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Tides

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T I D E S .

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It was known as early as the time of Julius Caesar, almost two thousand years ago, that there was some relation between the movement of the moon and sun and the tides. Following the differ- phases of the moon, the fishermen and sailors saw the tides change in a regular manner, becoming higher and higher and then steadily receding twice each month. They also noticed that the position of the sun had its effect upon the waters and that the equinoxes of March and September were also accompanied by very high tides. These phenomena of the sea and the movements of the sun and moon were marked by the earliest mariners, and the idea was rudely symbolized in their songs.

About two centuries ago Newton, the great English mathematician and astronomer, first gave a clear explanation of the way in which the sun and moon produce tides. Astronomers had determined the distance of the moon from the earth to be sixty terrestrial radii and its mass to be one eightieth of that of the earth. Newton applied the universal law that "the attraction of two bodies is proportional to the mass and inversely proportional to the square of the difference between their centers". He thus determined the attraction of the moon upon a particle at the center of the earth to be one-two hundred and eighty-eight thousandth of terrestrial gravity.

Tides are produced by the difference of attraction exercised upon the waters of different parts of the earth. As the attraction of the moon upon that part of the earth which is nearest it is greater than at a point near the poles, whose distance from the moon is equal to that of the center of the earth, the waters, whose particles have a faculty of gliding over one-another, swell towards the moon until their weight equalizes the attracting force. On the side of the planet farthest from the moon, another intumescence is formed from a precisely contrary reason, and the mass as a whole takes the form of a prolate spheroid, a solid formed by the revolution of an ellipse upon its longer axis.

The surface of the earth revolves with a velocity of about a thousand miles an hour; and owing to the friction of the bottom, the tide wave which is started on the line joining the centers of the earth and moon cannot travel so fast as the earth revolves, and hence falls behind. In this way thousands of waves are formed and the aggregate of them makes a wave which travels with a velocity equal to the revolution of the earth. This wave does not move directly under the moon, but follows it in the same way that a weight hung at the end of a long string, with a constant and regular force applied at the upper end of the string, swings with the same number of oscillations as the force, but is always behind it in its motion. In the same way Newton accounts for the tide- producing force of the sun; but owing to its great distance, its difference of attraction upon different parts of the earth is much less than the moon, being little more than one-third as much. Modified by friction and the interference of the land, the solar wave is not distinguishable, although its effect can be detected.

Whewell, the English natural philosopher, agrees with Newton that the sun and moon are the agents by which the phenomena of ebb and flow are produced; but he gives a different explanation of the origin and propagation of the tidal wave. His theory is that the wave originates in the Southern Pacific Ocean, anw then travels from east to west with a velocity dependent upon the depth of the sea. As this wave reaches the South American coast, he thinks it would rebound toward the north, follow the contour of the oceanic valley, and at last strike the coast of North America and the Old World at the same time. Observations have shown the movements of the sea to be much as Whewell has described them. There are, however, many points yet to be cleared up.

There is a theory that each ocean, considered as an isolated sea, is the cradle of its own waves; for it has been ascertained that in oceanic basin the tides seem to originate at the center and be propogated in all directions parallel to the general direction of the coast. It has also been observed that the various oceans are separated from one another by spaces where the tides are scarcely perceptible.

The moon moves around the earth once in 27d-7h,-43m, 11, 46s that its relative position with respect to the earth and sun is constantly changing. This has its effects upon the height of the tides. At full and new moon when the earth, sun and moon are in a straight line the maximum, or spring, tides occur, for in this position the solar and lunar forces act together. At first and third quarters the two forces act at right angles, and the minimum, or neap, tides occur. As the moon passes through its first quarter the solar time, having a shorter period than the lunar, gradually shoots ahead of the lunar and the crest of the resultant wave passes a little sooner than it would if the moon acted alone. Similarly in the second quarter the solar time retards the lunar and the resultant crest is a little behind. Corresponding phenomena occur in the third and fourth quarters, and this explains the regularly varying intervals of time which have been observed in successive high or low tides.

As the moon moves north or south of the equator, the zenith distance of the upper transit is not equal to the nadir distance of the lower transit and the successive high tides may not be of equal height. This inequality is called the diurnal tide. By observations it has been determined that the spring and neap tides pass about a day and a half after the passage of the new or full moon. Theoretically the lunar wave should be twenty and the solar nine inches high and the spring tide should be eleven-fifths of the neap tide; but here theory and reality do not agree.

The frictional resistance of the tidal wave must produce heat and this heat represents part of the enegy of the rotation of the earth. The tides must therefore be very gradually lengthening our days.

As no solid matter possesses the property of perfect rigidity, the earth is probably subject to a tidal elastic deformation. Its effective rigidity is calculated to be as great as that of a globe of glass of its size.

There are innumerable inequalities which occur in the phenomena of tides in consequence of the irregularities of the sea bottom, indentations of the shore, and the varying winds and currents. In the open sea, where the water is deep, the tidal waves move with great speed; but as they approach the shore and pass into shallower water, they slacken their speed and consequently gain in height what they lose in velocity. Fifteen hours are required for the passage of a wave from the Cape of Good Hope to the British Isles, a distance of six thousand miles; and in consequence of the decrease in the depth of the water, nineteen hours elapse during its passage around the Islands to the Strait of Dover, a distance of two thousand miles.

In the Bay of Fundy the contour of the surface and the shape of the shore are such that a wave nine feet high at the entrance increases to sixty feet towards the end of the channel.

In the estuary of La Plata, where the land formation is such that one would expect an enormous ebb and flow, the tides are scarcely perceptible. This phenomenon is explained by the presence of two tidal waves, the ebbof one crossing the flow of the other in such a way that the two neutralize each other and no perceptible in the level of the water takes place.

The tides, being a mere swelling of the ocean, produce no currents in the open sea. In straits and channels the change in sea level sometimes causes very violent currents and eddies.

In rivers and estuaries the interval from high to low water is less than from low to high water. In the case of rivers it is easy to understand that the river water neutralizes and shortens the flow and adds to and lengthens the ebb; but in the case of estuaries into which no rivers flow, the inequality is attributed to the revolution of the earth from west to east. The flow of the wave meeting a certain resistance from the waters in front becomes steep and the flow is shortened. For the same its ebb is lengthened. When entering the estuary of a river, the tidal wave must necessarily swell because of the narrow banks and the shallow water; and if the conditions are favorable, it attains enormous proportions and rises like a moving wall. In the Amazon it attains a height of from thirty to fifty feet.

On Lake Michigan, which contains five hundred thousand square miles, a tide of three inches is detected. Some have claimed this tide to be due to the wind, but the regularity of its occurrence goes to prove it to be a direct result of the attraction of the sun and moon. In lakes the duration of ebb and flow is very short.

If the energy which is stored in the tides could be controlled as effectually in rivers and estuaries as at Niagara, we might obtain all our power from them and do away with the noisy steam engine with its coal dust and smoke.