Astromechanics: gravity

Astronomy 101
Syracuse University, Fall 2017
Walter Freeman

October 3, 2017

"Truth is ever to be found in simplicity, and not in the multiplicity and confusion of things."

–Newton, *Rules for methodizing the Apocalypse*
(n.b.: "apocalypse" also means "revealing")

"We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances."

–Newton, *Philosophiae Naturalis Principia Mathematica*
(Mathematical Principles of Natural Philosophy)

So, this happened...

Announcements

- Exam scores should be up
- If you don't have a grade and you took Form E (on Wednesday)
  - Give me your paper if you have it
  - These wound up in the TA's hands and need to get back to me; I'll grade them myself
- If you don't have a grade and you took Form A/B/C/D
  - Send me mail and let me know; you probably messed up your SUID
- If you have a grade much lower than you saw in lab
  - Send me mail and let me know; you probably put down the wrong form
- Warmup question for Thursday will be sent out tonight

Paper submissions

If you didn't get it to the TA's mailboxes right in time, don't worry.

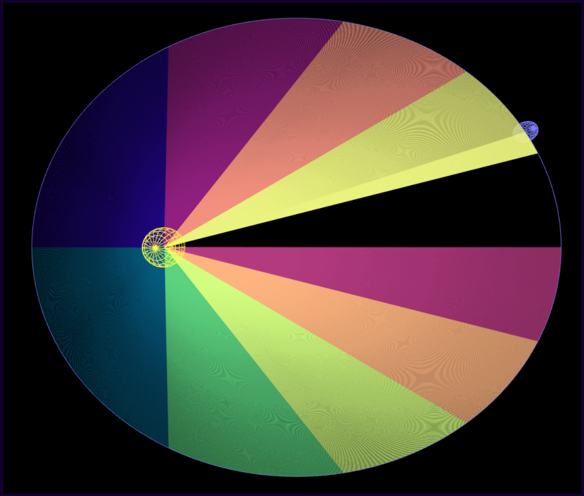
So long as you got the electronic copy to us sometime yesterday, we'll accept the paper copies today.

If you were sick or something more serious made you late, talk to your TA.

Kepler's laws, summarized

- 1. Planets travel in elliptical orbits, with the Sun at one focus
- 2. The line going from the Sun to the planet sweeps out equal areas in equal times
- 3. The time that a planet takes to go around the Sun increases as the 3/2 power of the long axis of the ellipse.

The line from the Sun to the planet sweeps out equal areas in equal times.



Each colored wedge has the *same area*, and the planet takes the *same time* to go through each.

Kepler's Third Law

Kepler's third law of orbital motion says that the square of a planet's *orbital period* is proportional to the cube of its *semimajor axis*.

Simply put: if a planet is further from the Sun, it takes longer to go around.

If the distance is doubled, the time required *more than doubles*.

Let's watch this...

Saturn's orbit is about 10 AU across, while Uranus' orbit is about 20 AU across.

Saturn takes about 30 years to orbit the Sun. About how long does Uranus take?

A: About 30 years

B: Between 30 and 60 years

C: More than 60 years

D: It depends on the masses of Uranus and Saturn

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E: I looked it up on Wikipedia...

Complete *Lecture Tutorials* pp. 21-24 (Kepler's second law) and pp. 25-28 (Kepler's third law).

We will do something else after this (15-20 min)

Where are we now?

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But he thought there was more: that the planets' orbits were *caused* by the interplay of more fundamental agents.

He didn't have a good name for them: we now call them "gravity" and "inertia". We'll learn about those soon.

Natural laws vs. their consequences

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- The motion of the stars
- The near-perfect-spheres of the planets and moons
- The elliptical motions of the planets (?)
- The colors in a rainbow

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- Seismic waves and earthquakes
- The colors in the Sun
- The weather
- The diversity of rocks on Earth

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- The diversity of rocks on Earth
- Even the simplest living things
- ... language, culture, music, art, and all the creations of humankind...

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He discovered...

- Forces cause objects to change their speed or direction of motion
- Calculus – the mathematics of changes
- Gravity is such a force
- The mathematical description of gravity

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- Calculus – the mathematics of changes
- Gravity is such a force
- The mathematical description of gravity
- Principles of optics
- The mathematics of cooling
- ... and much more

"Forces cause objects to accelerate"

$$F = ma$$

$$F/m = a$$

"The strength of a force, divided by the mass of the thing it acts on, gives that thing's acceleration"

The law of gravity

Newton showed mathematically what Kepler suspected.

All objects attract all other objects with a force that is:

- Proportional to the product of their masses
- Inversely proportional to the distance between them squared

In symbols:

$$F = \frac{Gm_1m_2}{r^2}$$

Suppose two asteroids are floating out in space. Asteroid A is twice as massive as asteroid B.

If the force of A's gravity on B is ten tons, the force of B's gravity on A will be...

A: 5 tons

B: 10 tons

C: 20 tons

D: 40 tons

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Notice I didn't say which mass was which. It doesn't matter!

Suppose two asteroids are floating out in space, 20 miles apart. Asteroid A is twice as massive as asteroid B, and the force of A's gravity on B is ten tons.

Suppose I now move the two asteroids closer, so they're only 10 miles apart. What will the force of A's gravity on B be now?

A: 5 tons

B: 10 tons

C: 20 tons

D: 40 tons