Newton’s Law of Gravitation

- All objects are attracted towards each other...this attraction is gravity, \((G)\)
- \(G\) is a function of mass and distance

- Gravitational Force = \(m_1 m_2 / (r_{12})^2\)
  (same as centripetal force)

- Tidal Force = \(G(m_1 m_2) / (r_{12})^3\)
Centripetal Force

- The force that “pulls” a rotating object towards the center of rotation
- **Gravity** is the origin of Centripetal Force
The Earth-Sun Also Rotate

- **Barysphere**: the center of rotation

- Located ca. 4700 km from center of Earth...located in lithosphere!

Net Force = Gravity and Centripetal Force
Equilibrium Theory

- 2 equal tidal bulges
- Ocean is uniform
- No friction
- No continents

Definitions...

- **Spring Tide**: Maximal tide height when sun and moon line up (doesn’t have anything to do with the season!)
- **Neap Tide**: Minimal tide height, only affected by sun
- **Diurnal Tide**: one max/min per day
- **Semidiurnal Tide**: 2 max/min per day
Lunar Time vs. Solar Time

- The Earth revolves once every 24 h
- The moon also rotates during that 24 h
- Net result: tides repeat every 24 h 50 minutes (so high tide every 12 h 25 min)

Every 24 hours, the Moon rotates 12 degrees
Precession and Ecliptics

- Combine the eccentric orbits of the earth and moon
- Over 18.6 years, the earth-moon plane wanders, while over one year, the earth orbits the sun, while over 1 lunar month, the moon wanders

Solar Tides

- Although the Sun’s force is a much smaller tidal force than the moon, it is important
The Ecliptic Effect

- The Earth is tilted, which affects the tides...

- The Moon is also 5 degrees off-plane, so the net result is a 28.5 deg. wander
Types of Tide

- **Diurnal** (once daily)--Gulf of Mexico

- **Semidiurnal** (twice daily; about same size)--Atlantic Coast

- **Mixed** (highs and lows are of different heights) Pacific Coast

Dynamic Theory of Tides

- Continents, friction, etc. mess up the perfect tidal theory
- **Amphidromic Points** are where tide bulges actually occur
- **Cotidal Lines** connect the amphidromic points
Progressive & Standing Waves

- Tidal currents have very long periods, so have corresponding fast speeds and large wavelengths
- Tides act as shallow-water waves in most basins

Summary of Dynamical Tides

- Must account for all large objects, including the sun, moon, other planets
- Takes into account orbits, precession, and the tilt of the earth
- Assumes tides are forced waves, and that they form cells or amphidromic points because of friction, continents
- For 1995 (San Francisco Bay), predictions were off by an average of 0.25 feet!
Tide Prediction Machines

c. 1912 tide prediction machine, with graphical display