Oceanography 11 / Laboratory 8 **Name ____________________________**

Ocean Waves and Tsunami

In this lab we will examine 2 types of ocean waves: wind waves and tsunamis.

As a part of this assignment, you will be asked to use common descriptions of ocean waves, including the following wave parameters:

Wave Height (H): the vertical distance separating the wave crest from the wave trough.

Significant Wave Height (Ho): Calculated as the average of the highest one-third of all of the wave heights during a 20-minute sampling period.

Wave Period (T): the time it takes two successive wave crests to pass a fixed location.

Wave Celerity (C): the speed of wave propagation (aka, the phase speed).

Wave Group Speed (Cg): the speed of advance of a wave group.

Wave Length (L): the horizontal distance separating two successive wave crests, L = CT.

Deep Water Wave: a wave in water that is deeper than about 1/2 the wavelength of the wave.

C (meters per second)= 1.56 T(seconds); Cg (meters per second)= ½ C

L (meters) = CT= $1.56T^2$

Shallow Water Waves: a wave in water shallower than about 1/20th of the wavelength of the wave.

C (meters per second) =3.1 $\sqrt{d}$, where d is the water depth in meters; Cg (meters per second) = ½ C

L (meters) = CT

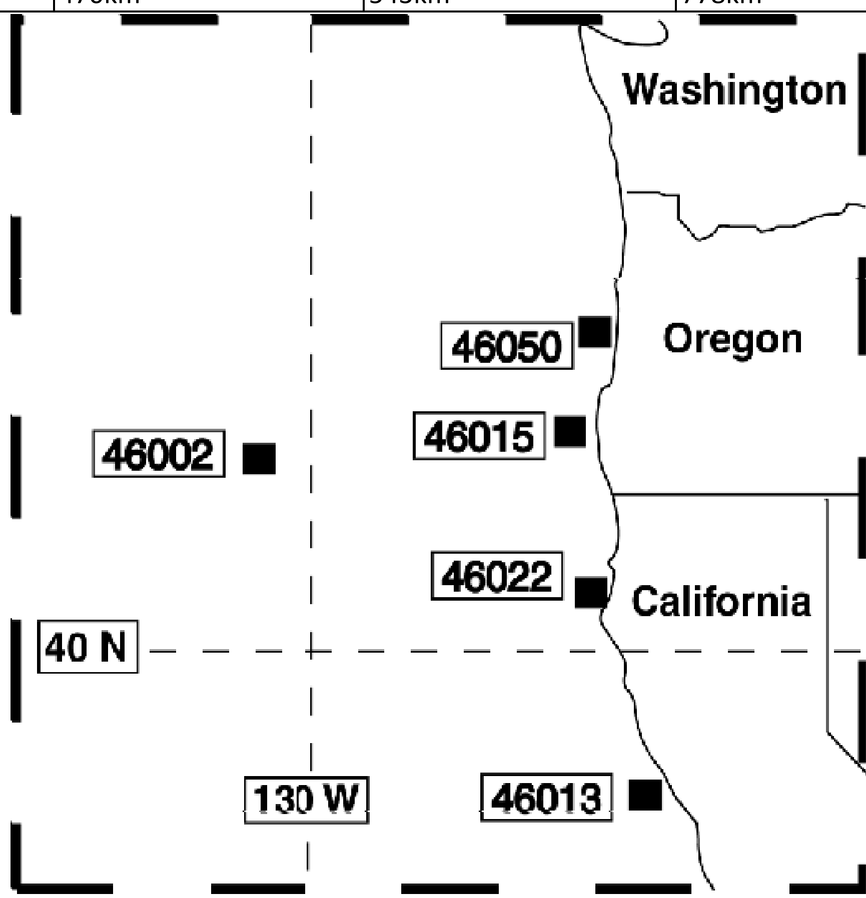
Intermediate Water Wave: a wave in water depths between 1/2 and 1/20th of the wavelength of the wave.

Handy Conversions: 1) convert speed in meters/sec to knots using the conversion **1 m/sec = 1.94 knots.**
2) convert speed in meters/sec to km/hr using the conversion **1 m/sec = 3.6 km/hr.**

A. WIND-GENERATED WAVES

Wind is very effective at generating a variety of ocean waves. In the tables below, you are provided measurements of significant wave height (Ho, in meters) and wave period (T, in seconds) made in the northeast Pacific during early January 2003. Measurements are from NOAA NDBC buoys #46002, #46050, #46015, #46022, and #46013. The distance (Great Circle Route) between buoy 46002 and the others are:

#46002 to #46050	#46002 to #46015	#46002 to #46022	#46002 to #46013
540km	470km	543km	778km



Part 1: Wind-Generated Waves

The sea state analysis forecast for 1/6/2003 suggested that the waves along the Pacific Northwest coast would be traveling east southeast toward the coast. Consider the measurements made at the offshore buoys below. **Notice that some large,** 25-second period waves **arrived at each buoy during this storm. Track the travel of these waves in the data provided to answer the following questions.**

1. On the tables provided, identify the time and date of the **first arrival** of these 25-second period storm waves.

What was the Significant Wave Height of these storm waves when they **first arrived**?

Buoy #46002	Buoy #46050	Buoy#46015	Buoy#46022	Buoy #46013
________m	________m	________m	________m	________m
________ ft	________ ft	________ ft	________ ft	________ ft

2. As waves continued to arrive from this storm, what was the **maximum** significant wave height?

________m	________m	________m	________m	________m
________ ft	________ ft	________ ft	________ ft	________ ft

3. Use the formula for Deep Water waves to calculate the speed of travel of these waves.

Deep Water Celerity = ____________m/sec Group Velocity =.____________. m/sec = ._____________. km/hour

4. Given the distance between buoy 46002 and the other buoys, calculate the time required for these waves to travel the given distance.

Buoy #46002 to

Buoy #46050	Buoy#46015	Buoy#46022	Buoy #46013
_________ Hours	________Hours	________Hours	________Hours

5. If the waves traveled directly from buoy 46002, when should they have appeared in the wave data record? When did they actually arrive?

	Buoy #46050	Buoy#46015	Buoy#46022	Buoy #46013
PREDICTED ARRIVAL	___________Day/Hr	___________Day/Hr	___________Day/Hr	___________Day/Hr
ACTUAL ARRIVAL	___________Day/Hr	___________Day/Hr	___________Day/Hr	___________Day/Hr

6. Did these waves travel directly from buoy #46002 to the coastal buoys? (i.e.. Did they arrive when expected? or Were they early? Or late?)

Buoy #46050__________ Buoy#46015___________ Buoy#46022____________ Buoy #46013___________

7. Assuming that you did the calculations correctly, from what direction must these waves have come from to explain the sequence of arrival at these three buoys? (e.g.. From the North-northeast). Explain.

____

____

____

Data Set. 1/06/03, 04:00 to 1/07/03,12:00. Significant Wave Height (meters) & Wave Period (seconds)										
	Buoy# 46002		Buoy# 46050		Buoy#46015		Buoy# 46022		Buoy#46013	
Year Mo Day Hr	H0(m)	T(sec)	HO(m)	T (sec)	HO(m)	T (sec)	HO(m)	T (sec)	HO(m)	T (sec)
2003 1 7 12	4.2	14.3	4.7	16.7	3.8	16.7	4.2	16.7	3.5	16.7
2003 1 7 11	4.7	16.7	4.2	16.7	3.8	16.7	4.3	0.0	3.7	20.0
2003 1 7 10	4.6	14.3	4.7	16.7	5.0	16.7	4.8	16.7	4.0	16.7
2003 1 7 9	4.8	16.7	4.7	14.3	4.8	16.7	5.5	20.0	3.6	16.7
2003 1 7 8	4.7	12.5	4.4	16.7	5.2	16.7	5.4	20.0	4.2	16.7
2003 1 7 7	4.8	14.3	4.7	16.7	5.1	16.7	5.1	16.7	3.8	16.7
2003 1 7 6	4.8	16.7	4.0	16.7	5.5	20.0	4.6	20.0	3.6	20.0
2003 1 7 5	5.5	16.7	4.8	16.7	4.0	20.0	6.0	20.0	3.4	20.0
2003 1 7 4	5.4	16.7	4.6	16.7	4.2	20.0	6.9	20.0	3.8	20.0
2003 1 7 3	5.1	16.7	4.2	20.0	4.7	20.0	6.1	20.0	3.0	20.0
2003 1 7 2	5.5	16.7	4.1	16.7	3.9	20.0	6.4	16.7	3.5	20.0
2003 1 7 1	5.8	16.7	5.0	20.0	3.6	20.0	6.2	20.0	3.3	20.0
2003 1 7 0	5.6	16.7	4.0	20.0	3.9	20.0	6.5	20.0	2.6	25.0
2003 1 6 23	6.0	16.7	4.1	20.0	3.8	20.0	6.2	20.0	3.3	25.0
2003 1 6 22	6.1	16.7	3.7	20.0	4.1	20.0	4.9	20.0	2.9	25.0
2003 1 6 21	7.0	16.7	4.0	25.0	4.7	20.0	4.8	25.0	3.6	14.3
2003 1 6 20	6.1	16.7	3.4	14.3	4.4	20.0	3.9	25.0	2.9	14.3
2003 1 6 19	6.8	20.0	3.2	12.5	4.3	25.0	3.9	25.0	2.8	12.5
2003 1 6 18	5.7	20.0	3.1	12.5	4.1	25.0	3.6	25.0	2.7	12.5
2003 1 6 17	5.9	20.0	2.7	14.3	3.8	25.0	3.2	14.3	2.5	14.3
2003 1 6 16	6.2	20.0	2.8	14.3	3.2	12.5	3.5	14.3	2.8	0.0
2003 1 6 15	6.5	20.0	2.8	14.3	3.0	0.0	3.3	14.3	3.0	14.3
2003 1 6 14	6.2	20.0	3.0	14.3	2.8	14.3	2.9	16.7	2.7	12.5
2003 1 6 13	5.5	20.0	2.7	14.3	2.6	0.0	2.8	14.3	2.9	14.3
2003 1 6 12	5.7	25.0	2.7	14.3	2.6	14.3	3.2	14.3	2.8	14.3
2003 1 6 11	4.9	25.0	2.7	14.3	2.5	14.3	3.2	12.5	3.0	14.3
2003 1 6 10	4.7	14.3	2.5	14.3	2.4	16.7	3.1	14.3	3.2	16.7
2003 1 6 9	4.5	14.3	2.4	14.3	3.0	14.3	3.9	14.3	3.0	14.3
2003 1 6 8	4.4	14.3	2.7	14.3	2.6	12.5	3.4	14.3	3.3	14.3
2003 1 6 7	4.5	14.3	2.9	14.3	3.4	14.3	4.1	14.3	3.3	14.3
2003 1 6 6	4.3	14.3	3.4	14.3	3.2	14.3	3.4	14.3	3.8	16.7
2003 1 6 5	4.6	14.3	3.2	14.3	3.7	14.3	4.2	14.3	3.6	14.3
2003 1 6 4	4.8	12.5	3.4	14.3	3.7	14.3	3.7	14.3	3.6	14.3

Table 7-2. Recorded tide gauge heights.

Gauge Location	Distance (km)	Wave Height cm (peak - trough)	Initial Motion	Travel Time hr:min	*
Arica, Chile	415	257	rise	0:35	1
Callao, Peru	609	80	rise	1:34	1
Antofagasta, Chile	856	90	rise	1:02	1
Valparaiso, Chile	1,886	60	rise	2:27	1
Talcahuano, Chile	2,283	250	rise	3:41	1
Santa Cruz, Galapagos Is.	2,523	90	rise	3:59	1
Easter Is., Chile	3,905	35	?	5:41	2
Cabo San Lucas, Mexico	5,960	25	?	8:56	2
La Jolla, CA	7,170	10	?	11:19	2
Los Angeles, CA	7,304	10	?	11:36	2
San Francisco, CA	7,887	7	?	12:51	2
Crescent City, CA	8,280	40	?	13:13	2
Hilo, HI	9,770	70	rise	13:27	1
Chatham Is., NZ	9,781	55	?	14:05	2
Sitka, AK	9,929	5	?	16:02	2
Apia, Western Samoa	10,450	25	?	14:49	1
Kodiak, AK	10,890	8	?	16:59	2
Sand Point, AK	11,298	24	?	17:08	2
Nukualofa, Tonga	11,489	20	?	15:07	1
Midway Is., USA	12,188	15	?	16:27	2
Adak, AK	12,317	20	?	17:27	2
Kwajalein, Marshall Is.	13,347	10	?	18:00	2
Wake Is.	13,679	10	?	18:11	2
Omaezaki, Honshu, Japan	16,259	25	?	21:39	2
Naha, Okinawa, Japan	17,565	10	?	23:05	2

* 1.) travel time measured from recorded arrivals
2.) travel time estimated from algorithm; source:http://wcatwc.gov/06-23-01.htm

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Part 2: Tsunami

Using the equation for shallow water waves ($C = \sqrt{gd}$), calculate the following water wave speeds for the following depths. This yields the speed in m/sec. Multiply by 1.94 to get the speed in knots.

8,000m:_______m/sec = _______knots; 4,000m: ________m/sec = _______knots, 200m:______m/sec =______knots; 100m: _____m/sec = _____knots; 10m: _____m/sec_____knots

A magnitude 8.2 earthquake occurred of the southern coast of Peru (16.2° S, 73.4° W) on June 23, 2001 at 2033 GMT. The earthquake generated a tsunami that was recorded on tide gauges around the Pacific basin. Using six of these tidal records calculate the arrival time, travel speed, average depth of travel, wave height, and damage hindcast for each site.

Site: ARICA, CHILE [18.4667°S, 70.3333°W; distance from epicenter: 412 km]

Arrival After Quake =______(hours)

Avg. Travel Speed________ (km/hr). Shallow-water Calculation, Avg Depth of Travel = _________(m)

Wave Height (cm) = __________ Expect Damage? Why or why not? ____

____

SITE: ANTAFOGASTA, CHILE [23.65°S, 70.4°W; distance from epicenter: 856 km]

Arrival After Quake =______(hours)

Avg. Travel Speed______ (km/hr). Shallow-water Calculation, Avg Depth of Travel = __________ (m)

Why was the speed faster to this location? ____

Wave Height (cm) = ____________Expect Damage? Why or why not? ____

____

SITE: CALLAO, PERU [12.05°S, 77.15°W; distance from epicenter: 609 km]

Arrival After Quake =______(hours)

Avg. Travel Speed______ (km/hr). Shallow-water Calculation, Avg Depth of Travel = __________ (m)

Wave Height (cm) = ____________ Expect Damage? Why or why not? ____

____

SITE: VALPARAISO,CHILE [33.0333°S, 71.6333°W; distance from epicenter: 1,886 km]

Arrival After Quake =______(hours)

Avg. Travel Speed______ (km/hr). Shallow-water Calculation, Avg Depth of Travel = __________ (m)

Wave Height (cm) = ____________ Expect Damage? Why or why not? ____

____

SITE: SANTA CRUX, GALAPAGOS ISLANDS [00.75°S, 90.3167°W; distance from epicenter: 2,531 km]

Arrival After Quake =______(hours)

Avg. Travel Speed______ (km/hr). Shallow-water Calculation, Avg Depth of Travel = __________ (m)

Wave Height (cm) = ____________ Expect Damage? Why or why not? ____

____

SITE: SAND POINT, ALASKA [55.3366°N, 160.4933°E; distance from epicenter: 11,298 km]

Arrival After Quake =______(hours)

Avg. Travel Speed______ (km/hr). Shallow-water Calculation, Avg Depth of Travel = __________ (m)

Wave Height (cm) = ____________ Expect Damage? Why or why not? ____

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<u>Tides, Seiche And Amphidromic System</u> Part3:

Part I MEASURING THE PERIOD OF A CLOSED BASIN

If energy is supplied to a closed basin, a standing wave, or a seiche, can set up in the basin. A simple seiche will have a node in the center of the container; the period of the basin is the time required for a standing wave in the basin to complete one full cycle. The basin period can be calculated if the length of the basin in the direction of oscillation (L) and the average water depth in the basin (d) are known. For a rectangular basin that is closed to the sea, the basin period (T) can be calculated using, $T = 2L / \sqrt{gd}$, where all units are metric and $g = 980\ cm/sec^2$ (or $9.80\ m/sec^2$).

Using the two rectangular basins:.

1. Measure the length of each basin record the data in the table on the following pages.
2. We will vary the depth of water 5 different times in each basin and measure the harmonic oscillatory period for each different water depth.
3. To do this, fill the basin to the desired depth, allow the water surface to calm, then slowly raise one end of the container a few centimeters. Carefully lower the container back down to start a seiche. Try to avoid creating surface waves in the process, and if they form allow them to dissipate before making your measurements. Measure the time required for five complete oscillations to occur at one end of the basin. An oscillation is one complete cycle of crest-to-crest. Record the average harmonic oscillation period (T_{obs}) of the basin.
4. Increase and record the depth of water in the basin. Repeat Step 3 the measurement of basin period.
5. Compare your observed harmonic oscillatory period of the basin (T_{obs}) with the calculated period (T_{calc}) using the formula above.
6. Repeat for the second container.

Period of Basin #1

Test #	L (cm)	d (cm)	Time (sec),5 Oscillations.	T_{calc} (sec)	Avg. T_{obs} (sec)
1					
2					
3					
4					
5					

Period of Basin #2

Test #	L (cm)	d (cm)	Time(sec),5 Oscillations	Avg. T_{obs} (sec)	T_{calc} (sec)
1					
2					
3					
4					
5					

Questions

A. How well do the calculated periods correspond to the observed periods? Explain discrepancies.

B. How did increasing the water depth alter the basin period? Why?

C. How does the harmonic oscillatory period of the longer basin compare to the period of the shorter basin?

D. If you repeated the experiment, oscillating the water across the short dimension of the container, what would you expect to observe for basin period?

Basin #1?

Basin #2?

Part II: PERIOD OF AN OPEN-ENDED BASIN

A bay or gulf can act as an open-ended basin, if the entrance is unrestricted. If a simple seiche is set up, the basin will have the node of oscillation located at the bay entrance. The period of an open-ended basin can be calculated in similar fashion to a closed basin, if the length of the basin in the direction of oscillation (L) and the average water depth (d) are known. For a rectangular basin that is open to the sea, the basin period (T) can be calculated using, $T = 4L / \sqrt{gd}$, where units are metric and g = 980 cm/sec^2 (or 9.80 m/sec^2).

Using the data below, calculate the basin periods to determine the most probable tide for each location. If the basin period is near 24 hours, the area would likely experience a diurnal tide, if near 12 hours, a semidiurnal tide, and if between 12 and 24 hours, a mixed tide.

Location	**Avg. d(m)**	**L (km)**	**T_{calc} (secs)**	**T_{calc} (hrs)**	**Tide Type Expected**	**Tide Type Observed**
Gulf of California	**750**	**1100**				
Humboldt Bay, Ca	**10**	**15**				
Bay of Fundy	**80**	**310**				
LA - MS - AL Coast	**177**	**900**				
Texas Coast	**1557**	**1800**				
Yucatan Coast	**430**	**1400**				