Week 4: 1st Term Exam

- September 15, 2009
- Mean = 65.73
- Standard Deviation = 12.23
- Range: 32 to 90.
- See completed version of the exam at: www.sci.angelo.edu/phys1302/termexam1.pdf

Congratulations Space Cadets!
You are now doing Rocket Science

Onward…

- Having completed Chapters 1-3 and done reasonably well on checking our learning…
  - We understand the scale of the universe
    ✓ And that we are studying a very small and local area
  - Also, apparent motions in the sky
  - Also, Earth-Sun-Moon relationships
  - Also, Copernican Revolution
  - And, how the scientific method has been employed to get us here

But…

Recall?

- Kepler et al. were trying to understand a constantly changing solar system…
  - Stuff is moving at different rates
    ✓ Closer objects move more quickly.
    ✓ Far away objects move more slowly.
  - Kepler’s 2nd Law describes \( \Delta V \)
    ✓ Where the symbol \( \Delta \) means “change”
  - But not a clue as to what was controlling things

Galileo

- Sometimes called father of modern science.
- Did numerous basic observations and experiments for the first time…
  - 1st astronomical observations with telescope
  - Invented kinematics
  - Recognized that tides are caused by the Moon
  - Best known for dropping balls experiment
    ✓ Rate of fall UNRELATED to weight of object

Enter Isaac Newton

- Created Calculus (also Leibnitz independently)
- Quantified the gravitational force
- His Laws of Motion form the basis of Newtonian Mechanics (Physics I)
What is Calculus?

- A set of mathematical tools for quantitatively describing things that change
- Measuring Change...things in motion.
- So that you can predict the future!
- His *Laws of Motion* form the basis of Newtonian Mechanics (Physics I).

The Fly in the Ointment

- No explanation of WHY the solar system behaved the way it did
  - Circular motion was major problem
- Newton came up with the answer
  - The Laws of Motion
  - Gravity, Force, Inertia, Mass

Maybe the smartest person who ever lived...

- Englishman, 1642-1727 (born the year Galileo died)
- Studied works of the Big 3
- Made a distinction between mass, inertia, and weight
- Friction, Gravity, Force

Laws of Motion

- I. A body continues in a state of rest or in a state of uniform motion in a straight line unless it is compelled to change that state by a force acting on it.
- II. When a force $F$ acts on a body of mass $m$, it produces an acceleration $a$ equal to the force divided by the mass. Thus, $a = F/m$, or $F = ma$.
- III. To every action there is an equal and opposite reaction.

Changing Planets

- The position is constantly changing.
- The velocity is constantly changing.
- But according to a precise mathematical description (Kepler).
- But we are back to an apparent contradiction! (circular motion)
Newtonian Gravity

Controlling Motion: Gravity
- An attractive force between objects with mass
- Weakest of the fundamental forces
- Directly proportional to mass
- Inversely proportional to the distance between objects (the $1/r^2$ law)
- Permeates everything

\[ F = \frac{GMm_2}{r^2} \]

\[ G = 6.6 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2} \]

Implications
- Each planet with a different mass will have a different local gravitational force
- The continuous forces of nature can be understood by quantitizing and modeling
- So a smooth orbital arc...
- Gravitational force decreases with distance
- It is possible to overcome the force of gravity

Stepping out into space
- \( V_{\text{orbital}} \) varies from
  - 7.7 km/sec (LEO)
  - 2.2 km/sec (GEO)
- \( V_{\text{escape}} \) exists for
  - Earth, 11.2 km/sec
  - Moon, 2.4 km/sec
  - Earth-Moon, 2.77 km/sec
  - Asteroid, \( \approx 3 \text{ m/sec} \)
  - Sun \( \approx 610 \text{ km/sec} \)

Escape Velocity
- If an object gains enough orbital energy, it may escape (change from a bound to unbound orbit)
- \( V_{\text{escape}} \) from Earth \( \approx 11 \text{ km/s} \) from sea level (about 40,000 km/hr)
Terminal Velocity

- Friction &/or Resistance in any atmosphere or fluid.
- Resistance is proportional to weight & orientation of an object.
- Terminal Velocity achieved when air resistance = weight
- Typically 125-200 MPH
- Joe Kittinger: Jumping from 20 miles up reached 614 MPH (1960)

So What?

- Planetary movements controlled by gravity from the Sun AND from each other.
- As long as the gravitational forces have been accounted for, you can predict velocity & direction.
- Knowing those same gravitational forces, you can calculate the paths of new objects inserted into the solar system.
- Modern space-faring is based on these laws: Newtonian Mechanics!

But he wasn’t done yet...

- Sir Issac (1643-1727)
- Also laid the foundations for understanding energy
- In particular: Light describe the scientific method