Homework #1, AST 203, Spring 2009

Due in class (i.e. by 4:20 pm), Thursday February 12

- To receive full credit, you must give the correct answer *and* show that you understand it. This requires writing your explanations in full, complete English sentences, clearly labeling all figures and graphs, showing us how you did the arithmetic, and being explicit about the units of all numbers given. All relevant mathematical variables should be explicitly defined. And please use your best handwriting; if we can't read it, we can't give you credit for it! Please staple together the sheets of paper you hand in.
- Most of the calculations in this course involve numbers that are only approximately known. The result of such a calculation should reflect this imprecision. In particular, it is *wrong* to simply write down all the digits that your calculator spits out. Your final answer should have the same number of significant figures as the least precise number going into your calculation. In many (but not all!) cases, it's best to do the problems without a calculator.
- Feel free to work with your classmates on this homework, but your write-up and wording should be your own. Answer all questions.

100 total points

1. Scientific notation review *20 total points*

Write the following in proper scientific notation, giving the proper number of significant figures. Full sentences are not required here.

a) Fifty-six million, seven hundred thousand (*2 points*)

b) π (the number pi) times 0.3 (*3 points*)

c) One two hundredth (*3 points*)

d) Six nanometers (expressed in meters) (*3 points*)

e) Divide the number $N \times 10^x$ by number $M \times 10^y$. Simplify the symbolic result, and then substitute the following values for the variables, expressing the answer in scientific notation: $N = 2.1$, $M = 1.2$, $x = 3$, $y = 1$. (*5 points*)

f) The speed of light is 3.0×10^8 meters per second. There are thirty-one million, seven hundred thousand seconds in a year. What is the speed of light in units of kilometers per year? (*4 points*)

2. Looking out in space and back in time *35 total points*

Because the speed of light is not infinite, we see objects as they were some time in the past. This usually doesn't matter in daily life on Earth as the distances (and therefore time delays) are small, but it is often important in astronomy and spacecraft engineering, or when considering communication among galactic civilizations.

The speed of light is 3.0×10^5 km/sec. The distance between the Earth and the Sun (one astronomical unit, or AU) is 150 million kilometers. Give all answers to the correct number of significant figures. Remember that all electromagnetic radiation (including radio waves) travels at the speed of light.

a) You look at the clock on the lecture room wall, which is 45 feet (15 meters) away from you. How far back in time are you seeing it? If you wanted to know the current time more precisely, how should you correct the reading shown by the clock? The light entering your eyes from the clock is ambient light in the surroundings that has reflected off the clock. (*5 points*)

b) A good internet connection is characterized by large bandwidth (amount of data you can push through at once) and low latency (how long it takes to reach the remote server). However, some things are beyond the control of your Internet Service Provider. Since internet signals propagate close to the speed of light, calculate the minimum possible latency (round trip travel time of signal) from Princeton to a server in:
1) Manhattan (50 miles from Princeton);
2) San Francisco (2600 miles);
3) Beijing (6800 miles).
Express your answers in milliseconds. (*10 points*)

c) Approximately, what is the farthest distance from the Earth at which an alien spaceship has any chance of detecting human-generated radio waves? (*Hint:* Humanity's first radio broadcast, Marconi's transmission to communicate across the Atlantic, took place on December 12, 1901). Express your answer in light years and in kilometers. (*5 points*)

Mars rovers Spirit and Opportunity are programmed to stop and ask for instructions when they run into trouble. After this, they wait for commands from mission controllers before they can start moving again. This is called "safe mode." If Spirit suddenly hits the Martian equivalent of a quicksand patch and enters "safe mode," what is the minimum time it has to survive before the controllers back on Earth can free it?

Mars and Earth are on nearly circular coplanar orbits around the Sun with radius 1.5 AU and 1 AU respectively. Consider two cases:

d) Mars is farthest from Earth in the two planet's orbits. Give your answer in minutes. (*10 points*)

e) Mars is nearest to the Earth in the two planet's orbits. Give your answer in minutes. (*5 points*)

3. Planetary Atmospheres *20 total points*

In this problem we will calculate the mass of the atmospheres of three planets: Earth, Venus and Mars. These are all "rocky" planets, which have held on to their thin (relative, e.g., to Jupiter!) atmospheres. The mass contained in an atmospheric column with a footprint of 1 square meter on each of these planets is: Earth (1.0×10^4 kg/m^2), Venus (1.0×10^6 kg/m^2), Mars (2.2×10^2 kg/m^2). To appreciate these numbers, think about how many tons of air are over your head when you walk outside. Each planet is roughly a sphere, of radius $R_{Earth} = 6371$ km, $R_{Venus} = 6051$ km, and $R_{Mars} = 3396$ km. Calculate the total mass contained in each of these atmospheres (in kilograms), and find the ratio between the most and least massive one.

4. Heliocentric orbits *25 total points*

Let's see how we can use Kepler's laws to learn some properties of the Solar System. The orbital periods of the major planets are: Mercury (87.97 days), Venus (224.7 days), Earth (365.26 days), Mars (687 days), Jupiter (11.86 years), Saturn (29.45 years), Uranus (84.02 years) and Neptune (164.8 years).

a) Using Kepler's third law, calculate the average distance from the Sun for all the planets (in AU). (*5 points*)

b) The orbits of these planets have low eccentricity, which means that their orbits are nearly circular. Calculate the orbital speed of each planet in kilometers per second. (*5 points*)

c) Halley's comet is on a heliocentric elliptical orbit. Its last closest approach to the Sun (perihelion) was in 1986 and the next one will be in 2061. At perihelion it comes to 0.6 AU from the Sun. Find the largest distance (aphelion) between the Sun and the comet over its orbit. Express your answer in AU. The orbit of which planet is closest to Halley's comet at aphelion? (*15 points*)