Newton's Laws of Motion—22 Jan

- What is the reason for Kepler's three laws?
- Newton's Law of Gravity
- Modern view of Kepler's Laws
  - K1 & K3 can be derived from Newton's laws of motion
  - Emmy Noether: K2 can be derived from fact that laws of physics do not depend on direction.

Announcements

- Angel homework
  - Homework 2 is due Thurs, 1/29, at 6:00am.
  - If you have a problem with Angel
    - Call the Angel helpdesk 355-2345 (open 24/7)
- Slides on Angel
  - Click on the date on the syllabus
- Public lectures tonight
  - Mark Voit (author of our textbook)
    - Milky Way's biggest black hole
    - Planetarium, 7:30
  - Neil deGrass-Tyson (TV personality)
    - Footprints in the Sands of Science
    - Wharton Pasant Theatre, 7:30 (Need ticket)

“Natural” motion for Newton & Aristotle

- Natural motion is motion that needs no explanation: the object naturally moves that way.
- Aristotle: For heavenly objects, natural motion is motion in a circle with the same speed. For base objects, natural motion is rest.
  - A book falls off the table and comes to rest on the floor. This needs no explanation because rest is the natural state.
- Newton: Natural motion is moving at the same speed in the same direction.
  - Newton’s First Law: In the absence of a force, an object moves at the same speed in the same direction.
- Q: A book falls off the table and lands on the floor. For Newton, what is natural?
  a. The book is on the floor.
  b. The book is halfway to the floor.
  c. The book is just starting to fall.
  d. I shove the book off the table.
- What do I need to find out before answering the question?

- Q: Venus moves around the sun in a circle at the same speed. Does Newton consider this motion natural?
  a. Yes, Venus is a heavenly object.
  b. Yes, the speed is the same.
  c. No, the direction is not always the same.
  d. No, Venus is not at rest.
- What do I need to find out? Definitions?

- Q: Venus moves around the sun in a circle at the same speed. Does Newton consider this motion natural?
  a. Yes, Venus is a heavenly object.
  b. Yes, the speed is the same.
  c. No, the direction is not always the same.
  d. No, Venus is not at rest.
- Newton: The direction of Venus' motion changes. Something is causing the direction to change.

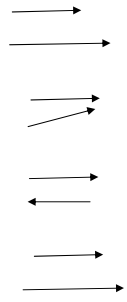
Newton's Second Law

- Newton's First Law: In the absence of a force, an object moves at the same speed in the same direction.
- Velocity is the combination of speed and direction of motion
  - Specify speed and direction: I drive 10° north of east at 50mph.
  - Draw an arrow. Length specifies speed

Change in velocity

- Q The velocity changed in
  a. Case A only
  b. Case B only
  c. Neither cases A nor B
  d. Both cases A and B

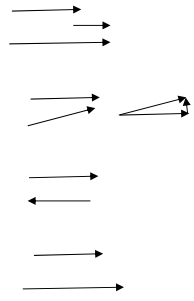
- Case A
  - Velocity at start
  - Velocity after 1 s
- Case B
  - Velocity at start
  - Velocity after 1 s
- Case C
  - Velocity at start
  - Velocity after 1 s
- Case D
  - Velocity at start
  - Velocity after 2 s



Acceleration

- Q The velocity changed in
  a. Case A only
  b. Case B only
  c. Neither cases A nor B
  d. Both cases A and B
- **Acceleration** is change in velocity divided by amount of time
  - Acceleration is arrow from the tip of the beginning velocity to the tip of the ending velocity divided by time
- Draw the acceleration for cases C & D. The length of the acceleration is greatest for which case? A, B, C, or D

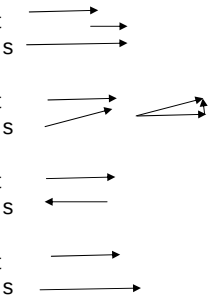
- Case A
  - Velocity at start
  - Velocity after 1 s
- Case B
  - Velocity at start
  - Velocity after 1 s
- Case C
  - Velocity at start
  - Velocity after 1 s
- Case D
  - Velocity at start
  - Velocity after 2 s



Newton's Second Law

- Newton's First Law: In the absence of a force, an object moves at the same speed in the same direction.
- Newton's Second Law tells how to find the motion if there is a force.
  - *Force = mass x acceleration*
    F = m x a
  - Acceleration is change in velocity divided by amount of time
- Q5 The velocity changed in
  a. Case A only
  b. Case B only
  c. Neither cases A nor B
  d. Both cases A and B
- Q6 The acceleration is greatest for which case? A, B, C, or D

- Case A
  - Velocity at start
  - Velocity after 1 s
- Case B
  - Velocity at start
  - Velocity after 1 s
- Case C
  - Velocity at start
  - Velocity after 1 s
- Case D
  - Velocity at start
  - Velocity after 2 s



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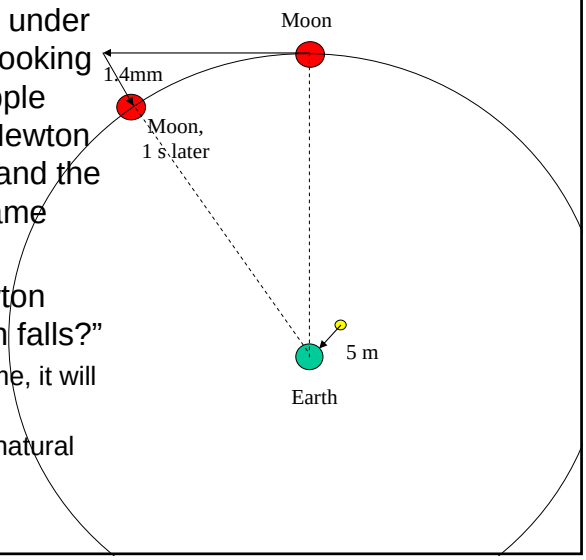
- Newton's Second Law tells how to find the motion if there is a force.
  - *Force = mass x acceleration*
    F = m a
- Q5 Me & my cat are in the car. My mass is 100kg, and the mass of my cat is 4kg. The car goes from 0 to 50mph in 5s.
- Q The acceleration of me and my cat are
  a. Same
  b. Different
- Q The car exerts a force on me & my cat. The forces are
  a. Same
  b. Different

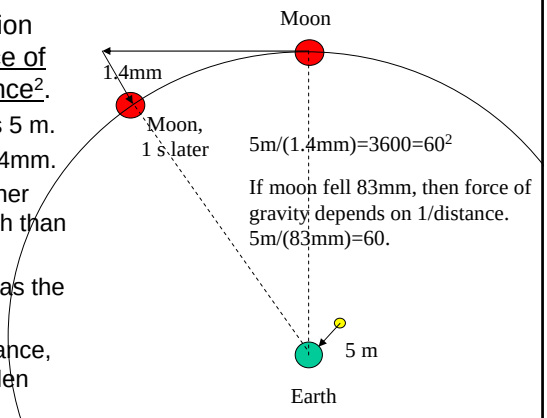
Newton discovers the law of gravity

- Newton was sitting under an apple tree and looking at the moon. An apple falls on his head. Newton realizes the moon and the apple fall for the same reason.
- Q: What does Newton mean by "the moon falls?"
  a. After a very long time, it will hit the earth.
  b. It is falling from its natural path.



Newton discovers the law of gravity

- Newton realizes the moon and the apple fall for the same reason. He does a calculation and concludes that the <u>force of gravity depends as 1/distance^2</u>.
  - In 1 second, an apple falls 5 m.
  - In 1 second, moon falls 1.4mm.
  - The moon is 60 times farther from the center of the earth than the apple.
  - Moon falls 1/60^2 as much as the apple.
  - If force depends on 1/distance, then moon would have fallen 83mm.



Newton's Law of Gravity

- Force between sun and earth

  Force = G $mass_{Sun}$ $mass_{Earth}$/ $Distance^2$

  - Force decreases with square of distance.
  - This is a universal law. Law applies to all. Two planets pull on each other.
  - This law is reciprocal: Sun pulls on the Earth; Earth pulls on the sun.
- Earth's natural motion is motion at constant speed in a straight line. How does sun make Earth deviate from its natural motion?
  - Force on earth = $mass_{Earth} \times$ acceleration (Newton 2^{nd})
  - G $mass_{Sun}$ $mass_{Earth}$/ $Distance^2$ = $mass_{Earth}$ acceleration
  - acceleration = G $mass_{Sun}$ / $Distance^2$
  - Acceleration (how much the velocity changes in 1 s) is proportional to the mass of the sun and inversely to the square of the distance.