

Astro 18-- Planets and Planetary Systems – Fall 2014

Homework 2: Gravity, Kepler's Laws, Newton's Laws

Due Thursday April 17th before class.

This Homework is largely based on Chapter 4 of Bennett.

Organization of this homework assignment:

Part 1 – Questions and problems that should be answered by everyone.

Part 2 – Each student should choose to answer either an algebra-based question or a calculus-based question. Both will be valued equally for grading purposes.

Homework Policy: Homeworks count as 30% of your final grade. Homeworks turned in one class period late will be graded with a grade reduction of 1/2. Homeworks more than one class period late will not be accepted. Your one lowest-graded homework assignment will not count toward your final grade. For each problem, in addition to giving the numerical answer you must show your reasoning (what steps you went through to arrive at your answers, with words and drawings as well as numbers) and state what units you are using.

Part 1:

1) Applets about Kepler's Laws.

Search the web to find at least two applets illustrating Kepler's laws of motion. (I searched under "applet about Kepler's laws" and found lots of choices.) Try out at least two of them, spending several minutes on each. Write a paragraph describing what you tried, what phenomena you saw, and what surprised you the most. Do you think this is a useful applet? Why? (or why not?) Be sure to list the web addresses you used.

2) Total Eclipse of the Moon.

If you were able to attend the Total Eclipse (either at home or at the class star-party) on Monday evening, write a paragraph describing what you saw. Be sure to state what time you started watching and what time you finished, and compare these times to the following eclipse stages to

state what stage the eclipse was in when you were watching it. If you also observed other planets, take a sentence to describe what you saw.

Partial eclipse starts 10:58 pm PDT

Total eclipse starts 12:07 am PDT

Total eclipse ends 1:25 am PDT

Partial eclipse ends 2:33 am PDT

3) Testing Kepler's third law: We can test Kepler's third law, $p^2/a^3 = \text{constant}$, for the classical planets and dwarf planets in our own Solar System. Use Appendix E in Bennett (page A-14) to fill in the second, third, and fourth columns of the following Table. Use three decimal places throughout the Table.

a) "Classical Planets"

Planet	a = Semimajor axis of orbit (AU)	p = Period (years)	Test Kepler's Law p^2/a^3 (years ² /AU ³)
Mercury			
Venus			
Earth			
Mars			
Jupiter			
Saturn			
Uranus			
Neptune			

b) "Dwarf Planets"

Do the same for a few of the “dwarf planets” (get information on their orbits from the big tables toward the bottom of the page in http://en.wikipedia.org/wiki/Dwarf_planet). For example:

Dwarf Planet	a = Semimajor axis of orbit (AU). Use average of closest and furthest approach to Sun	p = Period (years)	Test Kepler’s Law p^2/a^3 (years ² /AU ³)
Eris			
Ceres			
Pluto			
MakeMake			
Haumea			

What conclusion can you draw from this exercise? Is p^2/a^3 really constant? If p^2/a^3 is not exactly constant, over what percent difference from unity does it range?

4) Measuring Masses. Use Newton's version of Kepler's third law to answer the following questions. In each case show clearly how you reached your conclusion.

- a) The Moon orbits the Earth in an average of 27.3 days at an average distance of 384,000 kilometers. Use these facts to determine the mass of the Earth. You may neglect the mass of the Moon and assume $M_{\text{Earth}} + M_{\text{Moon}} \cong M_{\text{Earth}}$. (The Moon's mass is about 1/80 of Earth's.)
- b) Jupiter's moon Io orbits Jupiter every 42.5 hours at an average distance of 422,000 kilometers from the center of Jupiter. Calculate the mass of Jupiter. (Io's mass is very small compared to Jupiter's.)
- c) Pluto's moon Charon orbits Pluto every 6.4 days with a semimajor axis of 19,700 kilometers. Calculate the combined mass of Pluto and Charon. Compare this combined mass to the mass of the Earth.

5) Newton's Law of Universal Gravitation: Use Newton's Law of Universal Gravitation to answer each of the following questions:

- a) How does tripling the distance between two objects affect the gravitational force between them?

- b) Compare the gravitational force between the Earth and the Sun to that between Jupiter and the Sun. (Use Appendix E in Bennett or one of the planetary science web pages to look up characteristics you need to know.)
- c) Suppose the Sun were magically replaced by a star with twice as much mass. What would happen to the gravitational force between the Earth and the Sun?

Part 2: Answer one of the following two questions.

The first involves only algebra, while the second uses a bit of calculus.

6) Understanding Acceleration: (no calculus)

- a) What do we mean by *acceleration*? State your answer both in words and in an equation. What is the *acceleration of gravity*? Explain in words what we mean when we state an acceleration in units of meters / sec².
- b) It's wintertime in the Sierras and you have gone to the local snowy hill to go sledding. You and your sled accelerate downhill at the rate of 2 meters / sec². How fast will you be going after 5 seconds? After 10 seconds?
- c) You are driving along the freeway (for example Route 17) at a speed of 60 miles per hour when you see a deer crossing the road. You slam on your brakes to stop. Your brakes make your car *decelerate*. (Deceleration is simply negative acceleration.) If your rate of deceleration is 20 miles per hour per second, how long will it take you to come to a stop?

7) Conservation of Angular Momentum: (uses a bit of vector calculus)

Angular momentum is defined as $\vec{L} = \vec{r} \times \vec{p}$ where $\vec{p} = m\vec{v}$ is the linear momentum and \times is the vector cross product.

Use Newton's second law to prove that angular momentum \vec{L} is conserved ($d\vec{L}/dt = 0$) if the torque, $\vec{r} \times \vec{F}$, equals zero. Here \vec{F} is the force.