

The Marine Environment

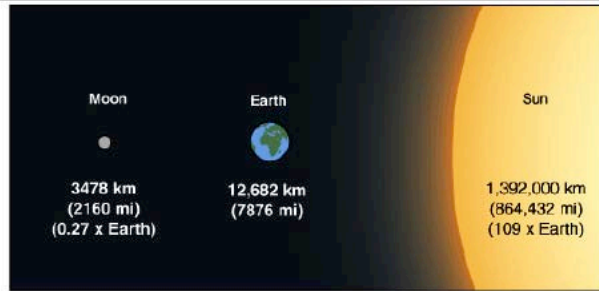
Ocea 101  
Raphael Kudela

## Tides

- Newton's Law and the forces driving tides
  - The major solar bodies
  - Gravitational (centripetal) vs. Centrifugal
- Equilibrium Theory
- Dynamic Theory
- Tidal currents and motion
- Measuring tides

## 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 =  $G(m_1 m_2) / (r_{12})^3$**



Tide-Generating Body	Distance from Earth (avg)	Mass (Metric tons)	Relative Tide-Generating Effects
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Moon	384,835 km (234,493 mi)	$7.3 \times 10^{19}$	Based on relative masses, the sun is 27 million times more massive than the moon and has 27 million times the tide-generating effect. However, since the sun is 390 times farther than the moon from Earth, its tide-generating effect is reduced by $390^3$ , or 59 million times.
Sun	149,758,000 km (93,016,845 mi)	$2 \times 10^{27}$	



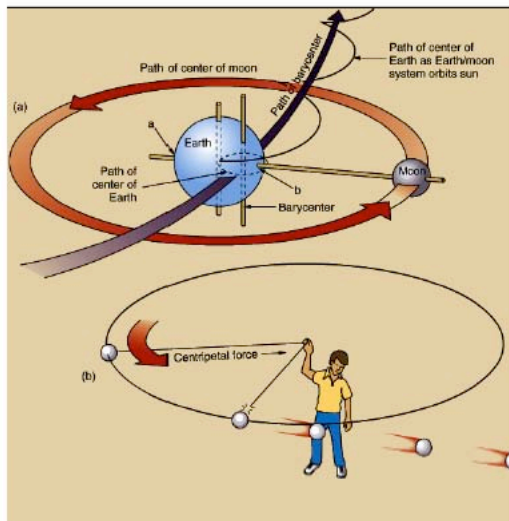
DETERMINATION OF TIDE-GENERATING FORCE OF SUN RELATIVE TO MOON

$$\text{Tide-generating force} \propto \frac{\text{Mass}}{(\text{Distance})^3} \propto \frac{\text{Sun}-27 \text{ million times more mass}}{(\text{Sun}-390 \text{ times farther away})^3}$$

$$(390)^3 = 59,000,000 \text{ Thus, } \frac{27 \text{ million}}{59 \text{ million}} = 0.46 \text{ or } 46\%$$

The sun has 46% the tide-generating force of the moon.

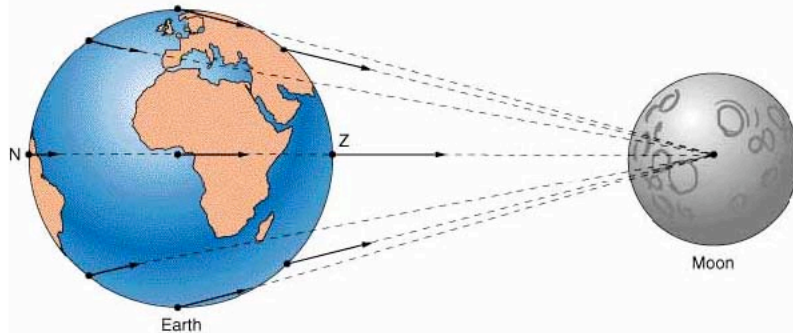
## Centripetal Force



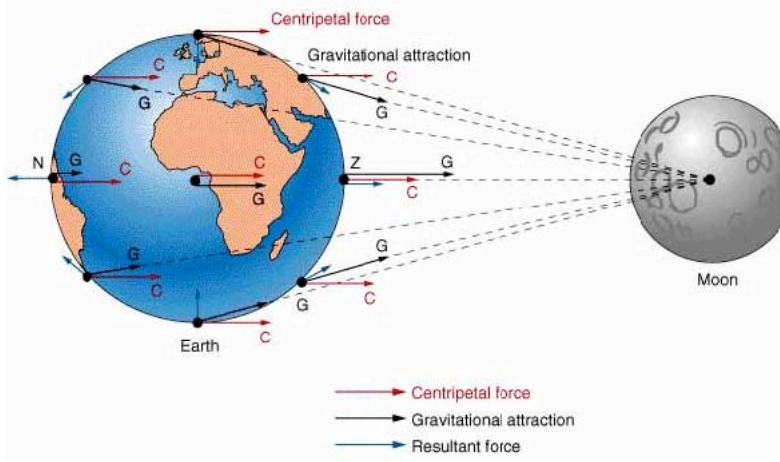
- The force that “pulls” a rotating object towards the center of rotation
- **Gravity** is the origin of Centripetal Force

# The Earth-Sun Also Rotate

- **Barysphere**: the center of rotation
- Located ca. 4700 km from center of Earth...located in lithosphere!

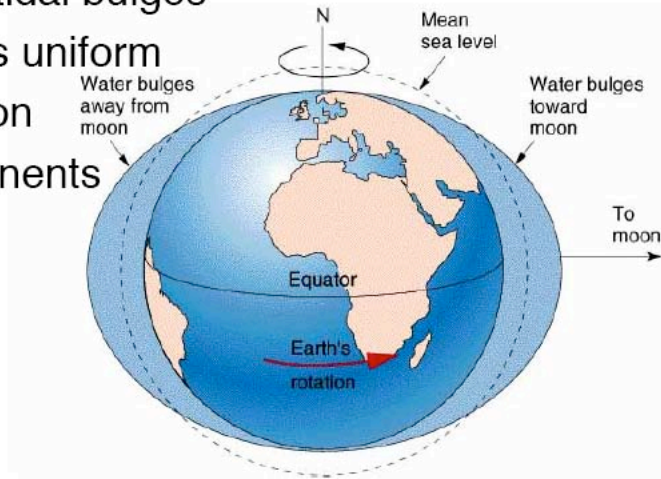


# Net Force = Gravity and Centripetal Force



# Equilibrium Theory

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

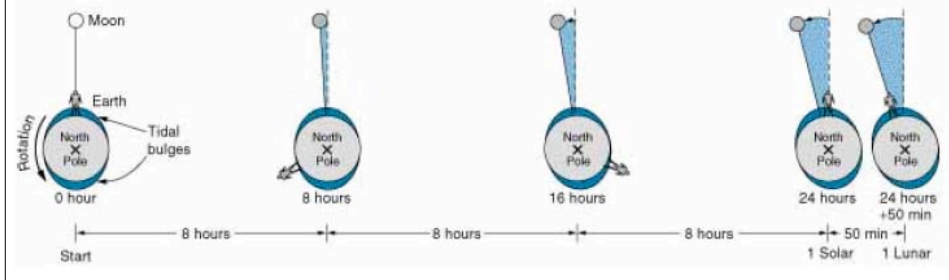


## Definitions...

- **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

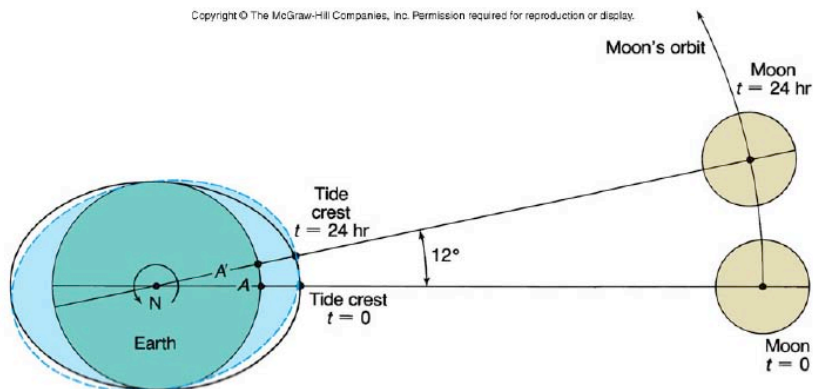
# Lunar Time vs. Solar Time

- 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)



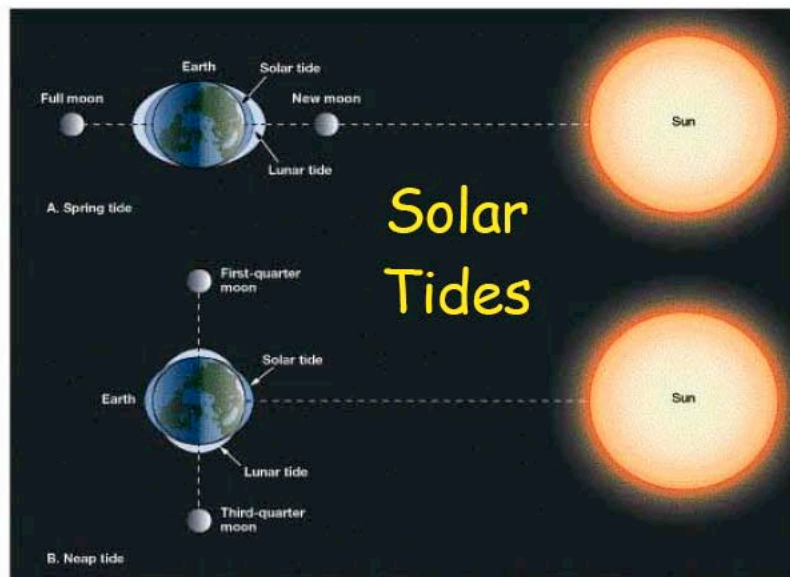
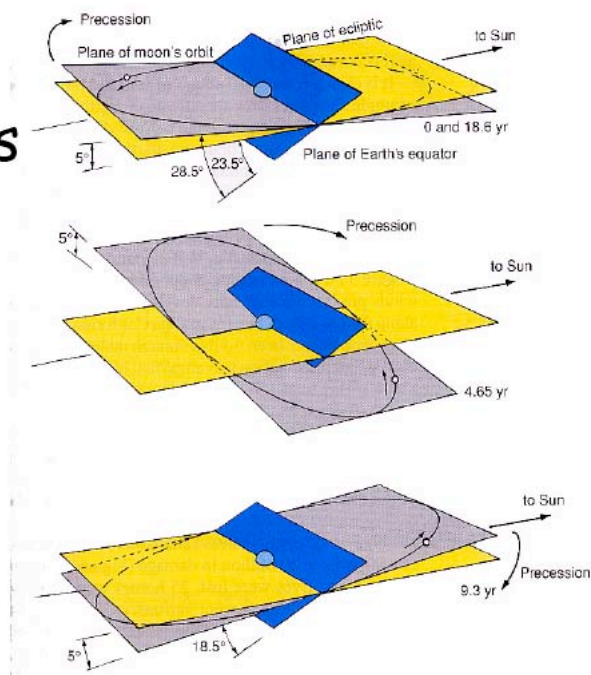
# Every 24 hours, the Moon rotates 12 degrees

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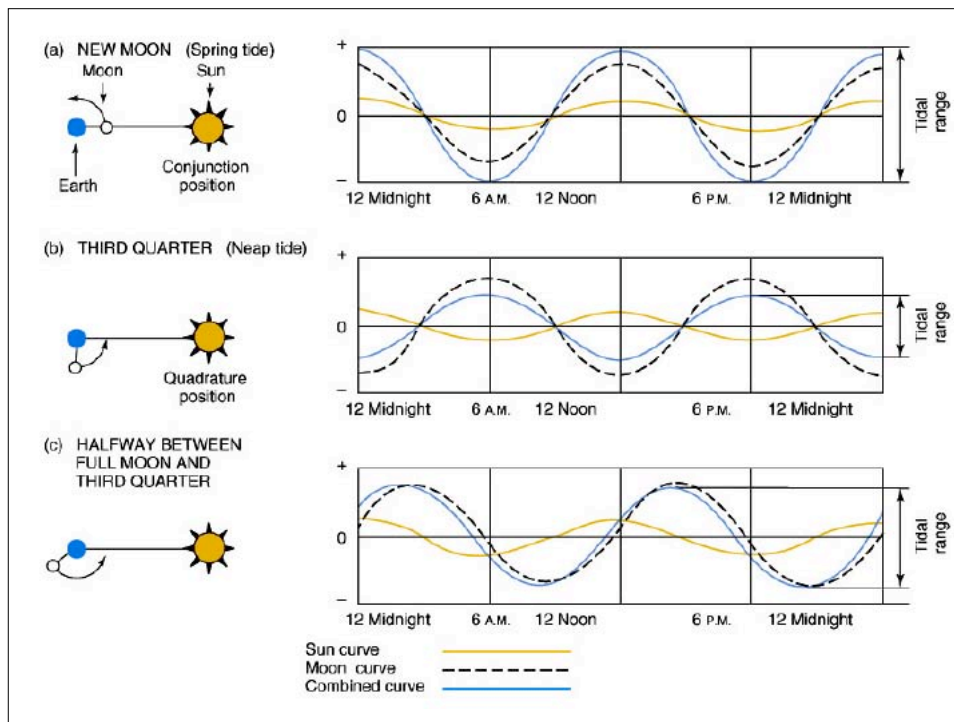


# Precession and Ecliptics

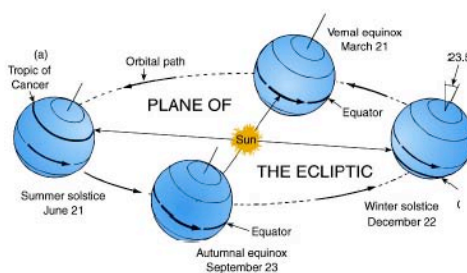
- Combine the eccentric orbits of the earth and moon
- Over 18.6 years, the earth-moon plane wanders, while over one year, the earth orbits the sun, while over 1 lunar month, the moon wanders



- Although the Sun's force is a much smaller tidal force than the moon, it **is important**

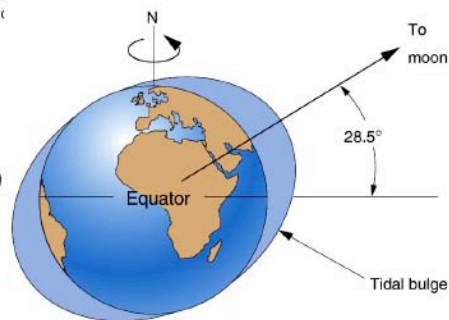


## The Ecliptic Effect



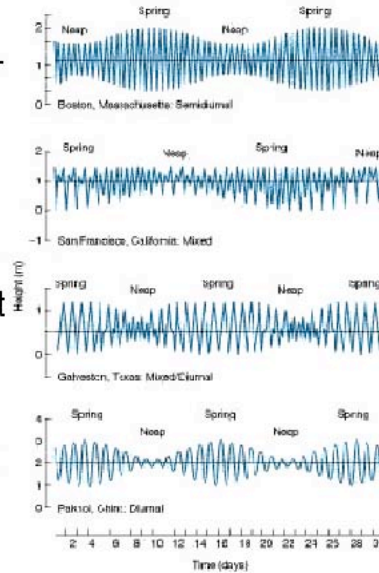
- The Earth is tilted, which affects the tides...

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



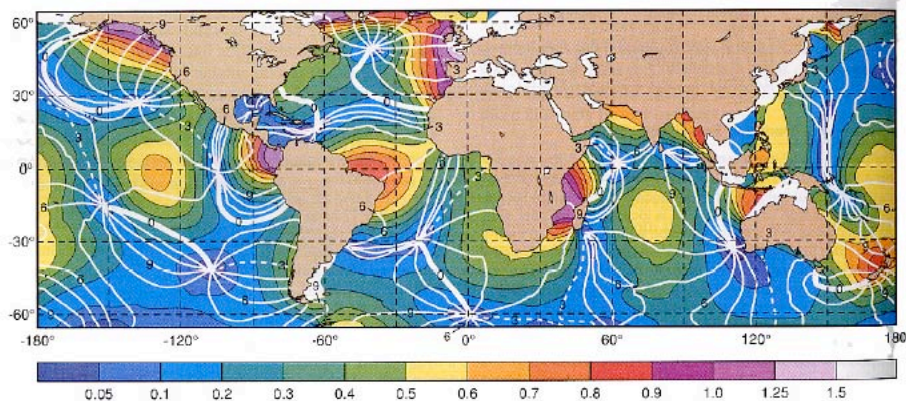
## Types of Tide

- **Diurnal** (once daily)-  
-Gulf of Mexico
- **Semidiurnal** (twice daily; about same size)--Atlantic Coast
- **Mixed** (highs and lows are of different heights) Pacific Coast



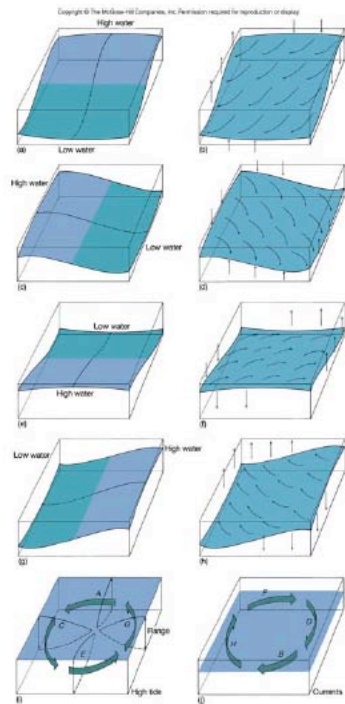
## Dynamic Theory of Tides

- 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

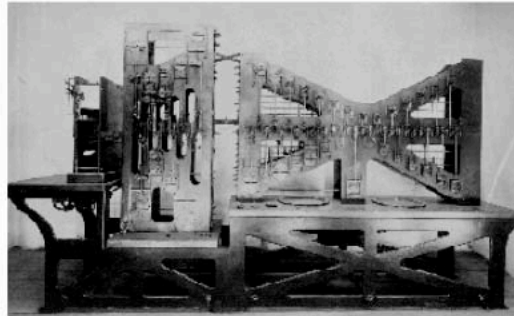
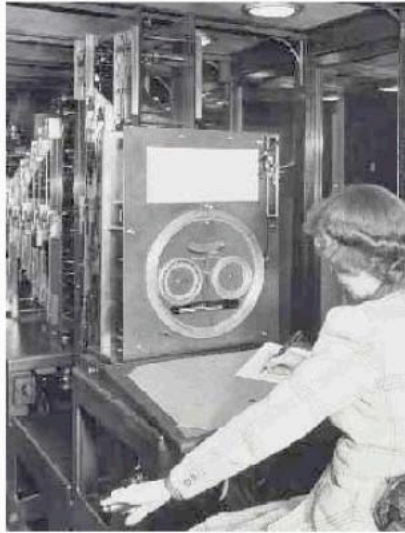
- Tidal currents have very long periods, so have corresponding fast speeds and large wavelengths
- Tides act as shallow-water waves in most basins



## 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



ca. 1912 tide prediction machine, with graphical display