EWCE 471
Coastal Engineering

Lecture 2-4: Tides and Currents



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MIST

What Are Tides?

- Tides are the periodic rise and fall of the ocean surface due to the gravitational force of the moon and the sun.
- Tides occur in all bodies of water.
- Occurs daily.



What Are Tides?

- Tides are waves that are caused by the gravitational attraction of the Moon and the Sun. Tidal waves are the longest of all waves. Wavelength can be up to half of the Earth's circumference.
- The changing tide produced at a given location results from the changing positions of the Moon and the Sun relative to the Earth coupled with the effects of the Earth's rotation.



High Tides

- High tides are when the water reaches its **highest** point.
- High tide occurs in those parts of the ocean which face the moon.





Low Tides

- Low tides are when the water reaches its lowest point.
- Low tide occurs at the same time in those parts which are at an angular distance of 90 degrees to the high tide.



Intertidal Zone

- Is the strip of seashore that is submerged at high tide and exposed at low tide.



Causes of Tides

- The various frequencies of astronomical forcing contributing to tidal variations are called constituents.
- Tides are caused by the interaction of Earth, the Moon, and the Sun. The main reasons for the occurrence of tides:
  - The gravitational attraction exerted on the earth by the sun and the moon.
  - Centrifugal force created due to the rotation of the earth.

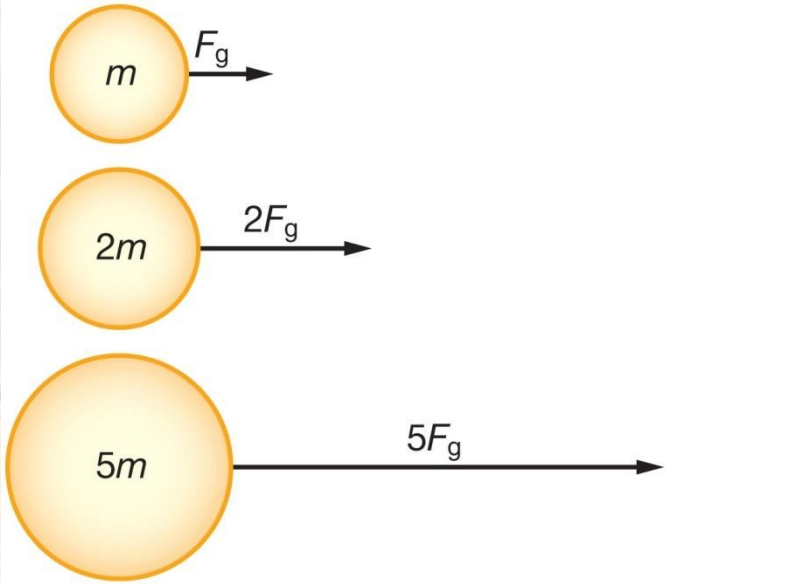
Watch the video from the following link:

https://www.youtube.com/watch?v=3RdkXs8BibE&t=180s

Tide-Generating Forces (TGF)

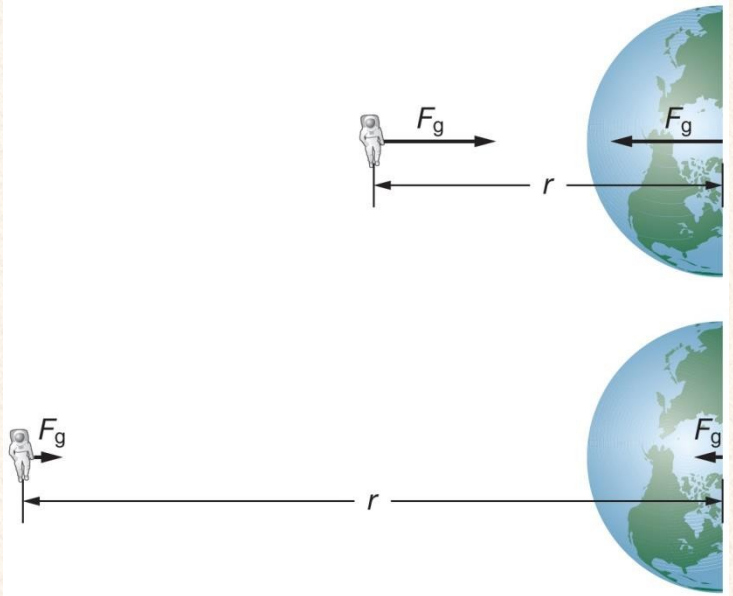
Gravitational Forces

- Every particle attracts every other particle
- Gravitational force proportional to the product of masses
  - Increase mass, increase force
- Inversely proportional to the square of separation distance



(a) The effect of mass on gravitational attraction

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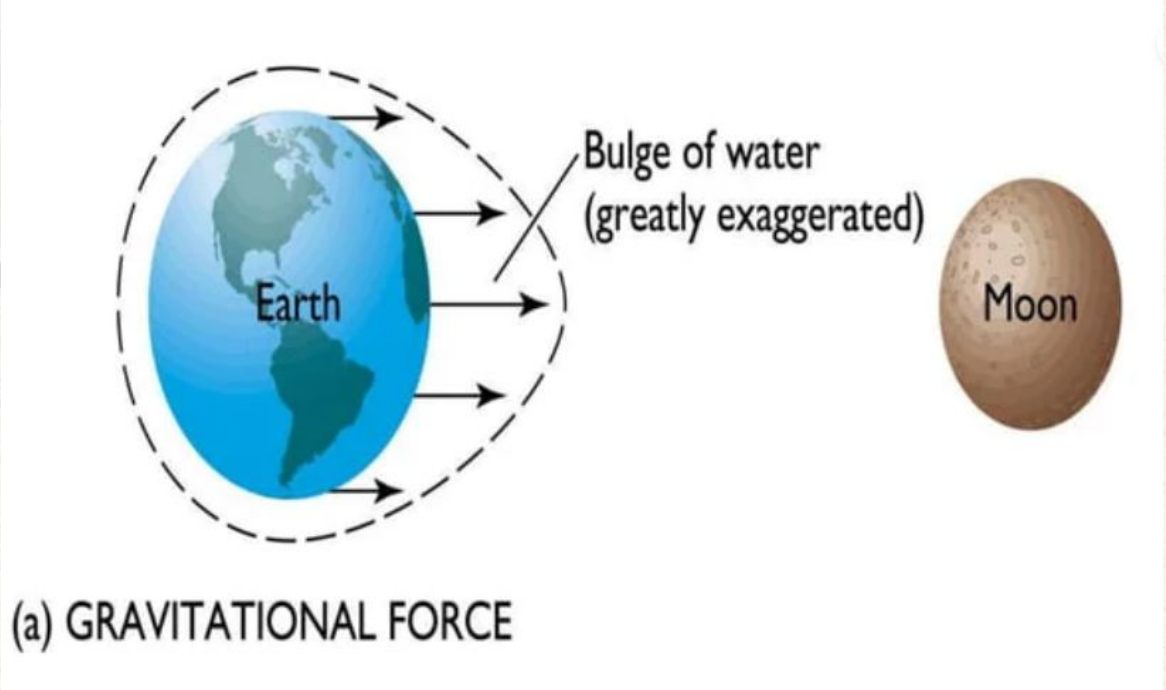
(b) The effect of distance on gravitational attraction

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Tide-Generating Forces (TGF)

Gravitational Forces

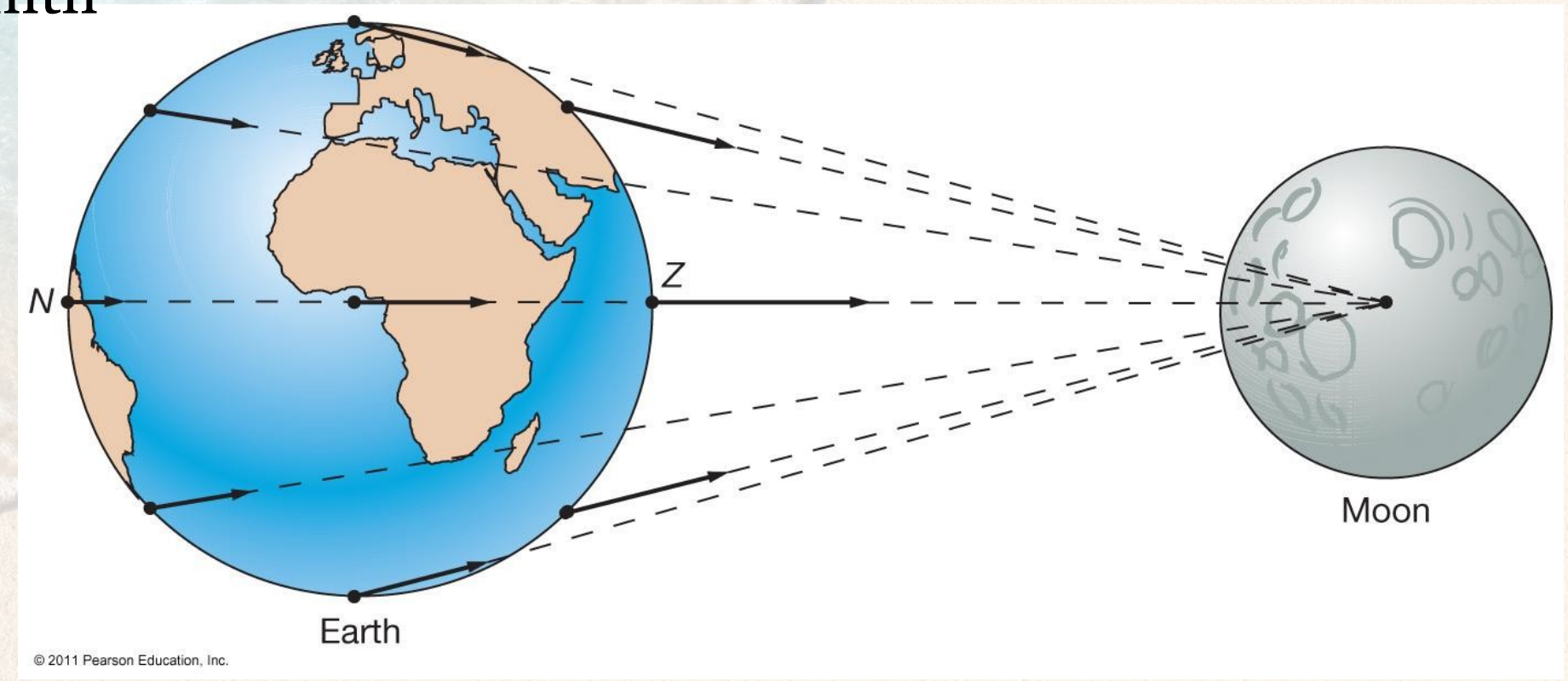
- Since the Moon is close to the Earth, it has a strong gravitational pull on it (closer objects have stronger gravitational pull).
- The gravitational effect of the moon creates a tidal bulge.



Tide-Generating Forces (TGF)

Gravitational Forces

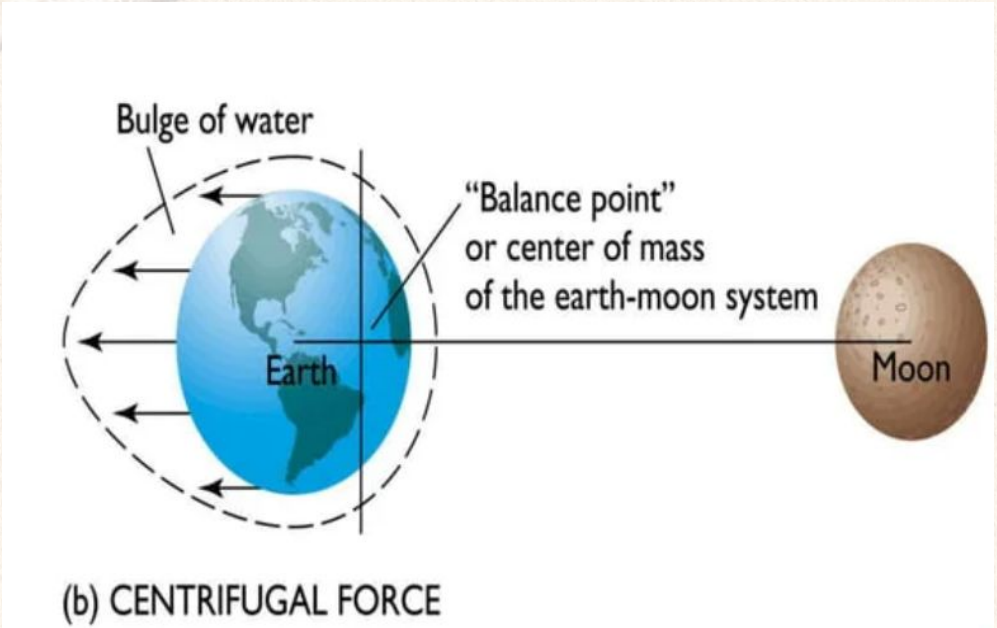
- Greatest force at zenith – closest to the moon
- Least force at nadir – furthest from the moon and opposite zenith



Tide-Generating Forces (TGF)

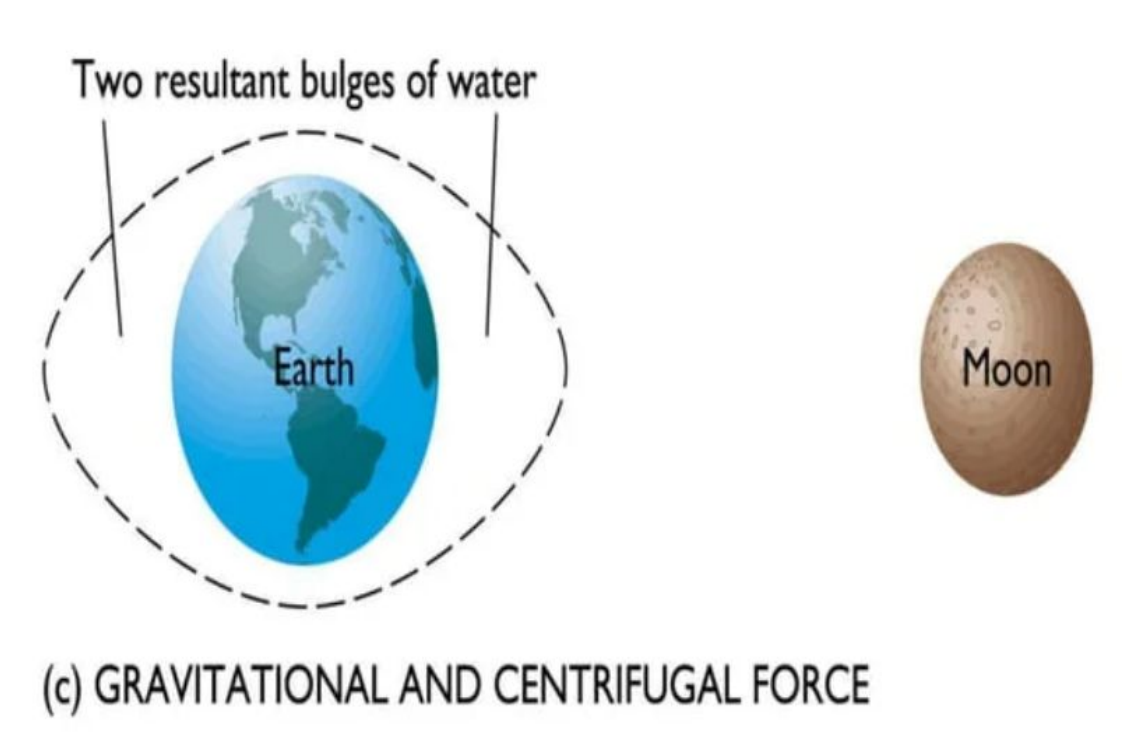
Centrifugal Forces

- Centrifugal forces arise as the Earth and the Moon revolve around one another.
- Because of the unequal masses of the earth and the Moon, the center of rotation lies beneath the Earth's surface.
- The water of the ocean shifts away from the center of rotation creating a second bulge.



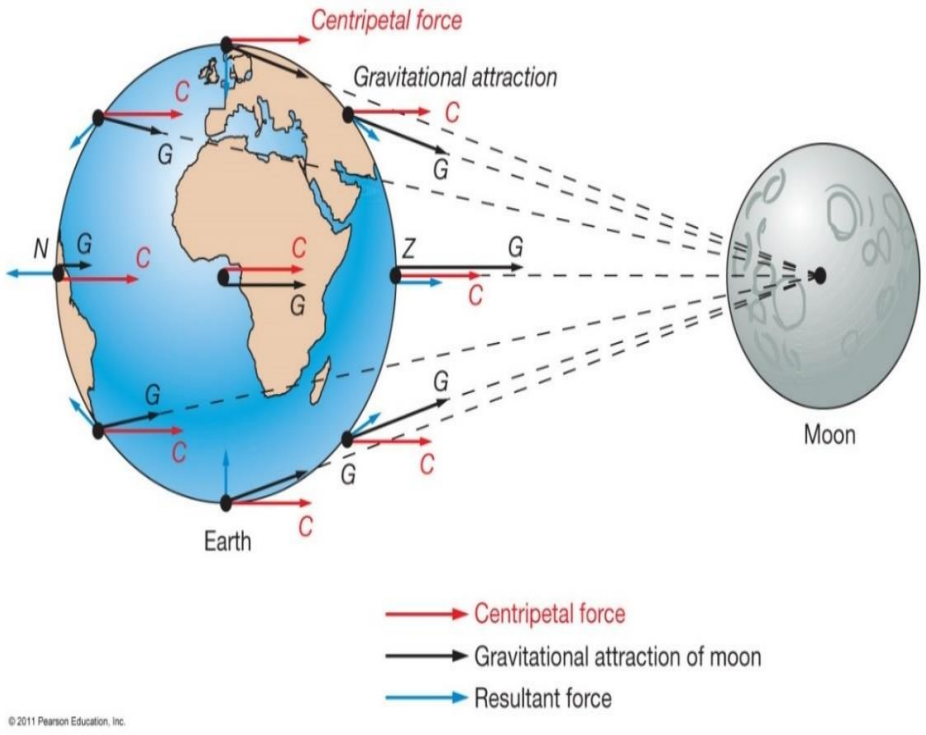
Tide-Generating Forces (TGF)

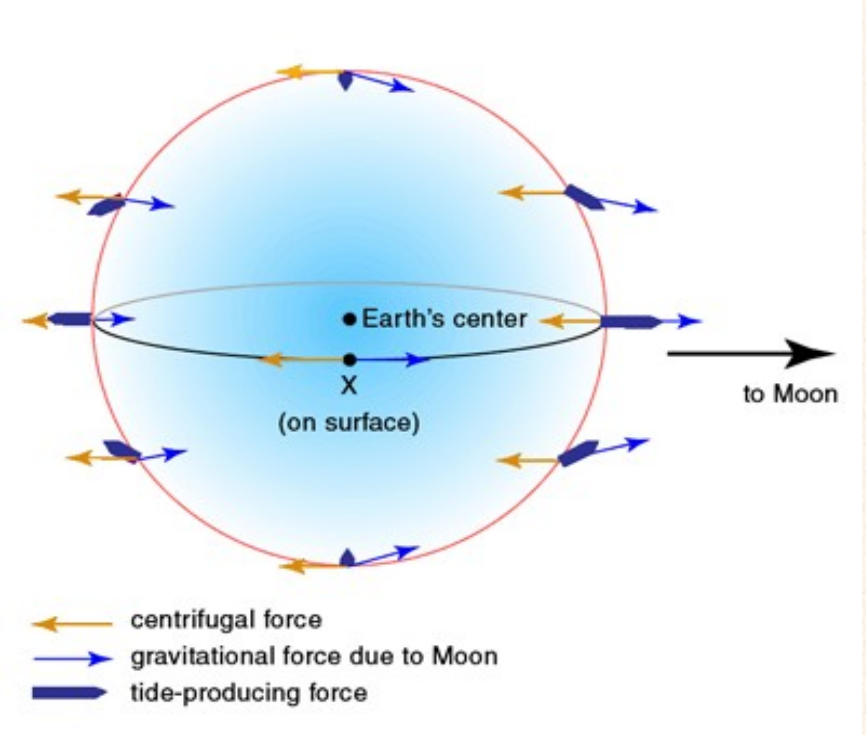
- Gravitational attraction and centrifugal force create two bulges.



Resultant Forces

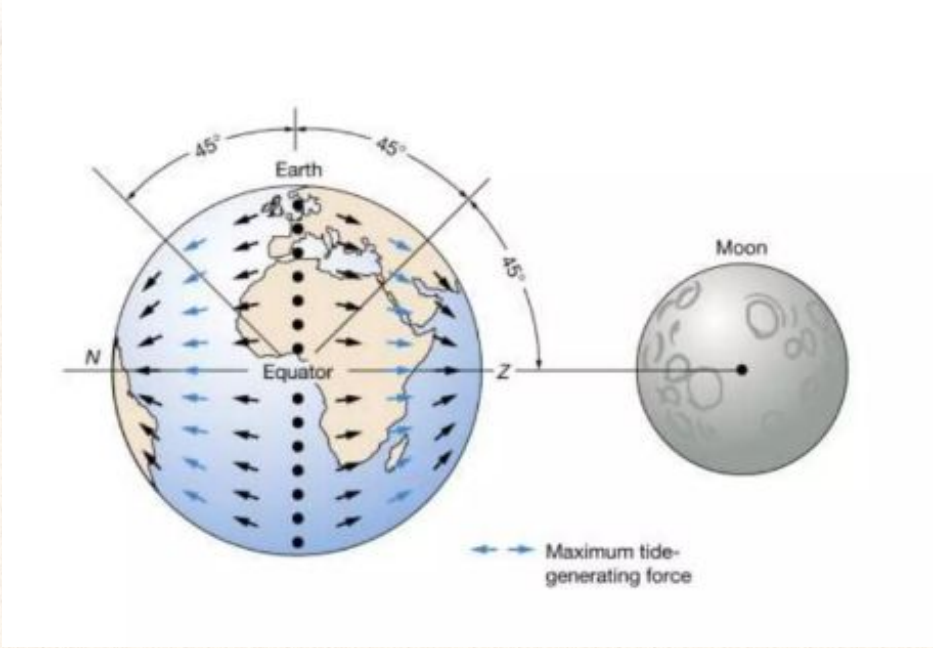
- Mathematical difference between gravitational and centrifugal forces
- Relatively small



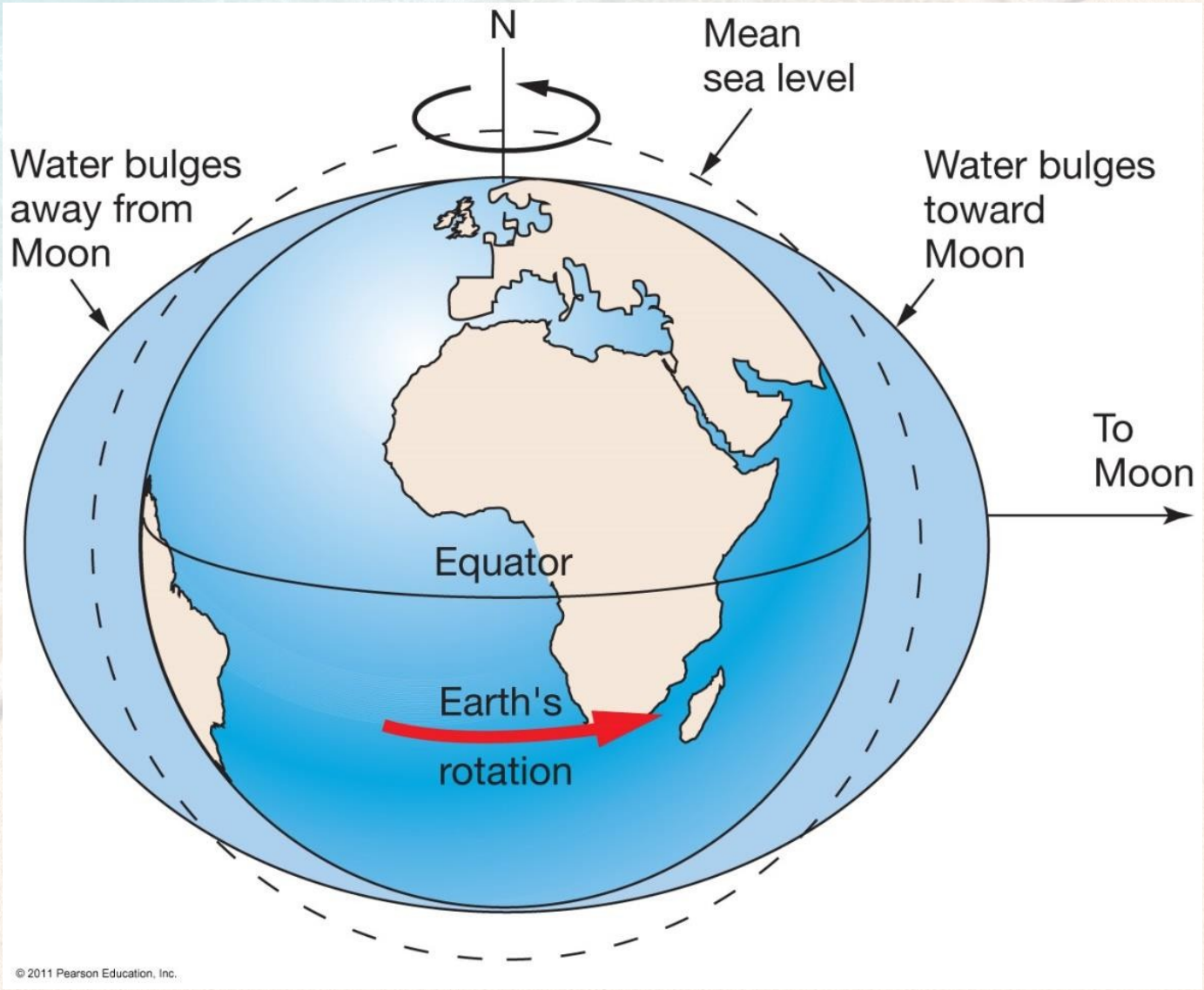


Tide-Generating Forces (TGF)

- Tide-generating forces are the horizontal component of the resultant force.
- Maximized along a latitude of 45° relative to the **equator** between the zenith and nadir.
- Pushes water into two simultaneous bulges - one toward the Moon and one away from the Moon
- Earth rotates into and out of tidal bulges, creating high and low tides.

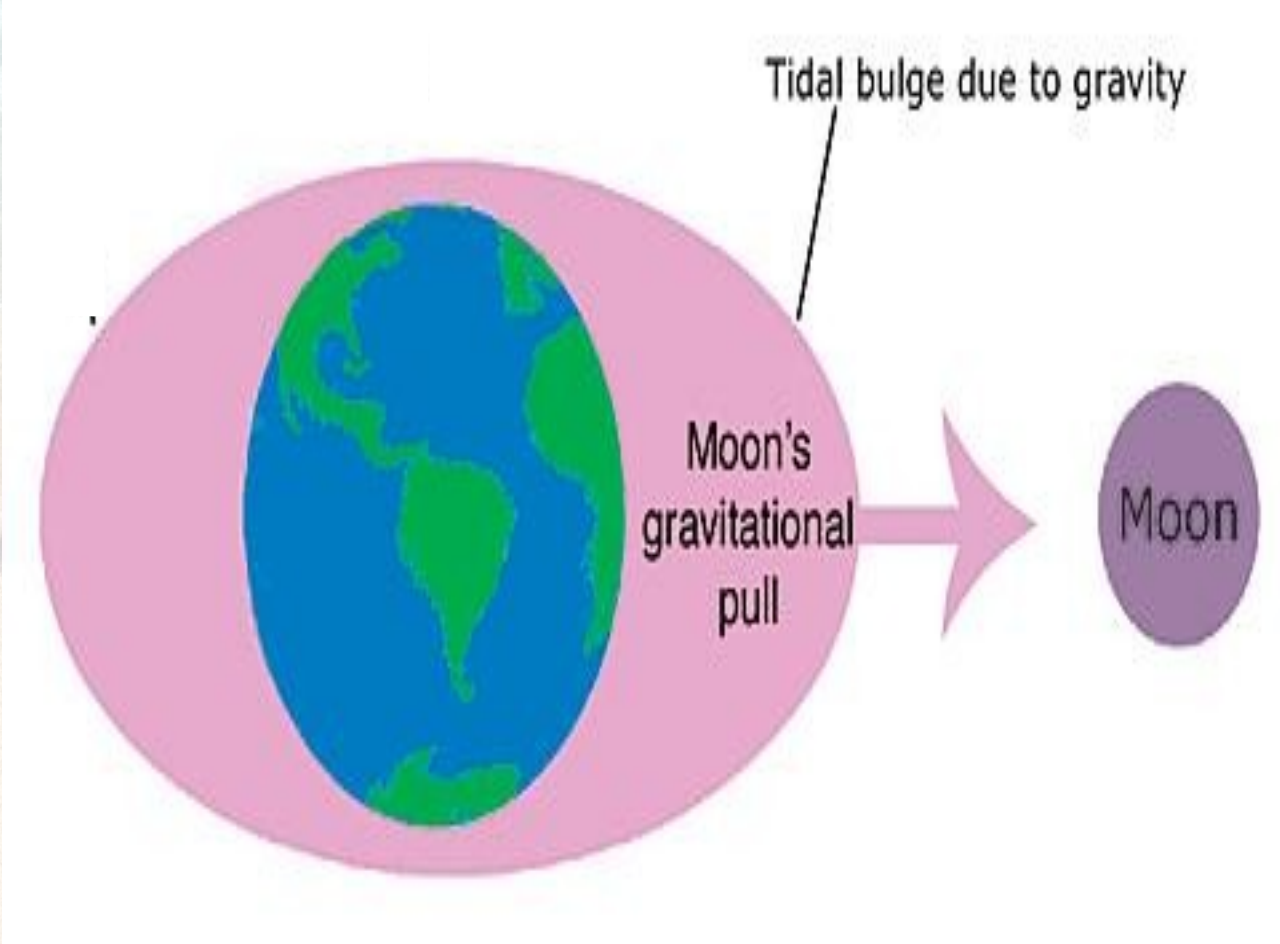


Tidal Bulges – Moon's Effect



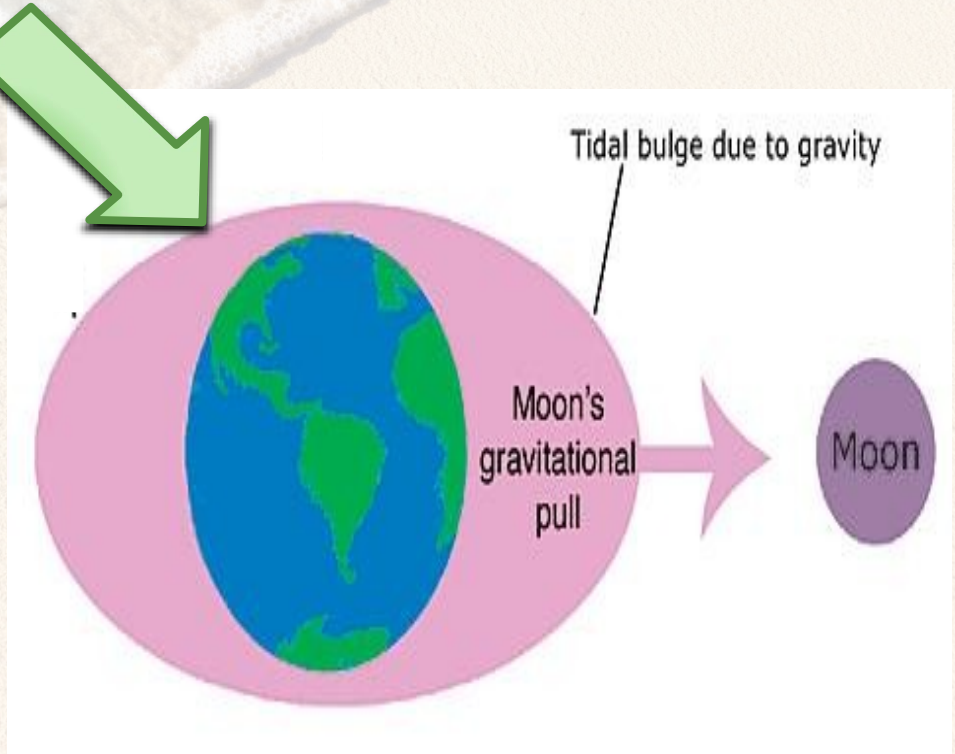
Moon's Gravity – Tidal Bulges

- This **pull** creates a bulge of water, called a **tide bulge**, on the side of Earth **facing the moon.**



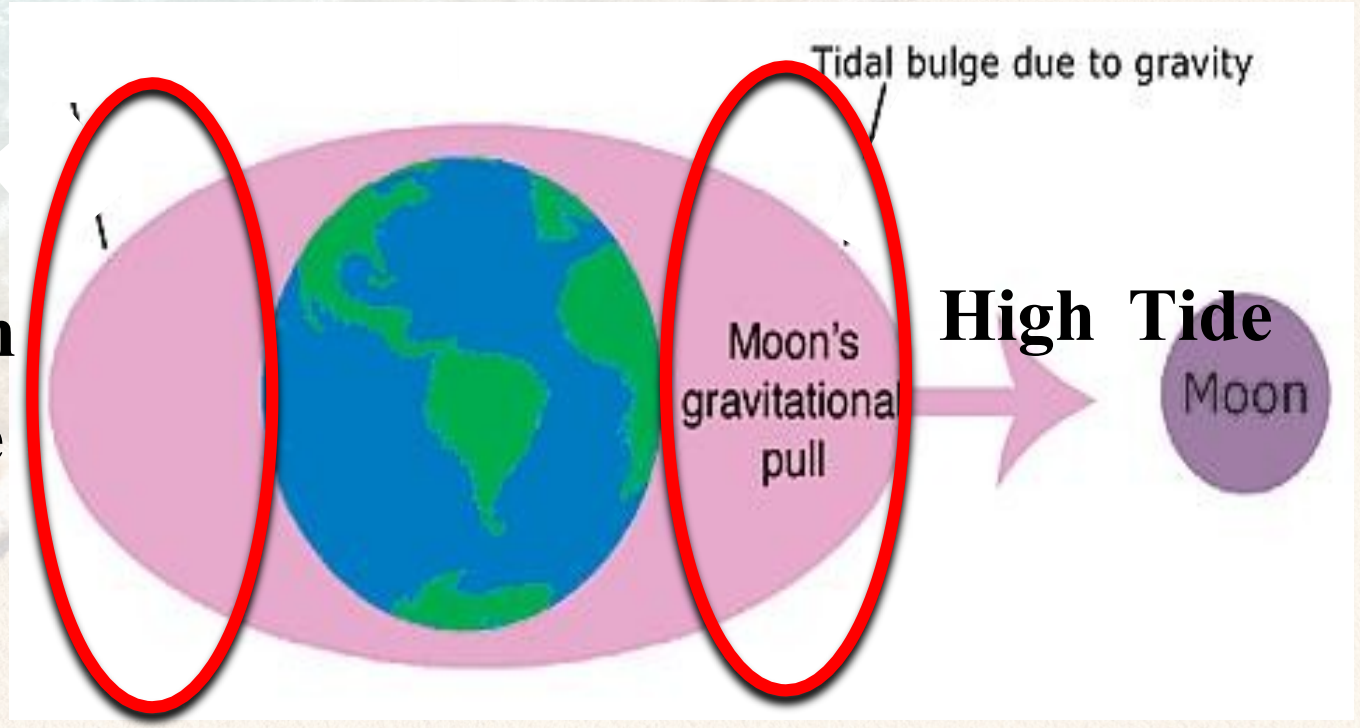
Moon's Gravity – Tidal Bulges

- The water on the side of Earth facing **away** is "**left behind**" and forms a **second** bulge.
- As Earth **rotates**, different places on the planet's surface pass through **the areas of the tidal bulges** and have changes in water levels.



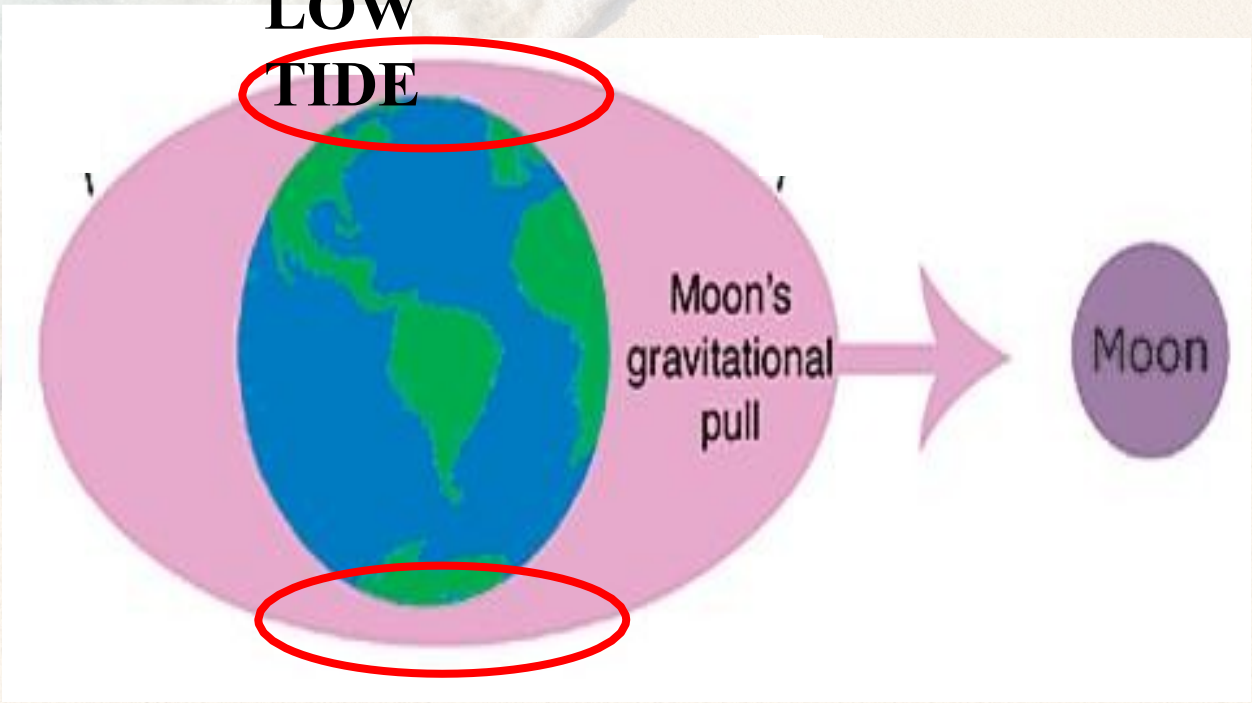
Tidal Bulges – High Tide

- In places where there are tidal bulges, **high tide** is occurring along the coastlines.



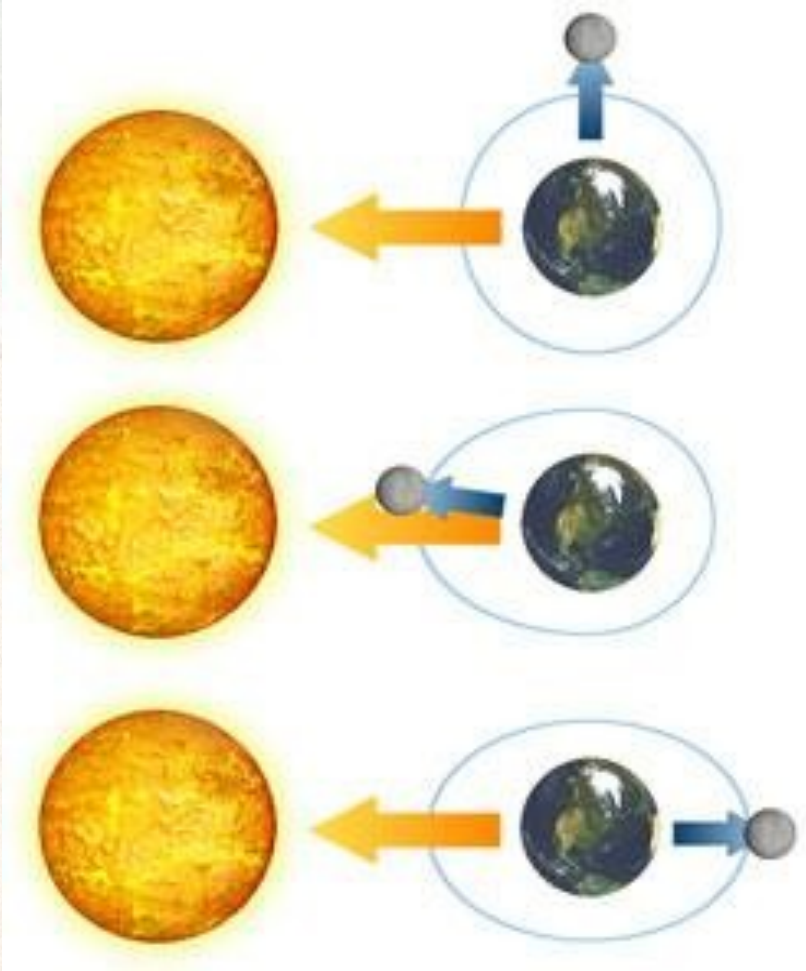
Tidal Bulges – Low Tide

- In places **between** the bulges, **low** tide is occurring.



Sun's Gravity and Tides

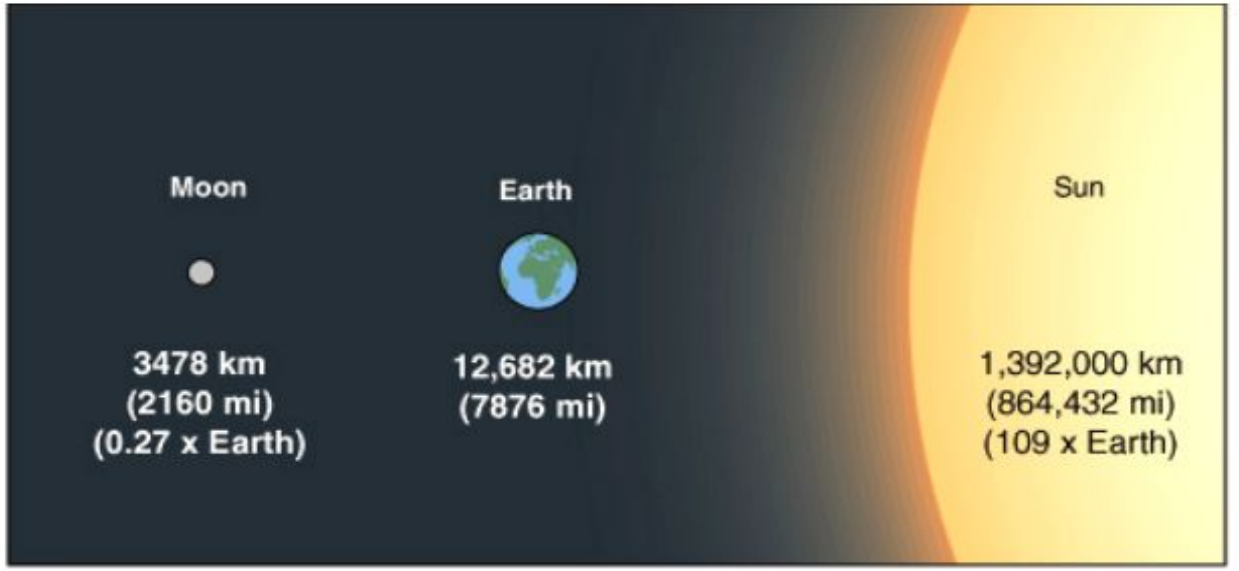
- The Sun is so **large** that its **gravity** also affects tides.
- The Sun and the Moon both have an effect on the tides.



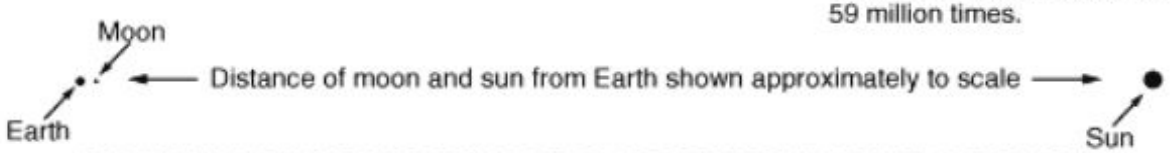
Sun and Moon

- The sun exerts a gravitational attraction on the Earth and its ocean - 46% of the Moon's effect.
- The Moon's proximity to the Earth has a greater gravitational effect on the Earth than the Sun, even though the Sun is much more massive than the Moon.

Why 46%?



Tide-Generating Body	Distance from Earth (avg)	Mass (Metric tons)	Relative Tide-Generating Effects
Moon	384,835 km (234,483 mi)	7.3×10^{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)	2×10^{27}	



DETERMINATION OF TIDE-GENERATING FORCE OF SUN RELATIVE TO MOON

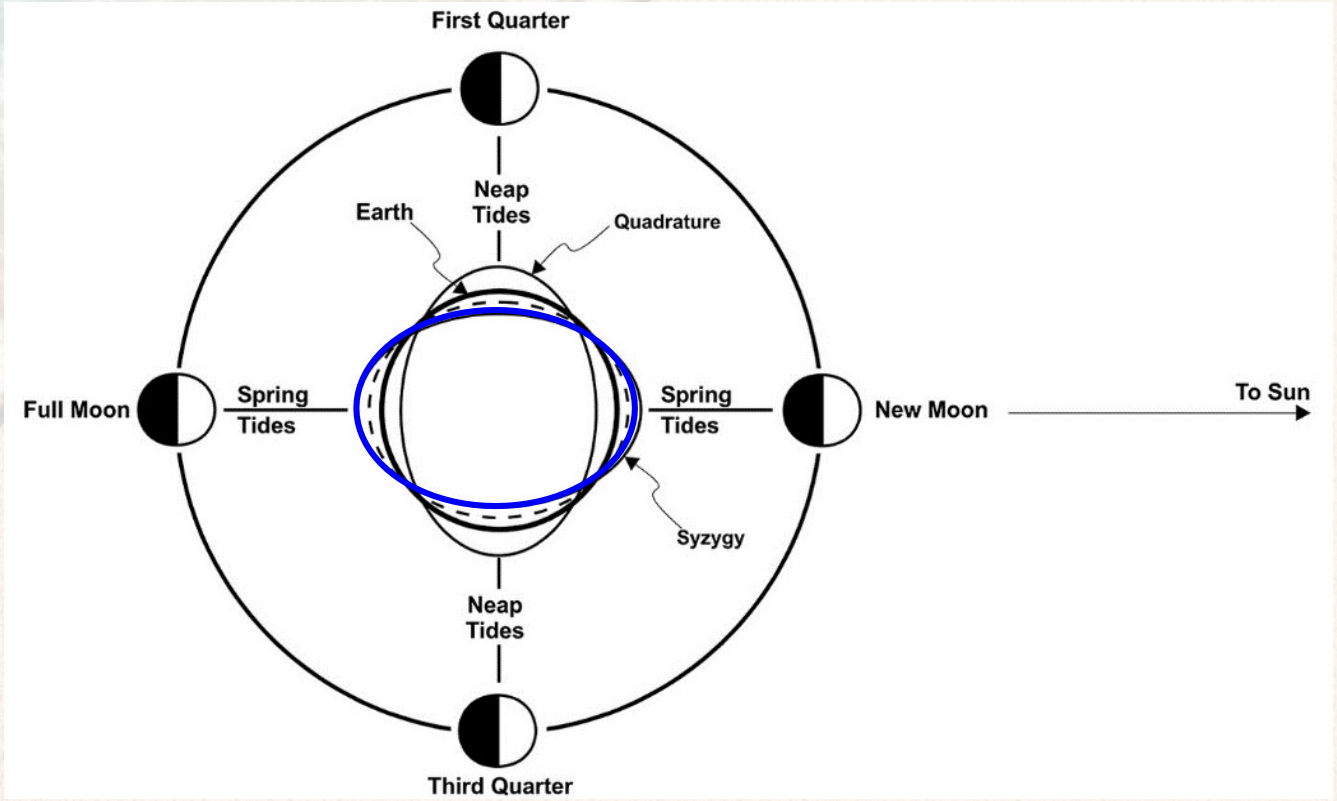
$$\text{Tide-generating force} \propto \frac{\text{Mass}}{(\text{Distance})^3} \propto \frac{\text{Sun–27 million times more mass}}{(\text{Sun–390 times farther away})^3}$$

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

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

Tidal Force Envelope

- Solid ellipses represent the tidal force envelopes produced by the moon in the positions of new moon/full moon.
- Dashed ellipse represents a smaller tidal force envelope produced by the sun.



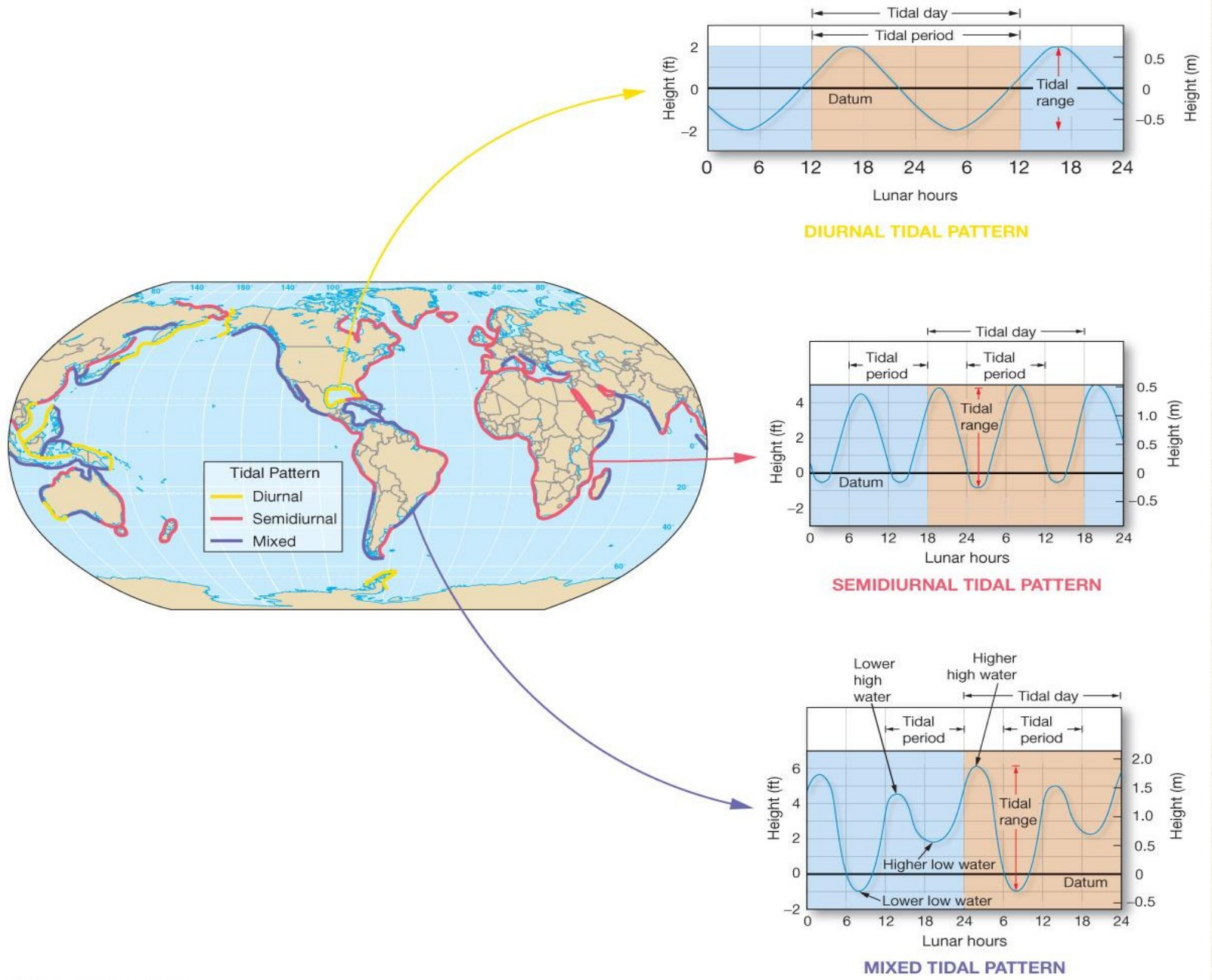
Tidal Phenomena

- Tidal Range – The difference in water level between the high and low tides
- Tidal period – the time between high tides
- Lunar day
  - The time between two successive overhead moons
  - 24 hours, 50 minutes
- Moon orbits Earth
- High tides are 12 hours and 25 minutes apart

Daily Tide Cycle

- Most seashores have **four** tides daily– **two** high tides and **two** low tides.
- The observable rise and fall of the sea level is influenced strongly by **shoreline topography, ocean currents, and the distribution of the continents** on earth.
- As a result, different tidal cycles can be experienced in different regions of the world.
- They are described as **semi-diurnal, diurnal, or mixed tidal cycles.**

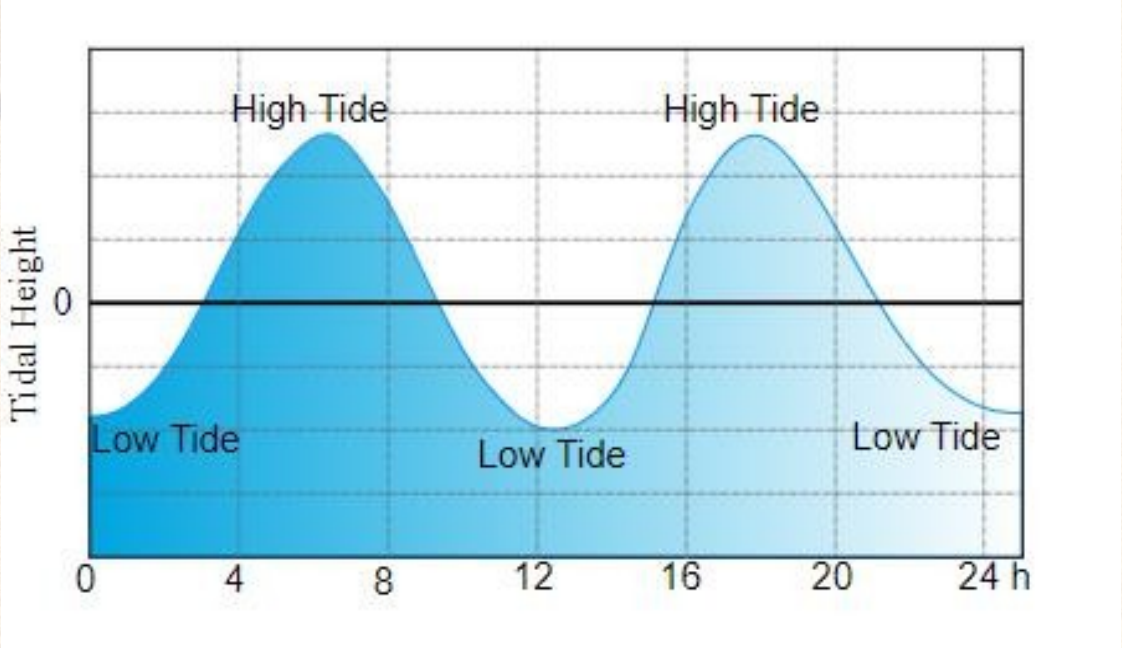
Tidal Pattern



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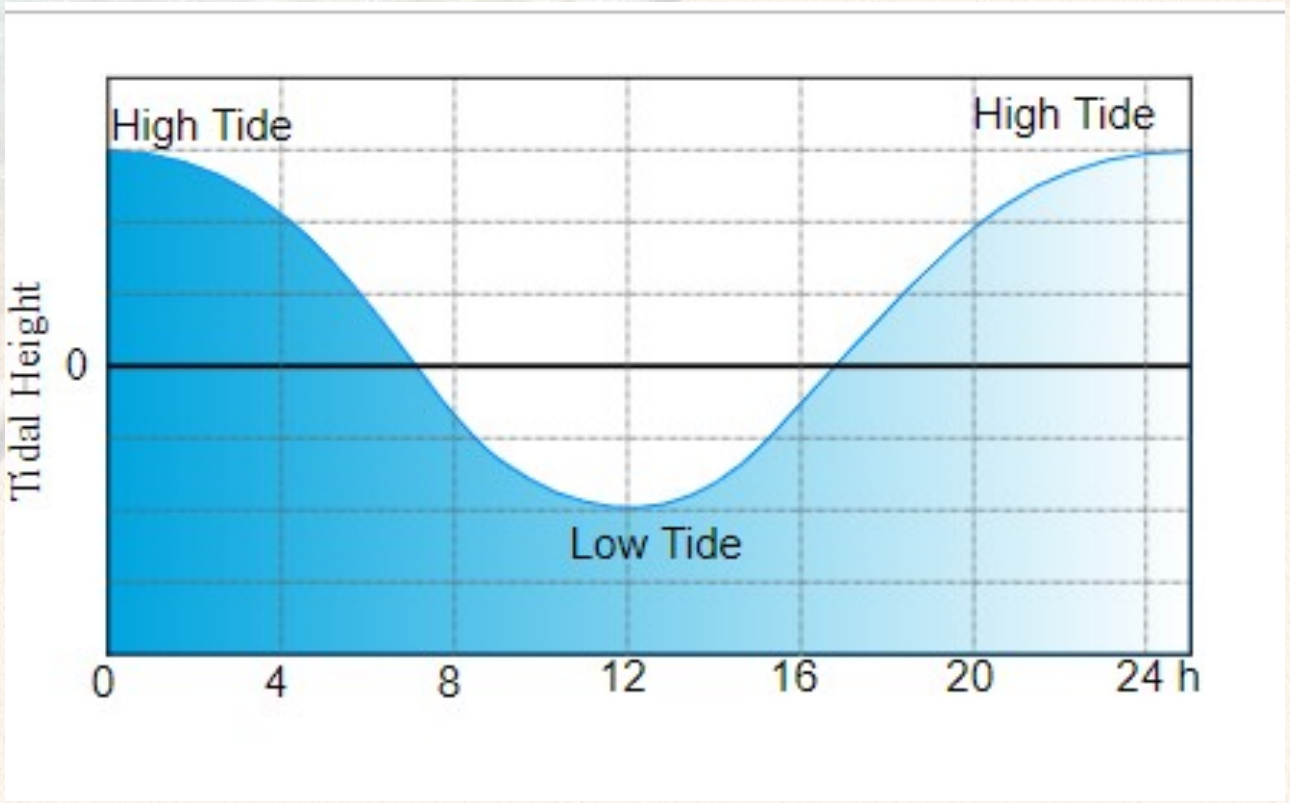
Semidiurnal Tides

- A semidiurnal tidal cycle is a cycle with two nearly equal high tides and low tides every lunar day.
- They have a period of 12 hours and 25 minutes and a wavelength of more than half the circumference of Earth.
- Semidiurnal tidal cycles can be found in Bangladesh, eastern coast of North America .
- The following diagram shows the sea level change over time for a typical semidiurnal tidal cycle:



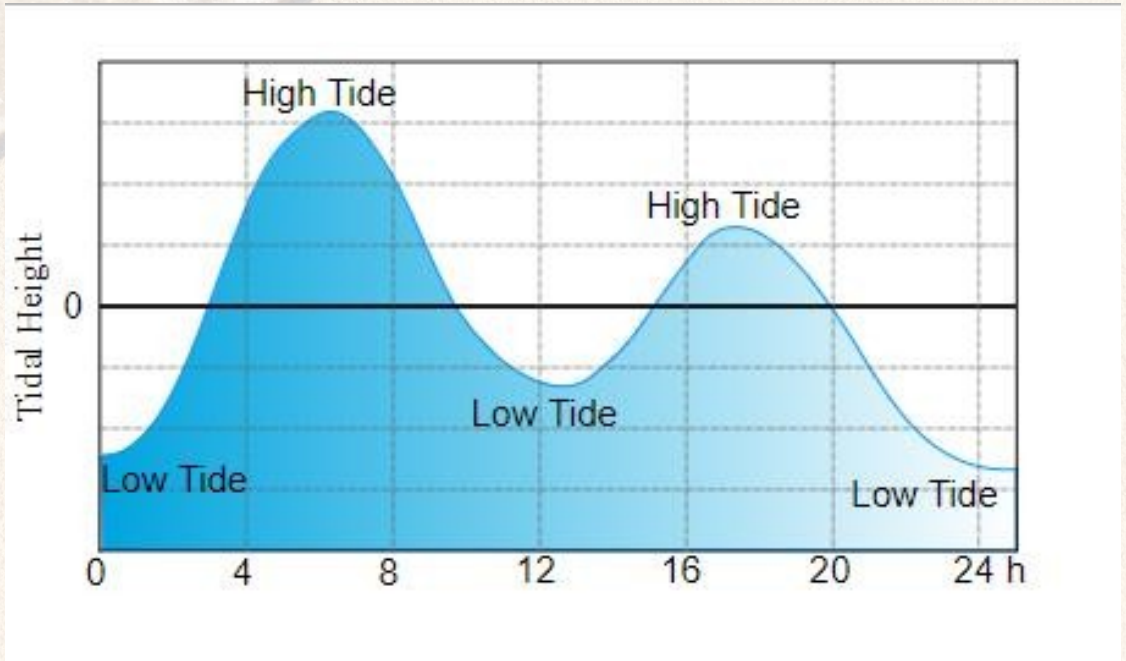
Diurnal Tides

- A diurnal tidal cycle is a cycle with only one high and low tide each lunar day. Diurnal tidal cycles can be found in the Gulf of Mexico and on the East coast of the Kamchatka Peninsula.

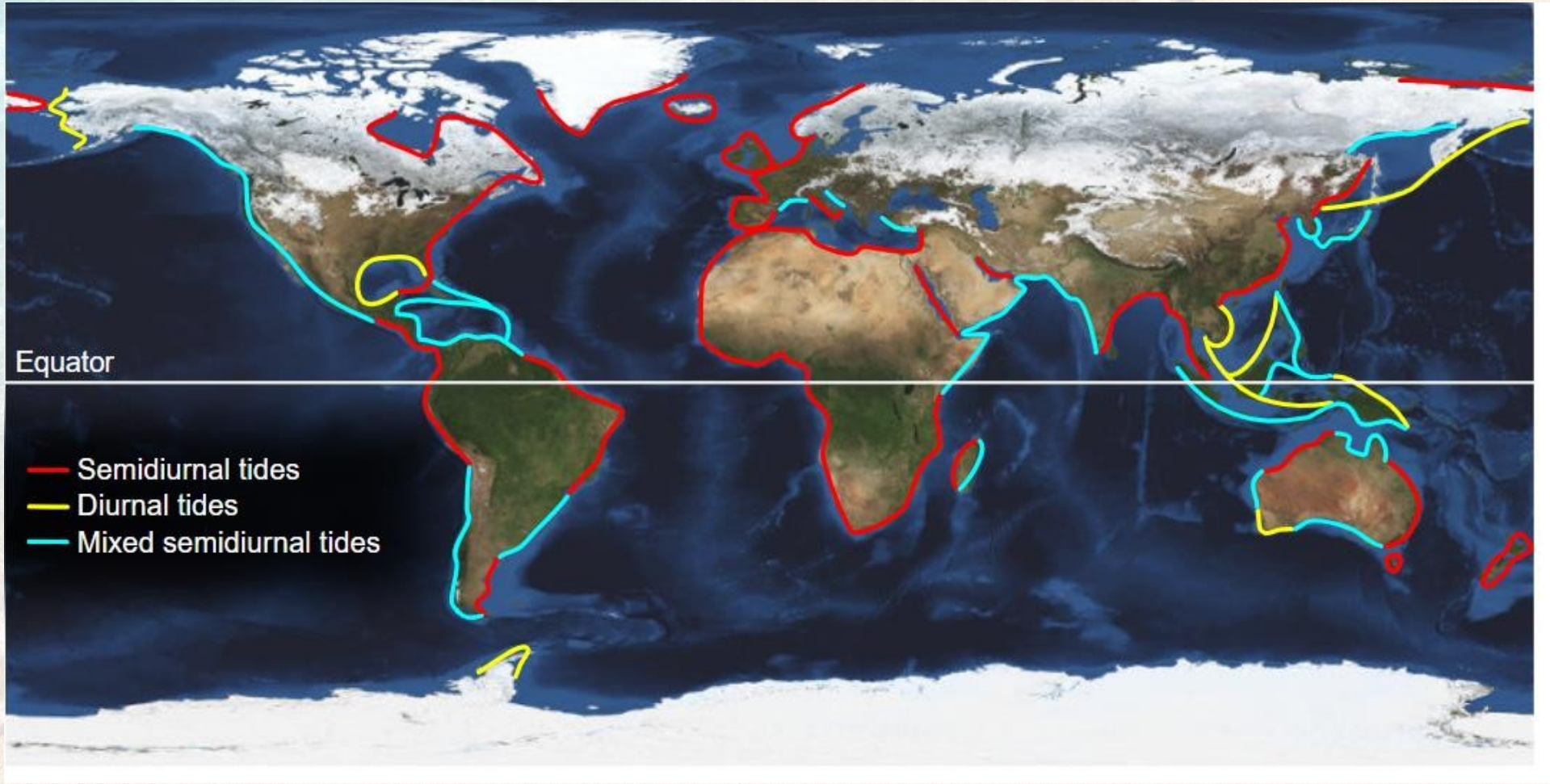


Mixed Tidal Cycle

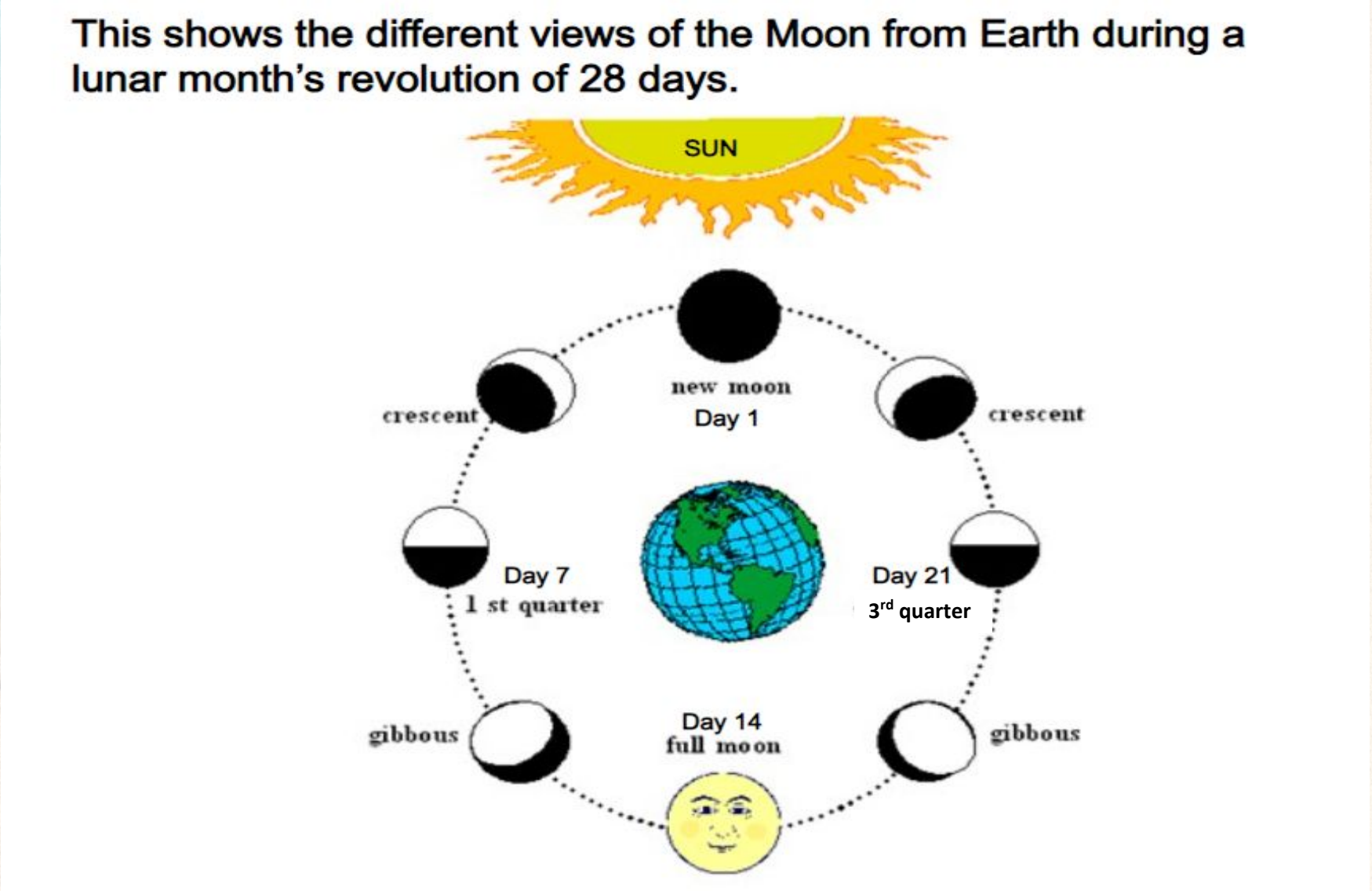
- A mixed tidal cycle is a cycle with two high and low tides with different sizes each lunar day.
- The difference in height between successive high (or low) tides is called the diurnal inequality.
- Areas with a mixed tidal cycle can be found alongside the western coast of North America, in parts of Australia and in South East Asia.



Daily Tide Cycle



Watch the following video to see the phases of the moon:
https://www.youtube.com/watch?v=1CCoP7y90PU&t=155s

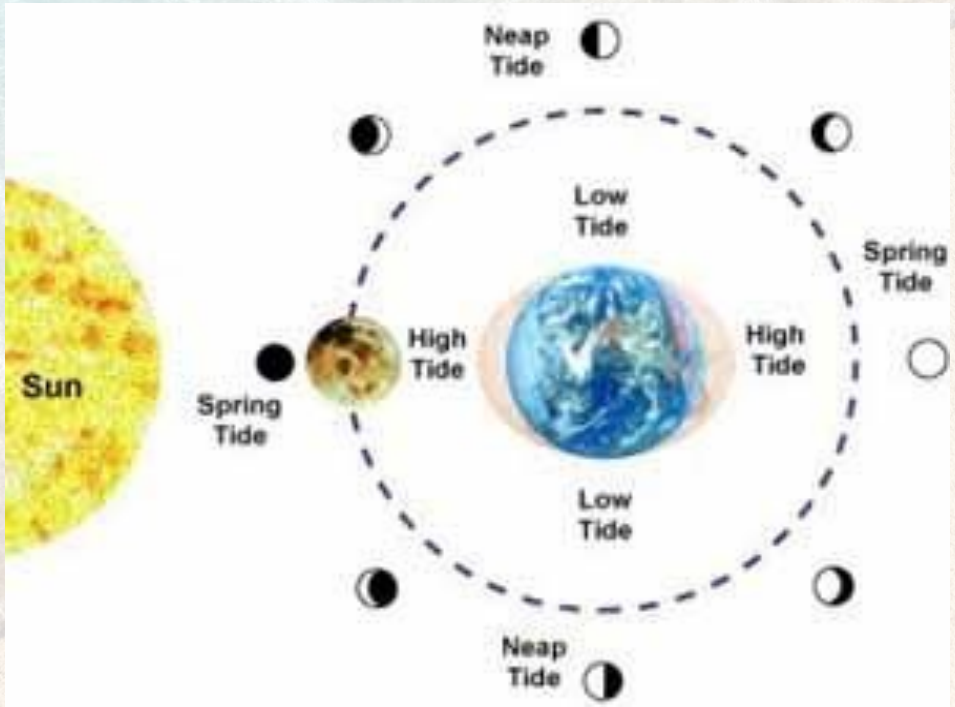


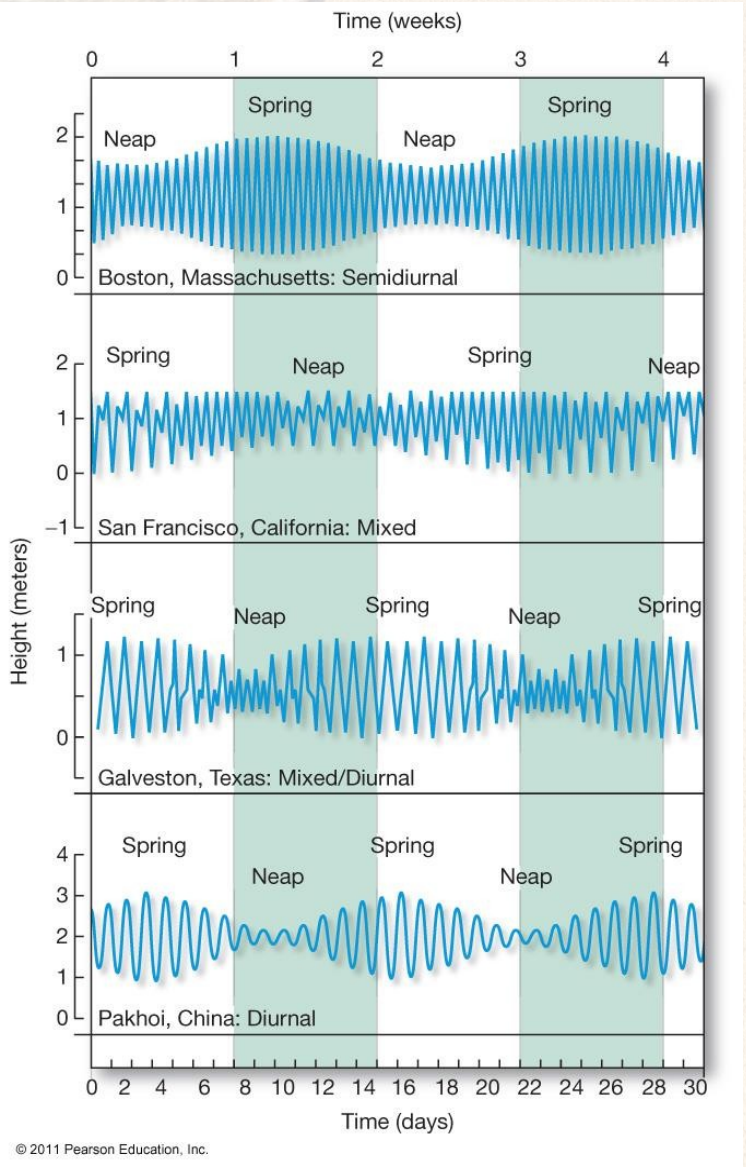
Watch the following video to see the phases of the moon:
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Monthly Tide Cycle

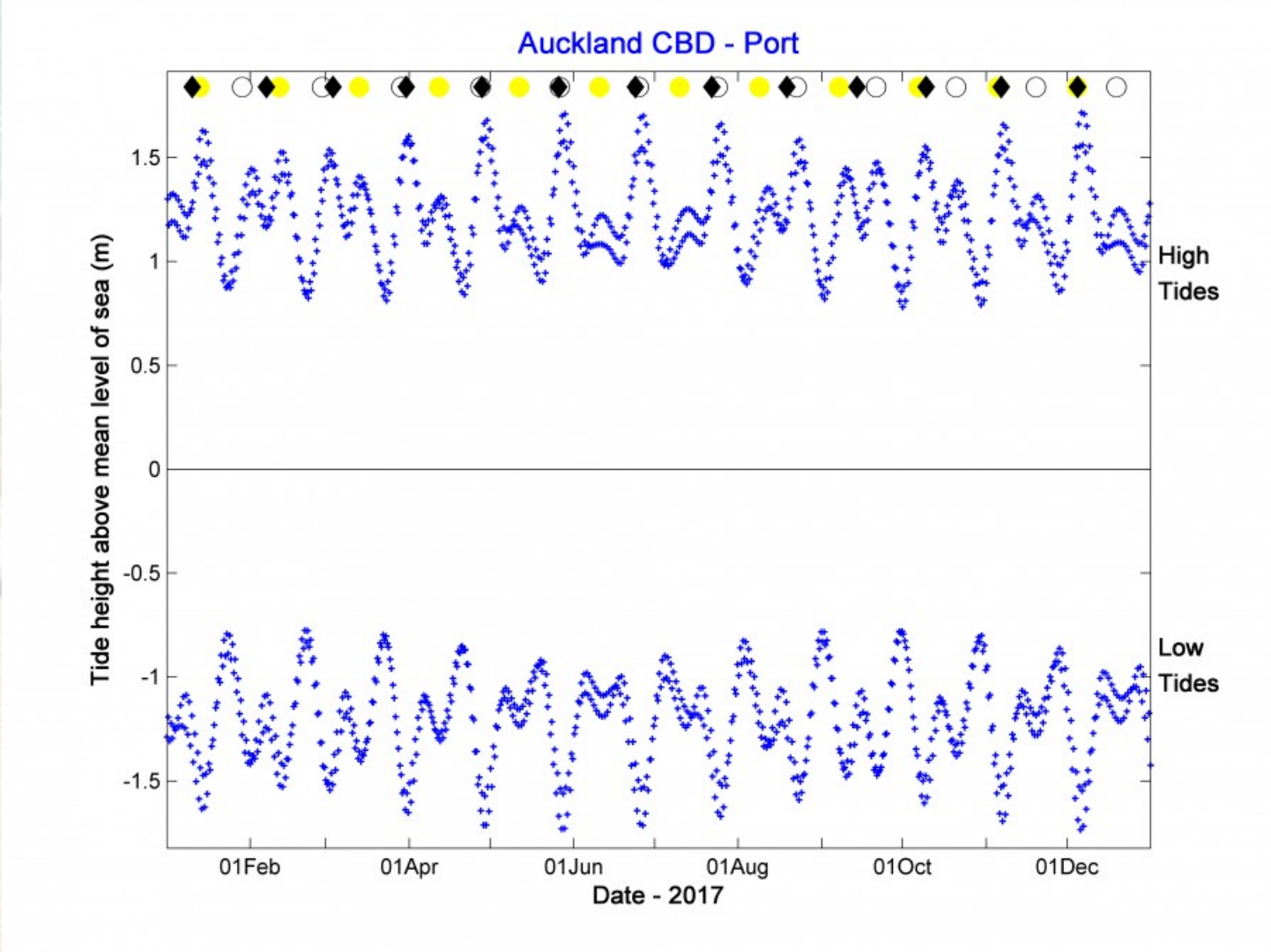
- Changes in the **positions** of the Earth, the Moon, and Sun affect the **height** of tides during a month.





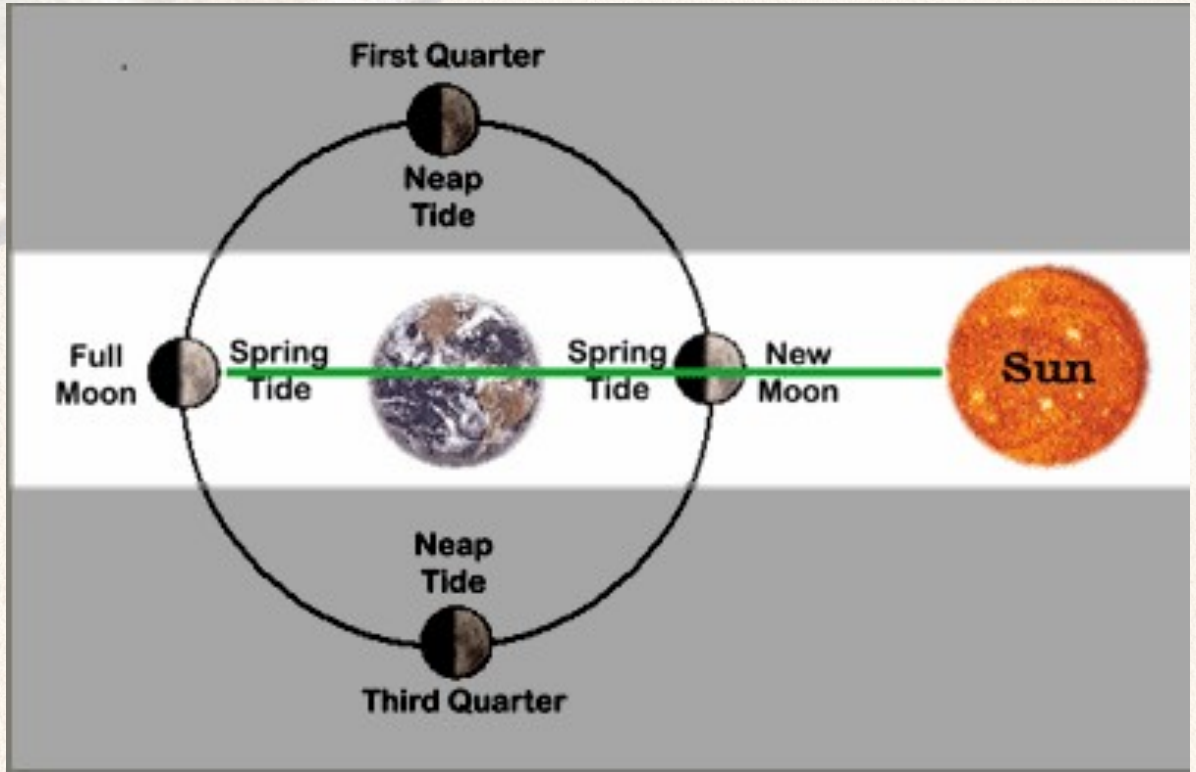
Tide Envelope

- The range for high and low tides throughout theyear across the country.



Spring Tide

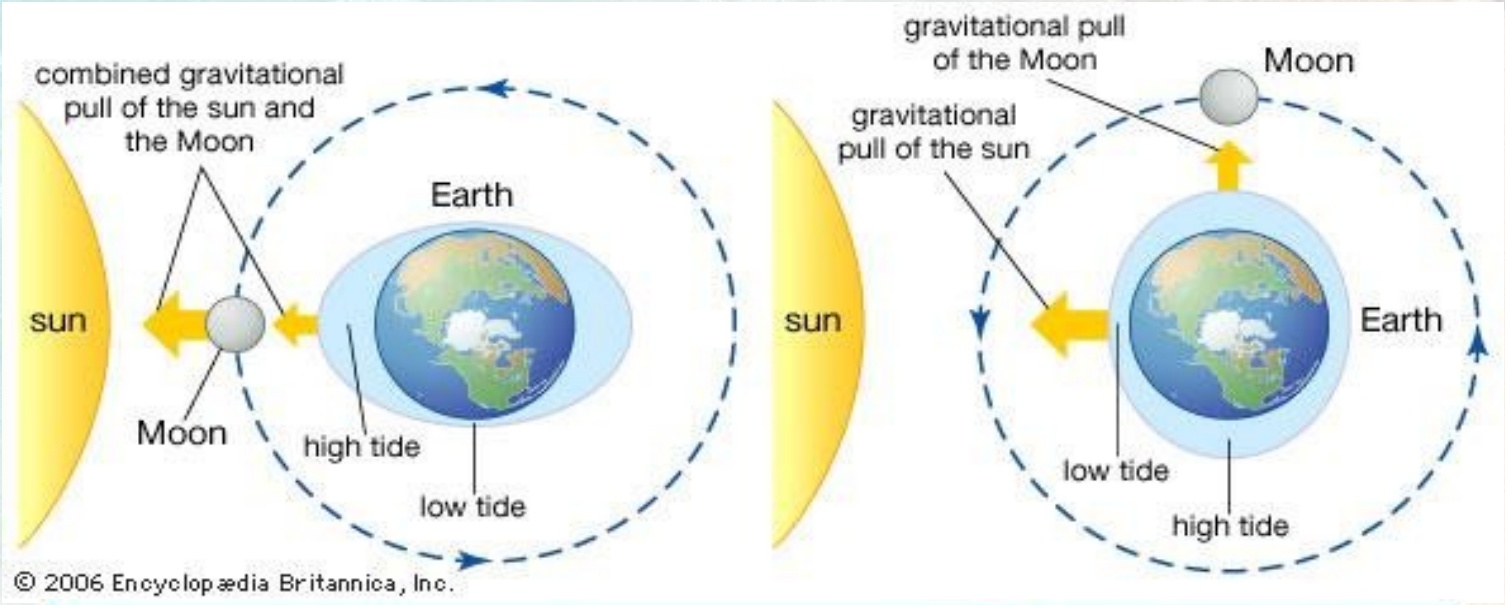
- **Spring** tides occur **2** times a month, during a **full** and **new**moon when the Earth, Sun, and Moon are lined up
- When thesun, moon, and earth fallin a line and the generating forces of the moon and sun are additive
- Spring tides are **higher** and **lower** than normal tides
- "**strong** tides"

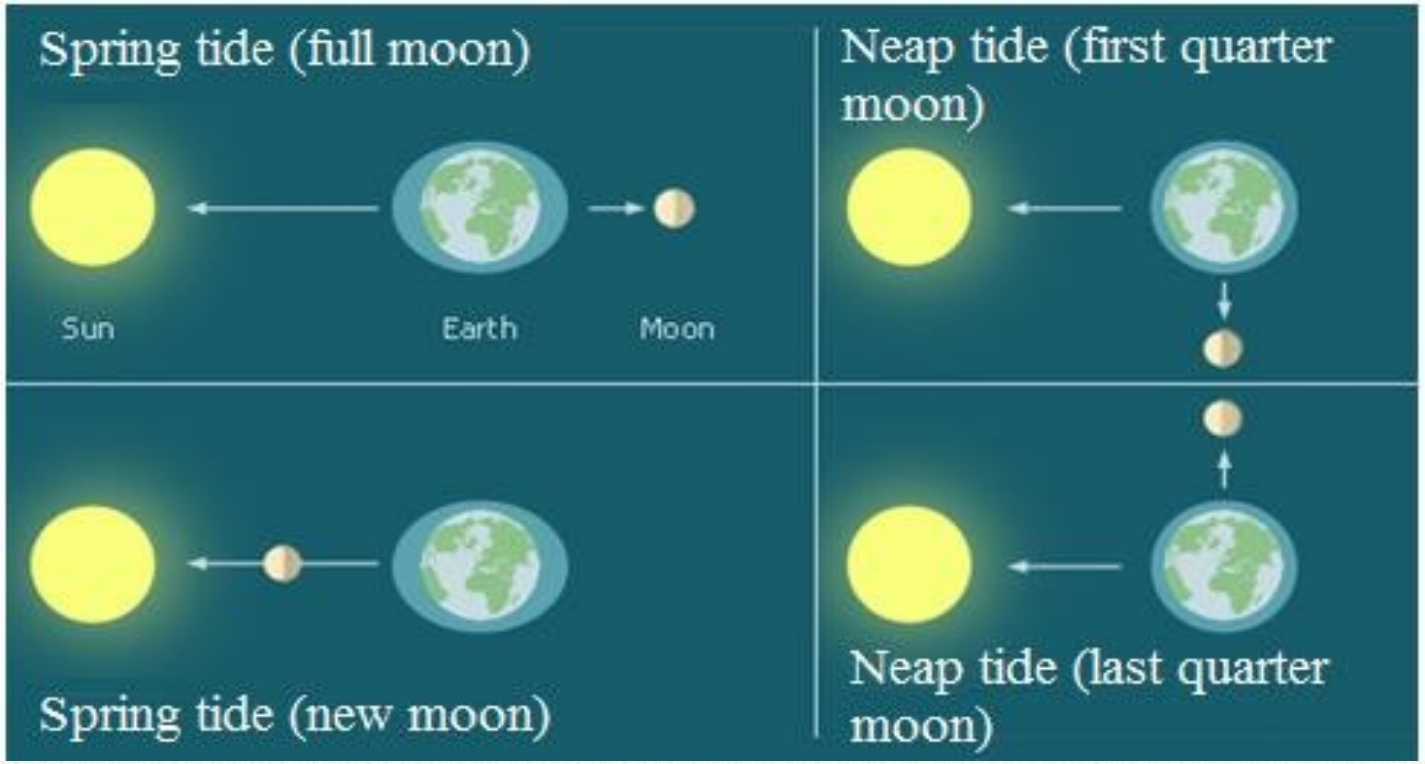


Neap Tide

- **Neap** tides occur in between spring tides, at the **first** and **third** quarters of the Moon when the Sun and Moon pull at **right** angles to each other.
- The actions of the moon and sun are subtractive
- Neap tides are **not** as high or low as normal tides
- "**weak** tides"




combined gravitational pull of the sun and the Moon
Earth
sun
Moon
high tide
low tide
gravitational pull of the Moon
Moon
gravitational pull of the sun
sun
Earth
low tide
high tide
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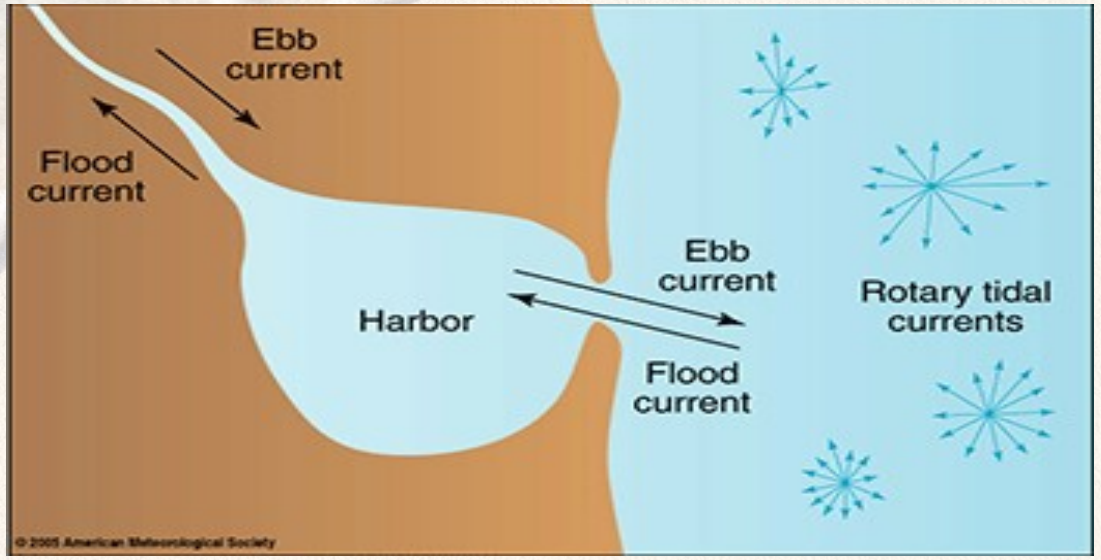

Spring tide (full moon)
Sun
Earth
Moon
Neap tide (first quarter moon)
Spring tide (new moon)
Neap tide (last quarter moon)

Tidal Currents

- The movement of water toward and away from the coast as a result of the rise and fall of the tides is called tidal current.

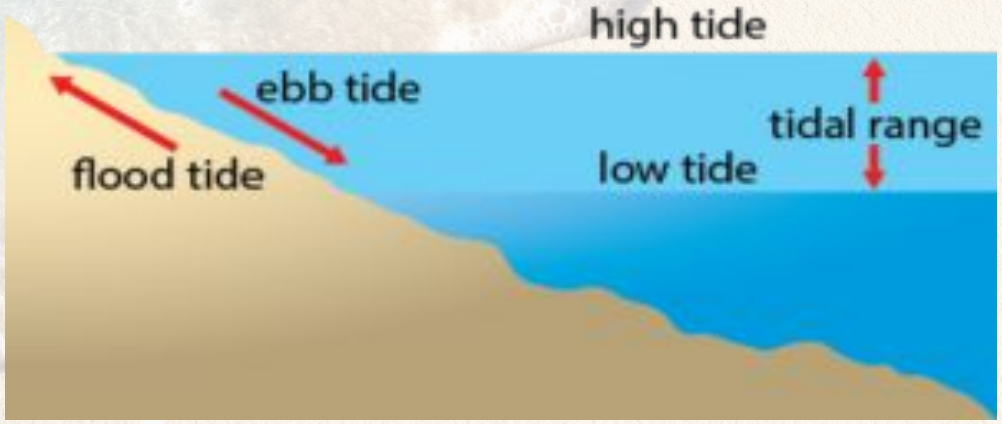
Ebb Current and Flood Current

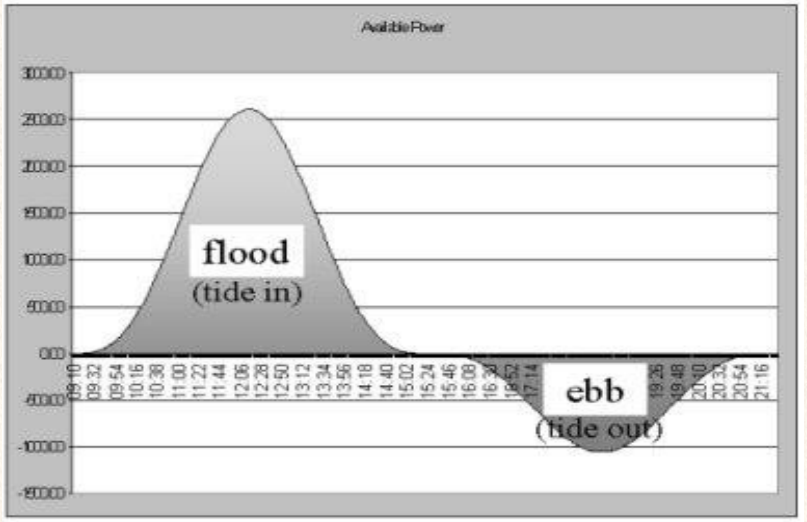
- When the tidal current flows toward the coast, it is called a flood current. When the tidal current flows towards the ocean, it is called ebb current.



Ebb Tide and Flood Tide

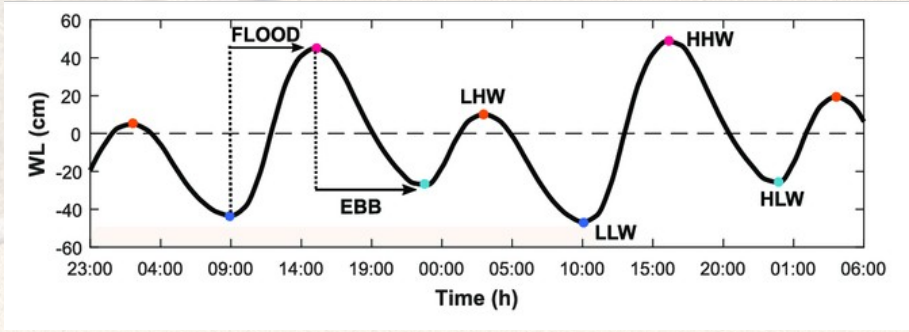
Ebb is the tidal phase during which the tidal current is flowing seaward (ebb current) and the water level is falling. Flood is the tidal phase during which the tidal current is flowing inland (flood current) and the water level is rising.





Tidal Curve

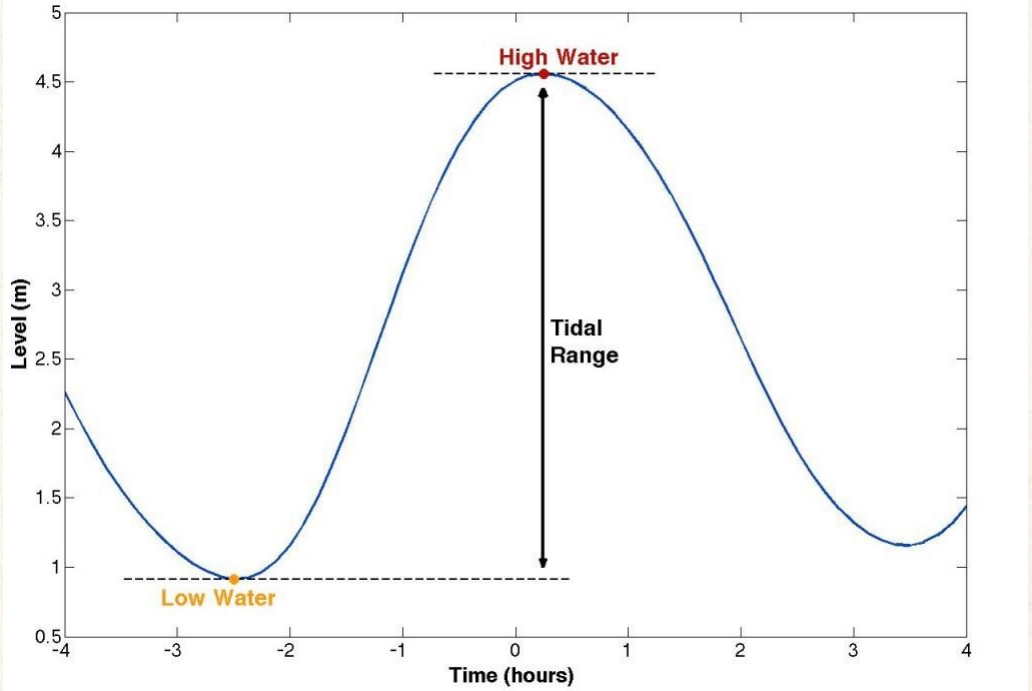
A graphic representation of the rise and fall of the tide in which time is usually represented by the abscissa and height by the ordinate.
For a semidiurnal tide with little diurnal inequality, the graphic representation approximate a cosine curve.



Tidal Range

The tidal range is the vertical difference in height between consecutive high and low waters ~~o~~ver a tidal cycle.

The range of the tide varies between locations and also varies over a range of time scales.



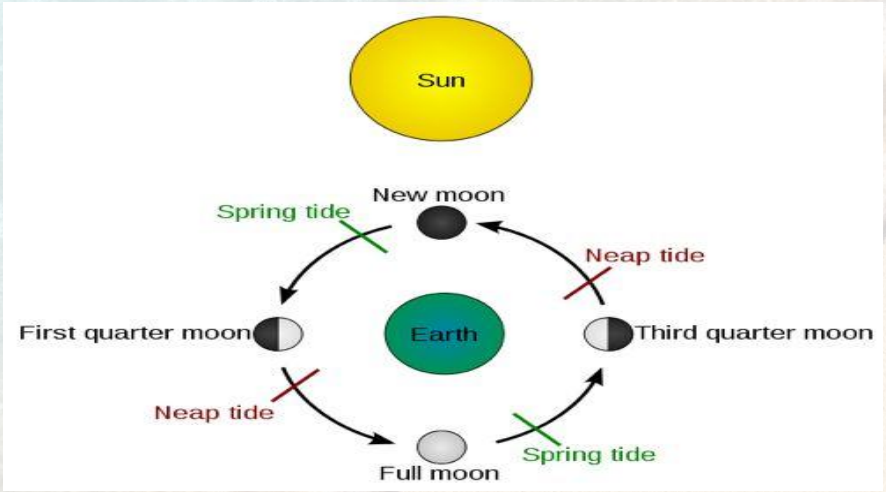
Tidal Levels

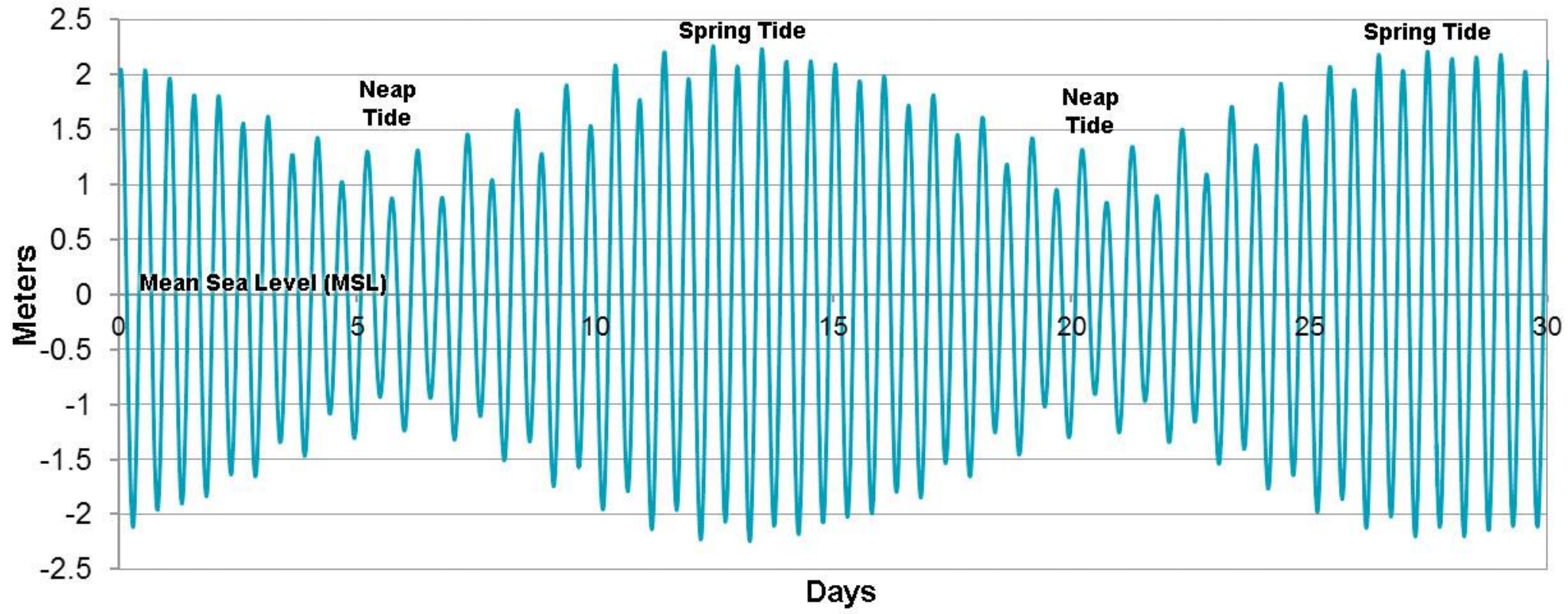
Tidal Levels are :-

- standard contour heights
- defined using the Astronomical Tide over a fixed duration at a specific location
- vertical datum used by hydrographers and surveyors in cartography
- legally boundaries used to establish territorial, ownership, access, and fishing rights
- used in setting the height of flood defenses.
- Some tidal levels are more appropriate for diurnal tides, and some are more relevant for semi-diurnal tides.

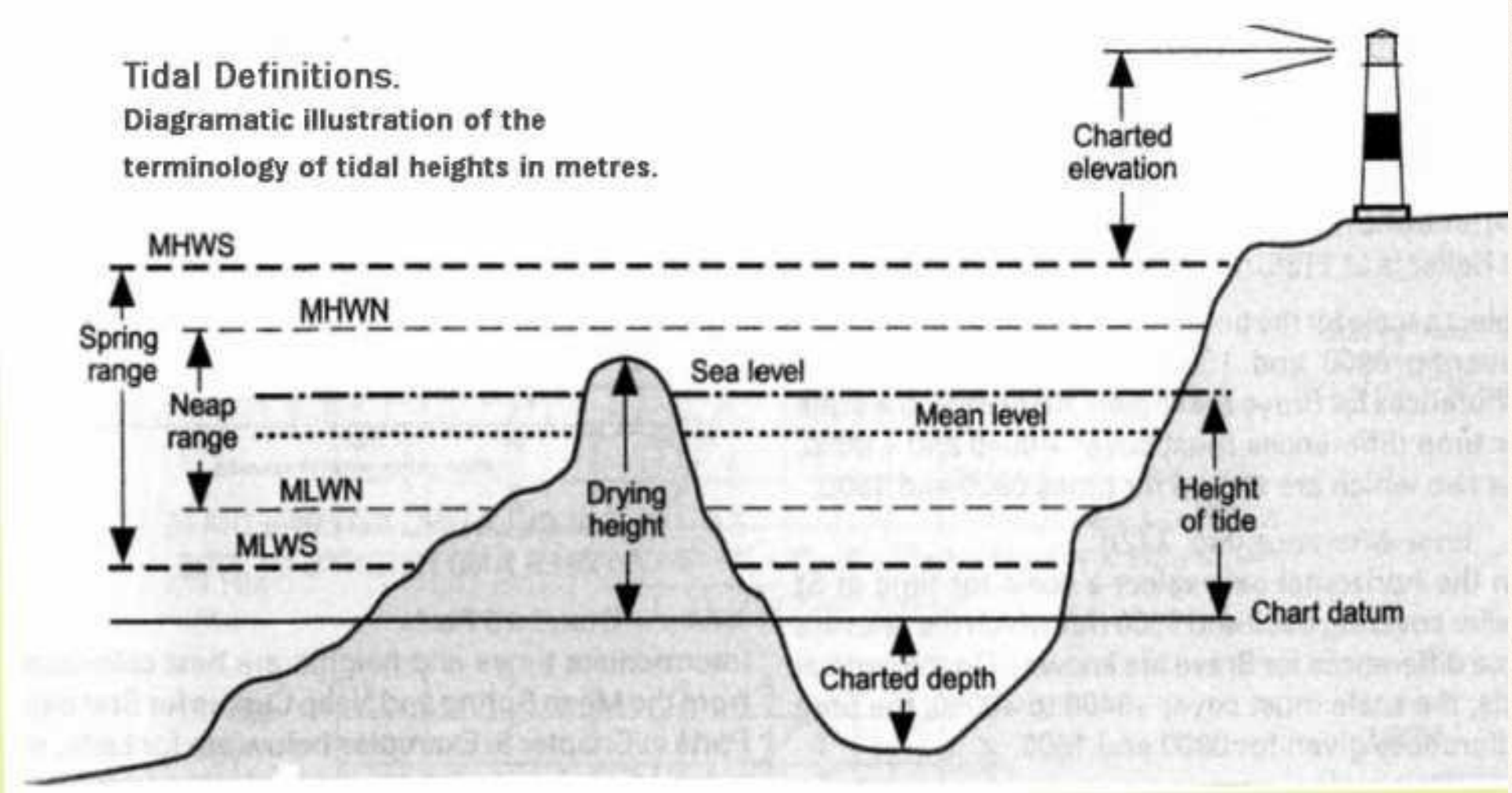
❖ Note that, the tide to which we refer is the "Astronomical Tide" - this is that part of the tide caused by the Moon and the Sun. The other part of the tide is caused by the weather (e.g. wind and pressure) and is known as the "Meteorological Tide". In most places the astronomical tide dominates.

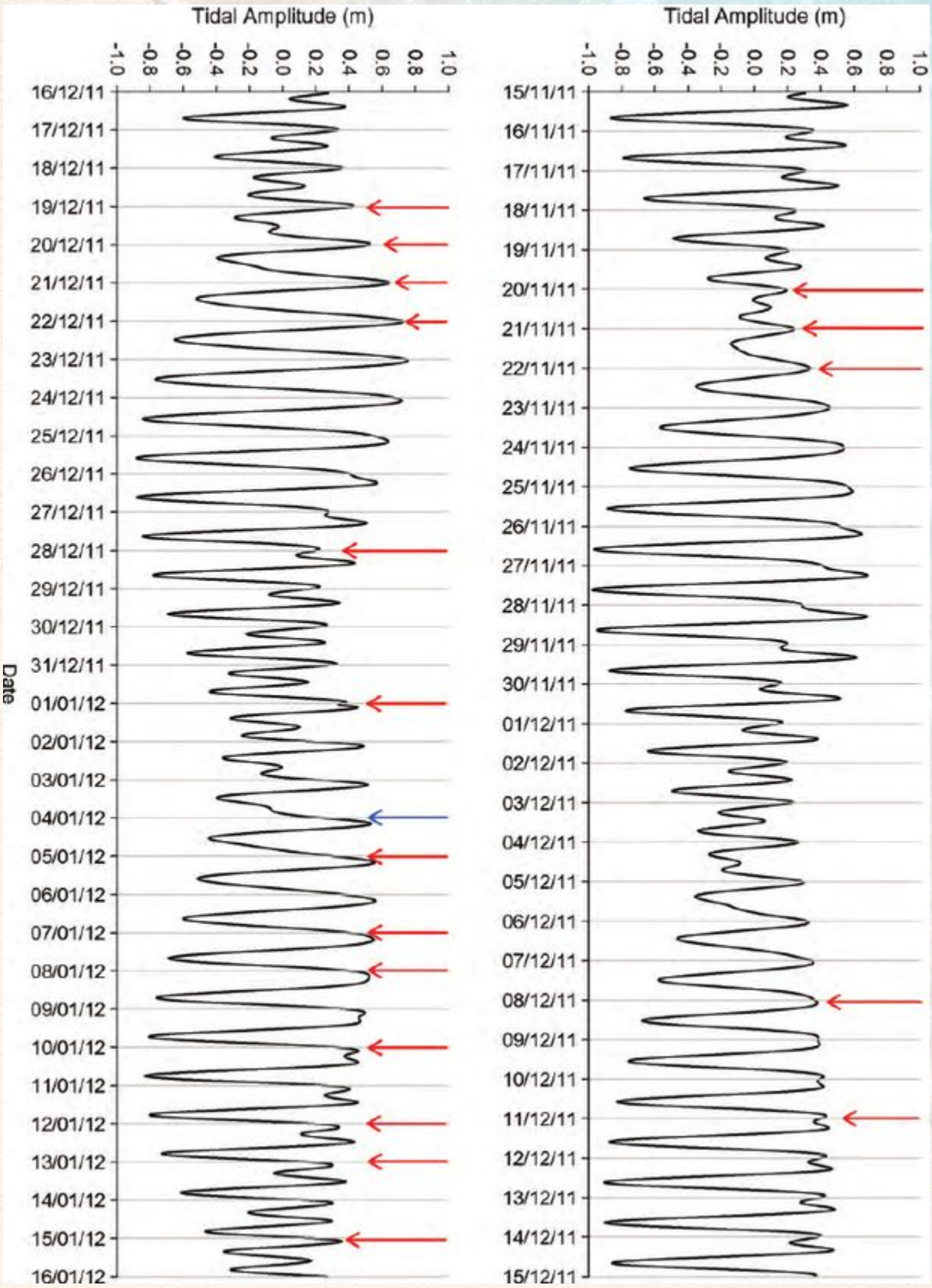
Tidal Levels





Graphical Representation of Tidal terms



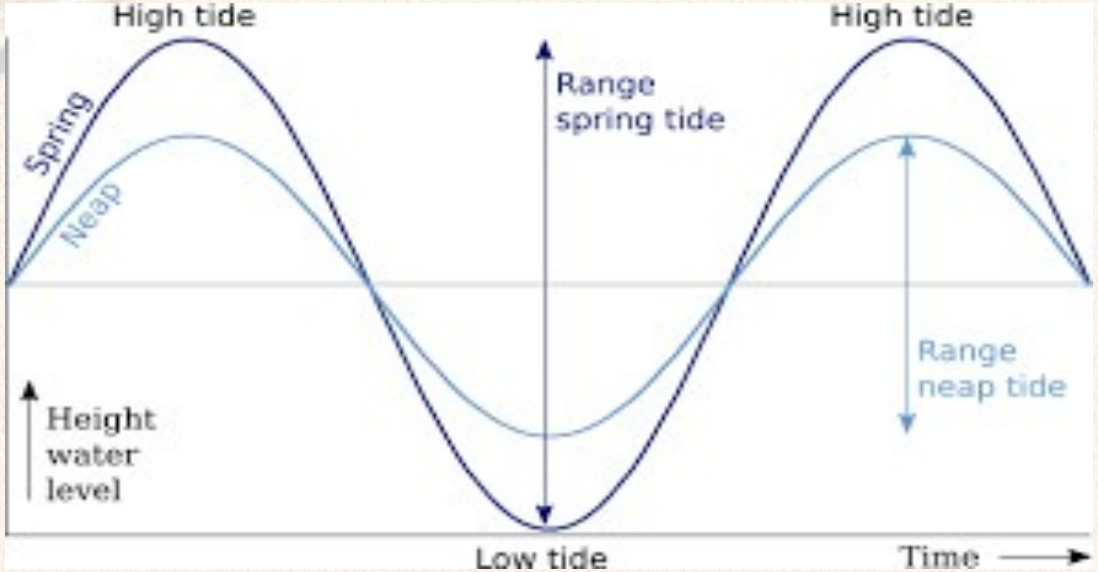

Tidal Amplitude (m)
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
Date
16/12/11
17/12/11
18/12/11
19/12/11
20/12/11
21/12/11
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28/12/11
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31/12/11
01/01/12
02/01/12
03/01/12
04/01/12
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06/01/12
07/01/12
08/01/12
09/01/12
10/01/12
11/01/12
12/01/12
13/01/12
14/01/12
15/01/12
16/01/12
Tidal Amplitude (m)
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
15/11/11
16/11/11
17/11/11
18/11/11
19/11/11
20/11/11
21/11/11
22/11/11
23/11/11
24/11/11
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08/12/11
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10/12/11
11/12/11
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14/12/11
15/12/11

MHWS-mean high water springs

The height of mean high water springs is the average of two successive high waters during those periods of 24 hours when the range of the tide is at its greatest throughout the year (when the average maximum declination of the moon is 23.5°).

MLWS - mean low water springs

The height of the mean low water springs is the average height obtained by the two successive low waters during the same period.



MHWN - mean high water neaps

The height of mean high water neaps is the average of two successive high waters during those periods of 24 hours when the range of the tide is at its least throughout the year (when the average maximum declination of the moon is 23.5°).

MLWN - mean low water neaps

The height of the mean low water neaps is the average height obtained by the two successive low waters during the same period.

Mean spring and neap ranges

The mean spring range is the difference between mean high water springs (MHWS) and mean low water springs (MLWS)

The mean neap range is the difference between mean high water neaps (MHWN) and mean low water neaps (MLWN)

Highest and lowest levels

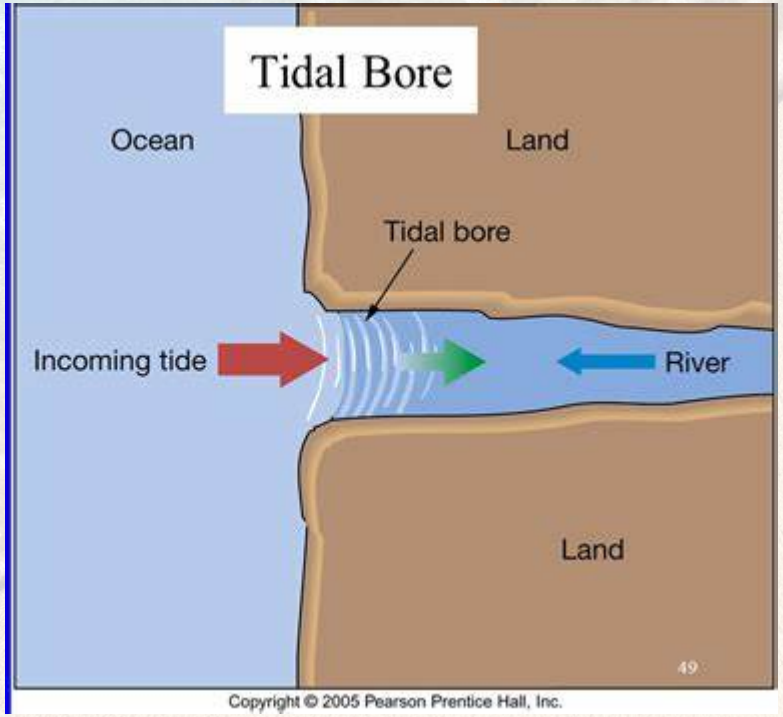
The highest and lowest tides shown for the particular years are an indication of the maximum levels under average meteorological conditions which can be expected during that year

Highest Astronomical and Lowest Astronomical Tide

Highest astronomical tide (HAT) is the highest level, and Lowest astronomical tide (LAT) the lowest level that can be expected to occur under average meteorological conditions and under any combination of astronomical conditions.

Tidal Bores

The tide may rise suddenly and rapidly as if a wall of water rushes up a channel. Such an in rush of water is known as tidal bores.



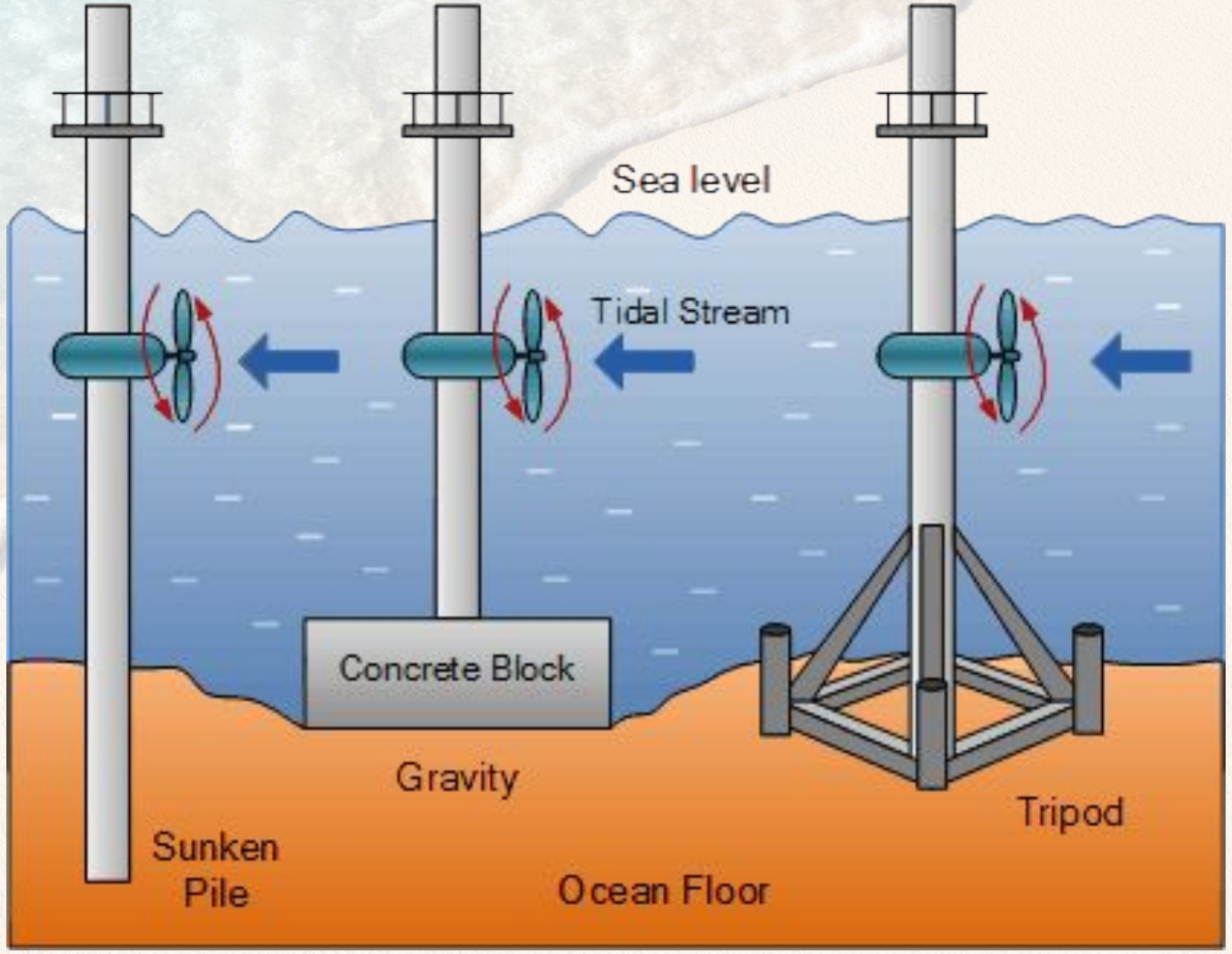


Characteristics of Tidal Bores

1. An extreme case of the shallow water effect
2. Occurs into a river or estuary with a steeply shelving bottom
3. The rapid and sudden rise of the tide
4. Produces a wall of water that moves up the channel
5. The wave front is steep or vertical varying in height between 0.3 m to 4.5 m
6. Advances in a speed of 3 knots to 20 knots
7. It may or may not break

Tidal Stream

Tidal stream is the horizontal movement of water due only to the tide-generating forces.



Tidal Flow

Tidal flow is the movement of the water actually experienced in a given area.

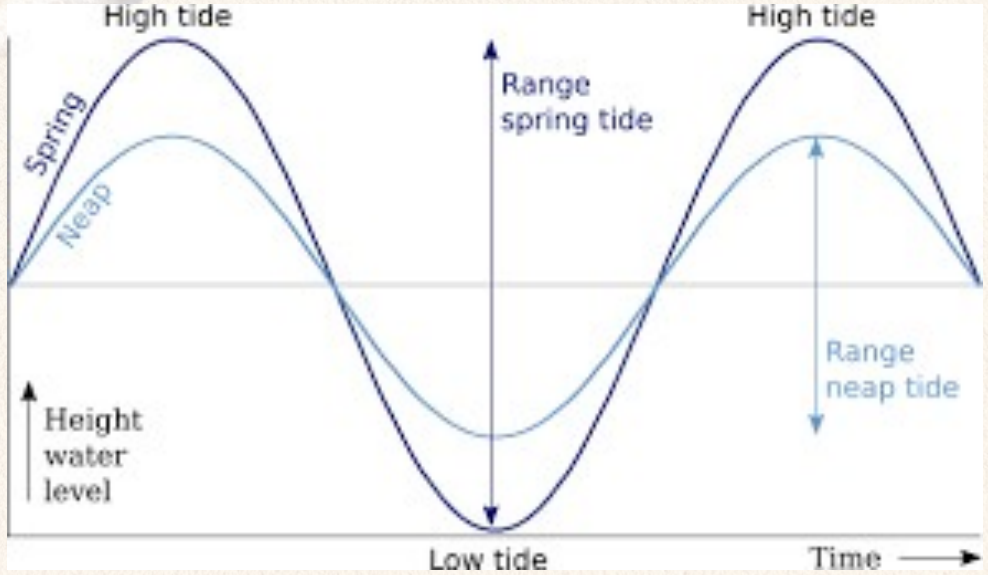
It is made up of true tidal streams and several other components such as short-period currents caused by meteorological and other effects.



Tidal Characteristics of Bangladesh

Based on the tidal range:

1. Microtidal zone:
   0-2 m; Tetulia river, Chandpur
2. Mesotidal zone:
   2-4 m, South Bhola- Hatia North
3. Macro tidal zone:
   >4m, East hatia- Sandwip



Tidal Characteristics of Bangladesh

1. The tidal waves observed along the coast of Bangladesh originate in the Indian Ocean.

2. It travels across the deep bay of Bengal and approaches the coast from the south arriving at Hiran Point and Cox's bazar at the same time.

3. Average tidal range is approx. 1.5 m in the west to over 4 m in Sandwip channel. At spring tide, the tidal range can be close to 6 m near Sandwip and Urirchar.

4. There is a seasonal variation in mean tidal level due to variation of pressure and wind

5. The tide is semi-diurnal on the Bangladesh coast, with two daily high and low tides

Tidal Characteristics of Bangladesh

6. Daily inequality of tides ranges between 0.55 m to 0.15 m

7. Tidal bores are frequently observed in south of Urirchar

8. The neap tide velocities are generally lower than spring tide velocities

9. Sediment distribution is mainly governed by magnitude and net flow direction of tidal flow

10. Erosion and accretion along the banks and shorelines are related to the flow velocities dominated by tidal flow

What Are Currents?

A body of water or air moving in a definite direction, especially through a surrounding body of water or air in which there is less movement is called current.

Types of Currents

Surface Current:

- These are currents that occur near the ocean's surface. They involve large masses of water moving horizontally.
- At the surface, currents are mainly driven by four factors—wind, the Sun's radiation, gravity, and Earth's rotation. All of these factors are interconnected. The Sun's radiation creates prevailing wind patterns, which push ocean water to bunch in hills and valleys. Gravity pulls the water away from hills and toward valleys and Earth's rotation steers the moving water.

Shoreline Current:

- Local currents that run along the shore are caused by winds and shifting sands

Longshore Current:

- type of shoreline current that carries large amounts of materials from one place to another.

Rip Current:

- Shoreline current that flows away from the beach.

Deep Ocean Current:

- caused by differences in water temperature. Cold water is heavier than warm water so it sinks.

THANK YOU