1st Quiz & 1st Homework

- **20 minutes Quiz today**
  - 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.**

  \[ F = m a \]

  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!

  \[ F = m_{\text{bfrt}} g \]

  \(g\): 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.

Newton’s Universal Law of Gravity

- **\(F_{\text{gravity}}\)** between two objects is given by
  
  \[ F_{\text{gravity}} = G \frac{M_1 M_2}{d^2} \]

  \(F_{\text{gravity}}\): force
  \(G\): gravitational constant
  \(M_1\): mass of object 1
  \(M_2\): mass of object 2
  \(d\): distance between the objects

  - Orbiting around Earth is equivalent to freely falling.
explains motion of planets and comets around the Sun

- It’s $F_{\text{gravity}} = G \frac{M_1 M_2}{d^2}$, 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

$F_{\text{gravity}} = G \frac{M_1 M_2}{d^2}$ 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.