Lecture 27 Blackboard #1

Leasts Universal Gravitation

1687: Newton "Math. Principia of Natural Philosophy"

"Every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them."

History:

- Ancient astronomers attempted to explain the motions of planets against stellar background.
- Day-night cycle.
- Annual precession of seasons.
- Predicative motion of planets.

Observations:

- Accurate calendars
- Star maps
- Planetary movements

Problems with Model:

- Sun and planets did not move uniformly.
- Planets boxed in brightness why?
- Some planets relative to stars showed retrograde motion!!

1. Pythagoras (582-497 BC)

- Spherical stationary earth
- Heavenly bodies move in circles
- Stars fixed on a distance shell
- Sun moves; planets move on epicycles to match their periods.
- Earth-centered
Lecture 27 Blackboard #2

1. Pythagoras (582–497 BC)
   - Spherical, stationary earth
   - Heavenly bodies move in circles
   - Sun, moon, planets move in spheres
earth
   - Sun, moon, planets move in spheres
to match their periods.
   - Earth-centered

2. Plato (427–347 BC)
   - Sun and planets did not move
   - Planets moved in brightness
   - Some planets relative to stars
   - Should retrograde motion

3. Copernicus
   - Proposed new theory
   - Sun is at center
   - Earth and planets
   - Moved about sun
   - Epicycles for uniform
   - Retrograde motion
   - Explained
Kepler's Laws

1. Law of Ellipses
2. Law of Areas
3. Law of Squares

Kepler (1571-1630)

Gravitational Potential Energy

\[ U = \frac{-GMm}{r} \]

\[ U = \frac{-GMm}{R_E} \]

Newton's Law of Gravity

\[ F = \frac{Gm_1m_2}{R^2} \]

\[ F_{12} = \frac{-Gm_1m_2}{R_1^2} \]

Gravitational Constant: \( G = 6.674 \times 10^{-11} \text{ Nm}^2\text{kg}^{-2} \)

Infinite Range

Principle of Superposition

\[ F_{\text{Total}} = F_1 + F_2 + F_3 + \ldots \]

\[ U_{\text{Total}} = U_1 + U_2 + U_3 + U_4 + \ldots \]

Newton's 3rd Law

\[ F_{12} = -F_{21} \]

Inertial Reference Frame
**Cannonball Experiment**

- **Force acting on M:** $F = G\frac{Mm}{r^2}$
- **Torque on Wire:** $\tau = \frac{F}{2}$
- **Reflection of Laser from Plane Mirror:** $d\theta = 2\phi$

**Parameters**

- $r = 4.65 \text{ cm} \quad [\text{Ball center to center}]$
- $m = 15 \text{ kg}$
- $m' = 0.015 \text{ kg}$
- $L = 10 \text{ cm}$
- $L' = 18.7 \text{ m} \quad [\text{Distant mirror to wall}]$
- $F = 8.5 \times 10^5 \text{ N/m} \quad [\text{N/m}]$
- $T = 10 \text{ rpm}$

**Image on Wall:**

$\Delta \theta = \frac{4LGMm}{K \pi r^2}$

$\Delta \theta = 4 \times 0.010L \times 6.72 \times 10^{-10} \times 0.015 \times 1.50 \times 8.5 \times 10^5 \times 0.0165$

$\Delta \theta = 0.037L (\text{m})$

$L = 19.7 \text{ m}$

$\Delta \theta = 69.4 \text{ cm}$

$\Delta \theta \exp = ??$