Topics: definition of eccentricity, orbits of objects with more nearly equal masses; planetary atmospheres – basics

Reading:

- Review Fig. 3.6, paying special attention to the definition of eccentricity, e. And read the paragraph at the bottom of p. 69 ("Consider the point..."), including eqn. 3.36.
- Ryden and Peterson, §3.1.3 (pp. 72-73), on deriving Kepler's third law.
- https://phet.colorado.edu/sims/my-solar-system/my-solar-system_en.html – Try the *java-free orbit simulator* linked from the right side of our class website and try making a circular orbit, by adjusting the initial velocity, for two objects with a mass ratio that's close to one.
- Ryden and Peterson, back to Ch. 8. Start at eqn. 8.11 on p. 198 and read through p. 199. You've already read that, a few classes ago. Now go on and carefully read starting at the top of p. 200 through the middle of p. 201. The last paragraph, containing eq. 8.16 will be especially tough. But the rest of this page-and-a-half also has some unfamiliar things. Please read my commentary, below, carefully, along with the text.

Summary of work to submit:

- Bring your solutions to problems 1 and 2 to Thursday's class.

Overview:

Before we leave Kepler's third law, we need to take a look at the case where $m \approx M$ (eqn. 3.53). Note that in an orbit, it's the *center of mass* that both objects mutually orbit. Given Kepler's third law, we can weigh planets, comets, etc. by...sending spacecraft to orbit them. If they have moons (the planets, not the spacecraft!) then we can use those moons' orbits to weigh the planet. This is stated on p. 196, at the beginning of §8.2 *Physical Properties of Planets*. And it's noted that a planet's mean density can be calculated from its mass and radius, and that density provides clues about composition.

Next, the textbook considers temperature (we discussed this a few classes ago), and notes that some planets have atmospheres that are heat-trapping and lead to temperatures above what we'd expect simply from solar heating. The new reading starts (p. 200) by considering what wavelengths a planet emits most of its radiation at and then goes on to consider how the atmosphere interacts with that radiation. Reflected sunlight – modified by a planet's atmosphere – is considered next. "What does the light of a planet look like?" really means, "what is its spectrum?" – see Fig. 8.2. The absorption of light (either emitted by the planet, which tends to be in the infrared, or reflected sunlight, which is modified by wavelength-dependent absorption) affects the apparent color of a planet (see the discussion of why Mars looks red). The reading concludes with a discussion of the particles in the atmosphere and how high up you need to go before particles can escape from the atmosphere and so aren't bound to the planet. This exobase in some sense defines the top, or effective edge, of a planet's atmosphere.

Commentary on the reading, viewing, and other preparation:

You can specify the distance from the Sun (or whatever object is being orbited) at every point on an elliptical orbit using Fig. 3.6, and see how the eccentricity defines the *aspect ratio* of the ellipse (b/a) – how round vs. long and skinny it is. That's eqn. 3.35, 3.36. And also that you can use the figure to figure (!) out how close the Sun is to the orbit at the point of closest approach.

Problem 1

If Halley's Comet has an eccentricity of $e = 0.967$ and an orbital period of 76 years, what is its closest approach to the Sun? AU would be great units to use. Is that closer than Mercury's orbit?

Using the orbit simulator, with the traces on, convince yourself that each object has its own orbit and that no matter what, the two objects are always on the opposite sides of their orbits; a straight line between the two objects always goes through the center of mass. Does it look like, for circular orbits, the two orbits are separate, concentric circles centered on the center of mass of the system? It should!

The center of mass is defined by $Mr_1 = mr_2$ where the rs are the distance of each object from the center of mass. (This should make sense. Thinking of two kids sitting on a see-saw – if one is twice as heavy as the other, that one has to sit twice as close in order to balance.)

The semi-major axis in Kepler's third law is the sum of the two orbits' semi-major axes, $a = a_1 + a_2$. This is always true. But for circular orbits, you'll note that a is also the separation of the objects (which in principle is pretty easy to measure).

Confused about the distinction between a and r? Consult Fig. 3.6.

Problem 2

Where is the center of mass of the Sun-Jupiter system? (You could give your answer in terms of distance from the Sun's center?) Compare your answer to the Sun's radius. You can look up the Sun's and Jupiter's mass in tables near the back of the textbook.

Now, the derivation of Kepler's third law on p. 72: Is it at least plausible that the area of an ellipse is πab? Note the invoking of Kepler's second law to motivate that equation. And the $L/2m$ term comes directly from our discussion in the last class about angular momentum of the area of the triangle inscribed in an orbit. The next step involves the definition of the eccentricity. The step at the top of the next page uses eqn. 3.43. We won't worry about the derivation of this equation, but think – should a circular orbit or a highly elliptical orbit have more angular momentum? What does your physical intuition tell you? What does eqn. 3.43 say?

That wasn't really that bad (but again, we didn't derive one of the equations we used). But to see more clearly where the $M + m$ term comes from, we will consider in class deriving it from $F_{cent} = F_{grav}$ for a circular orbit.

Next, top of p. 200. Remind yourself of the peak wavelength of the Planck spectrum (for a blackbody emitter).

Optical depth, τ, is a way to quantify how opaque ($\tau > 1$) or transparent ($\tau < 1$) a medium is.

Planet composition. The Sun – and the Universe on average – is 98% hydrogen and helium. They are the simplest atoms, with one and two electrons, respectively.

At the bottom of p. 200, note the phrase "random thermal speeds." Heat is manifest as the random motion of particles. The hotter matter is, the faster those random motions are. (Temperature is proportional to the square of the speed.)

Particles in a gas travel in a random direction, collide with another particle, and go off in some other random direction. The average distance they go between collisions is called the mean free path. As you can imagine, it is inversely proportional to the density of gas. And so it increases with altitude, as the density of gas decreases.

Escape velocity: every massive object has a minimum velocity for something (a rocket, a random gas particle in the atmosphere) to escape.

Comfortable with the concept of the *exobase*? What's going on with the gas above it, the *exosphere*?

Finally, for now, the *cross section* of a particle is an area, as its name implies, and has units of m^2 particle^{-1}. Think of it as being related to the probability that the particle will interact with another particle. ...we'll talk more about this paragraph.