

OCEAN TIDES

3.1.1. Tides - Introduction

Tides are produced by the attractions of the moon and sun on the waters of the ocean and are noticeable as a regular rise and fall of water. They occur in the ocean as progressive or standing long waves. Among all the oceanic long waves, tides are of maximum importance for people living near the sea shore and for those travelling the sea. Many activities like navigation shipping, reclamation of land from the sea, military operations, disposal of pollutants in coastal waters and fishing depend upon tides in the ocean. For safe navigation and shipping, it is necessary to know the **tide levels** and tidal currents at any moment for a particular harbor. Information about the water levels and about the currents is required for the construction of structures along the banks of tidal inlets, like drainage sluices for the removal of water from low-lying lands, dykes for the protection of the land against inundation and, jetties, wharves, piers, etc. For the design of these structures it is necessary to know the nature or extreme high tides and lowest water levels.

The rise and fall of the tide is a continuous phenomenon and varies from day to day and from place to place. Tides also differ in the character of the rise and fall. Tidal currents significantly increase the volume of the receiving waters at the outfall site; turbulence due to tide mixes the pollutants through the water column and the tidal current dramatically increases the rate at which pollutants diffuse horizontally, and in certain cases, tidal residuals can carry a pollutant away from the outfall site.

Coastal fisheries are always influenced by tides. Some fish react to the tide in their biological cycle. Tides also influence the movement of intertidal organisms. Several fishing methods rely on tidal currents.

3.1.2. Definition and terms

Tides are bulges of water produced by the gravitational attraction of the Sun and Moon on the ocean and by the centrifugal force resulting from rotation of the Earth –Sun and Earth-Moon systems. **Gravity** is the force of attraction between two bodies. It is proportional to the mass of the objects and inversely proportional to the square of the distance between them. The greater the mass and smaller the distance, the stronger the gravitational attraction.

$$G \propto M_1 M_2 / d^2$$

Where G is gravity M_1 and M_2 represent the mass of body 1 and body 2 and d is distance between the center of the two masses.

3.1.3. Tidal phenomenon

A tide is the alternative rise (high) and fall (low) of sea level due to the gravitational forces exerted on the earth by the moon and the sun. More commonly, there will be two highs and two lows in a day in most areas. These are known as semi-diurnal tides. But in some areas there will be one high and one low in a day. These are known as diurnal-tides.

At a given place, the tide generally has two cycles per lunar day (24 h 50 min). A time lag exists between the moment when the moon crosses the meridian (in the north or in the south) and the high water. This time lag, which has a fixed value for each place, is called HWF&Ch (high water full and change). The solar tide has two cycles per day (24 h). High water due to this solar tide is at the same time each day.

The gravitational attraction of the sun and the gravitational attraction of the moon always affect two sides of the earth at the same time. On one side, the waters of the ocean are drawn away from the earth; on the other, the earth is drawn away from the water. The gravitational

attraction of the moon and the sun are added together. Thus, the combined gravitational attraction of the sun and the moon produces the highest tide called the [spring tide](#). This can occur both at full moon and at new moon. However, this does not happen when the sun and the moon are exactly in the same direction (new moon), or in the opposite direction (full moon). It occurs generally later (mostly one or two days). The time lag is called the age of the tide. The tide are least when the gravitational attraction of the sun is counter acting that of the moon, or when the sun and the moon are at right angles in relation to the [earth](#). Thus, the weakest tide, called neap tide occurs one week later i.e., 7 days after the occurrence of [spring tide](#) (first and third quarter of the moon). Due to the moon's influence only, the tide each day would be exactly 50 min and 28s later than the preceding day. Because of the sun's contribution, this phase lag is not constant. It is less just before and after [spring tide](#) (about 35 min) and more around neap tide, one week later (about 80 min).

The moon and the sun are rarely on the equator. They may have a (northerly or southerly) declination, which may be about 23.5° for the sun and 28.5° for the moon. The effect of this is that the tide generating force, $H-H_0$ does not describe two equal sinusoids, while the [earth](#) makes a complete revolution and the maxima will be different. This difference is called the daily inequality and the tidal curve may have a shape like that shown in.

When the declination of a celestial body is considerable, the resulting tide will then not be so strong as the tide which is generated by the same celestial body when it is on the equator. For the sun the latter is the case in the equinoxes (21st march and 22nd September). In those periods extra high [tides](#) may occur. These are called as equinoctial spring [tides](#).

3.1.4. Tides and Tidal ranges

As the [earth](#) revolves on its axis coastal areas periodically pass through the tidal bulges and experience high and low [tides](#). As the crest of a bulge passes, high tide occurs. Troughs between bulges result in low [tides](#). [Tidal range](#) is the difference in height between high and low [tides](#). A continuous record of the daily change in sea level because of [tides](#) is a **tidal curve**.

Tidal curves show that [tides](#) change daily in range and time of occurrence. The variation results from the complex interaction of the [earth](#) sun and moon. The interaction of these three bodies is so complex that a given coast may experience the same tidal conditions only once each 1600 years.

Solar [tides](#): Is the [tides](#) produced by the Sun which occur approximately at the same time each day because the [earth](#) rotates on its axis once each 24 hours. Coastal areas experience a solar high or low tide each 12 hours. **Lunar [tides](#)** are more complex because the Moon moves forward in its orbit as the [earth](#) rotates on its axis. Thus, a point on the [earth](#) directly below the Moon requires 24 hours and 50 minutes before it is again below the Moon. Lunar [tides](#) occur 50 minutes later each day. Coastal areas experience a lunar tide each 12 hours and 25 minutes interval.

Chapter 2: [Ocean Tides](#)-2

3.2.1. Types of tide

About twice each month, lunar and solar tidal bulges are in-phase and experience constructive interference. Tidal bulges overlap and produce a very high, high-tide and a very low, low-tide. Bimonthly maximum tidal ranges are called **spring [tides](#)**. Spring [tides](#) result from the "straight" line arrangement of the [Earth](#), Moon and Sun and occur during full and new moons. Similarly, twice each month lunar and solar tidal bulges are out-of-phase and experience destructive interference when high [tides](#) of lunar tidal bulges overlap troughs

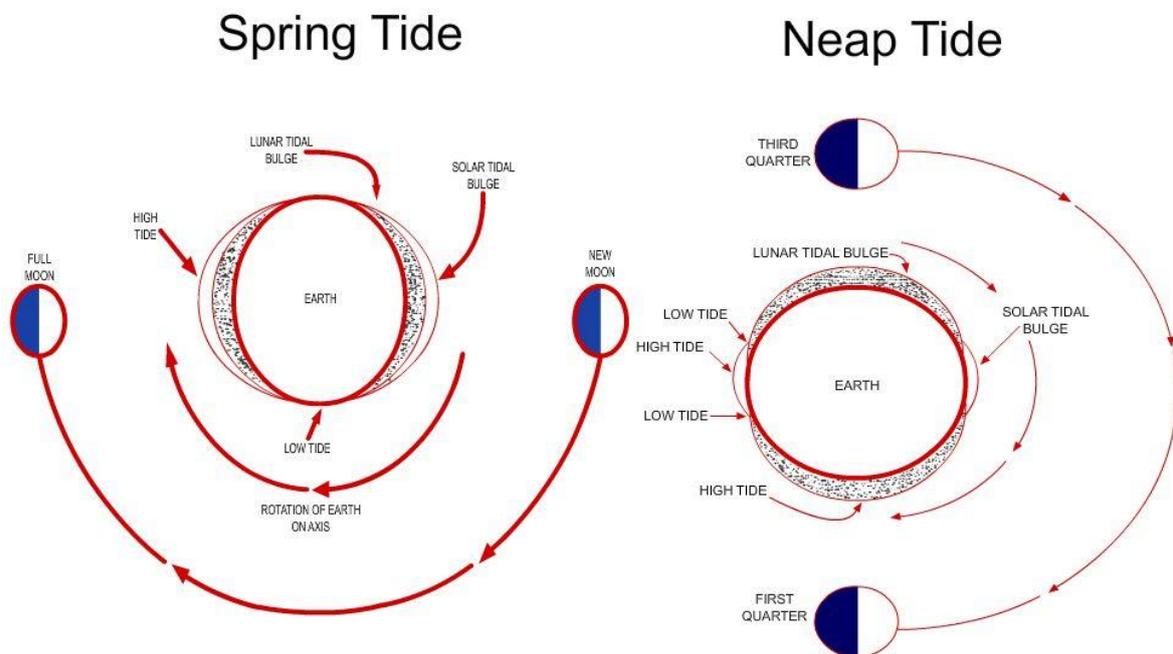
between solar tidal bulges. Minimal tidal ranges result. These [tides](#) are called **neap tides**. They occur during the first and third quarter moon, when the Moon is at 90° from the Sun relative to the [earth](#).

Term to describe the phases of moon: Full moon means that the Moon is on the opposite side of the [Earth](#) from the Sun and the entire side of the Moon facing the [Earth](#) is illuminated in the night sky.

New moon occurs when the Moon lies directly between the [Earth](#) and the Sun. Because the Moon is on the daylight side of the [Earth](#), there is no moon in the night sky during a new moon.

If the monthly trip of the Moon “around” the [Earth](#) is divided into quarters beginning with the new moon, the first and last quarter Moon occur when the [Earth](#), Sun and Moon align to form a 90° angle. From the [Earth](#), half of the Moon is illuminated, at the first and last quarter. It is called a quarter moon because it is seen at the first quarter and last quarter of the lunar orbit.

Waxing of the Moon describes the period between new moon and full moon. Each night more of the Moon is illuminated. **Waning of the Moon** refers to the period between the full moon and new moon. Each night less of the Moon is illuminated.



Tide producing forces

All objects in space exert a gravitational attraction on the oceans, but only the Sun (because of its great mass) and the Moon (because of its proximity / exert sufficient attraction to produce a noticeable bulge of water. Despite its great mass (332,960 x the mass of the [Earth](#)), the distance between the [Earth](#) and Sun (149,700,000km) reduces the solar tidal attraction to only 46% of the attraction by the Moon. The Moon is much smaller than the Sun [even smaller than the [Earth](#)], but it is closer to the [earth](#) and thus exerts a gravitational attraction disproportionately strong for its size.

Centrifugal force is the force directed away from the center of rotation. As the [Earth](#) revolves on its axis, centrifugal force attempts to throw objects from the [Earth](#)'s surface into space. If [earth](#)'s gravity was sufficiently weak or its speed of rotation sufficiently great, objects would be hurled into space.

As the [earth](#) travels in its orbit about the Sun, centrifugal force act on the side of

the [earth](#) away from the Sun and attempts to fling the Ocean into space. Gravitational attraction between the [earth](#) and ocean is greater than centrifugal force and the ocean remains on the [earth](#), but a tidal bulge is produced.

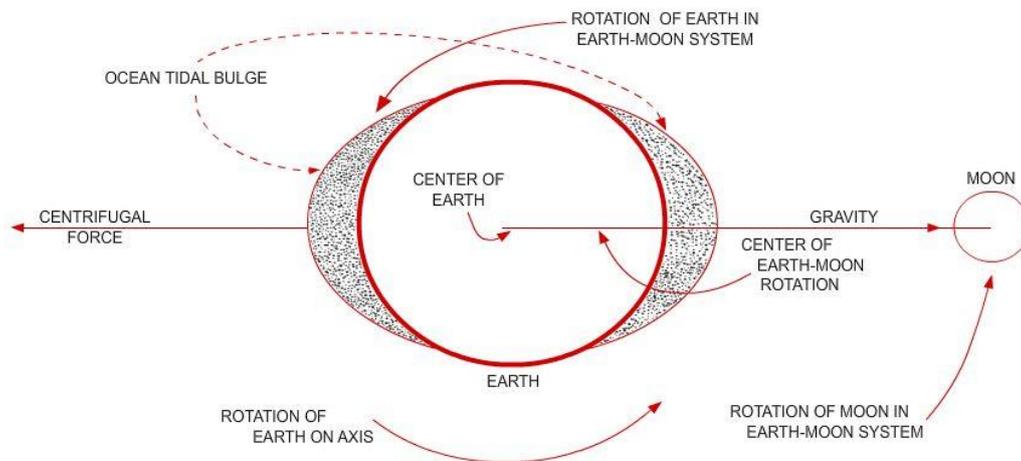
In contrast to common belief, the moon does not revolve about the [earth](#), but rather the [earth](#) and moon rotate about a point 4700km toward the moon from the center of the [earth](#). As the [earth](#) and Moon revolve around this point, centrifugal force produces a tidal bulge on the side of the [earth](#) facing away from the moon. Thus, the Sun and Moon each produce two tidal bulges in the ocean. One pair of bulges is produced by gravitational attraction and the other pair by centrifugal force.

To understand the tide-producing forces, let us first consider the influence of the moon alone. The [earth](#) and the moon form a single system mutually revolving around a common centre of mass. The period of this revolution is 27.3 days. Even though the orbits are slightly elliptical, for simplification they can be treated as circular. So, all points upon the [earth](#) follow circular paths, which have same radius and each point will also have the same angular velocity of $2\pi/27.3$ days. Since all the points travel with the same angular velocity and the radius of their circular paths are the same, all points on the [earth](#) experience an equal centrifugal force. The total of all centrifugal forces resulting from the motion of the [earth](#)-moon system around its common centre of gravity completely balances the forces of gravitational attraction between the two bodies and hence the system as a whole is in complete equilibrium. The centrifugal forces are directed parallel to a line joining the centers of the [earth](#) and the moon.

However, the magnitude of the gravitational force exerted by the moon on the [earth](#) is not the same at all points on [earth](#), because all these points are not at the same distance from the moon. The gravitational force of the moon is largest at the point E, which is closed to the moon, the weakest at the point A on the [earth](#)'s surface, which is farthest from the moon. The gravitational force is dominant on the half of the [earth](#) facing away from the moon. In addition, the direction of the moon's gravitational force at all points will be directed towards the centre of the moon, and therefore will not be strictly parallel to the line joining the centers of the [earth](#) and the moon except for those points which on the line joining the centers of the [earth](#) and the moon. The combined effect of the centrifugal force and gravitational force is the tide-producing force. Only at the centre of the [earth](#) 'X' these two forces cancel each other. At all other points on the [earth](#), there will be tide-producing forces.

Similarly, the sun is also the source of a tide-producing force. Because of the greater distance of the [earth](#) from the sun, the tide-producing force due to sun is smaller than that of the moon. At the tide-producing forces are given by the difference between the gravitational forces and the centrifugal forces, and as these forces depend on the distance of the [earth](#) from the sun and the moon, the tide-producing forces will vary according to the changing distances of the sun and the moon from the [earth](#).

Moon-Induced Tidal Bulges



Controls on tidal range

In addition to the alignment of the Sun and the Moon, [tidal range](#) is also controlled by variation in gravitational attraction, declination of the [Earth](#) relative to the orbits of the Sun and Moon, and distribution of land. The orbit of the [earth](#) about the Sun, and the Moon and [Earth](#) about each other, are elliptical not circular. At times the [Earth](#) and Sun, and [Earth](#) and Moon are closer together, because gravity decreases as objects move apart and increases as they move together, the tidal bulges respond to changes in the orbits. When in perigee, the Sun and [Earth](#) or Moon and [Earth](#) are closer together in their orbit the tidal bulges are higher. In contrast, when in apogee, the [Earth](#) and Sun or Moon and [Earth](#) are farthest apart in their orbit the tidal bulges are smaller. It is estimated that lunar [tides](#) at perigee have about a 20% greater range than at apogee.

Declination is the inclination of the [earth](#)'s axis relative to the orbital plane of the [Earth](#) around the Sun or of the Moon. It is a measure of the relative angular position north or south of the equator that the Sun or Moon appears in the sky. Each month the lunar declination varies from 28.5°N to 28.5°S. The more similar the declination of the Sun and Moon, the greater the overlap of the tidal bulges and the greater the [tidal range](#).

Distribution of land greatly influences the expression of [tides](#). If [earth](#) was an ocean-covered planet, [tides](#) would sweep westward unimpeded. All points along the same line of longitude would experience [tides](#) at the same time. Except around Antarctica and in the Arctic Sea, continents interrupt tidal flow by dividing the ocean into a series of interconnected basins. Basin shape and depth determine the period of the basin and how the body of water responds to [tides](#). Period of a basin is the time required for a standing wave in the basin to complete one oscillation. If the period of the basin is in phase with the tidal period, the [tides](#) will reinforce the standing wave in the basin. For a large basin, such as the North Atlantic, the standing wave migrates around the basin as a rotary [seiche](#) and is called an amphidromic system. In this system, the ocean surface displays the same motion as would the water surface in a round bowl as the bowl is swirled in a circular motion.

The center of the amphidromic system is called the amphidromic point. It is a node and experiences no tide. [Tidal range](#) increases outward and lines connecting points of equal [tidal range](#) from concentric circles, called corange circles, about the amphidromic point. Lines

connecting points that experience the tide at the same time are called **cotidal lines** and these radiate out from the amphidromic point.

In a basin with a period of about 12 hours (e.g. Atlantic Basin) semidiurnal (or semidaily) [tides](#) will develop. Each day two [tides](#) of about equal range will affect the coast. Diurnal(or daily) [tides](#) are produced in basins with a period of about 24 hours. These basins experience only one tide a day. Basins with periods other than 12 or 24 hours will display mixed [tides](#) and have two [tides](#) of unequal range. The difference between the height of successive high [tides](#) or successive low [tides](#) within a day is the daily inequality of a mixed tide. For mixed [tides](#), the two crests are referred to as **high high-water** and **low high-water**; the troughs are high low-water and low low-water. Mixed [tides](#) are developed in many areas, for example the Caribbean Sea and Pacific Ocean.

Distribution of land may alter the [tidal range](#). Where land funnels the tide into a narrowing valley or long arm of the sea, [tidal range](#) is greatly increased at the distal end. In contrast, [tidal range](#) will be considerably decreased where an opening restricts the inflow of the tide.

Chapter 3: [Ocean Tides](#)-3

3.3.1. Tidal bore

In some tidal rivers, which are shallow, steep and funnelshaped, the tide advances as a single roaring wall of water, called **tidal bore**. Here, the duration of rise of the tidal wave decreases very much and the rise occurs suddenly in the form of a breaking wave, which travels upstream with its steep, wall-like front. As the tide enters the river, it is slowed down by the constriction. Additional water entering the river continuously catches up with the initial water, with the result that a Churning wall of water moves up the river. The formation of a tidal bore depends upon the strength of the incoming tidal wave, slope and depth of the channel and river flow.

Tidal bores may move at speeds of up to 25km/h and have heights up to 8m. The most famous bore in North America is the bore of the Petticodiac river at the head of the Bay of Fundy. In this river, which empties into the Bay of Fundy at Moncton, New Brunswick, Canada, the tide comes in as a “bore” i.e., as an almost vertical wall of water, which may be as high as 1.5-2m. In India, on the east coast in the Hooghly river near Calcutta, the flow of the tide is occasionally marked by abrupt wave called the “tidal bore”. Hooghly is the major river in India which experiences tidal bores. In the Hooghly, when bore forms, the colour of the water where the breaks indicates a very concentrated syrup of sand water mix. On the west coast of India, in the upper parts of the Gulf of Cambay, tidal bores form near the entrances of Sabarmati river and Mahi river. One of the bores travels up the Sabarmati river, while another one travels up the Mahi river. Each of these bores sweeps through the respective channel as a line of disturbed and breaking water. The bore in Mahi river may be about 2.5m in height and attains a speed of 18km/h at the highest spring [tides](#). The bore in Sabarmati river is similar but less pronounced.

3.3.2. Tide Measurement

Tide gauges

[Tides](#) are [waves](#) of long wavelength and known period, so the major properties of interest for measurement are wave height, or tidalrange, and wave induced current. The latter is measured with currentmeters;any type is suitable. Two types of tide gauges are use to measure the [tidal range](#)(1). The stilling-well gauge consists of a cylinder with anconnection to the sea at the bottom. This connection acts as a lowpass filter: it is so restricted that the

backward and forward motion of the water associated with wind [waves](#) and other [waves](#) of short period cannot pass through; only the slow change of water level associated with the tide can enter the well. This change of water level is picked up by a float and recorded. Stilling-well gauges allow the direct reading of the water level at any time but require a somewhat laborious installation and are impracticable away from the shore(2). In offshore and remote locations it is often easier to use a pressure gauge. Such an instrument is placed on the [sea floor](#) and measures the pressure of the water column above it, which is proportional to the height of water above it. The data are recorded internally and not accessible until the gauge is recovered. Tide gauges are increasingly used to monitor possible long term changes in sea level linked with climate variability and climate change. The expected rate of sea level change is only a few millimeters per year at most, so very high accuracy is required to verify such changes. Most tide gauges are not suitable for such a task, for a number of reasons. For example, a long term trend in observed sea level can also be produced by a rise or fall of the land on which the tide gauge is built. (This is known as benchmark drift). The wire in a stilling-well gauge that connects the float with the recording unit stretches and shrinks as the air temperature rises and falls. Such effects are insignificant when the gauge is used to verify the depth of water for shipping purposes but not when it comes to assessing trends of millimeters per year. A new generation of tide gauges is being installed worldwide which gives water level recordings to absolute accuracies of a few millimeters with long term benchmark stability. In these instruments the float and wire arrangement of stilling-well gauge is replaced by a laser distance measurement, and the data are transmitted via satellite to a world sea level centre which monitors the performance of every gauge continuously.

Tidal theories

The first [theory](#) which attempted to explain the [tides](#) in the ocean was the **equilibrium theory** developed by Newton (1687). In order to get an idea regarding the effect of the [tide producing forces](#) on the ocean's [water mass](#), Newton assumed an ideal ocean of equal depth and covering the entire [earth](#). Newton showed that the attractive forces of the moon on the side of the [earth](#) nearest to the moon would be greater than the average forces on the opposite side of the [earth](#) and therefore the water would be pulled less than the average forces and therefore the water would move away from the moon. In an ocean completely covering the [earth](#) and of equal depth; the horizontal component of the tide generating forces pulls the water towards the points nearest and farthest away from the moon, thus causing elevation of the water at these points, with a corresponding depression in the water level halfway between these two points on the [earth](#)'s great circle. The sun also would tend to give similar effects related to itself. According to Newton, this process can continue only till the resultant horizontal pressure differences in the ocean tend to return the water to its former position, so that the free surface of the water would be in equilibrium.

Equilibrium [theory](#) can explain certain characteristics of [ocean tides](#), especially the occurrence of semidiurnal [tides](#). If we assume that the moon is stationary and is directly above the equator, then the maximum Since the [earth](#) required a day for one complete revolution, an observer on the equator would notice two high [tides](#) in a day. The time that would elapse between two high [tides](#), i.e., the tidal period would be half a day. An observer at any latitude north or south of the equator would also notice a similar period for the [tides](#). Thus this [theory](#) can explain the occurrence of semi-diurnal [tides](#). This [theory](#) can also explain the formation of spring and neap [tides](#). When the sun and the moon are in line with respect to the [earth](#) (full moon and new moon) their tide generating forces are added, producing highest high [tides](#) known as spring [tides](#). When the sun and the moon are perpendicular to one another with respect to the [earth](#), their effects tend to cancel one another,

producing the lowest low [tides](#) known as **neap tides**.

But the equilibrium [theory](#) fails to explain the time of occurrence of high water at a place. In accordance with this [theory](#), the high water of the lunar tide can occur when the moon passes through the meridian of that location. However, actual observations have shown that the high water occurs at a place with some delay after the moon's passing through the meridian. The tidal ranges also are not according to the equilibrium tidal [theory](#). Observations made at several places along the coasts of the world oceans have shown wide variations with regard to tidal ranges. At some places the [tidal range](#) may be negligible, while at some other places it may reach more than 10 m.

The main criticism about this [theory](#) is the assumption of having a constant equilibrium between the tide generating forces and the pressure. According to the equilibrium [theory](#), the tidal elevations form on the [earth](#) at the points nearest and farthest away from the moon. To remain in this position with respect to the moon as the [earth](#) rotates below the moon, the elevations which would be separated by a distance of about 20,000 km (half the [earth](#)'s circumference), would have to move across the [earth](#), at a speed of more than 1600km/h. For the tidal wave to travel at the enormous speed of 1600km/h, the ideal ocean's depth would have to be enormous. At the enormous speed of 1600km/h, the ideal ocean's depth would have to be 22km. Since the [tides](#) are considered as shallow water [waves](#), their velocity is proportional to the square root of the water depths. Taking the average depth of the ocean as 3.9km, the speed of the tidal elevations can be about 700km/h only. Therefore, the equilibrium position at any instant required by this [theory](#) cannot be established. The most important aspect with regard to [ocean tides](#) is not a static one as assumed in the equilibrium [theory](#), but a hydrodynamic one.

Dynamic [Theory of Tides](#)

Nearly a century after Newton put forward his equilibrium [theory](#), Laplace (1775) formulated the dynamic [theory of tides](#). According to this [theory](#), the [tide producing forces](#) produce tide [waves](#) in the ocean whose period corresponds to that of the generating forces. The dynamical [theory](#) attempted to understand [tides](#) by considering the effect of the depth and width of the ocean basins, [earth](#)'s rotation and friction on the behaviour of fluids which are subjected to rhythmic forces.

To understand the dynamic [theory](#), let us consider the simplest case, where the sun and moon are both at zero declination and in synergy, such that solar and lunar [tides](#) coincide. Now we have to consider only one equilibrium tide. As indicated in the equilibrium [theory](#), an ocean depth of 22km would be necessary for the equilibrium tide at the equator to keep up with the moon's passage around the [earth](#). Since the oceans are less than 22km deep everywhere, the actual tide will "lag" behind the equilibrium tide. At lower latitudes on either side of the equator, the "lag" is about 6 h 12 min and 18 h 36 min after the moon's passage overhead. This type of [tides](#) are known as "indirect [tides](#)". At latitudes more than 26°, the "tidal lag" is less than 6 h 12 min. This lag decreases with increase in latitude and at 65° latitude there is "no lag" at all. Hence, from 65° latitude onwards up to poles, the actual tide will keep up with the theoretical lunar equilibrium tide. Therefore, theoretically high [tides](#) would occur (after 12 h and 25 min) at the moon's passage. Such type of [tides](#) are known as "direct [tides](#)". Thus, according to this [theory](#) all [tides](#) in the equatorial regions (less than about 26°) would be "indirect [tides](#)", and all [tides](#) in the polar regions (more than about 65°) of an ocean would be "direct [tides](#)".

The Coriolis force (deflection due to [earth](#)'s rotation) is zero at the equator and increases with latitude towards the poles. It varies with the speed of the tidal current. Thus, the [earth](#)'s rotation has a major role in the formation of [tidal currents](#) and on the general nature of [ocean tides](#). Friction also influences the [tides](#), since the force of friction reduces the speed of the [tidal currents](#).

In the simplest case so far, we have considered the moon to be directly above the equator. But actually the moon has a declination which changes up to a maximum of 28.5° north and south. Due to this reason the tidal forces will not be symmetrical with [reference](#) to the equator. Therefore, the problem of wave motion in latitudinal channels would become more complicated. In spite of the complexities of the dynamic [theory](#), it has one important advantage, in that it enables to predict the course of the [tides](#) for any given location along a coast.

Modern Tidal [Theory](#)

Our knowledge on [tides](#) has not yet reached the final stage, so as to explain the [tides](#) satisfactorily and quantitatively without referring to observed values, attempts are being made. The following three fundamental ideas have provided the basis from which the investigation is proceeding successfully (Macmillan, 1966).

1. The [theory](#) of standing oscillations
2. The [theory](#) of resonance between the natural oscillation periods of water masses in bays, gulfs, seas and oceans and cyclic rhythms of the astronomical disturbing forces which can be predicted accurately.
3. The application of gyroscopic principles to determine the effect of the [earth](#)'s rotation upon these water masses, which are set in motion horizontally by hydraulic factors, due to the differences in level of the sea surface induced by the attractive forces.

Terminologies

[Tidal range](#)

Difference in height between mean high water and mean low water, measured in feet or meters.

Tidal bore very rapid rise of the tide in which the advancing water forms an abrupt front; occurs in certain shallow estuaries having large [tidal range](#).

Tidal bulge (tidal crest) long-period wave associated with the tide-producing forces of the moon and sun identified with the rising and falling of the tide. The trough located between the two tidal bulges present at any give time on the [earth](#) is known as the tidal trough.

Tidal constituent an element in a mathematical expression for the tide-generating forced, [tides](#), or [tidal currents](#). Each constituent represents a periodic change or variation in the relative positions of the [Earth](#), moon, and sun.

Tidal current alternating horizontal movement of water associated with the rise and fall of the tide.

Tidal day interval between two successive upper transits of the moon over a location. A mean tidal day, some times called a lunar day, is 24 hours, 50 minutes.

Tidal flats marshy or muddy areas which are covered and uncovered by the rise and fall of the tide; also called tidal marshes. Usually covered by plants.

Tidal period elapsed time between successive high or low waters.

[Tidal range](#) difference in height between consecutive high and low waters.

Tide periodic rise and fall of the ocean and atmosphere, caused by the gravitational attraction of moon and sun acting on the [Earth](#).

Tide curve presentation of the rise and fall of tide; time (in hours or days) is plotted against height of the tide.

[Tide producing forces](#) slight local difference between the gravitational attraction of two astronomical bodies and the centrifugal force that holds them apart. Gravitational attraction predominates at the surface point nearest to the other body while centrifugal "repulsion" predominates at the surface point farthest from the other body.

Tide pool depression-usually water filled-in the intertidal zone, alternately submerged and

exposed by the rise and fall of tide or wave action.

Tide tables tables that predict the times and heights of tidal phenomena at specified locations. Tide wave long-period gravity wave that has its origin in the tide-producing force; manifests itself in the rising and falling of the tide.

Tide winds wind system, in most of the tropics, which blow from the subtropical highs toward the equatorial lows. Trade winds are from the northeast in the northern Hemisphere, from the southeast in the Southern Hemisphere.

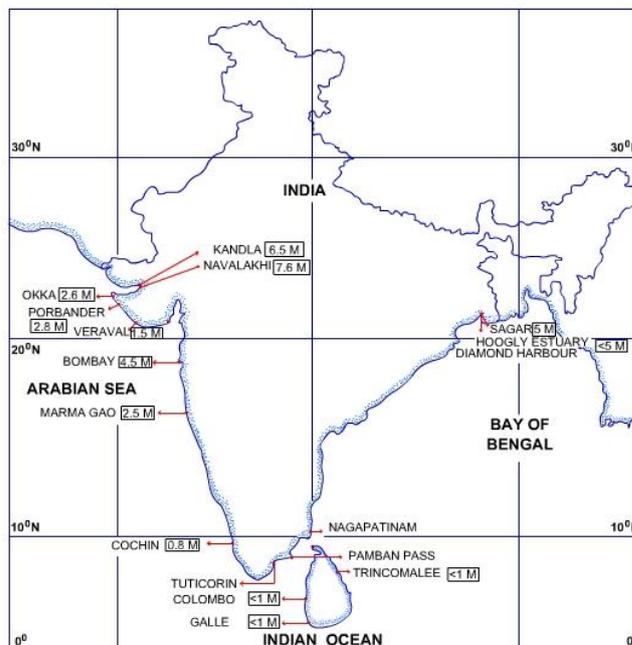
Thermocline marked vertical temperature change in a body of water; also a layer in which such a temperature change occurs.

[Thermohaline circulation](#) circulation induced by differences in water density which is controlled primarily by temperature and salinity.

[Spring tide](#) tide of increased range that occurs about every 2 weeks when the moon is new or full.

Neap tide lowest range of the tide, occurring near the times of the first and last quarters of the moon.

Tidal range for some important locations along the Indian coasts



Tidal predictions

Astronomical [tides](#) do not include weather effects. Also, changes to local conditions (sandbank movement, dredging harbour mouths, etc.) away from those prevailing at the measurement time affect the tide's actual timing and magnitude. Organisations quoting a "highest astronomical tide" for some location may exaggerate the figure as a safety factor against analytical uncertainties, distance from the nearest measurement points, changes since the last observation time, ground subsidence, etc. to avert liability should an engineering work be overtopped. Special care is needed when assessing the size of a "weather surge" by subtracting the astronomical tide from the observed tide.

Careful Fourier data analysis over a nineteen-year period (the national Tidal Datum Epoch in the U.S) uses frequencies called the tidal harmonic constituents. Nineteen years is preferred because 19 years, which is long enough to include the 18.613 year lunar nodal tidal

constituent. This analysis can be done using only the knowledge of the forcing period, but without detailed understanding of the mathematical derivation, which means that useful tidal tables have been constructed for centuries. The resulting amplitudes and phases can then be used to predict the expected [tides](#). These are usually dominated by the constituents near 12 hours (the semidiurnal constituents), but there are major constituents near 24 hours (diurnal) as well. Longer term constituents are 14 day or fortnightly, monthly, and semiannual. Semidiurnal tide dominated coastline, but some areas such as the south china sea and the Gulf of Mexico are primarily diurnal. In the semidiurnal areas, the primary constituents M_2 (lunar) and s_2 (solar) periods differ slightly, so that the relative phases, and thus the amplitude of the combined tide, change fortnightly (14 day period). In the M_2 plot above, each cotidal line differs by one hour from its neighbors, and the thicker lines show [tides](#) in phase with equilibrium at Greenwich. The lines rotate around the amphidromic points counterclockwise in the northern hemisphere so that from Baja California peninsula to Alaska and from France to Ireland the M_2 tide propagates northward. In the southern hemisphere this direction is clockwise. On the other hand M_2 tide propagates counterclockwise around New Zealand, but this is because the islands act as a dam and permit the [tides](#) to have different heights on the islands opposite sides. (The [tides](#) do propagate northward on the east side and southward on the west coast, as predicted by [theory](#).)

The exception is at Cook Strait where the [tidal currents](#) periodically link high to low water. This is because cotidal lines 180° around the amphidromes are in opposite phase, for example high water across from low water at each end of Cook Strait. Each tidal constituent has a different pattern of amplitudes, phases, and amphidromic points, so the M_2 patterns cannot be used for other tide components.