HOW THE TIDES WORK

Explained by Dr CJC Rees (York)

TIDES AND WATER MARKS

TIDES and the EARTH-MOON SYSTEM

The earth-moon system rotates in space about its common centre of mass, there being a stabilising balance of centrifugal force tending to pull it apart with the gravitational attraction between the two bodies tending to keep it together. On the side of the Earth nearer the Moon, there is a slight excess of gravitational force; on the side opposite the moon there is a slight excess of centrifugal force. These create tidal bulges in the ocean, below which the Earth is rotating about its polar axis, so that the bulges (separated by 180º of longitude) seem to travel around the Earth. The bulges (tides) are not separated by exactly 12 hours because the Moon is revolving round the Earth as well, so that the bulges are actually separated in time at any one point on the Earth's surface (in theory) by about 12 hours and 26 minutes. The Moon appears at its highest point in the sky (azimuth) over any point on the Earth's surface 52 minutes later each Earth day (Figs 1a and lb).

TIDES and the SUN-EARTH-MOON SYSTEM

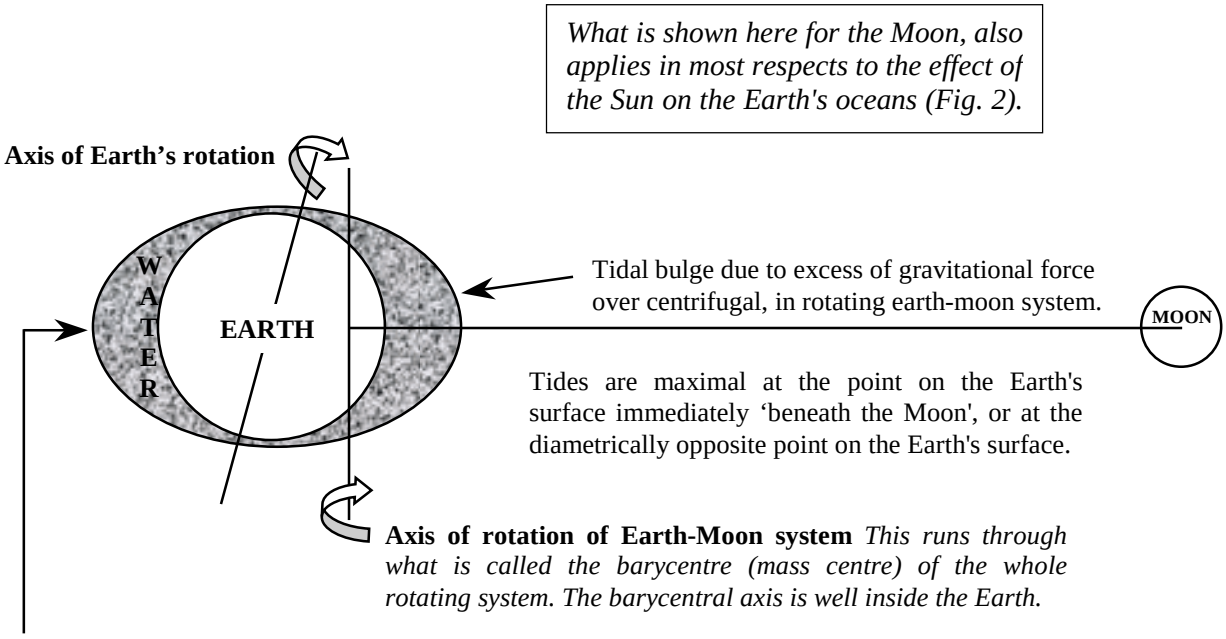
The Sun can also cause tidal effects (Fig. 2a). When the Sun, Earth and Moon are all in line in space, the tidal forces are greater and the tidal bulges larger than when the Sun, Earth and Moon form a right angle in space. All three are in line at new moon and full moon, and it is then (or slightly after, for much more complex reasons) that the biggest tidal ranges (high to low water mark) are. These are SPRING TIDES (NOTHING to do with the season; from a Norse word meaning “swell” (in the English, not American, sense). New and full moon are separated by half a lunar month (27.3 days/2 = 13.65 days) so Spring tides come round approximately every 13½ days. Halfway in time between new and full moons are the first and third quarters [Half Moon]. The Sun, Earth and Moon then form a right angle in space (Fig. 2b), and the tidal forces are at their smallest, because Sun and Moon are pulling at 90° to each other. The smallest tidal ranges happen then, called NEAP TIDES (derived from another Norse word, meaning scarce). These are also separated in time by about 13½ days.

TIDE LEVELS

There is a MEAN TIDE LEVEL (MTL) about which the tidal oscillation is, on average, symmetrical. This is in mid-shore. High waters of SPRING and NEAP tides leave different high water marks. These are MEAN HIGH WATER SPRINGS (MHWS) and MEAN HIGH WATER NEAPS (MHWN). Similarly, with low waters, we have MEAN LOW WATER SPRINGS (MLWS) and MEAN LOW WATER NEAPS (MLWN). Particularly high or low tides occur when the Sun is at its nearest to us at the Equinoxes and create EXTREME high and low waters (EHWS or EHWN, ELWS or EHWN). Classically, these happen close to the Vernal (21 March) and Autumnal (21 September) Equinoxes. These abbreviations appear frequently in marine biological writings and on Ordnance Survey maps.

THE EARTH, THE MOON AND THE TIDES

Fig. 1a <u>Tide-generating forces</u>

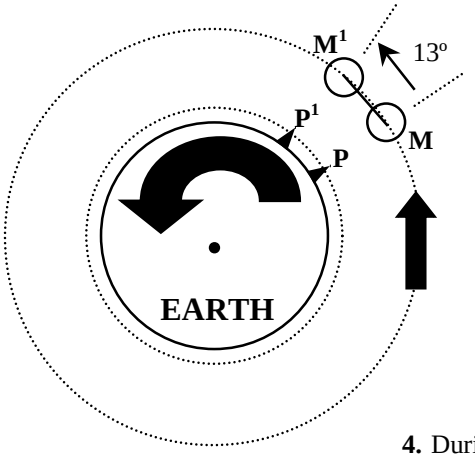


OF COURSE, the tidal water bulges shown above are ENORMOUSLY exaggerated, but the effect is the same, and at a human scale tidal forces are pretty big, as are their sizes.

Fig. 1b <u>Why High (and Low) tides recur somewhat later (52 minutes) each Earth Day</u>

In the diagram below, imagine that you are looking down onto the Earth-Moon system from above.

The Earth is rotating about its own axis, and the Earth-Moon system is rotating about its own axis, in the <u>same direction</u> in space.



1. In one Earth day, a given point P on its surface moves through 360º as the Earth rotates.

2. However, the Moon has gone a further 13º in that time (see 3. opposite). So, to catch up, and again be 'beneath the Moon', our reference point on the Earth has to go a further 13º. This takes the 52 minutes by which the tides are later each full Earth day. The point has now reached P^1.

3. In one earth day, the Moon moves through about 13º of its orbit round the Earth, from M to M^1.

4. During this Earth day + 52 minutes, our point will have passed through <u>two</u> high tide positions (One under the Moon, and one when diametrically opposite it).

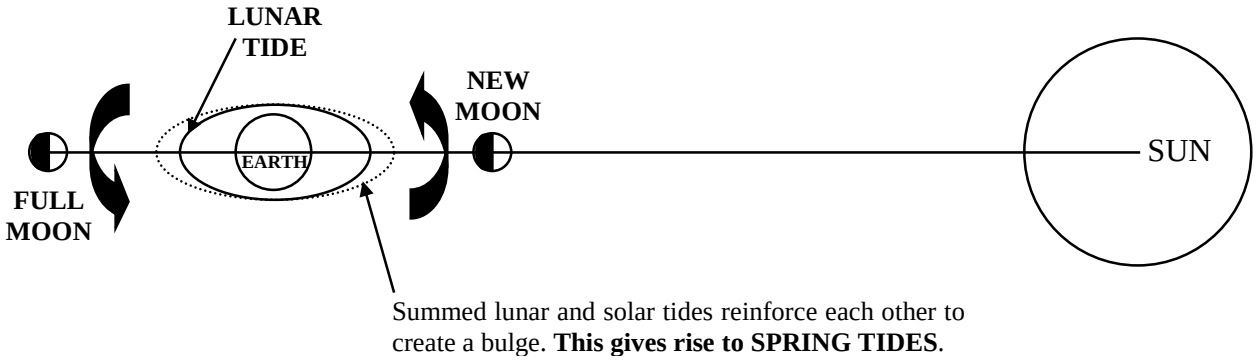
This means that each high tide is separated by approximately 12 hours + 26 minutes.

[Lunar Cycle: Orbit Period about $27^1/_3$ days. So 360/27.3 degrees per day = about 13º]

SPRING AND NEAP TIDES
The Position of Earth, Sun and Moon

Fig. 2a <u>The Position at SPRING tides.</u>

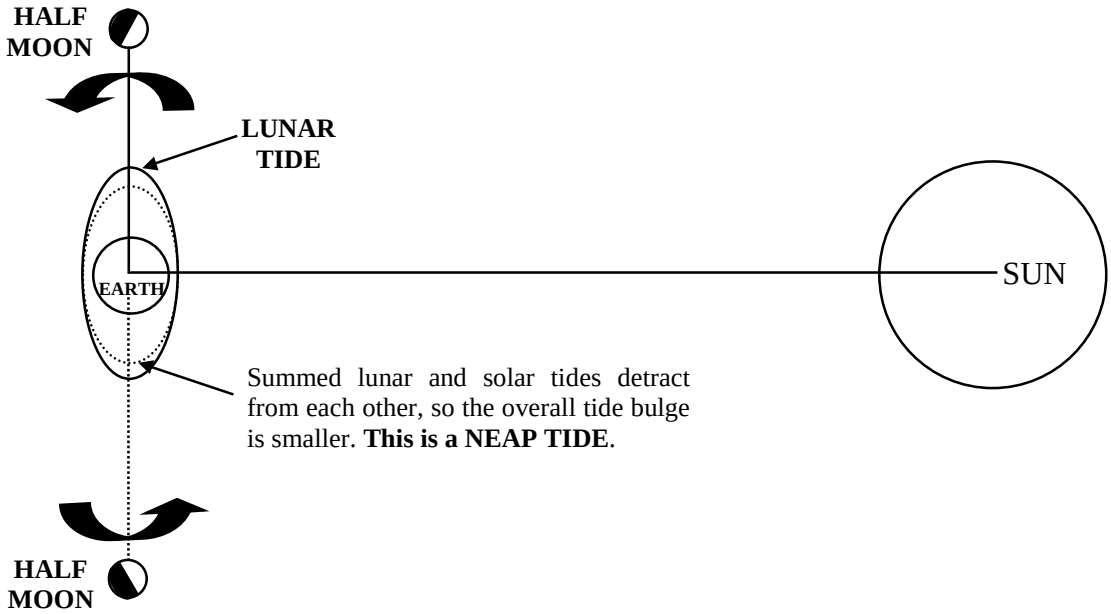
WHEN THE SUN-EARTH-MOON SYSTEM IS IN ALIGNMENT



This happens twice every lunar month, once every 13½ days.

Fig. 2b <u>The Position at NEAP tides</u>

WHEN THE SUN-EARTH-MOON SYSTEM FORMS A RIGHT ANGLE



This also happens twice every lunar month, once every 13½ days.