DF —— second attempt ⟶ RS (c/o G.S.)

Tides on the Earth

2011, May 22

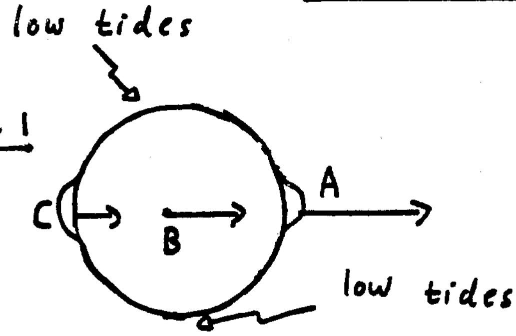
The principal tidal phenomena are the rising, or flood tide, and the falling, or ebb tide, of the ocean waters, twice in an average interval of 24h 50m. Since the Moon, due to its revolution around the Earth, appears to move twelve to thirteen degrees day^{-1} eastward, with respect to the Sun, the interval between successive transits of the Moon across the celestial meridian, indicates that the gravitational attraction of the Moon on the water of the Earth is the main force which causes the tides.

This tide-raising force is the difference between the attraction of the Moon upon the water on the surface of the Earth and its attraction on the almost rigid Earth. Thus, per unit mass, the Moon attracts the ocean waters directly beneath it with a greater force than it attracts the solid Earth, the mass of which may be thought of as concentrated at its centre; and the attraction upon the solid Earth is greater than upon the waters on the far side of the Earth.

The result of this differential attraction is to pile up high waters beneath the Moon and, simultaneously, on the opposite side of the Earth, with low water between. In effect, then, a point on the rotating Earth twice passes through regions of high and low water in the 24h 50m interval.

Terrestrial Tides (G.C.S.E. Astronomy Treatment)

Diagram 1



Maximum water bulges at A and C

Moon: ⟶

(Far away = 60 R_E

A schematic representation of the tidal effects caused by the Moon. The arrows represent the acceleration of each point that results from the gravitational pull of the Moon.

The water at point A has a greater acceleration towards the Moon than does the water at point B; Since the Earth is solid, the whole Earth moves with point B. Similarly, the solid Earth is moved away from the water at point C.

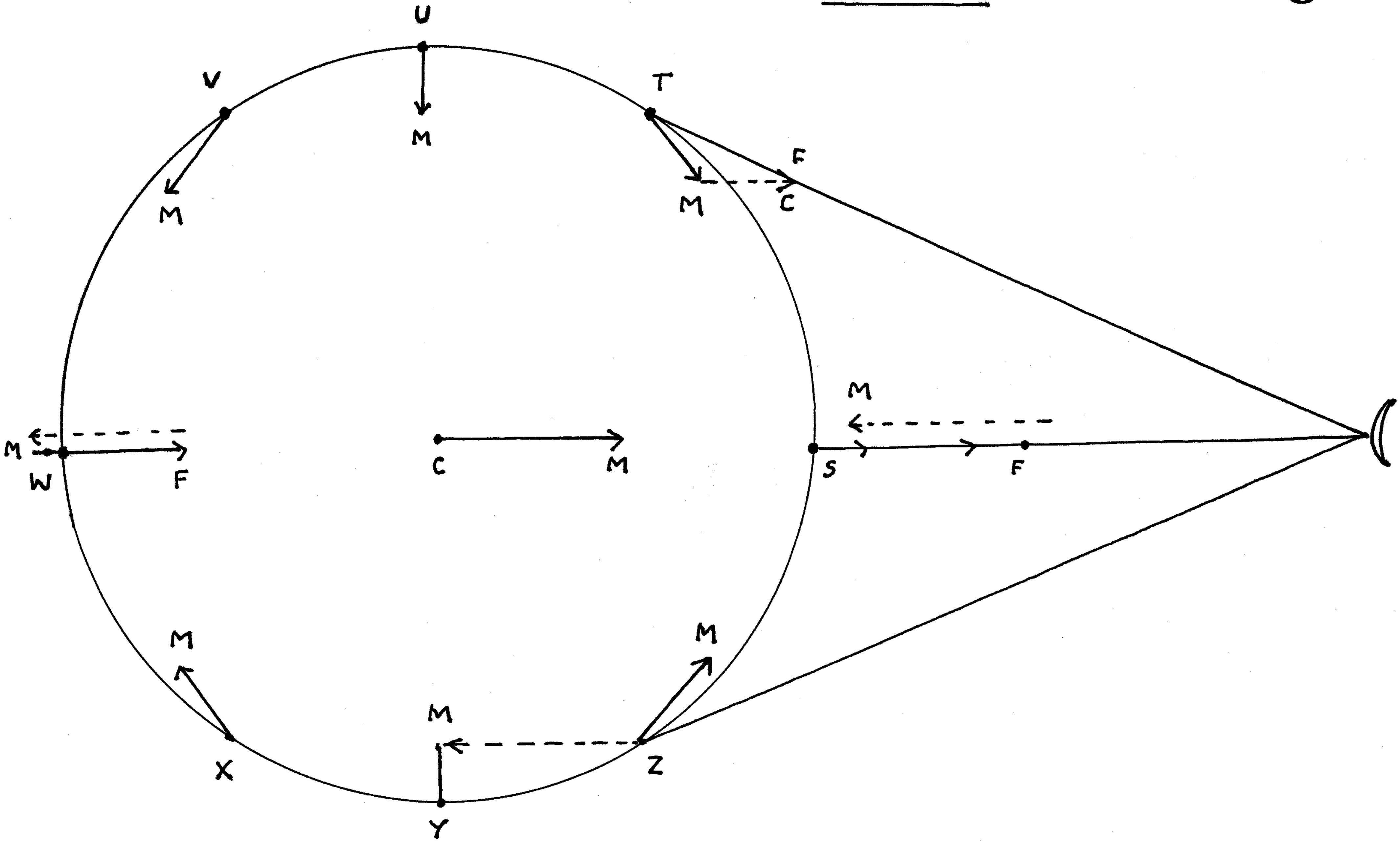
∴ Tides depend on the difference between the gravitational attraction of a massive body at different points on another body.

Two high tides occur daily, separated roughly by $12\frac{1}{2}$ hours. Thus, the high tide on the side of the Earth that is nearer to the Moon is a result of the water's being pulled away from the Earth. The high tide on the opposite side of the Earth results from the Earth's being pulled away from the water. In between the locations of the high tides, the water has rushed elsewhere, so we have low tides.

Since the Moon is moving in its orbit around the Earth, a point on the surface of the Earth has to rotate longer than 12 hours to return to a spot nearest to the Moon. Thus, the tides repeat every $12\frac{1}{2}$ hours.

Though the Sun exerts the greater gravitational force on the Earth than does the Moon, the Sun is so far away ($d_S = 400\, d_M$) that its force does not change very much from one side of the Earth to the other. It is only the change in force that counts for tides.

Diagram 2



In Figure 2, S, T, U, V, W, X, Y and Z are different points on the Earth. The arrows (vectors) SF, CM and WF show the direction and amount of the gravitational attraction of the Moon for points S and W and for the centre, C, of the Earth

Since the distance of the Moon increases from S to C and from C to W, the gravitational forces of the Moon decrease from S to C to W.

The vectors representing these forces have been drawn with progressively shorter lengths for the points S, C and W.

The difference between the gravitational of the Moon between any point on the surface of the Earth and its centre can be obtained by reversing the direction of the vector CM and applying it to SF and WF. The resulting vector differences are the tide-raising forces, SM and WM, both of which tend to lift the water into high tides. Figure 2 also illustrates these forces for several other points on the surface of the Earth. For example, the vector TF, representing the attraction of the Moon at this point, is directed towards the Moon and is intermediate in length between SF and CM. The difference between the gravitational force of the Moon upon this point and upon the centre of the Earth is found by subtracting the vector CM from the vector TF. The resulting tide-raising force is the vector TM.

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Similarly, the tide-raising forces at other points around the Earth are UM, VM, XM, YM and ZM. The combined effect is to pile up the waters into high tides at S and W, and to depress them into low tides at U and Y.

The existence of continents, of prevailing winds, of variations of barometric pressure, etc., makes the detailed study of tides extremely complicated. For example, one of the two daily high tides does not always occur at the moment the Moon crosses the Meridian. For a given port, the average interval between high water and the transit of the Moon across the Meridian is called the establishment of the port.

When the Moon is far North or far South of the Equator, the two daily high tides can have different heights, resulting in the diurnal inequality. The average range between high and low water can range from 0·6 m to 1 m in the open ocean to 13 m in narrow, funnel-shaped bays separated from the deeper oceans by wide continental shelves.

Delicate measurements have shown that the Moon and the Sun also raise tides in the solid surface of the Earth, and in the atmosphere of the Earth. At the time of the spring tides, the surface rises about twenty-five cm. From this, it has been deduced that the Earth is almost elastic.