Lecture 8: Newton’s laws - Motions and objects of the solar system
Where we’re at (~1700 AD): 5 planets revolve around the Sun governed by Kepler’s/Newton’s laws. Earth and Jupiter have moons, Saturn has ears...
Newton’s laws can be used to
1) Derive Kepler’s laws
2) Confirm Galileo’s ideas about feeling motion
3) And they work even when Kepler’s laws do not.

Smarty pants ➔
Newton’s law of Motion

I. An object moves at a constant velocity if there is no net force on it.
II. Force = mass x acceleration (a = F/m)
III. For any force there is an equal reaction force

“Oh shi....”
Physics terminology

Speed = how fast something is moving
Velocity = speed AND direction
Acceleration = change in velocity
Accelerating?

What force?
The dynamics of perfectly circular orbits:
Force pulls towards Sun
Velocity points tangent to circle
Speed is constant
What is this force that holds the solar system together? Gravity.

\[ F_1 = F_2 = G \frac{m_1 \times m_2}{r^2} \]

Sun = 99.985% of the mass, so ignore planet-planet gravitation
A little bit more complex for the ellipse
Important, non-equationey stuff about Gravity:

1) Forces have a size and direction.

2) Gravity points in a straight line between the two gravitating bodies.

3) Gravity gets bigger as either of the two masses increases.

4) Gravity gets smaller as the distance increases.
“Universal” is really important. These laws hold everywhere; we can do experiments on Earth that tell us about the heavens.
Newton’s laws work. Holy crap do they work....
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Discovery of Neptune
Newton’s laws work. Holy crap do they work....

Rendezvous with 433 Eros

Near Earth Asteroid Rendezvous - Journey to Eros
Keplerian orbit: An ellipse. Happens when the gravitational force of only one body is important.

Non-Keplerian orbit: Not an ellipse. Happens when two or more bodies exert gravity on the orbiting thing. (Or another force is present).
Armed with telescopes and mathematical laws, people explore the Solar system.

**Discovery timeline:**
1781  Herschel discovers Uranus (is a planet)
1801  Ceres
1846  Le Verrier predicted Neptune
1930  Pluto
1992  Kuiper belt
????  Oort cloud?
The Sun... 99.86% of the stuff in the solar system
Inner planets, or Terrestrial planets

Rocky, atmospheres, few moons
0.4-5 AU, <0.002% of the total mass of the S.S.
Asteroid belt
Mostly like charcoal briquettes, a few “oddities” shaped by resonances
2-3.5 AU

950km - 1km
Outer planets, or Jovian planets

Gaseous, atmospheres, many moons and rings
5-30AU, about 0.14% of the total mass of the S.S.
Kuiper (pronounced like ‘viper’) Belt
Bits of ice and rock
30-50 AU
Estimated ~70,000 substantially-sized ones
Comets

Random orbits - eccentric, inclined
Made of dust and ice typically
Oort Cloud:
Hypothesized cloud of stuff beyond the Kuiper Belt
Ends at ~50,000 AU
Source of long-period comets
Does only the 99.85%-of-mass Sun matter when computing orbits?

When do we need to consider another body?

\[ F_1 = F_2 = G \frac{m_1 \times m_2}{r^2} \]
Experience for yourself the aggravation of trying to make a stable orbit configuration of more than three bodies:

http://www.stefanom.org/spc/
Asteroid Resonances
These gaps are from where asteroids orbit “in synch” with Jupiter and get slowly tugged out of stable orbits.
Where does all this “perturbed” stuff go?
65 Million years ago....
50,000 years ago....
104 years ago....
**Oort cloud** (out to 50,000 AU): Icy planetesimals from the jovian planet region ejected by gravitational encounters.

**Kuiper belt** (30–100 AU): Icy leftovers of the outermost solar nebula; “sculpted” by orbital resonances with jovian planets.

**Asteroid belt** (2–3 AU): Rocky leftovers from planet formation could not become a planet due to influence of Jupiter’s gravity.

Oort cloud comets affected by passing stars can strike Earth.

Jovian planet “nudges” send objects toward Earth and other planets.

Asteroid and comet impacts affect Earth’s geology and biology.

Not to scale!
Key Terms: Force, acceleration, Keplerian, Non-Keplerian orbits, ellipse, asteroid belt, Kuiper belt, Oort cloud

Key Ideas:
What are Newton’s laws of motion/gravity and how do they explain the motions of the planets?

Why do we call Newton’s laws “Universal”?

What is your favorite flavor of ice cream?

What are Keplerian and Non-Keplerian orbits?

What are Force and Acceleration?

What are some of the consequences of unstable (non-Keplerian) orbits?