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An inquiry into Tides

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Introduction

Classic earth science textbooks present a rather generalized treatment of the topic of tides, but to the majority of mid-westerners the descriptions are largely without intrinsic meaning because of the lack of firsthand experience with marine tides. The suggestion contained herein provides a vicarious experience with tides for landlocked Iowans, that will hopefully stimulate discussion resulting in an improved understanding of tidal phenomena.

Procedure

The data given in Table 1 is reprinted with permission from a U.S. government document, *Tide Tables, High and Low Water Prediction, 1975 (Europe and West Coast of Africa*, p. 43). The location chosen is a peninsula located in France's Bay of Biscay. It was chosen because it displays an almost perfect example of semi-diurnal tides of the type generally described in textbooks.

It is suggested that this page, or a current page from the reference given above, be reproduced and given to students with the assignme t to discover as many regularities or patterns present in the data as possiole. Some time should be allowed for this. Perhaps one could raise general questions with the students to guide them to see these regularities.

Suggested questions include:

1) How does the height of high water change each day?
2) How does the height of low water change each day?
3) Is there a pattern in the change in heights of highs and lows?
4) What is the average time interval between any two successive tides (express in hours and minutes)?
5) What is the highest tide each month? How many "highest" tides occur each month?
6) What is the time interval between any two successive "highest" tides (express in days and fraction of days)?

Finally, after the data has been examined for a fairly extended period of time, the question can be raised concerning the explanation for this phenomena. Inevitably students will indicate that it is "because of the

Table 1

Times of heights of high and low waters
Pointe de Grave, France, 1975

October

DAY	TIME H.M.	HT. FT.	DAY	TIME H.M.	HT. FT.
1 W	0121	14.3	16 TH	0242	14.6
	0706	5.9		0833	5.7
	1354	15.1		1503	15.3
	1943	5.2		2055	5.2
2 TH	0223	15.3	17 F	0321	15.3
	0813	4.8		0914	5.1
	1448	16.2		1538	15.7
	2041	3.9		2133	4.6
3 F	0312	16.4	18 SA	0355	15.9
	0907	3.6		0951	4.4
	1534	17.4		1609	16.2
	2132	3.0		2207	4.3
4 SA	0355	17.7	19 SU	0424	16.4
	0956	2.8		1023	4.1
	1617	18.7		1639	16.6
	2218	2.5		2239	3.9
5 SU	0437	18.7	20 M	0454	16.7
	1040	2.5		1054	3.8
	1658	19.5		1708	16.9
	2302	2.3		2309	3.8
6 M	0519	19.2	21 TU	0523	16.9
	1124	2.3		1125	3.8
	1740	19.5		1738	16.9
	2346	2.3		2341	3.8
7 TU	0602	19.0	22 W	0554	16.9
	1205	2.5		1156	3.8
	1823	18.9		1809	16.7
8 W	0029	2.8	23 TH	0012	3.9
	0645	18.2		0625	16.7
	1252	3.0		1229	4.1
	1907	17.6		1842	16.4
9 TH	0114	3.4	24 F	0047	4.4
	0730	17.1		0659	16.4
	1336	3.8		1305	4.4
	1953	16.2		1918	15.9
10 F	0158	4.6	25 SA	0123	4.9
	0818	15.9		0738	15.7
	1421	4.9		1342	5.1
	2046	15.3		2000	15.3
11 SA	0247	5.7	26 SU	0203	5.6
	0917	14.9		0823	15.3
	1515	6.1		1427	5.7
	2152	14.1		2053	14.6
12 SU	0347	6.7	27 M	0253	6.2
	1031	14.1		0927	14.6
	1625	6.9		1525	6.2
	2315	13.5		2204	14.1
13 M	0505	7.2	28 TU	0400	6.6
	1201	13.8		1046	14.4
	1748	7.1		1639	6.4
				2331	14.1
14 TU	0045	13.3	29 W	0520	6.4
	0630	7.1		1215	14.6
	1321	13.9		1801	5.9
	1907	6.6			
15 W	0152	13.9	30 TH	0054	14.6
	0740	6.4		0638	5.7
	1419	14.6		1327	15.3
	2008	5.9		1913	5.1
			31 F	0157	15.4
				0744	4.8
				1423	16.2
				2013	4.1

November

DAY	TIME H.M.	HT. FT.	DAY	TIME H.M.	HT. FT.
1 SA	0247	16.6	16 SU	0321	15.4
	0840	3.8		0913	5.1
	1510	17.2		1538	15.7
	2106	3.3		2133	4.9
2 SU	0333	17.6	17 M	0355	16.1
	0930	3.1		0952	4.6
	1555	18.2		1610	16.2
	2155	2.8		2209	4.4
3 M	0416	18.4	18 TU	0426	16.6
	1017	2.8		1026	4.1
	1637	18.7		1642	16.6
	2241	2.6		2244	4.1
4 TU	0459	18.9	19 W	0459	16.9
	1103	2.6		1101	3.9
	1720	18.7		1715	16.7
	2325	2.8		2318	4.1
5 W	0542	18.7	20 TH	0532	17.1
	1148	2.8		1135	3.8
	1804	18.0		1750	16.7
				2354	4.1
6 TH	0010	3.1	21 F	0608	16.9
	0627	18.0		1212	3.9
	1233	3.3		1826	16.6
	1849	17.2			
7 F	0056	3.8	22 SA	0031	4.3
	0711	17.1		0645	16.7
	1318	3.9		1251	4.1
	1934	16.2		1905	16.2
8 SA	0139	4.6	23 SU	0112	4.6
	0758	16.1		0726	16.4
	1402	4.9		1333	4.6
	2022	15.3		1949	15.7
9 SU	0226	5.6	24 M	0154	5.1
	0851	15.3		0814	15.9
	1451	5.7		1418	5.1
	2122	14.4		2042	15.3
10 M	0319	6.4	25 TU	0244	5.4
	0955	14.6		0914	15.4
	1549	6.6		1512	5.4
	2232	13.8		2148	14.9
11 TU	0424	7.1	26 W	0343	5.7
	1110	13.9		1024	15.1
	1659	6.9		1617	5.7
	2350	13.5		2304	14.8
12 W	0536	7.2	27 TH	0452	5.9
	1230	13.9		1143	15.1
	1812	6.9		1728	5.6
13 TH	0103	13.8	28 F	0021	14.9
	0646	6.9		0634	5.6
	1332	14.3		1256	15.4
	1917	6.4		1839	5.2
14 F	0159	14.3	29 SA	0127	15.4
	0745	6.2		0712	4.9
	1422	14.8		1356	15.9
	2009	5.9		1944	4.6
15 SA	0243	14.9	30 SU	0223	16.1
	0833	5.6		0813	4.3
	1502	15.3		1448	16.6
	2054	5.4		2042	3.9

December

DAY	TIME H.M.	HT. FT.	DAY	TIME H.M.	HT. FT.
1 M	0313	16.7	16 TU	0324	15.4
	0909	3.8		0919	5.1
	1537	17.1		1544	15.6
	2135	3.6		2140	5.1
2 TU	0400	17.6	17 W	0402	16.1
	1001	3.3		1001	4.6
	1622	17.6		1620	16.1
	2225	3.3		2221	4.6
3 W	0444	17.9	18 TH	0438	16.6
	1049	3.1		1041	4.1
	1706	17.6		1657	16.4
	2311	3.3		2300	4.1
4 TH	0529	18.0	19 F	0516	17.1
	1134	3.1		1119	3.8
	1751	17.4		1735	16.7
	2357	3.4		2340	3.8
5 F	0613	17.7	20 SA	0555	17.4
	1218	3.4		1200	3.4
	1834	16.9		1815	16.9
6 SA	0041	3.9	21 SU	0020	3.8
	0655	17.2		0635	17.4
	1302	3.8		1241	3.4
	1916	16.2		1856	16.7
7 SU	0122	4.4	22 M	0103	3.8
	0738	16.6		0717	17.2
	1343	4.4		1323	3.6
	2000	15.6		1939	16.4
8 M	0203	5.1	23 TU	0145	4.1
	0822	15.7		0804	16.7
	1425	5.2		1408	3.9
	2048	14.9		2029	16.1
9 TU	0247	5.7	24 W	0231	4.4
	0915	15.1		0857	16.2
	1511	5.9		1455	4.4
	2143	14.4		2128	15.6
10 W	0336	6.4	25 TH	0323	4.9
	1013	14.4		0959	15.7
	1603	6.6		1551	4.9
	2245	13.9		2232	15.3
11 TH	0432	6.9	26 F	0423	5.4
	1119	14.1		1108	15.4
	1704	6.9		1655	5.4
	2353	13.6		2345	14.9
12 F	0537	7.1	27 SA	0530	5.6
	1227	13.9		1222	15.1
	1810	6.9		1806	5.6
13 SA	0059	13.8	28 SU	0058	15.1
	0642	6.9		0642	5.4
	1329	14.1		1331	15.3
	1912	6.6		1917	5.4
14 SU	0155	14.3	29 M	0201	15.4
	0742	6.4		0752	5.1
	1419	14.6		1431	15.6
	2008	6.1		2025	4.9
15 M	0242	14.9	30 TU	0259	15.9
	0833	5.7		0855	4.6
	1504	15.1		1526	16.1
	2057	5.6		2124	4.4
			31 W	0351	16.6
				0951	3.9
				1614	16.4
				2216	3.9

TIME MERIDIAN 15° E. 0000 IS MIDNIGHT. 1200 IS NOON.
HEIGHTS ARE RECKONED FROM THE DATUM OF SOUNDINGS ON THE LARGEST SCALE CHARTS OF THE LOCALITY.

moon." However, this glib answer is not enough to explain some of the subtleties observed in the data. Therefore, it is proposed that when the "moon" answer is given, the students be given a table (Table 2) for the same time period and be asked to build a model involving the observed regularities and the phases of the moon.

Table 2.

Phases of Moon
October – December, 1975

Date	Phase
Oct. 4	New
Oct. 11	1st Quarter
Oct. 20	Full
Oct 27	3rd Quarter
Nov. 3	New
Nov. 10	1st Quarter
Nov. 18	Full
Nov. 26	3rd Quarter
Dec. 2	New
Dec. 10	1st Quarter
Dec. 18	Full
Dec. 25	3rd Quarter

Hopefully, the students will see the correlation between the occurrence of the full and new moons and the so-called *spring* tides and the occurrence of the *neap* tides near first and third quarter (Fig. 1). A more complete discussion of tides could occur at this time. It would then be instructive to distribute sections of tide tables that show other locations where there are pronounced inequalities between high tides or from locations where the pattern is diurnal rather than semi-diurnal. Such tables illustrate that the simple model put forth in most beginning references is a limited one.

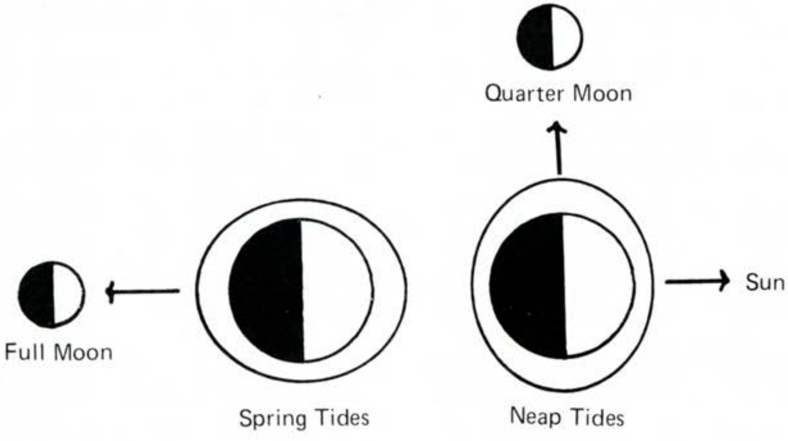

Fig. 1. Relationship of sun, moon and earth during spring tides and neap tides.

Careful examination of the original data will also reveal an interesting irregularity. Since a full moon rises near sunset, it is on the observer's meridian at midnight. Therefore, according to sketches usually given, one would expect a high tide at midnight during a full moon. (For a similar reason one would expect a high tide at midnight during a new moon as well.) Yet an examination of the data reveals that such is not the case. For example, there was a full moon on October 20th and therefore a spring tide occurred near that time, yet the high tides occurred at 0454 hours and 1708 hours. The explanation for this fact opens up the discussion of the tidal slowing by the earth's rotation.

The earth's tidal bulge points generally in the moon's direction but it is drawn ahead of the earth-moon line because of the earth's rotation (Figure 2). Frictional forces between the water and the surface of the earth (particularly in shallow seas) are set up because the earth rotates once in 24 hours, but the moon revolves (in the same direction) once in a synodic period of 29.5 days. The consequences of these facts are the advance of the highs from the earth-moon line (already mentioned) and the gradual slowing of the earth's rotation. This slowing, though gradual, accumulates such that had a constant running clock started two centuries ago, compared with a clock geared to the rotation of the earth, would have "gained" about 3½ hours during that time. Careful examination of historical eclipse records supports this contention.

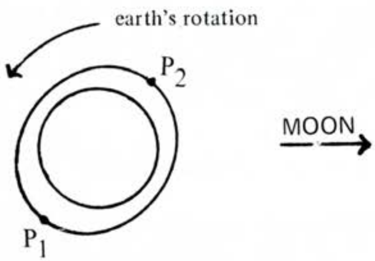

Fig. 2. Relationship of high tides to moon due to tidal lag caused by the earth's rotation.
(P_1 = nocturnal high tide; P_2 = diurnal high tide)

Summary

This exercise investigates the effects of the moon's orbital movement, the earth's and moon's rotational movement, and the spatial relationship of the earth, moon and sun, on the periodicity and magnitude of marine tides. Some of the factors discussed are not normally considered in classroom situations and provide a more complete and accurate understanding of tidal phenomena and the factors influencing them. A more thorough understanding of tides may someday help man harness the tremendous amounts of tidal energy.

References

1. Abell, George. 1975. *Exploration of the universe (3rd ed.).* Holt, Rinehart and Winston pp. 94-104.

2. Hicks, S.D. 1965. Ocean Tides. *Science Teacher* 32 :11-14.

3. Runcorn, S. K. 1966 Corals as Paleontological Clocks. *Scientific American* 215(4):26-33.

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UNI Symposium

The University of Northern Iowa will host its fifteenth annual Sience and Mathematics Symposium on November 10-11, 1977. The afternoon of November 10 will be used for scholarship testing. Five to eight fee exemption scholarships ($2500 each) will be awarded at the close of the Symposium on November 11. There will also be cash scholarships awarded in biology, chemistry, earth science, mathematics and physics.

Friday, November 11 will be a symposium of speakers. Topics include Earthquake Prediction, Atmospheric Matter and we are presently negotiating for a speaker on Recombinant DNA. Communications on the Symposium may be addressed to Science Symposium, Wright Hall 101, University of Northern Iowa, Cedar Falls, Iowa, 50613.

Intelligent Zinc

"Recently, Professor Adon A. Gordus of the University of Michigan has been directing a study of more than 800 well-documented hair samples. Using atomic absorption spectroscopy and neutron activation, his study has uncovered some interesting correlations between academic performance and trace metal content of hair. Those students with the highest gradepoint averages frequently tend to have higher than normal zinc and copper content in their hair, but lower than normal iodine content. The reverse is generally true of students at the lower end of the gradepoint spectrum . . ."

From an article, "Hair . . . The Body's Trace Metal Diary" in *Varian Instrument Applications* 8:12, (1974).