ASTR 120 Problem Set 3: Due Tuesday, September 19, 2017

General reminders: You must show all your work to get full credit. Also, if any website was useful, you need to give the URL in your answer. Note that any website is fair game; you just have to cite it. If any book including our textbook was useful, you need to indicate where in the textbook you used a particular fact. This will be true in all homeworks.

1. [5 points] We argued that Kepler's second law is implied by the conservation of angular momentum. Linear momentum (mass times velocity) should also be conserved. And yet the Earth clearly changes its direction over the year; in fact, its velocity reverses its direction! Explain this apparent paradox.

2. [5 points] Dr. I. M. N. Sane, an independent researcher, has come up with a revolutionary idea. His "EM drive" uses complex electromagnetic principles to produce a reactionless drive: that is, this drive can accelerate spacecraft without having any thrust or applying a force to anything else. NASA has expressed interest in this drive, which promises to be cheap and fast. Write your evaluation of Dr. Sane's idea, based on your understanding of Newton's laws of motion.

3. [5 points] We mentioned that a generalization of Kepler's first law is that orbits are conic sections (circle, ellipse, parabola, hyperbola). Suppose you have a rock that passes by the Sun too fast to be gravitationally bound to the Sun; that is, the rock moves in a hyperbolic orbit. Based on our discussion of the physical basis of Kepler's second law, make a concise case either *for* or *against* the claim that the "equal areas in equal times" law applies to the rock's hyperbolic orbit as well as to elliptical orbits.

4. [5 points] Using Kepler's laws:

a. Compute the ratio of the orbital speed of a planet with an orbital eccentricity of e at its smallest distance to the Sun (the perihelion) to the orbital speed at its greatest distance to the Sun (the aphelion).

b. Specifically, compute this ratio for Venus (which has the most circular orbit of the eight planets) and Mercury (which has the most eccentric orbit of the eight planets). In both cases, report the URL of the page you used to find their eccentricities.

5. [5 points] One of the philosophical bases for skepticism about elliptical orbits is that only one of the two foci of the ellipse plays a role. But let's explore this a little further. Please note that in the following problems, only Kepler's laws and the eccentricity of the ellipse are needed, not masses, semimajor axes, or times.

We are interested in the angular velocity (which is the rate of change of direction) of the planet as seen **from the focus that is not occupied by the Sun**. In all of the following, compute the *ratio* of the observed angular velocity seen when the planet is at the closest point of its orbit around the Sun (the perihelion) with the observed angular velocity when the planet is at the farthest point of its orbit around the Sun (the aphelion). Note that at these two points (and only at these two points!), the angle between the direction of motion and the direction to the Sun is $\theta = 90°$.

a. The Earth.

b. Mars.

c. Mercury.

In each case, look up the eccentricity and indicate the reference (URL or book). What trend do you notice about the ratio as a function of eccentricity? For example, is the fractional difference proportional to the eccentricity, or to the square of the eccentricity, or is there some other relation?

Bonus Question [2 points]

Kepler's laws were developed for the Solar System. Do they apply to other systems as well? Look up the orbit of the Sirius double-star system, and present evidence based on Web pages that this system moves in an ellipse.