Homework #2, AST 203, Spring 2012

Due in class (i.e. by 4:20 pm), **Tuesday** *February 28*

- 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. Please read `http://www.astro.princeton.edu/ast203/writeup.pdf`
- 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.
Please read `http://www.astro.princeton.edu/ast203/mathtips.pdf`
- A number of useful formulas and quantities are summarized at `http://www.astro.princeton.edu/ast203/formulas.pdf`
- 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. Neptune and Pluto *20 points total*

The planet Neptune, the most distant gas giant from the Sun, orbits with a semimajor axis $a = 30.066$ AU and an eccentricity $e = 0.01$. Pluto, the next large world out from the Sun (though much smaller than Neptune) orbits with $a = 39.48$ AU and $e = 0.250$.

a. To correct number of significant figures given the precision of the data in this problem, how many years does it take Neptune to orbit the Sun? (*4 points*)

b. How many years does it take Pluto to orbit the Sun? (*4 points*)

c. Take the ratio of the two orbital periods you calculated in parts (a) and (b). You'll see that it is very close to the ratio of two small integers; which integers are these? Thus the two planets regularly come close to one another, in the same part of their orbits, which allows them to have a maximum gravitational influence on each other's orbits. This is an example of an orbital resonance (other examples in the solar system can be found among the moons of Jupiter, and between the moons and various features of the rings of Saturn). (*4 points*)

d. What is the aphelion distance of Neptune's orbit? Express your answer in AU. (*3 points*)

e. What are the perihelion and aphelion distances of Pluto's orbit? Is Pluto always farther from the Sun than Neptune? (*5 points*)

2. Satellites *30 points total*

In this problem we will talk about properties of satellite orbits.

a) A satellite in geosynchronous orbit (GEO) orbits the Earth once every day. A satellite in geostationary orbit (GSO) is a satellite in a circular GEO orbit in Earth's equatorial plane. Therefore, from the point of view of an observer on Earth's surface, a satellite in GSO seems always to "hover" in the same point in the sky. For example, the satellites used for satellite TV are in GSO so that satellite dishes can be stationary and need not track their motion through the sky. Take a look; you'll notice all satellite dishes on people's houses point towards the Equator, i.e., South. How far above Earth's equator (i.e., above the Earth's *surface*) is a satellite in GSO? Express your answer in kilometers, and in Earth radii. (*10 points*)

b) Space station MIR traveled 3.87 billion kilometers during its life. It's circular orbit was 200 km above the surface of the Earth. How many years was it in orbit? (*10 points*)

c) How many times did MIR circle the Earth per day (i.e., 24 hours)? Can you put a satellite into such an orbit that it circles the Earth 20 times per day? (*10 points*)

3. Emission of Light *10 points total*

This problem concerns the luminosities, sizes, and temperatures of stars and planets. You may assume that all radiate as blackbodies.

(a) (*5 points*) Venus has an average surface temperature of about 700 K, while the Sun's surface temperature is about 6000 K. Venus' radius is roughly 6050 km, and the radius of the Sun is roughly 700,000 km. What is the ratio of luminosity of the Sun to that of Venus? At what wavelength does Venus' emitted radiation peak? Express your answer in microns.

(b) (*5 points*) Consider a red giant star that has a diameter eighty times that of the Sun, but a surface temperature of only 3,000 K. What is the ratio of its luminosity to that of the Sun? At what wavelength does the red giant's emitted radiation peak? What color is it?

4. Radioactive Decay *10 points*

You will need to refer to the periodic table, e.g. in Appendix D of the text, to answer this problem.

Uranium-238 (^{238}U), an isotope of uranium that cannot be used to make a nuclear explosion, can absorb a neutron in a nuclear reactor. Which isotope does it then become? The resulting nucleus then undergoes beta decay with a half-life of 24 minutes. In the beta decay, one of the neutrons in the nucleus of the atom decays into a proton and an electron, and the electron is emitted from the nucleus. What type of atom results? This element is also unstable, and undergoes another beta decay with a half-life of 2.4 days. What type of atom results from this second beta decay? The resulting isotope is one that can be used in an atomic weapon. This is why nuclear reactors provide one potential route to atomic weapons. For all of the above, give the the symbol of the resulting isotope and its atomic mass.

5. Dating a lunar meteorite *10 points*

You have been asked to determine the age of a strange meteorite that, from its appearance, you hypothesize used to be part of a volcanic lava flow on the Moon. You are using the potassium-argon (^{40}K/^{40}Ar) method, and (in the simplified form in which we've discussed it) you know that the half-life for this decay is 1.3 billion years. Your measurement gives $^{40}\text{K}/^{40}\text{Ar} = 1/7$. How old is the meteorite?

6. Cratering on the Moon *20 points*

This problem asks you to work with a lunar photograph returned by one of the Apollo missions to estimate the age of a surface on the lunar far side.

The photo you will be working with is posted on the Blackboard site for the course under Course Materials, as "Apollo photo AS16-4136" – indicating that this photograph (recorded on film) was obtained by the Apollo 16 orbiter. The orbiter was at an altitude of 119 km when the photo was taken. What is important for us is the 10 km scale bar reproduced with the photo. The text (from a NASA special publication) that accompanies the photo is interesting, but not directly germane to this problem.

a) (*5 points*) AS16-4136 is called figure 103 in the page reproduced and available on Blackboard. Print out a copy of the page, including the photo. Note the 10 km scale bar. Using a centimeter ruler, and noting the direction north indicated at the opposite corner of the photo, determine the east-west and north-south extent of the photo, in km. Then determine the total number of square kilometers captured by the photo. Report your results to two significant figures only.

b) (*5 points*) Using the 10 km scale bar, determine the diameter on your hardcopy that corresponds to a crater 4 km in diameter. Survey the photo and circle with a pen or pencil every crater 4 km or larger that you see. Circles may overlap. Note that some craters are sharp and others may be very degraded. Do your best; crater counting, especially with a small image such as this, has subjectivity to it. Count any partial craters that are more than 50% in the photo. Include this sheet, with the circles, in the homework that you hand in. How many craters greater than 4 km in diameter do you count?

c) (*5 points*) Now refer to the lunar cratering histogram, also posted on the blackboard site under course materials. Note that its y-axis is in units of number of craters bigger than 4 km across (per million square kilometers). Using ratios and your results from steps 1 and 2 of this problem, convert your results these units.

d) (*5 points*) To 2 significant figures, in billions of years, how old is the lunar terrain photographed in AS16-4136? Do we have evidence that there was life present on Earth at this time, or does this surface predate the origin of life on Earth (at least as far as we can tell from the evidence available)?

If you want to see exactly where this image is situated on the lunar far side, you may look for the number 103 on the lunar far-side map in figure 96 of NASA SP-362, available at `http://history.nasa.gov/SP-362/ch5.1.htm` .