1st Quiz & 1st Homework

- 20 minutes Quiz today
  - 2:10 to 2:30. Notification at 2:25.
  - See left screen for a correction to #12.
- Homework due next Thursday (Sep. 16)
  - Please type! *No handwritten homework will be accepted.*
  - Before you come into a class room on Sep.16, put your homework in a box located at the entrance hall. *No homework will be accepted after the class.*

Lecture 4
Laws of Motion

Reading: Chapter 5

Sir Isaac Newton (1642-1727)

- No astronomical phenomena can be understood without Newton's laws of motion and gravity.
- In fact, Newton's laws describe *both* physical phenomena on Earth and those in the Universe --- Unification of Earth of the Heavens.

Newton's First Law of Motion

- **No net force, no change in velocity.**

A spacecraft in space does not need any fuel --- it will keep going forever.

•No change on velocity (no acceleration), no net force.

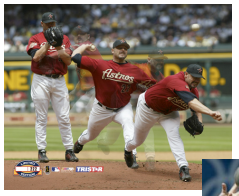
You don't feel any sensation of motion while you are in the airplane at constant velocity.

Newton's Second Law of Motion

- **Force causes acceleration.**

Force = (mass) x (acceleration)

$$F = m\,a$$



•You will need more force(=*F*) to throw a shot-put, because mass(=*m*) of a shot-put is much larger than mass of a baseball. It's hard to give a shot-put as much acceleration(=*a*) as to give a baseball.

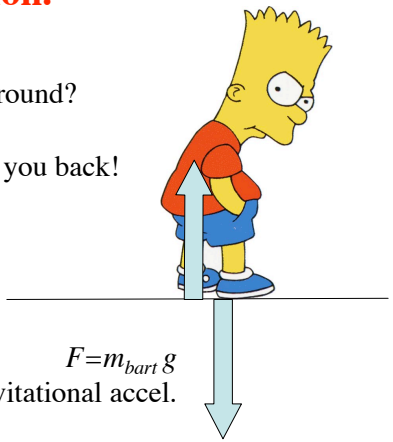
•Who can throw a shot-put at 100 miles/hour anyway?!

Newton's Third Law of Motion

- **Force in one direction, the same force in the opposite direction.**

Q: Why can we stand on the ground?

A: Because the ground pushes you back!

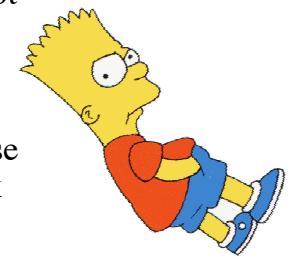


$F=m_{bart}\,g$

g: gravitational accel.

Zero Gravity?

- When nothing pushes Bart back, he is *freely falling*.
- While there is gravity, he does not feel it when freely falling.
- Likewise, while astronauts are certainly influenced by Earth's gravity, they do not feel it because they are freely falling! They look weightless not because of zero gravity, but because of free-fall.
  - Orbiting around Earth is equivalent to freely falling.



$F=m_{bart}\,g$

Newton's Universal Law of Gravity

- $F_{gravity}$ **between two objects is given by**

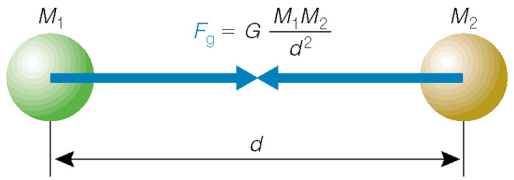
(gravitational constant)

x (mass of object 1)

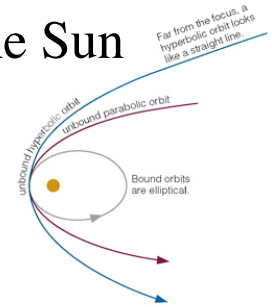
x (mass of object 2)

/ (distance between the objects)^2

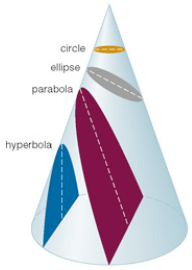
$$F_{gravity} = G\,M_1\,M_2 / d^2$$



explains motion of planets and comets around the Sun



- It's $F_{gravity} = G\,M_1\,M_2 / d^2$, where
  - M_1 = mass of the Sun
  - M_2 = mass of a planet/comet
  - d = distance to a planet/comet
- Newton's calculations agree well with observational facts established by Kepler (Kepler's Laws):
  1. Planet's orbits are slightly elliptical.
  2. Planets move faster when they are closer to the Sun.
  3. The inner planets orbit faster than the outer planets.



Changing Orbits

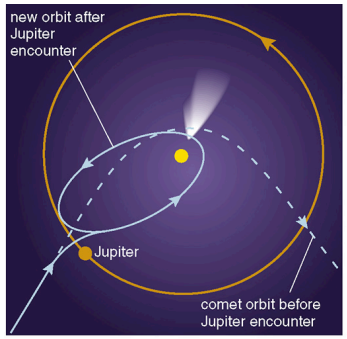
orbital energy = kinetic energy + gravitational potential energy

conservation of energy implies:

orbits can't change spontaneously

An object can't crash into a planet unless its orbit takes it there.

An orbit can only change if it gains/loses energy from another object, such as a gravitational encounter:



If an object gains enough energy so that its new orbit is unbound, we say that it has reached **escape velocity**.

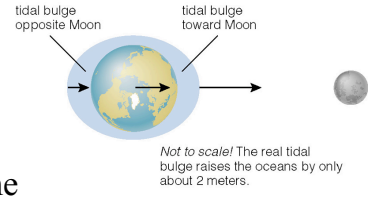
Tides

- $F_{gravity} = G\,M_1\,M_2 / d^2$ causes tides!

•Since gravitational force decreases with (distance)^2, the Moon's pull on Earth is strongest on the side facing the Moon, and weakest on the opposite side.

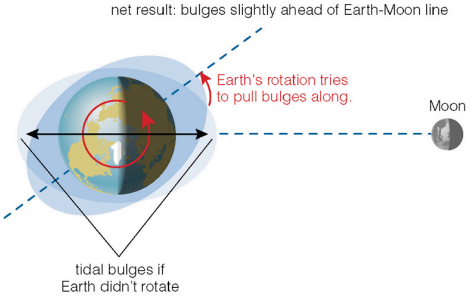
•The Earth gets stretched along the Earth-Moon line.

•The oceans rise relative to land at these points.



Tidal Friction

- This fight between Moon's pull & Earth's rotation causes friction.
- Earth's rotation slows down (1 sec every 50,000 yrs.)



- Conservation of angular momentum causes the Moon to move farther away from Earth.

Look at the Moon…

- *Synchronous Rotation*: The rotation period of a moon, planet, or star equals its orbital period about another object.
- Tidal friction on the Moon (caused by Earth) has slowed its rotation down to a period of one month.
- The Moon now rotates synchronously.
  - We always see the same side of the Moon.
- Tidal friction on the Moon has ceased since its tidal bulges are always aligned with Earth.

Next lecture: Understand Light

Reading: Chapter 6

Have a good weekend.