\text{distance}}{\text{time}} = \frac{\text{miles}}{\text{hour}} = \text{mi/hr}
\]
34. The equatorial circumference of Earth is about 24,000 miles. What is the approximate equatorial rotational velocity of Earth per hour? Hint: think about the number of hours in one day!

Velocity = (distance/time) = (miles) / (hour) = \text{mi/hr}

35. How many times faster is Jupiter’s equatorial rotational velocity than Earth’s?

36. Compare the planet’s periods of rotation to their period of revolution and then complete the following statement by circling the correct responses.

The Terrestrial planets all have \textbf{(Long or Short) days} and \textbf{(Long or Short) years}, while the Jovian planets all have \textbf{(Long or Short) days} and \textbf{(Long or Short) years}. Circle the correct answers.

37. In one Earth year, how many revolutions will the planet Mercury complete and what fraction of a revolution will Neptune accomplish?

<table>
<thead>
<tr>
<th>Planet</th>
<th>Revolutions in one Earth Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td></td>
</tr>
<tr>
<td>Neptune</td>
<td></td>
</tr>
</tbody>
</table>

Neptune: \[\text{of a revolution in one Earth year.}\]

38. Using Kepler’s third law (a planet’s orbital period squared is equal to its mean solar distance cubed) or \((p^2 = d^3)\), calculate the period of revolution of a hypothetical planet that is 15 AUs from the Sun.

39. How many rotations on its axis will Venus complete in 1 of its years?

40. Explain the relationship between a planet’s period of rotation and period of revolution that would cause one side of a planet to face the Sun throughout its year. (Hint: think about our Moon, we typically only see one side of it each night.)

(Rotation < Revolution; Rotation > Revolution; Rotation = Revolution) Circle the best answer.

Extra Credit Questions from the (Summary / Report Page) at the end of chapter 18:

1. This question is similar to #5 from the first couple of pages of this packet. Once again, you will be making a scale model of the four inner Terrestrial planets of the Solar System. Use large points to represent the four terrestrial planets and place them at the appropriate distance from the Sun. Use the mean distance from the Sun in AU's listed in table 18.1 on the first page of this packet. Measure the scale below in either cm or mm to produce the scale of this model, i.e. 1 cm = so many AUs or 0.17 AU = so many cm. Once you have your scale calculated you can convert the mean distance between the terrestrial planets and the Sun into mm or cm and plot their location on the strip provided. Don’t forget to name each planet and to include arrows to represent the orbit and spin directions for each planet.
2. Using Kepler’s third law (a planet’s orbital period squared is equal to its mean solar distance cubed) or \( (p^2 = d^3) \), calculate the period of revolution of a hypothetical planet that is 10 Aus from the Sun.

\[ \text{Years} \]

3. Using Kepler’s third law (a planet’s orbital period squared is equal to its mean solar distance cubed) or \( (p^2 = d^3) \), calculate the period of revolution of a hypothetical planet that is 20 Aus from the Sun.

\[ \text{Years} \]

4. Define the following (Keep in mind that you should not define something by itself!):

- Revolution:

- Rotation:

- Mass:

- Diameter:

- Astronomical Unit:

\[ \text{The End!!!} \]