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ABSTRACT

This unit for students in grades 6-12 is designed to provide an introduction to the variables that cause tides. Included are teacher background materials, a possible three-day schedule, master sheets for transparencies, student activity materials, tests, and references to selected films and books. (RH)

THE MOON, THE SUN, AND TIDES

A Learning Experience for
Coastal and Oceanic
Awareness Studies

Produced by

MARINE ENVIRONMENT CURRICULUM STUDY
MARINE ADVISORY SERVICE
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Please send evaluations

of learning experiences

to

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TITLE: THE MOON, THE SUN, AND TIDES

*CONCEPT: I.A.

I. The earth is a finite natural system.

A. THE PROPERTIES AND INTERACTIONS OF WATER, AIR, AND THE PHYSICAL EARTH SET THE LIMITS OF THE NATURAL SYSTEM.

**MARINE CONCEPT: 2.23

2. The oceans interact with the earth and its atmosphere.

2.2 The ocean waters are influenced by the earth's rotation, revolution, and position in the solar system.

2.23 TIDES RESULT FROM GRAVITATIONAL FORCES OF THE EARTH, THE MOON, AND THE SUN.

SUBJECT: Earth Science

GRADE LEVEL: 6-12

PERIODS: 3-4

AUTHOR: Grelis

* From A Conceptual Scheme for Population-Environment Studies, 1973. Cost $2.50.

** From Marine Environment Proposed Conceptual Scheme, 1973. No charge.

Both conceptual schemes are available from Robert W. Stegner, Population-Environment Curriculum Study, 310 Willard Hall, University of Delaware, Newark, DE 19711.

INTRODUCTION

Since early times, man has been conscious of the sea's periodic rise and fall. Those who lived near the shore or who depended upon the sea's bounties for existence soon learned the pattern of the water's movement. Man learned that the behavior of fish and other creatures of the sea was determined to a large extent by the condition of the tide. He also learned that the sea's rise and fall could be used to his advantage such as in freeing objects from a muddy bottom and for beaching boats. As man progressed in technology and his activities became more complex, his need to plan ahead became more important. For people working along the coast as commercial fishermen, pilots of boats, etc., the ability to predict tides became a necessity. Today tides can be predicted years in advance. Predictions are fairly accurate, but limited insofar as the wind current, air pressure, and run-off from rivers can appreciably affect the tides.

Knowledge of tidal movement is important to all phases of marine science. Greater ranges between high tide and low tide mean to the marine biologist that the sea animals of such areas must adapt to long periods of submergence and exposure. Predictions of tidal times and height are essential not only to the pilot of a marine research vessel, but to a marine ecologist and a teacher planning a field trip to the beach or marsh as well.

OBJECTIVES

At the conclusion of this unit the student should be able to explain in writing, using appropriate diagrams:

a. Why the earth experiences a high tide on both the side facing the moon and the side facing away from the moon.

b. What effect perigee and apogee have on the tides.

c. The different types of tides, such as spring and neap tides, diurnal, semidiurnal, and mixed tides.

d. What effect the sun has on ocean tides, particularly at perihelion and aphelion.

Given a tide table and a table of tidal differences, the student should be able to:

a. Determine the time of high tide or low tide and the total tidal range at a particular place included in the table.

b. Graph the tidal range for a particular place over a given period of time.

SCHEDULE

First Day

Pre-Test, p. 17
Teacher Background information with accompanying overheads, pp. 3-8
Activity 1, p. 9

Second Day

Typical Tide Curves, pp. 10-11
Tide Tables, pp. 12-14

Third Day

Activities 2 and 3, pp. 15-16
Post-test, p. 19

TEACHER BACKGROUND

On all the seacoasts of the earth, the ocean waters rise and fall daily in a rhythmic movement known as the tides. The tides are obviously related to the moon. Like the moon rise, they occur fifty minutes later each day on the average. The tidal range (i.e. the difference between high tide and low tide levels) is larger at the times of new and full moon and smaller at times of quarter moon. Sir Isaac Newton was the first to explain how the moon and tides are related. Using his law of gravitation, Newton explained the production of tides by the moon as an effect of the difference in the gravitational attraction for the solid earth and the ocean waters. The oceans on the side of the earth facing the moon are nearest the moon and are therefore attracted most strongly. The waters on the far side are attracted least. The solid earth is attracted at its center of gravity. The moon's attraction for the waters on the near side is stronger than its attraction for solid earth; this causes these waters to rise or bulge. This is the direct high tide. On the far side of the earth the moon's attraction for the waters is less than that for solid earth. Here the waters bulge away from the surface in an indirect or opposite high tide. Halfway between the high-tide points, two areas of low tides are formed by the withdrawal of water to high tide locations.

As the earth rotates on its axis, it brings all parts of the surface under the moon in 24 hours and 50 minutes. In 1/4 of this time (roughly 6 hours and 13 minutes) each moves from high tide or low tide. After 12 hours and 26 minutes the tide changes again. As the earth rotates, the tides continue to rise and fall rhythmically in a cycle that is repeated about fifty minutes later each day.

Some coastal areas may have a diurnal tidal cycle--with only one high tide and one low tide a day, e.g., the Gulf of Mexico. Two daily high and low tides are typical of both sides of the Atlantic Ocean. This is called a semidiurnal tidal cycle.

The sun has the same gravitational effect on the earth's waters that the moon has, but because of its greater distance from the earth this effect is only about half as great as the moon's. While the moon is the chief maker of tides, the sun can help or hinder the moon's effect. Tides are always high on the part of the earth in line with the moon and low on parts that are at right angles to the moon. But when the sun is in line with the moon, its effect is added to the moon's. When the sun-earth line is at right angles to the moon-earth line, the sun's effect is opposed to the moon's.

At new moon and full moon phases both sun and moon are causing high tides and low tides at the same places on the earth. This results in higher high tides and lower low tides. The tidal range is greatest at these times. These tides are called spring tides. They occur twice every month and are not related to the season of spring.

At first quarter and third quarter phases of the moon the sun is in a position to raise the moon's low tide levels and to lower the moon's high tide levels. This results in lower high tides and higher low tides. These tides are called neap tides. (Neap means scanty.)

Another variation in the height of the tide is the result of the moon's elliptical orbit around the earth. At perigee, the nearest point in its orbit, the moon is fifteen thousand miles closer than it is at apogee, the moon's farthest point in its orbit. At perigee, smaller distance causes tides which are twenty percent higher and lower than average. Perigee and apogee both occur once a lunar month (i.e., once during lunar orbit); rarely does this coincide with the in-phase alignment of sun, earth and moon. But at least twice a year both effects coincide; full moon or new moon occurs at perigee. The perigee tides add to the spring tides to produce perigee spring tides, the highest tides of the year.

As we have said, the sun also affects the tides. Once a year (January 3) the earth's elliptical path around the sun is such that it is at its nearest point to the sun, perihelion. Gravitational attraction is greatest at this time; this causes higher high tides and lower low tides. Likewise, once a year (July 4) the earth is farthest from the sun; this is called aphelion. At this time, the attraction is smaller and this causes lower high tides and higher low tides. Perihelion perigee spring tides are the tides with the greatest range. They occur when the moon is nearest the earth and at full or new moon and at the time when the earth is nearest the sun. Conversely, aphelion apogee neap tides are tides with the smallest range.

The difference between the level of high tide and the level of low tide--tidal range--may vary for reasons other than the phase of the moon. Small lakes show no tides at all. Even a great lake such as Lake Michigan is raised only a couple of inches by the tides. In the open ocean the tidal range averages two to three feet but on the shores of the same ocean the tidal range may be as large as 60 feet, as in the Bay of Fundy on the coast of Nova Scotia, or as little as two feet, as in the Gulf of Mexico.

Oceanographers have shown that the size and shape of each ocean basin, gulf, or bay play a large part in determining how much its waters will rise and fall under the differential pull of moon and sun. They also know that high tidal ranges develop when water is tunneled from the open oceans into V-shaped bays such as the Bay of Fundy. Bays that become wider from mouth to shoreline spread out the incoming water and have small tidal ranges, e.g., as in the Gulf of Mexico.

Direct and indirect tides also differ in height unless the moon is in line with the earth's Equator.

Figure 1

TIDE-PRODUCING FORCES

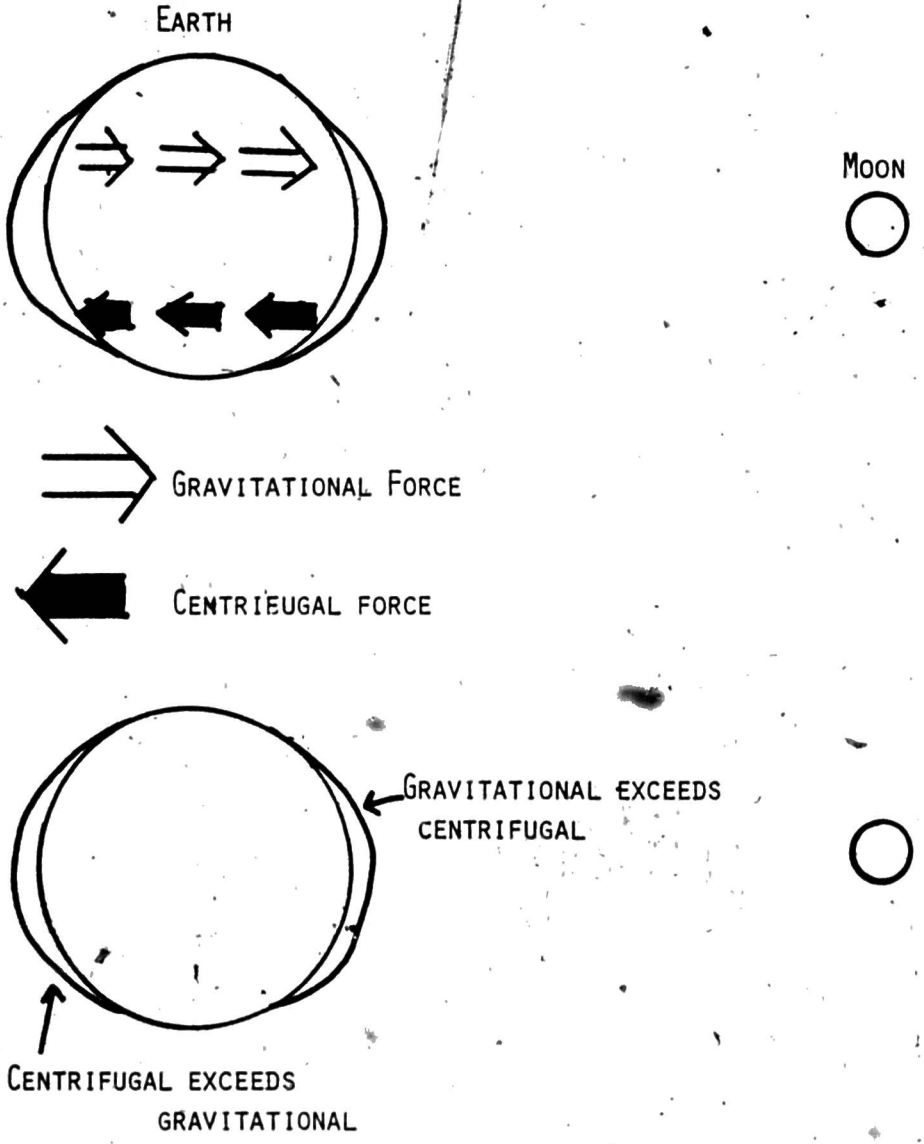
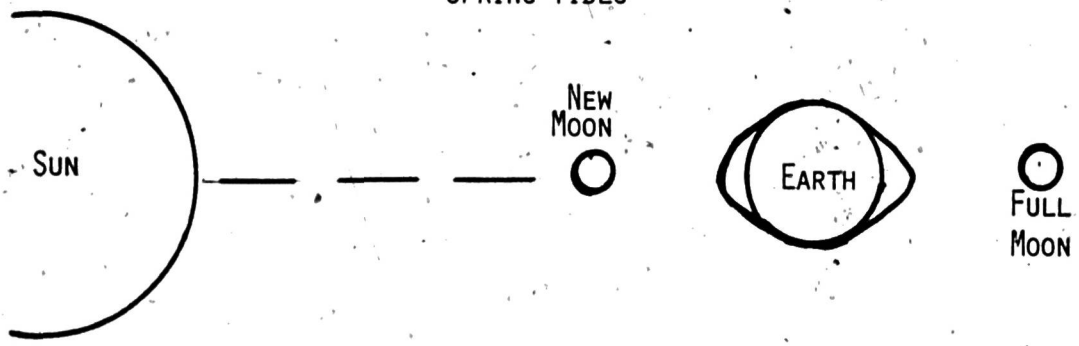


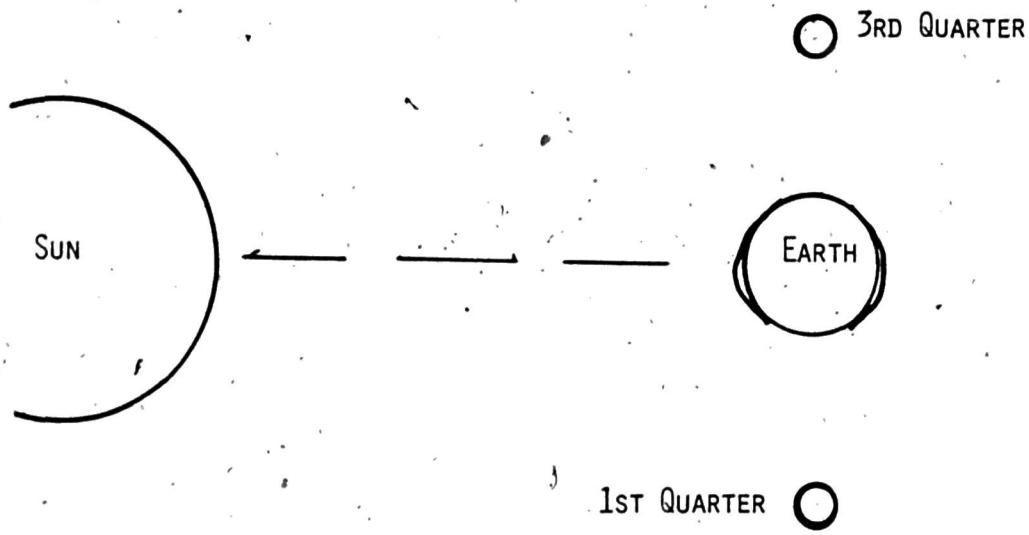
Figure 2

SPRING TIDES



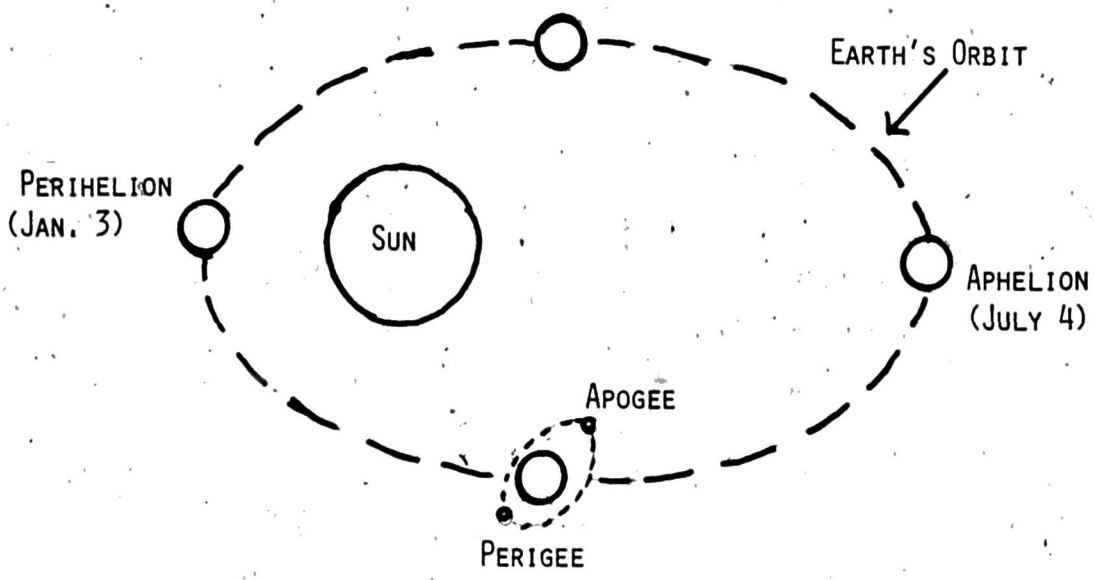
HIGH HIGH TIDES; LOW LOW TIDES

NEAP TIDES



HIGH LOW TIDES; LOW HIGH TIDES

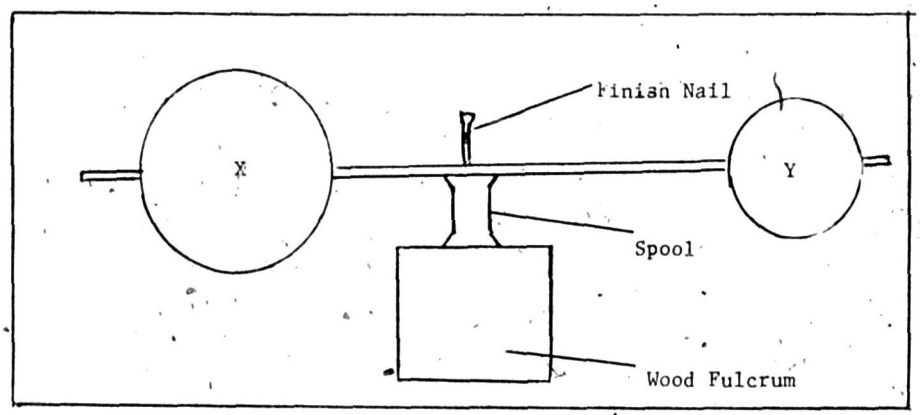
PRINCIPAL ASTRONOMICAL FACTORS AFFECTING TIDES



ACTIVITY I

Materials needed: 2 spheres of unequal mass, with holes bored through their centers.
1 wooden dowel capable of sliding through the holes in the spheres and with a small hole at its mid-length.
1 heavy piece of wood for a fulcrum.
1 finish nail small enough to fit through the hole in the dowel.
1 empty spool of thread.

Set up as indicated in the figure:



Spin X and Y rapidly around the nail.

1. What happens as the dowel revolves?

2. What larger objects might X and Y represent?

ANSWERS TO ACTIVITY I

1. The spheres fly off the ends of the rod.

2. X and Y represent the earth and moon.

TYPICAL TIDE CURVES

The variations in the tide from day to day and from place to place are illustrated in Figure 5, p.11 by the tide curves for seven ports along the Atlantic and Gulf coasts of the United States. The tidal range for stations along the Atlantic coast varies from place to place but the type of tide is uniformly semidiurnal with variations due to the change in the moon's distance and phase. Along the Gulf of Mexico the tidal range is small but the type of tide differs greatly. At Pensacola, Florida, the type of tide is diurnal while at other ports such as Galveston the inequality of tidal height is such that the tide is semidiurnal at the time the moon is on the Equator but it becomes diurnal around the times of maximum north and south declination of the moon. In the Gulf of Mexico the principal variations in the tide are due to the changing declination of the moon.

In general, this shift from semi-diurnal to diurnal tides can be explained by referring to Figure 4. Latitude and longitude lines are marked on the two hemispheres. The dark spot near 30° latitude represents the moon's northernmost declination, 28° north. The rings around this spot, and the corresponding spot in the southern hemisphere in the left diagram, indicate tide levels caused by the moon's influence. The innermost dash ring represents a tide level 1½ feet above average. The next two rings represent tide levels of 1 foot and ½ foot above average respectively. The ring with dots represents average water level and the next outer ring represents a tide level ½ foot below average. The large outer ring indicates a water level 1 foot below average.

For simplicity's sake, let Galveston be an island on the 28th parallel. As the earth rotates, Galveston will go through a succession of high to low tides in one revolution. This can be seen by moving your finger along the thirtieth parallel. If, however, the moon was at right angles to the equator instead of the 28th parallel, the succession from high to low tides would occur twice each day. One cycle would be attributable to the direct effect of the moon and the other to the indirect effect.

Figure 4

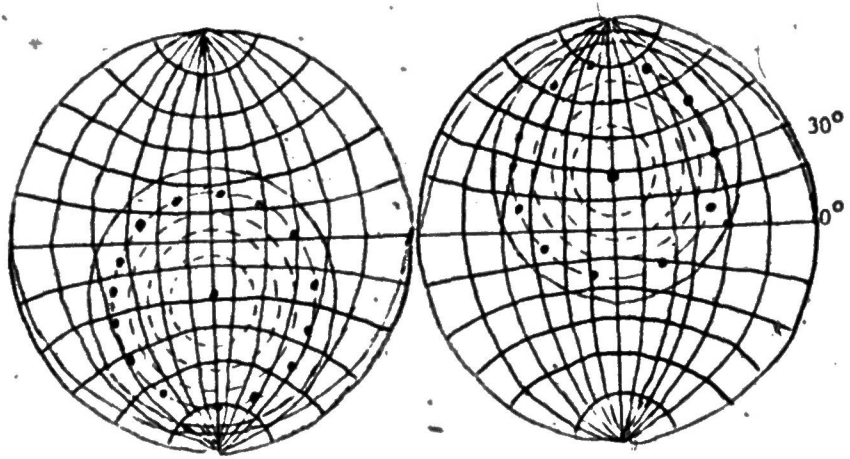
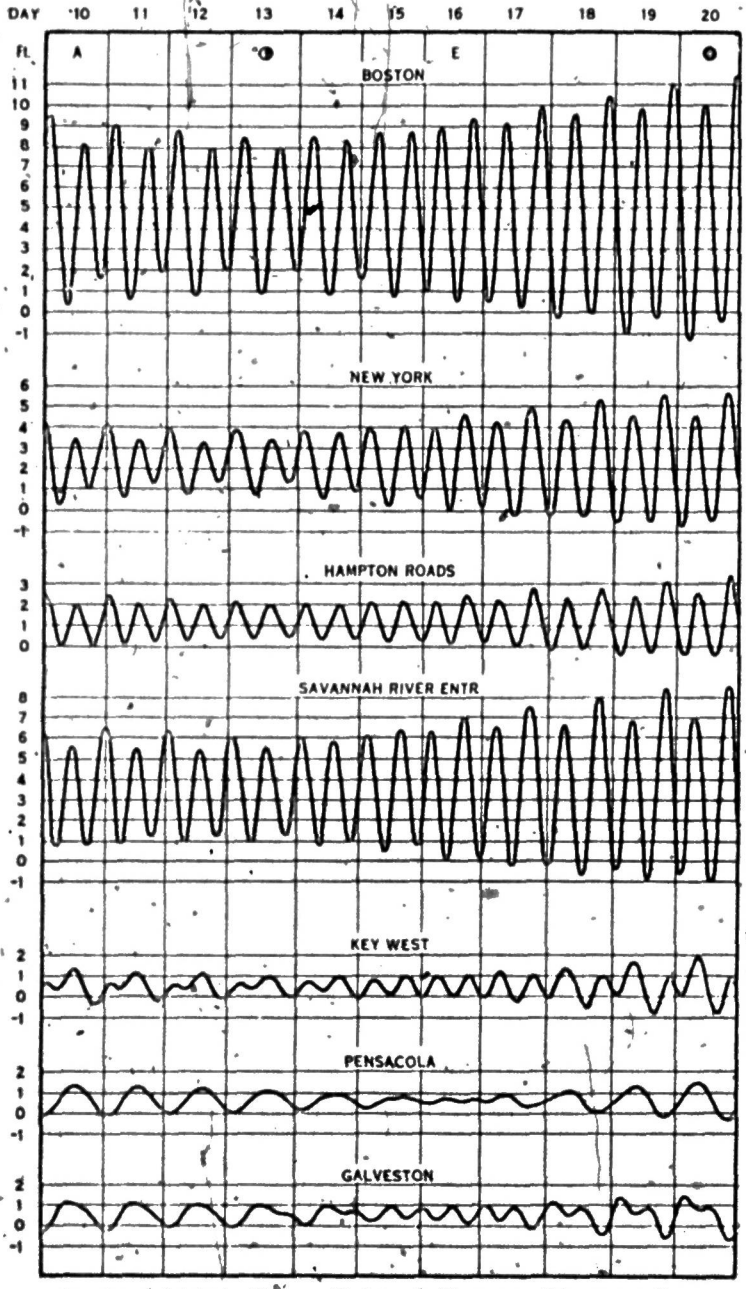


Figure 5 TYPICAL TIDE CURVES FOR UNITED STATES PORTS



Lunar data: max S. declination, 9th; apogee, 10th; last quarter, 13th; on equator, 18th; new moon, 20th; perigee, 22d; max. N. declination, 23d.

A discussion of these curves is given on opposite page.

Taken from Tide Tables U.S. Department of Commerce 1970

Coast and Geodetic Survey

TIDE TABLES

Table 1 is a tide table for Breakwater Harbor, Delaware. The date and day are given in the first column and the time in the second column. The time is based on the 24-hour clock used by mariners. 0218 would be 2:18 a.m. while 1442 would be 2:42 p.m. 0000 is 12 midnight and 1200 is 12 noon.

The state of the tide is given in column three. Heights are reckoned from the data of soundings on charts of the locality which are based on the mean low water. A number preceded by a negative (-) sign means the level of the water is below mean low water. No sign before the number indicates the given height is above mean low water.

Example

On October 13, 1970 low tide was to occur at 0024 (12:24 a.m. EST or 1:24 a.m DST) and the level of the water was -0.3 below sea level. High tide occurred at 0648 (6:48 a.m.) and the level was 5.0 above sea level. The total tidal range for this area during the interval mentioned is obtained by algebraically subtracting the low level from the high level. 5.0 - (-0.3) = 5.3 feet

To compute the tide at a place which is not covered by the tide tables, a table of tidal differences is used. Table 2, p. 14, is such a table.

Example

High and low tides at Cape Henlopen, Delaware would occur 5 minutes before their occurence at Breakwater Harbor, Delaware. Low tide at Mispillion River entrance would occur one hour after low tide occurs at Breakwater Harbor. The high water level would be 0.5 feet higher at the Mispillion River entrance than at Breakwater Harbor.

Table 1

TIMES AND HEIGHTS OF HIGH AND LOW WATERS

	OCTOBER						NOVEMBER						DECEMBER					
	TIME	HT.		TIME	HT.		TIME	HT.		TIME	HT.		TIME	HT.		TIME	HT.	
DAY	M.M.	FT.	DAY	M.M.	FT.	DAY	M.M.	FT.	DAY	M.M.	FT.	DAY	M.M.	FT.	DAY	M.M.	FT.	
1	0210	0.1	16	0236	-0.5	1	0254	0.0	16	0142	0.0	1	0318	-0.3	16	0400	0.0	
TH	0848	4.9	F	0906	5.6	SU	0924	5.0	M	1024	5.0	TU	0954	5.0	W	1042	4.4	
	1442	0.1		1524	-0.4		1542	0.1		1642	0.1		1618	-0.1		1706	0.1	
	2054	4.2		2136	4.4		2142	5.0		2248	5.4		2212	5.4		2312	5.1	
2	0248	0.1	17	0318	-0.3	2	0336	0.1	17	0424	0.2	2	0406	-0.2	17	0448	0.2	
F	0912	4.8	SA	0954	5.4	M	1006	5.0	TU	1106	4.7	W	1042	4.9	TH	1124	4.2	
	1524	0.2		1612	-0.2		1630	0.2		1736	0.3		1706	-0.1		1748	0.2	
	2130	4.8		2218	4.8		2224	5.3		2336	5.2		2306	5.3		2354	5.1	
3	0324	0.2	18	0418	0.0	3	0418	0.2	18	0512	0.5	3	0500	-0.1	18	0536	0.3	
SA	0948	4.8	SU	1042	5.2	TU	1054	4.9	W	1200	4.4	TH	1136	4.7	F	1206	3.9	
	1600	0.2		1706	0.1		1724	0.3		1824	0.5		1800	-0.1		1830	0.3	
	2200	5.0		2312	5.7		2312	5.1										
4	0400	0.3	TU	0454	0.3	4	0506	0.3	19	0036	5.1	4	0006	5.4	19	0042	5.1	
SU	1018	4.8	M	1130	4.9	W	1142	4.7	TH	0606	0.7	F	0600	0.1	SA	0630	0.5	
	1642	0.4		1806	0.4		1818	0.4		1248	4.1		1230	4.9		1254	3.7	
	2242	5.6								1924	0.6		1854	-0.1		1912	0.3	
5	0442	0.4	20	0036	5.4	5	0012	5.2	20	0136	5.8	5	0106	5.5	20	0136	5.1	
M	1112	4.7	TU	0548	0.6	TH	0606	0.4	F	0706	0.8	SA	0706	0.2	SU	0724	0.6	
	1736	0.6		1230	4.9		1242	4.6		1348	3.9		1330	4.3		1342	3.6	
	2326	5.4		1900	0.7		1918	0.4		2012	0.6		1954	-0.1		2000	0.1	
6	0530	0.5	21	0106	5.2	6	0118	5.5	21	0236	5.1	6	0210	5.7	21	0230	5.3	
TU	1200	4.6	W	0648	0.8	F	0712	0.5	SA	0806	0.9	SU	0812	0.2	M	0818	0.6	
	1836	0.7		1330	4.2		1354	4.5		1448	3.7		1436	4.1		1436	3.2	
				2006	0.8		2018	0.5		2100	0.6		2048	-0.2		2042	0.3	
7	0018	5.5	22	0218	5.1	7	0236	5.5	22	0330	5.3	7	0324	6.0	22	0324	5.5	
W	0624	0.6	TH	0748	1.0	SA	0826	0.5	SU	0906	0.8	M	0924	0.2	TU	0918	0.6	
	1300	4.5		1442	4.1		1500	4.4		1542	3.6		1542	3.9		1530	3.1	
	1936	0.8		2136	0.9		2118	0.2		2148	0.5		2142	-0.2		2130	0.3	
8	0124	5.2	23	0124	5.2	8	0342	5.8	23	0418	5.6	8	0424	6.3	23	0412	5.7	
TH	0724	0.7	F	0848	1.0	SU	0936	0.3	M	1006	0.7	TU	1030	0.1	W	1018	0.5	
	1412	4.5		1542	4.0		1606	4.4		1630	3.6		1642	3.8		1624	3.0	
	2042	0.7		2206	0.8		2212	0.0		2230	0.4		2236	-0.3		2218	0.3	
9	0242	5.3	24	0418	5.4	9	0442	6.3	24	0500	5.9	9	0518	6.6	24	0500	6.0	
F	0836	0.6	SA	0954	1.0	M	1042	0.1	TU	1100	0.6	W	1136	-0.1	TH	1112	0.3	
	1524	4.6		1636	4.0		1706	4.4		1712	3.5		1736	3.7		1712	3.0	
	2142	0.5		2254	0.7		2306	-0.2		2306	0.3		2330	-0.4		2306	0.0	
10	0400	5.6	25	0506	5.6	10	0536	6.7	25	0542	6.2	10	0612	6.9	25	0548	6.3	
SA	0948	0.4	SU	1048	0.8	TU	1148	-0.1	W	1148	0.4	TH	1230	-0.2	F	1206	0.1	
	1630	4.7		1718	4.0		1800	4.4		1754	3.5		1830	3.6		1800	3.0	
	2242	0.3		2330	0.6		2354	-0.4		2348	0.1					2354	-0.1	
11	0500	6.0	26	0548	5.9	11	0630	6.1	26	0624	6.9	11	0818	-0.4	26	0630	6.9	
SU	1054	0.2	M	1136	0.6	W	1242	-0.3	TH	1236	0.2	F	0700	5.8	SA	1254	-0.1	
	1724	4.9		1800	4.1		1848	4.3		1836	3.5		1324	-0.3		1848	3.1	
	2336	0.0											1924	3.6				
12	0554	6.5	27	0600	0.4	12	0042	-0.5	27	0030	0.0	12	0106	-0.4	27	0042	-0.3	
M	1154	-0.1	TU	0624	6.2	TH	0718	5.3	F	0700	6.7	SA	0748	5.8	SU	0718	6.7	
	1818	5.0		1224	0.4		1330	-0.4		1318	0.0		1412	-0.4		1342	-0.2	
				1836	6.0		1936	6.2		1918	6.5		2012	5.9		1936	6.2	
13	0024	-0.5	28	0036	0.2	13	0124	-0.5	28	0106	-0.1	13	0154	-0.4	28	0130	-0.5	
TU	0648	5.8	W	0700	6.5	F	0800	5.4	SA	0742	6.9	SU	0836	5.8	M	0806	6.9	
	1254	-0.4		1306	0.2		1424	-0.4		1400	-0.1		1454	-0.3		1424	-0.4	
	1912	6.9		1912	6.8		2024	6.8		2000	6.9		2100	6.4		2024	6.8	
14	0112	-0.5	29	0106	0.1	14	0212	-0.4	29	0148	-0.2	14	0236	-0.3	29	0212	-0.4	
W	0736	5.5	TH	0736	6.7	SA	0848	5.4	SU	0824	5.8	M	0918	6.0	TU	0854	5.8	
	1348	-0.5		1342	0.1		1506	-0.3		1442	-0.2		1542	-0.2		1512	-0.5	
	2000	6.8		1948	6.9		2112	5.8		2042	6.4		2142	6.3		2142	6.4	
15	0154	-0.6	30	0142	0.0	15	0254	-0.3	30	0230	-0.3	15	0318	-0.2	30	0306	-0.7	
TH	0824	5.9	F	0806	6.9	SU	0936	5.2	M	0900	5.8	TU	1000	6.7	W	0942	5.8	
	1436	-0.5		1424	0.0		1554	-0.2		1530	-0.2		1624	-0.1		1600	-0.6	
	2048	6.8		2024	5.8		2200	5.6		2124	6.4		2224	6.2		2206	6.5	
			31	0218	0.0										31	0554	-0.6	
			SA	0842	5.8										TH	1030	6.9	
				1500	0.0											1648	-0.6	
				2100	5.7											2254	6.6	

TIME MERIDIAN 75° W. 0000 IS MIDNIGHT. 1200 IS NOON.
HEIGHTS ARE REFERRED FROM THE DATUM OF SOUNDINGS ON CHARTS OF THE LOCALITY WHICH IS NEAR LOW WATER.

I.A.
(Mar. 2.23)
p. 14

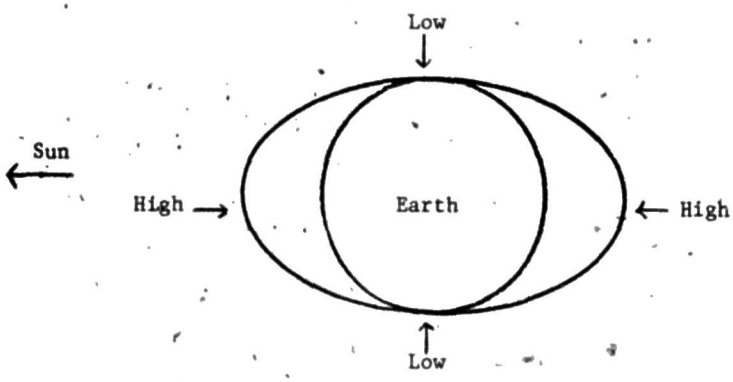
TABLE 4.—TIDAL DIFFERENCES AND OTHER CONSTANTS 223

No.	PLACE	POSITION Lat.	POSITION Long.	DIFFERENCES Time: High water	DIFFERENCES Time: Low water	DIFFERENCES Height: High water	DIFFERENCES Height: Low water	RANGES Mean	RANGES Spring	Mean Tide Level
		° ′	° ′	h. m.	h. m.	feet	feet	feet	feet	feet
	NEW JERSEY, Outer Coast—Continued	N.	W.	on SANDY HOOK, p. 70						
				Time meridian, 75°W.						
	Great Egg Harbor River									
1719	Scull Landing	39 22	74 43	+1 43	+1 54	-0.9	0.0	3.7	4.5	1.8
1721	Mays Landing	39 27	74 44	+2 34	+2 39	-0.6	0.0	4.0	4.8	2.0
1723	Peck Bay (34th Street bridge)	39 15	74 38	+0 51	+1 02	-0.9	0.0	3.7	4.5	1.8
1725	Devils Island, Crook Horn Creek	39 14	74 39	+0 37	+0 22	-1.0	0.0	3.6	4.4	1.8
1727	Corson Inlet (bridges)	39 13	74 39	+0 09	+0 04	-0.7	0.0	3.9	4.7	1.9
1729	Ben Hands Thorofare	39 12	74 40	+0 48	+0 32	-0.9	0.0	3.7	4.5	1.8
1731	Sea Isle City (Ludlam Thoro. bridge)	39 09	74 42	+0 45	+0 49	-0.8	0.0	3.8	4.6	1.9
1733	Sea Isle City (beach)	39 09	74 41	-0 19	-0 19	-0.5	0.0	4.1	5.0	2.0
1735	Townsend Inlet	39 07	74 43	+0 06	+0 04	-0.8	0.0	3.8	4.6	1.9
1737	Long Reach	39 06	74 45	+0 53	+0 53	-0.8	0.0	3.8	4.6	1.9
1739	Great Sound (ent. to Cresse Thoro.)	39 05	74 47	+1 03	+1 05	-0.5	0.0	4.1	5.0	2.0
1741	Stone Harbor (Great Chan. bridge)	39 03	74 46	+0 42	+0 26	-0.5	0.0	4.1	5.0	2.0
1743	Hereford Inlet (North Wildwood)	39 01	74 48	+0 02	+0 02	-0.5	0.0	4.1	5.0	2.0
1745	Wildwood (beach)	38 59	74 48	-0 15	-0 19	-0.5	0.0	4.1	5.0	2.0
1747	Grassy Sound Channel (hwy. bridge)	39 02	74 49	+0 40	+0 28	-0.5	0.0	4.1	5.0	2.0
1749	W. Wildwood (Grassy Sound bridge)	39 00	74 50	+0 45	+0 29	-0.3	0.0	4.3	5.2	2.1
1751	Swain Channel	38 59	74 52	+0 54	+0 27	-0.2	0.0	4.4	5.3	2.2
1753	Cape May Harbor	38 57	74 53	-0 02	-0 16	-0.2	0.0	4.4	5.3	2.2
1755	Cape May, Municipal Pier	38 56	74 55	+0 02	-0 17	-0.3	0.0	4.3	5.2	2.1
	NEW JERSEY and DELAWARE									
	Delaware Bay, Eastern Shore			on BREAKWATER HBR., p. 74						
1757	Five Fathom Bank	38 51	74 38	-0 43	-0 38	0.0	0.0	4.1	4.9	2.0
1759	McCrie Shoal	38 51	74 51	-0 22	-0 21	+0.2	0.0	4.3	5.2	2.1
1761	Cape May Point	38 56	74 58	-0 10	-0 04	+0.6	0.0	4.7	5.6	2.3
1763	Bay Shore Channel	38 58	74 58	-0 09	-0 03	+0.8	0.0	4.9	5.8	2.4
1765	Miami Beach	39 02	74 56	+0 17	+0 26	+1.0	0.0	5.1	6.1	2.5
1767	Dennis Creek entrance	39 10	74 54	+0 48	+1 04	+1.5	0.0	5.6	6.6	2.8
1769	East Point, Maurice River Cove	39 12	75 02	+0 53	+1 12	+1.6	0.0	5.7	6.7	2.8
	Maurice River									
1771	Port Norris	39 14	75 02	+1 14	+1 38	+1.6	0.0	5.7	6.7	2.8
1773	Mauricetown	39 17	75 00	+1 48	+2 21	+1.7	0.0	5.8	6.8	2.9
1775	Millville	39 24	75 02	+2 37	+3 23	+1.9	0.0	6.0	7.0	3.0
1777	Egg Island Point	39 11	75 08	+0 33	+1 02	+1.6	0.0	5.7	6.7	2.8
				on REEDY POINT, p. 78						
1779	Fortescue	39 14	75 10	-2 05	-2 19	+0.4	0.0	5.9	7.0	2.9
1781	Ben Davis Point	39 17	75 17	-1 40	-1 49	+0.5	0.0	6.0	6.9	3.0
	Cohansey River									
1783	Entrance	39 21	75 22	-1 30	-1 29	+0.5	0.0	6.0	6.9	3.0
1785	Laning Wharf	39 23	75 20	-1 10	-1 14	+0.5	0.0	6.0	6.8	3.0
1787	Fairton	39 23	75 14	+0 05	-0 24	+0.7	0.0	6.2	7.0	3.1
1789	Bridgeton	39 25	75 14	+0 27	-0 13	+1.0	0.0	6.5	7.3	3.2
1791	Bay Side	39 23	75 24	-1 23	-1 22	+0.6	0.0	6.1	6.9	3.0
	Delaware Bay, Central Lighthouses			on BREAKWATER HBR., p. 74						
1793	Brandywine Shoal Light	38 59	75 07	+0 09	+0 28	+0.8	0.0	4.9	5.9	2.4
1795	Fourteen Foot Bank Light	39 03	75 11	+0 18	+0 48	+1.1	0.0	5.2	6.2	2.6
1797	Miah Maull Shoal Light	39 08	75 13	+0 28	+1 08	+1.4	0.0	5.5	6.5	2.7
1799	Elbow of Cross Ledge Light	39 11	75 16	+0 40	+1 21	+1.5	0.0	5.6	6.5	2.8
				on REEDY POINT, p. 78						
1801	Ship John Shoal Light	39 18	75 23	-1 32	-1 36	+0.2	0.0	5.7	6.6	2.8
	Delaware Bay, Western Shore			on BREAKWATER HBR., p. 74						
1803	Cape Henlopen	38 48	75 05	-0 05	-0 05	0.0	0.0	4.1	4.9	2.0
1805	BREAKWATER HARBOR	38 47	75 06	Daily predictions				4.1	4.9	2.1
1807	Roosevelt Inlet	38 49	75 12	+0 09	+0 13	+0.3	0.0	4.4	5.2	2.2
1809	Mispillion River entrance	38 57	75 19	+0 33	+1 00	+0.5	0.0	4.6	5.4	2.3
1811	Murderkill River entrance	39 04	75 24	+0 56	+1 32	+0.7	0.0	4.8	5.7	2.4

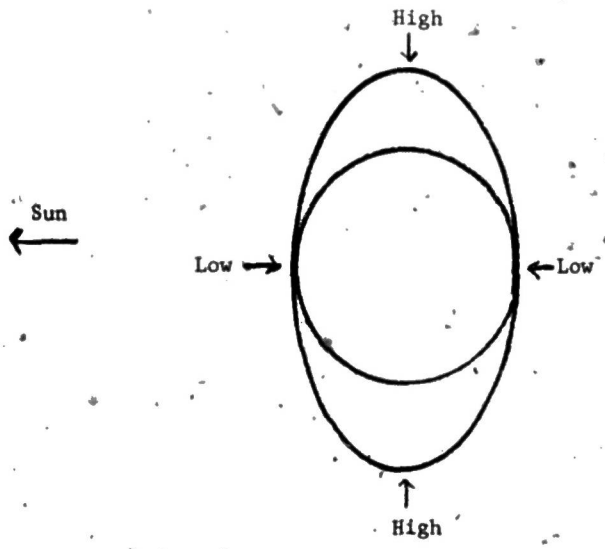
ACTIVITY 2

Make a labeled diagram showing high and low tides in relation to the phases of the moon. (You will need to indicate the positions of the moon and of the sun in your diagram.)

ANSWER TO ACTIVITY 2



New Moon and Full Moon



Moon at First and Third Quarter

ACTIVITY 3

Observe the relation of the tidal range to the moon's phases from actual observations or the Tide Tables.

Given: Tide Tables for Breakwater Harbor, Delaware, 1970

Oct. 15	Time H.M.	HT. Ft.	Oct. 22	Time H.M.	HT. Ft.
	0154	-0.6		0218	3.1
	0824	5.5		0748	1.0
	1436	-0.5		1442	4.1
	2048	4.6		2112	0.9
Oct. 16	0236	-0.5	Oct. 23	0324	3.2
	0906	5.6		0848	1.0
	1524	-0.4		1542	4.0
	2136	4.4		2206	0.8

From the information given above which days seem to indicate spring tides? neap tides? Indicate on which days new or full moon might occur and on which days first or third quarter moon might occur.

ANSWERS TO ACTIVITY 3

The information given indicates spring tides on October 15 and 16 and neap tides on October 22 and 23. New or full moon might occur on October 15 and 16 and first or third quarter moon might occur on October 22 and 23.

PRE-TEST

1. What are the phases of the moon? List them.

2. Name two extra-terrestrial bodies that affect tides on earth.

3. What is another name for "ebb" tide?

4. At what times of the month are the ocean tides highest? lowest?

5. Is it true that tides occurring during spring are called "spring tides"?

6. The sun is a much larger mass than the moon. Which has a greater effect on the tides of earth and why?

7. Breakwater Harbor, Delaware, is located at 38° 47' latitude 75° 06' longitude. Cape Henlopen is 38° 48' latitude and 75° 06' longitude. Where would high tide occur first - at Breakwater Harbor or at Cape Henlopen?

8. How many high tides and low tides occur at Rehoboth Beach each day? On the average, how long does it take between a high tide and the next low tide? Is this figure the same for all East Coast beaches?

PRE-TEST (Answers)

1. The phases are new, full, 1st and 3rd quarter.

2. The moon and the sun affect earth tides.

3. Low tide is sometimes referred to as "ebb" tide.

4. Tides are highest and lowest when the moon is full or new and at perigee, i.e., when the moon is nearest to earth. Tidal range is smallest at 1st and 3rd quarter and at apogee, i.e., when the moon is farthest from earth.

5. Spring tides occur at full and new moon during every season.

6. The moon has a greater effect because it is closer to the earth.

7. Cape Henlopen would experience high tide approximately five minutes before Breakwater Harbor did.

8. Two high and two low occur each day. Therefore, there are approximately 6 hours and 13 minutes between tides. Yes.

POST-TEST

1. High tides occur on opposite sides of the earth at the same time. With respect to the moon, what causes these tides on both the near and far side of the earth?

2. Why is it that the moon has a much greater influence in producing tides on earth than does the sun, considering that the sun's size is so many times greater than that of the moon?

3. What are spring tides? How and when do they occur?

4. If the earth did not rotate would we still have tides? If the earth always kept the same "face" toward the moon (in the same way the moon does toward the earth), would there be any tides?

5. Do the gravitational forces of both the sun and moon affect tides on earth? Explain why at certain times high tides are considerably higher and low tides lower than at other times.

6. Using Tables 1 and 2, pp. 13-14, find the time and height of high water and the time and height of low water at Roosevelt Inlet, Delaware during the p.m. of December 25, 1970.

7. Using Tables 1 and 2, pp. 13-14, graph the tidal range for Cape Henlopen between November 27 and December 6.

POST-TEST (Answers)

1. The tide on the near side occurs because of its closeness to the moon. On the far side the tide occurs because water there is farther from the moon than the center of mass, i.e., the earth is pulled "away" from the water.

2. The moon is much closer to the earth. The sun does cause tides on earth, but they are much smaller than those caused by the moon.

3. Spring tides are higher high tides and lower low tides which occur during new and full moons.

4. Non-rotation would have no effect on tides. If the earth always kept the same face toward the moon, each location would always experience high tide, low tide or something in-between. This applies to the lunar tides. The solar tides would still sweep around the earth. Though they are much smaller in effect than lunar tides they would be readily observed.

5. The gravitational forces of both the sun and moon affect tides on earth. When the moon is between the earth and the sun, tidal range is greatest. When the moon is at right angles to the earth-sun line, the tidal range is smallest.

6. Breakwater, Delaware, December 25, 1970

H.M.	Ft.
1206	0.1
1800	3.0
2354	0.0

Roosevelt Inlet

1206 + 0013 = 1219	Low tide 12:19 p.m.
+0.1 + 0.0 = 0.1	Height 0.1' feet above mean low water
1800 + 0009 = 1809	High tide 6:09 p.m.
3.0 + 0.3 = 3.3'	Height 3.3 feet above mean low water
2354 + 0013 = 2407	Low tide 12:07 a.m. December 26
-0.1 + 0.0 = -0.1'	Height 0.1 feet below mean low water

FILMS

1. The Moon and How It Affects Us --- Coronet, 11 min. B & W

2. Ocean Tides --- Encyclopedia Britannica - color 14 min.

3. Tides and Currents --- ESSA Washington Science Center; Rockville, Md. - Color 15 min.

FILMSTRIPS

1. Physical Oceanography --- National Acad. of Science, Washington, DC

RECORD

1. Physical Oceanography --- National Acad. of Science, Washington, DC 12 in. 33 1/3 RPM

TIDE TABLES

1. Tide Tables --- U.S. Dept. of Commerce Environmental Science Service Administration Coast and Geodetic Survey, U.S. Government Printing Office, Washington, DC

GLOSSARY

Apogee - time at which the moon is farthest from the earth; occurs once each lunar month

Aphelion - time at which the sun is farthest from the earth (July 4)

Perigee - time at which the moon is nearest the earth; occurs once each lunar month

Perihelion - time at which the sun is nearest the earth (January 3)

Tidal Range - difference between the level of high tide and the level of low tide

Tides - the daily rising and falling of the ocean waters in a rhythmic movement.

Diurnal tides - one high and one low tide per day. The tides along the Vietnam coast are diurnal.

Semi-diurnal tides - two high and two low tides each day with little or no difference between consecutive high and low tides. The tides along the east coast of the United States are semi-diurnal.

Mixed tides - both diurnal and semi-diurnal; i.e., there are two high and two low tides each day but with considerable difference between heights of successive high and low tides. The tides along the Pacific coast of the United States are mixed tides.

Neap tides - tides occurring when the moon, sun and earth form a right angle (1st and 3rd quarters); the pulls oppose each other and the tidal range is smallest.

Spring tides - tides occurring when the moon and the sun are in a straight line with the earth (new and full moon); the pulls reinforce each other and the tidal range is greatest.

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Language Arts Supplement

#214 THE MOON, THE SUN, AND TIDES

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