

Astrophysics Problem Set #1

Due Friday, Sept. 4 at 4pm

NOTE: I will be at a Conference on the Milky Way in Heidelberg, Germany the week before this problem set is due. If you are stuck on a problem, please talk to Dr. Craig. You can also email me at cabanela@mnstate.edu. I will try to respond to the emails in a timely manner, but be aware Germany is 8 hours ahead of Minnesota.

In the homework problems below, “R&P” refers to your textbook. You may work together on this problem set, but all work presented here must be your own. **You must clearly acknowledge any people you collaborated with.**

ASSUMED READING: Before starting this homework, read R&P Chapters 1 (focus on 1.5), 2 (focus on 2.3 and 2.5) and 3.

1. **[R&P 2.2 modified]** On 2003 August 27, Mars was in opposition as seen from the Earth. On 2005 July 14 (687 days, a.k.a. a Martian Sidereal Period, later), Mars was in western quadrature as seen from the Earth. What was the distance of Mars from the Sun on these dates, measured in astronomical units (AU)? How does this distance compare to the semimajor axis length of the Martian orbit (see Table A.3 attached to this problem set for semimajor axis)? What does this mean?

You may assume the Earth’s orbit is a perfect circle. **[Big Hint:** The sidereal period of Mars is also 687 days. Use this information and make a drawing of where the planets are on 2003 August 27 and 2005 July 14.]

2. **[R&P 2.3 with a hint]** In the 1670s, the astronomer Ole Røemer observed eclipses of the Galilean satellite Io as it plunged through Jupiter's shadow once per orbit. He noticed that the time between observed eclipses became shorter as Jupiter came closer to the Earth and longer as Jupiter moved away. Røemer calculated that the eclipses were observed 17 minutes earlier when Jupiter was in opposition than when it was close to conjunction. This was attributed by Røemer to the finite speed of light. From Røemer’s data, compute the speed of light, first in AU min⁻¹, then in m s⁻¹. **[HINT:** This question is really simple if you understand the definitions of “opposition,” “conjunction,” and “AU.”]

3. Using orbital data for Earth's Moon (reproduced to the right), find the mass of the Earth. Compare it to the value listed in Table A.3 attached to this problem set. Can you explain any difference? **(HINT:** If necessary, you can safely assume the Moon's mass is much less than the Earth's mass.)

Orbital Parameters for the Moon (from Table A.4 of R&P)	
Orbital Radius:	384,400 km
Orbital Period:	27.32 days
Radius of World:	1737 km
Mass:	7.348×10^{22} kg

4. **[Feel free to talk to Dr. Cabanela or Dr. Craig if get truly stuck on this one]**
 A low Earth orbit for a satellite (or the Space Shuttle), no more than a few hundred kilometers over the surface of the Earth, has an orbital period of 90 minutes. Interestingly, the *Messenger* spacecraft, scheduled to enter a low orbit around Mercury in March 2011, also has an orbital period of about 90 minutes. The orbital periods of the spacecraft in low Martian orbit are also in the neighborhood of 90 minutes (actually just a bit longer). These are objects with radically different masses. Why would all these orbits have similar periods?
- What physical characteristics do the Earth, Mercury, and Mars all have roughly similar values of despite their differing masses? **HINT:** Orbits depend on gravity and gravity depends on mass. So this physical characteristic must be related to mass. **HINT #2:** Consider what is similar about the Earth, Mercury, and Mars and see if you can use the data in Table A.3, attached to this problem set, to compute the corresponding physical characteristic. Reviewing Chapters 8.1 to 8.2 of the textbook might give you a few hints as to which physical characteristic to consider.
 - Derive the relationship between orbital period of a "low orbit" and this physical characteristic from part (a) assuming a "low orbit" essentially has an semimajor axis equal to the planet's radius and the satellite has much lower mass than the planet.
 - Given your derivation in part (b), should a low Jovian orbit around Jupiter have a period higher or lower than 90 minutes.

5. **[R&P 3.1 modified]** Comet Hale–Bopp has an orbit about the Sun with eccentricity $e=0.9951$ and semimajor axis length $a = 186.5$ AU.
- Try to accurately sketch the orbit, labeling the Sun and the perihelion and aphelion of Hale-Bopp’s orbit. Get the axial ratio, b/a , right! For a sense of scale, note that Neptune’s orbit approximately 30 AU in radius. **[HINT:** Figure 3.6 might help you relate perihelion and aphelion distances to a and e . Attending class might help too!]
 - What is the sidereal orbital period of Comet Hale–Bopp? What is Comet Hale–Bopp’s distance from the Sun at perihelion? What is its distance from the Sun at aphelion? Comet Hale–Bopp passed through perihelion in 1997 April 1. When did the previous perihelion passage of Comet Hale–Bopp occur?
6. **[R&P 3.6 tweaked]** Communications and weather satellites are often placed in *geosynchronous* orbits. A geosynchronous orbit is an orbit about the Earth with orbital period P exactly equal to one sidereal day (which is 86160 seconds, or about 4 minutes less than a solar day). What is the semimajor axis a_{gs} of a geosynchronous orbit? What is the orbital velocity v_{gs} of a satellite on a circular geosynchronous orbit?

Table A.3 (from Ryden and Peterson) listing the Physical Properties of the Planets.

Name	Mean radius (R_{\oplus}) ^a	Mass (M_{\oplus}) ^b	Rotation period (days)	Orbital semimajor axis (AU)	Orbital eccentricity	Orbital period (years)
Planets						
Mercury	0.383	0.0553	58.6	0.387	0.2056	0.241
Venus	0.950	0.8150	-243.0	0.723	0.0068	0.615
Earth	1.000	1.0000	0.997	1.000	0.0167	1.000
Mars	0.532	0.1074	1.026	1.524	0.0934	1.881
Jupiter	10.97	317.8	0.414	5.203	0.0484	11.86
Saturn	9.14	95.16	0.444	9.537	0.0539	29.45
Uranus	3.98	14.50	-0.718	19.19	0.0473	84.02
Neptune	4.18	17.20	0.671	30.07	0.0086	164.8
Dwarf Planets						
Ceres	0.075	0.00016	0.378	2.767	0.0795	4.599
Pluto	0.188	0.00220	-6.387	39.45	0.2502	247.9
Haumea ^c	0.11	0.00070	0.163	43.13	0.1950	283.3
Makemake	0.12	~ 0.0007	unknown	45.43	0.1612	306.2
Eris	0.20	0.00280	~ 1	67.90	0.4362	559.6

a. $R_{\oplus} = 6371$ km (Note: this table uses mean radius rather than equatorial radius.)
b. $M_{\oplus} = 5.974 \times 10^{24}$ kg
c. Haumea is ellipsoidal due to its rapid rotation ($0.15R_{\oplus} \times 0.12R_{\oplus} \times 0.08R_{\oplus}$).