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| **How The Moon Affects Ocean Tides...** |

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| The word "tides" is a generic term used to define the alternating rise and fall in sea level with respect to the land, produced by the gravitational attraction of the moon and the sun. To a much smaller extent, tides also occur in large lakes, the atmosphere, and within the solid crust of the earth, acted upon by these same gravitational forces of the moon and sun. **What are Lunar Tides**Tides are created because the Earth and the moon are attracted to each other, just like magnets are attracted to each other. The moon tries to pull at anything on the Earth to bring it closer. But, the Earth is able to hold onto everything except the water. Since the water is always moving, the Earth cannot hold onto it, and the moon is able to pull at it. Each day, there are two high tides and two low tides. The ocean is constantly moving from high tide to low tide, and then back to high tide. There is about 12 hours and 25 minutes between the two high tides.  |
| http://home.hiwaay.net/~krcool/Astro/moon/moontides/Dia1.jpg | Tides are the periodic rise and falling of large bodies of water. Winds and currents move the surface water causing waves. The gravitational attraction of the moon causes the oceans to bulge out in the direction of the moon. Another bulge occurs on the opposite side, since the Earth is also being pulled toward the moon (and away from the water on the far side). Ocean levels fluctuate daily as the sun, moon and earth interact. As the moon travels around the earth and as they, together, travel around the sun, the combined gravitational forces cause the world's oceans to rise and fall. Since the earth is rotating while this is happening, two tides occur each day.  |
| **What are the different types of Tides**When the sun and moon are aligned, there are exceptionally strong gravitational forces, causing very high and very low tides which are called spring tides, though they have nothing to do with the season. When the sun and moon are not aligned, the gravitational forces cancel each other out, and the tides are not as dramatically high and low. These are called neap tides.  |

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| **Spring Tides**When the moon is full or new, the gravitational pull of the moon and sun are combined. At these times, the high tides are very high and the low tides are very low. This is known as a spring high tide. Spring tides are especially strong tides (they do not have anything to do with the season Spring). They occur when the Earth, the Sun, and the Moon are in a line. The gravitational forces of the Moon and the Sun both contribute to the tides. **Spring tides occur during the full moon and the new moon.** **Neap Tides**During the moon's quarter phases the sun and moon work at right angles, causing the bulges to cancel each other. The result is a smaller difference between high and low tides and is known as a neap tide. Neap tides are especially weak tides. They occur when the gravitational forces of the Moon and the Sun are perpendicular to one another (with respect to the Earth). **Neap tides occur during quarter moons.**  | Tides |
| **The Proxigean Spring Tide** is a rare, unusually high tide. This very high tide occurs when the moon is both unusually close to the Earth (at its closest perigee, called the proxigee) and in the New Moon phase (when the Moon is between the Sun and the Earth). The proxigean spring tide occurs at most once every 1.5 years.  |

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| **High Tide / Low Tide Examples** |
| http://home.hiwaay.net/~krcool/Astro/moon/moontides/inout-tide.gif | A view of the tides at Halls Harbour on Nova Scotia's Bay of Fundy. This is a time lapse of the tidal rise and fall over a period of six and a half hours. During the next six hours of ebb the fishermen unload their boats on the dock. That's a high tide every 12 and 1/2 hours! There are two high tides every 25 hours.  |

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| **A Few Facts About Lunar Tides**  |
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| * **The gravitational force of the moon is one ten-millionth that of earth, but when you combine other forces such as the earth's centrifugal force created by its spin, you get tides.**
* **The sun's gravitational force on the earth is only 46 percent that of the moon. Making the moon the single most important factor for the creation of tides.**
* **The sun's gravity also produces tides. But since the forces are smaller, as compared to the moon, the effects are greatly decreased.**
* **Tides are not caused by the direct pull of the moon's gravity. The moon is pulling upwards on the water while the earth is pulling downward. Slight advantage to the moon and thus we have tides.**
* **Whenever the Moon, Earth and Sun are aligned, the gravitational pull of the sun adds to that of the moon causing maximum tides.**
* **Spring tides happen when the sun and moon are on the same side of the earth (New Moon) or when the sun and moon are on opposite sides of the earth (Full Moon).**
* **When the Moon is at first quarter or last quarter phase (meaning that it is located at right angles to the Earth-Sun line), the Sun and Moon interfere with each other in producing tidal bulges and tides are generally weaker; these are called neap tides.**
* **Spring tides and neap tide levels are about 20% higher or lower than average.**
* **Offshore, in the deep ocean, the difference in tides is usually less than 1.6 feet**
* **The surf grows when it approaches a beach, and the tide increases. In bays and estuaries, this effect is amplified. (In the Bay of Fundy, tides have a range of 44.6 ft.)**
* **The highest tides in the world are at the Bay of Fundy in Nova Scotia, Canada.**
* **Because the earth rotates on its axis the moon completes one orbit in our sky every 25 hours (Not to be confused with moon's 27 day orbit around the earth), we get two tidal peaks as well as two tidal troughs. These events are separated by about 12 hours.**
* **Since the moon moves around the Earth, it is not always in the same place at the same time each day. So, each day, the times for high and low tides change by 50 minutes.**
* **The type of gravitational force that causes tides is know as "Tractive" force.**
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| **FAQs About Lunar Tides From - *"The Astronomy Cafe"***  |
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| **Why are there no ocean tides at the equator?**"Tides are a very complex phenomenon. For any particular location, their height and fluctuation in time depends to varying degrees on the location of the Sun and the Moon, and to the details of the shape of the beach, coastline, coastline depth and prevailing ocean currents. The tidal bulge of the Moon follows along the path on the earth's surface which intersects with the orbital plane of the Moon. This plane is tilted about 23 degrees with respect to the equatorial plane of the earth. The result is that near the equator, the difference between high tide and low tide is actually rather small, compared to other latitudes. To see this, draw a circle inscribed in an ellipse, with the major axis of the ellipse rotated by 23 degrees with respect to the circle's horizontal diameter. Now measure the height of the elliptical contour just above the 'equator' of the circle. You will see that it is quite small compared to other positions on earth, particularly at latitudes of 23 degrees or so. Even larger differences can occur depending on the shape of a bay or inlet or continental shelf." - *Dr. Odenwald's ASK THE ASTRONOMER***Why are ocean tides so different everywhere?**"Because they depend on many factors including the geometry of your local coastline, and exactly where the Sun and Moon are located. Also, like the surface of a vibrating drum, the world oceans have vibratory modes that get stimulated in changing ways from minute to minute. Finally, there are storms at sea and elsewhere which move large quantities of water. Detailed forecasts are available for high and low tides in all sea ports." - *Dr. Odenwald's ASK THE ASTRONOMER* **Why aren't the Atlantic and Pacific coast tides the same?**"The nature of tides on the Earth's oceans is very complex. The oceans are, of course, being periodically 'forced' by a number of tidal sources including the Moon and the Sun, but this forcing has a number of different periods and harmonics. The two dominant periods are sue to the Sun and Moon, these are referred to as the S1 and M2 'modes' which have roughly 12 hour periods because they raise TWO water tides on the ocean diametrically opposite each other. But, for a variety of reasons, any given port will not have two high and two low tides each day; also called 'semi-diurnal tides'. A careful monitoring of the tides at any port for several years will show that in addition to the major modes, there are as many as 300 minor or 'harmonic' modes as well. The World Ocean is a complex dynamical system. The natural velocity of a water disturbance depends on the depth and salinity of the water at each point it passes. When bodies of land circumscribe bodies of water, they produce a collection of resonating systems that favor water oscillations with certain frequencies over others. From among the 300+ harmonics that can be measured, every port and coastal location has its own unique signature depending on its latitude, longitude, water depth and salinity. The result is that the 'two high two low' tide rule can be strongly modified so that the time between successive high tides can be greater than or less that 12 hours in many cases. The result is that for some locations, there can be days when only one high tide occurs. Looking at the Atlantic and Pacific Coast tide tables for 1995, the data for the various 'Standard Ports' showed that virtually all days had two high tides and two low tides in San Diego, San Francisco, New York and Charleston. There were, however a few days every few months when only a single high tide occurred." - *Dr. Odenwald's ASK THE ASTRONOMER* **What is a Proxigean Spring Tide?**"The Moon follows an elliptical path around the Earth which has a perigee distance of 356,400 kilometers, which is about 92.7 percent of its mean distance. Because tidal forces vary as the third power of distance, this little 8 percent change translates into 25 percent increase in the tide- producing ability of the Moon upon the Earth. If the lunar perigee occurs when the Moon is between the Sun and the Earth, it produces unusually high Spring high tides. When it occurs on the opposite side from the Earth that where the Sun is located ( during full moon) it produces unusually low, Neap Tides. The High, High Tide is called the Proxigean Spring Tide and it occurs not more than once every 1.5 years. Some occurrences are more favorable that others. A very interesting book "Tidal Dynamics" by Fergus J. Wood, published in 1986 by Reidel Publishing Company, talks at great length about these tides, and their environmental consequences. Because of the gravitational nature of the interaction between the Earth, the Moon, and the water on the Earth, there is a curious amplification event called 'evection' that occurs when the Moon is at its closest 'perigee' distance called its 'proxigee'. The Moon draws even closer to the Earth than its ordinary perigee distance. Because of the complex dynamics of the Earth's oceans, their inertia, friction with the ocean floor, internal viscosity and the distribution of the continents, the maximum tides do not always coincide with the optimal times of proxigee. Still, these tides can produce enormous damage when all factors come together optimally. There are many recorded instances of unusually high storm or coastal flooding during the proxigean times. On January 9, 1974 the Los Angeles Times reported 'Giant Waves Pound Southland Coast". During the last 400 years, there have been 39 instances or 'Extreme Proxigean Spring Tides' where the tide-producing severity has been near the theoretical maximum. The last one of these was on March 7 1995 at 22:00 hours Greenwich Civil Time during a lunar Full Moon. There were, in fact cases of extreme tidal flooding recorded during these particular spring tides which occur once every 31 years." - *Dr. Odenwald's ASK THE ASTRONOMER* **If the Moon were to escape, what would happen to the Earth's oceans?**"What happens is that the lunar water tides on the Earth go away, but the solar water tides still occur, but with about 1/3 or so the amplitude. There are still daily high and low tides, but they would be noticeably smaller. There would be no 'Spring' or 'Neap' tides, however."- *Dr. Odenwald's ASK THE ASTRONOMER* **Why does the Moon produce TWO water tides on the Earth and not just one?**"It is intuitively easy to understand why the gravitational pull of the Moon should produce a water tide on the Earth in the part of the ocean closest to the moon along the line connecting the center of the Moon with the center of the Earth. But in fact not one but TWO water tides are produced under which the Earth rotates every day to produce about two high tides and two low tides every day. How come? It is not the gravitational force that is doing it, but the change in the gravitational force across the body of the Earth. If you were to plot the pattern of the Moon's 'tidal' gravitational force added to the Earth's own gravitational force, at the Earth's surface, you would be able to resolve the force vectors at different latitudes and longitudes into a radial component directed towards the Earth's center, and a component tangential to the Earth's surface. On the side nearest the moon, the 'differential' gravitational force is directed toward the Moon showing that for particles on the Earth's surface, they are being tugged slightly towards the Moon because the force of the Moon is slightly stronger at the Earth's surface than at the Earth's center which is an additional 6300 kilometers from the Moon. On the far side of the Earth, the Moon is tugging on the center of the Earth slightly stronger than it is on the far surface, so the resultant force vector is directed away from the Earth's center. The net result of this is that the Earth gets deformed into a slightly squashed, ellipsoidal shape due to these tidal forces. This happens because if we resolve the tidal forces at each point on the Earth into a local vertical and horizontal component, the horizontal components are not zero, and are directed towards the two points along the line connecting the Earth and the Moon's centers. These horizontal forces cause rock and water to feel a gravitational force which results in the flow of rock and water into the 'tidal bulges'. There will be exactly two of these bulges. At exactly the positions of the tidal bulges where the Moon is at the zenith and at the nadir positions, there are no horizontal tidal forces and the flow stops. The water gets piled up, and the only effect is to slightly lower the weight of the water along the vertical direction. Another way of thinking about this is that the gravitational force of the Moon causes the Earth to accelerate slightly towards the Moon causing the water to get pulled towards the Moon faster than the solid rock on the side nearest the Moon. On the far side, the solid Earth 'leaves behind' some of the water which is not as strongly accelerated towards the Moon as the Earth is. This produces the bulge on the 'back side' of the Earth."- *Dr. Odenwald's ASK THE ASTRONOMER* **What Causes Tides?**"There are several kinds of tides. The ones that break upon a beach every 10 seconds to a minute are caused by sea level disturbances out in the ocean produced by such things as storms. Also, the various circulation currents of sea water can have velocity components directed towards the land which will bring water up onto the beach. As this water travels towards the beach from deep water to shallow water, its amplitude will increase until it finally 'breaks' as a full-fledged breaker, suitable for surfing etc. Now, underlying this minute to minute activity is a slower water wave which causes an alternating pattern of high-tide, low-tide, high-tide, low-tide in most places on the Earth that are directly on the ocean. This roughly 6 hour cycle is caused by the gravitational tugging of the Moon upon the Earth. This 'tidal' pull causes the shape of the solid Earth to be not perfectly round by something like a few dozen yards over its entire 27,000 mile circumference. The Earth gets distorted a small bit, but because it is solid rock its a small effect. The water in the oceans, however, gets distorted into a roughly ellipsoidal ( football-like) shape with a much larger amplitude. The orientation of this shape changes from minute to minute as the Moon orbits the Earth, which is why the high and low tide times change all the time. The Moon causes these tides by deforming the oceans, and as the Earth rotates under this ocean bulge, it causes a high tide to propagate onto beaches. Because there are two bulges, we get two high tides, and also two low tides each day. The Sun also causes tides on the Earth because even though it is so far away, it is very massive. These solar tides are about half as strong as the ones produced by the Moon, and they cause the so-called Spring tides and the Neap Tides. When the bulge of ocean water raised by the Moon is added the a similar tidal bulge raised by the Sun, you get a higher, high tide called the Spring Tide. When the solar low tide is added to the lunar low tide, you get the Neap Tide. There may be even weaker tides caused by the gravitational influences of the planets Mars and Venus, but they are probably lost in the daily noise of individual tides."- *Dr. Odenwald's ASK THE ASTRONOMER* **When the Earth, Moon and Sun are aligned for Spring Tides, are they highest at Full or New Moon?**"Spring tides are about the same height whether at New or Full Moon, because the tidal bulge occurs on both sides of the Earth...the side toward the Moon ( or sun) and the side away from the Moon (or Sun). They will not be equally high because the distance between the Earth and Sun, and the Earth and Moon both vary and so will their tide producing effectiveness. The highest Spring tides occur when the Moon is at its closest to the Earth...the so-called Perigee Tide."- *Dr. Odenwald's ASK THE ASTRONOMER*  |

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