

Tides

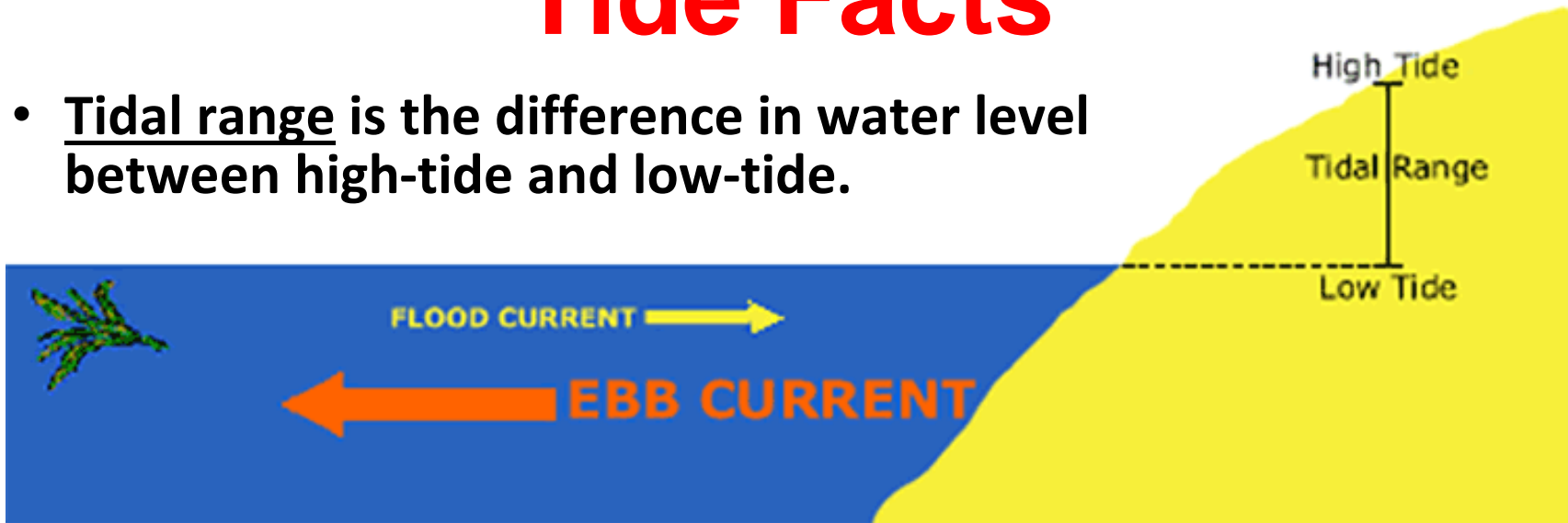
Tides are the slow, periodic **vertical rise and fall of the ocean surface** caused by **gravitational pull of the Moon and Sun** on the rotating Earth.



- Tidal forces affect the entire Earth, but the gravitational pull on LIQUIDS is much more noticeable than on SOLIDS (because liquids move more easily than solids).
- While tidal changes in sea level are easier to observe where land and water meet, they **exist everywhere** - even in the middle of the ocean.

Tide Facts

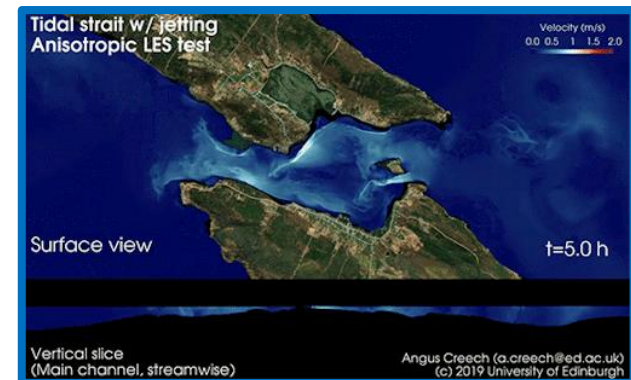
- Tidal range is the difference in water level between high-tide and low-tide.



- Tides produce oscillating currents known as tidal streams.



Bay of Fundy Tidal Streams

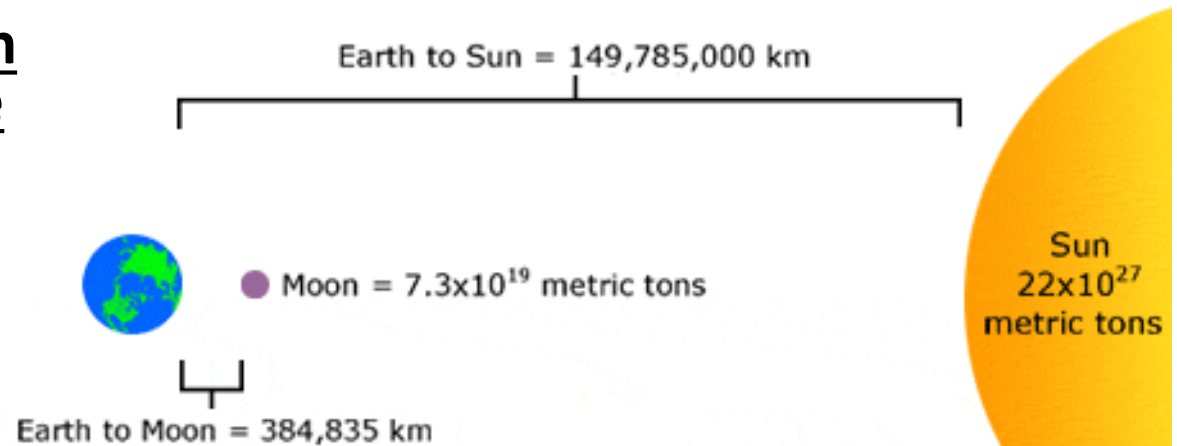


- One low-tide/high-tide cycle takes about **12 hours and 25 minutes** (the *lunar day* is equal to about 24.8 hours).

Gravitational Pull of the Moon and Sun

The relationship between the *masses* of the Earth, Moon and Sun and their *distances* to each other play a critical role in affecting the Earth's tides.

- The Sun is 27 million times more massive than the Moon.
- It is also 390 times further away from the Earth than the Moon.
- As a result, the Sun's tide-generating force is about **half** that of the Moon.



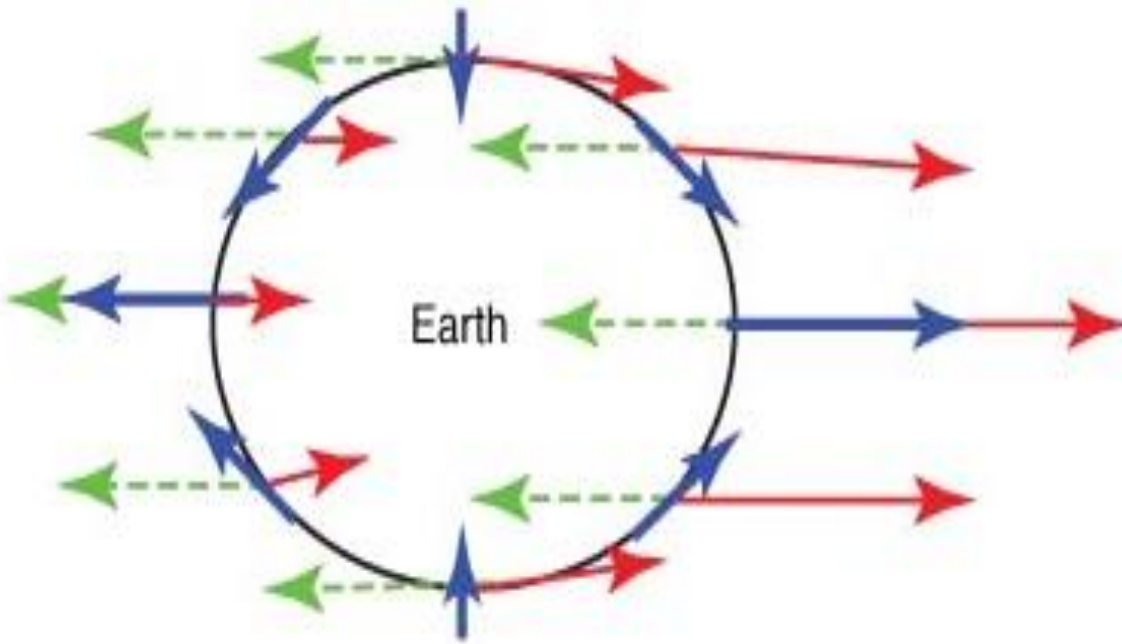
$$\text{Tide-Generating Force} \sim \frac{\text{Mass}}{(\text{Distance})^3}$$

The **Moon** is the **dominant** force affecting the Earth's tides.

Tide-Generating Force

For any two massive bodies rotating around the common center, let's consider the following two forces:

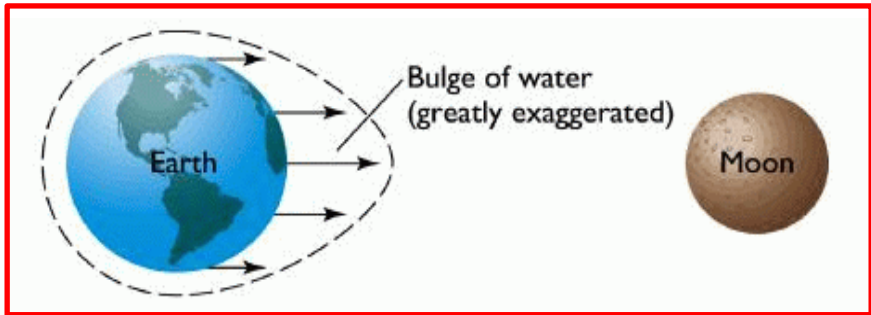
1. **Gravitational pull** (varies with distance)
2. Apparent **centrifugal force** (same everywhere)



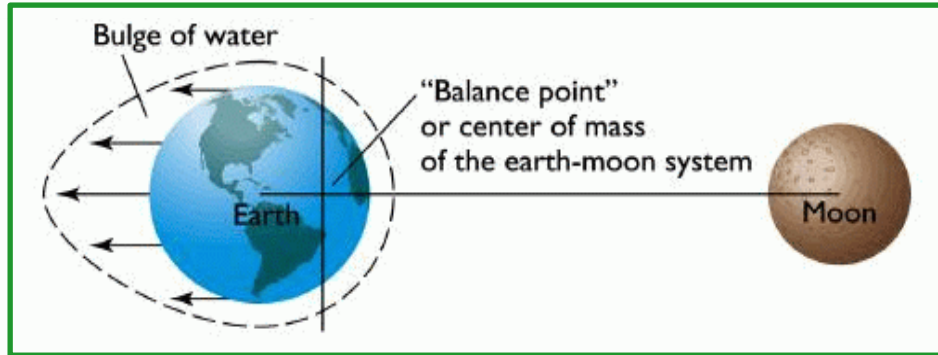
**Tide-
generating
force results
from their
difference
(and is called a
differential force)**



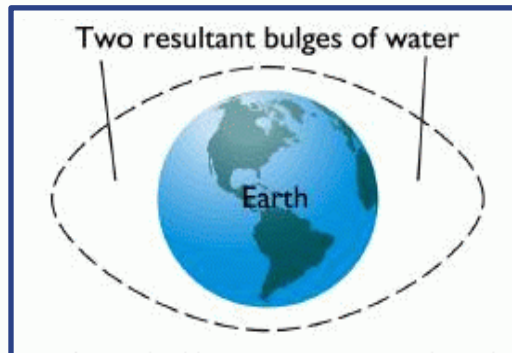
Tidal Bulges



gravitational attraction of the Moon dominates on the near side



centrifugal force due to Earth-Moon rotation dominates on the opposite side



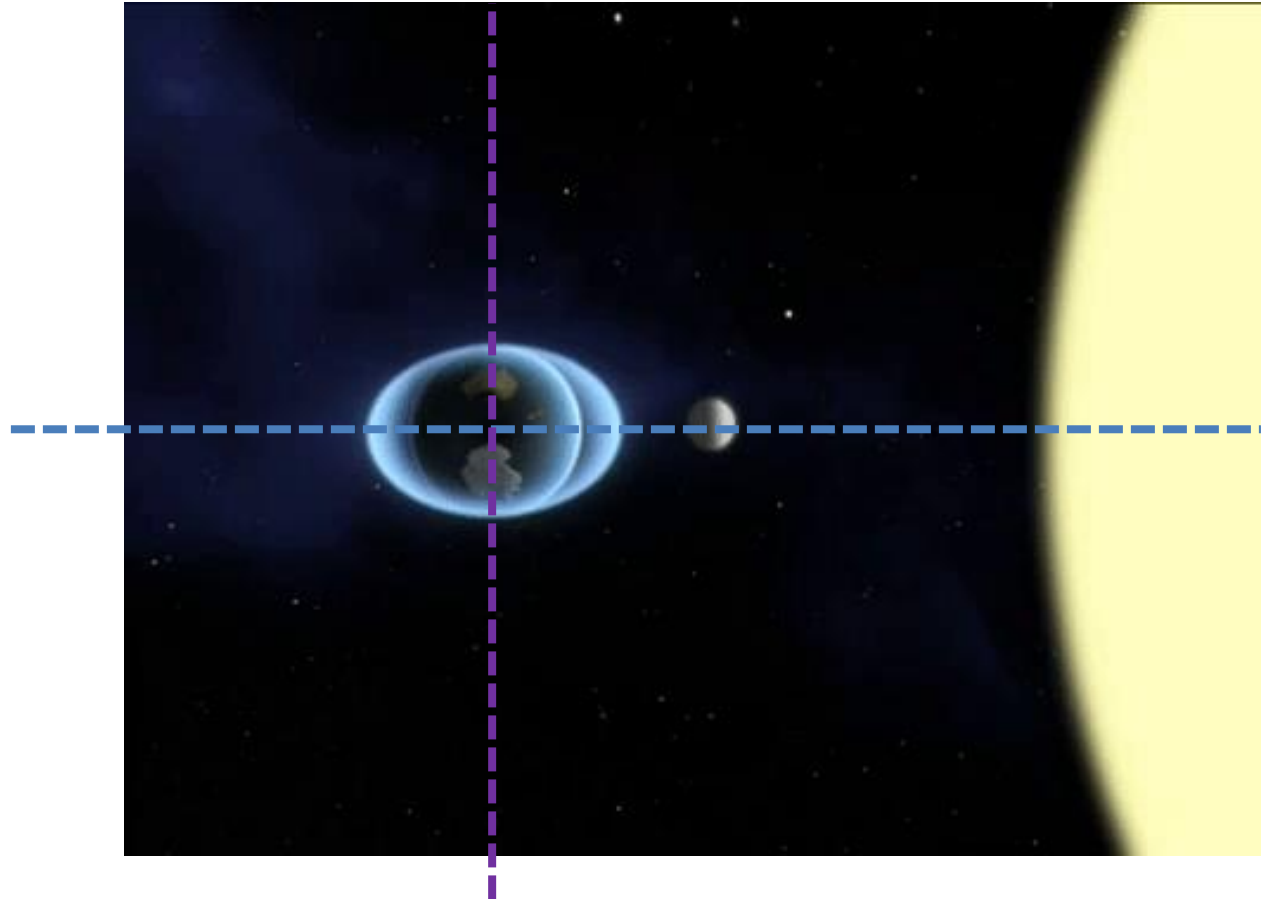
two tidal bulges of water

The Sun has a similar effect, however ~2 times smaller.

Combined effect of the Moon and the Sun

(water bulges shown are greatly exaggerated!)

When tidal forces are aligned, tidal bulges add up.



When tidal forces act at right angle, tidal bulges are at right angle (larger one pointing towards the Moon, smaller one pointing towards the Sun)

Monthly Tidal Cycle (29½ days)

About every 7 days, Earth alternates between:

Spring Tide



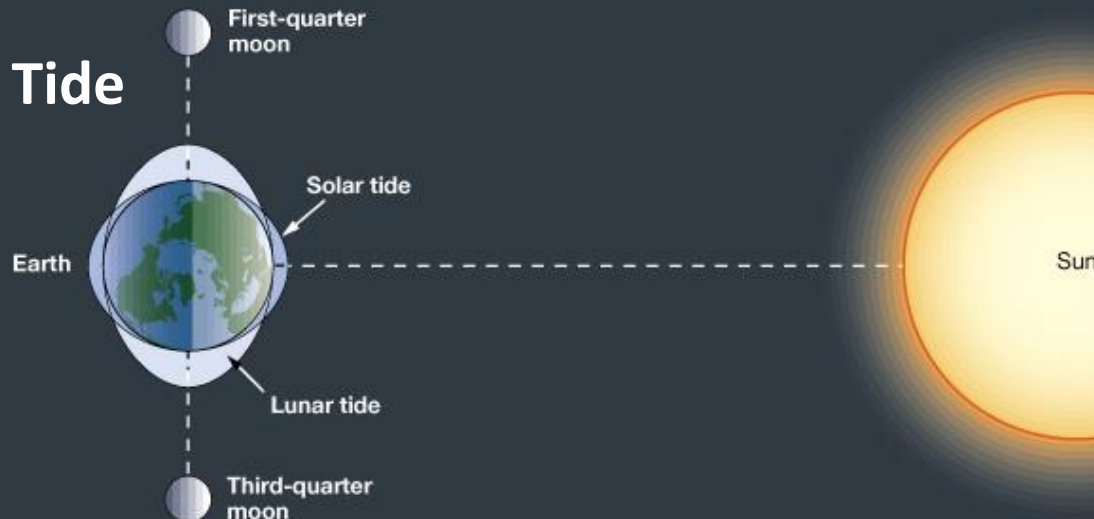
Alignment of Earth-Moon-Sun system (syzygy)

Spring Tide

large tidal range,

highest high tide and lowest low tide

Neap Tide



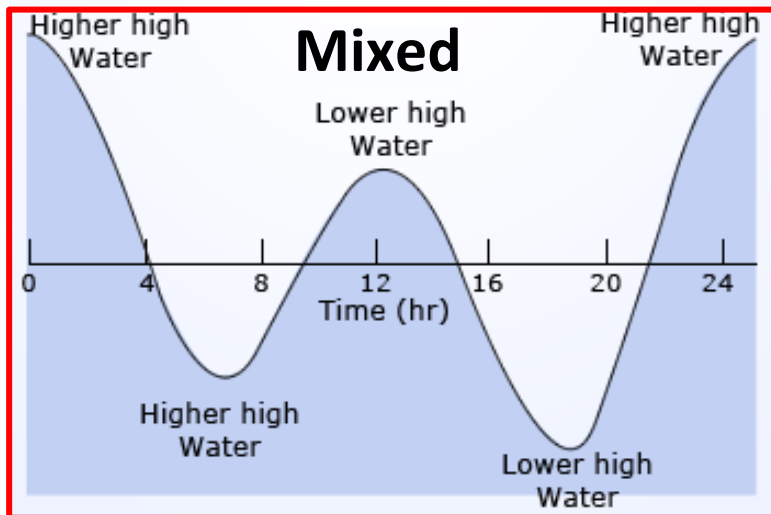
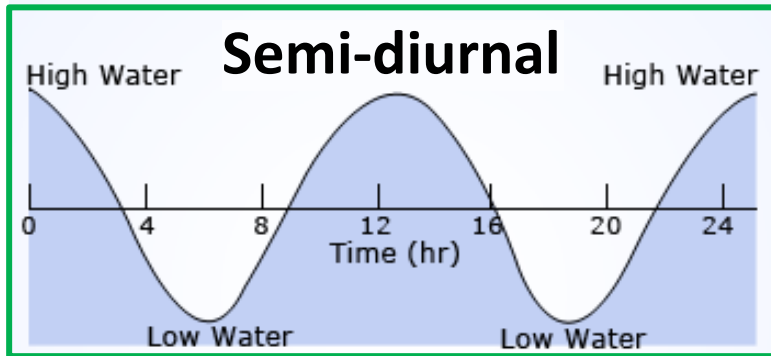
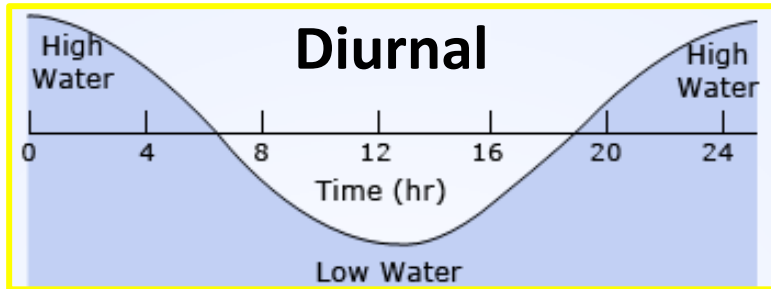
Earth-Moon-Sun system at right angles (quadrature)

Neap Tide

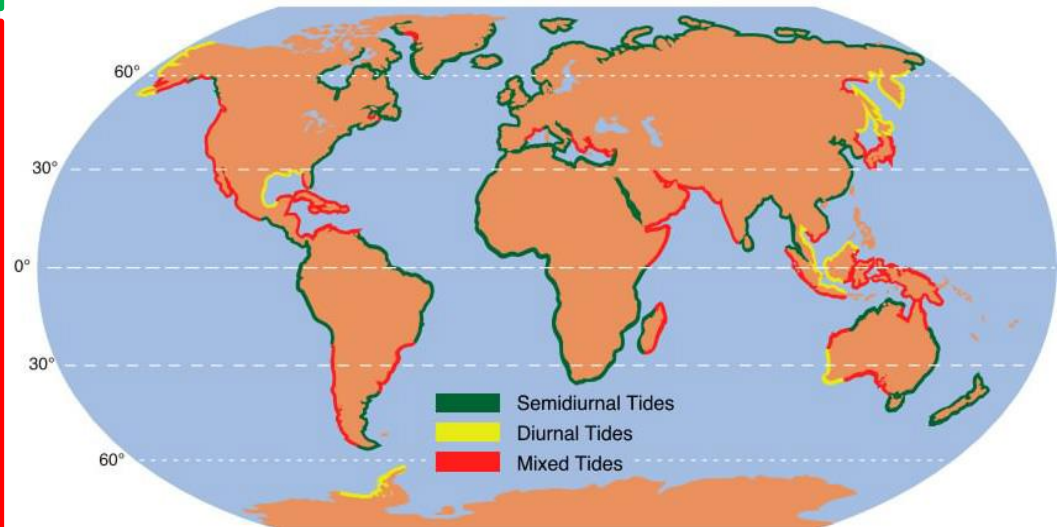
moderate tidal range

Types of Tides

depend strongly on the location and shoreline



- **Diurnal**: one tidal cycle per day (Gulf of Mexico)
- **Semi-diurnal**: two high waters and two low waters each day (Boston, MA)
- **Mixed**: two high and two low waters each day, all four with different heights (Los Angeles, CA).



The Bay of Fundy, Canada: world's largest tidal range

- Tidal energy is focused by shape and shallowness of bay.
- Maximum spring tidal range in Minas Basin = 17 meters (**56 feet!**).

Alma harbor at **High Tide** and **Low Tide**

