Chapter 10

Regular Waves Experiment

10.1 Computer Programming Laboratory

1. Using MATLAB, create a wave made from combining two sinusoidal waves with frequencies 2 and 5 Hz. The 2 Hz wave has a wave amplitude of 1 m with a phase of 10° (remember to convert to radians!). The 5 Hz wave has an amplitude of 1.2 m with a phase of 80°.

   (a) Plot the wave for 4 seconds (be sure to properly label your plot!).

2. Consider waves generated in the 120-ft tow tank in the Hydro Lab (it has a water depth of 5 ft). The wavemaker can generate regular waves with frequencies from 0.4 to 1.4 Hz.

   (a) Using deep water linear wave theory and MATLAB, create a graph of wave length (ft) versus frequency (Hz). Find the frequency that is the limit of deep water waves. *Remember that deep water is considered when the water depth is greater than half the length of the wave. What is the frequency when the wave length is twice the water depth?*

   (b) Using deep water linear wave theory and MATLAB, create a graph of velocity (ft/s) versus frequency (Hz). Include separate lines for the celerity and group velocity (but put both lines on the same graph). Include a legend (MATLAB command `legend('Wave Celerity','Group Velocity')`) and double-check the labels correspond to the correct lines.

Save your MATLAB codes. You will need to bring them to the lab.
10.2 Experimental Laboratory

10.2.1 Regular Waves PreLab Assignment

1. What is the equation for the wave celerity based on wave frequency in deep water? What is the equation for the wave celerity in shallow water?

2. What is equation for the group velocity based on wave frequency in deep water? What is the equation for the group velocity in shallow water?

3. What is the relationship between the wave celerity and the group velocity in deep water?

4. Is the relationship between wave celerity and group velocity the same in deep water and in shallow water? If not, what is the relationship in shallow water?

5. Complete problem 7 in the Regular Waves Problems from Chapter 3.

6. The wavemaker will be used to generate regular waves with frequencies between 0.4 and 1.4 Hz. Assuming you will have a total of 10 to 12 runs, create a test matrix for the lab. Give 10 to 12 wave frequencies and wave heights to test that fall within the allowed range. The wave slope for each condition should be no greater than 1/30. Be sure to include at least one repeat condition to determine repeatability.
10.2.2 Regular Wave Experimental Assignment

1. **Purpose:** The lab is intended to introduce the students to the wavemakers that are positioned at the ends of each of the towing tanks in the USNA Hydromechanics Laboratory. The lab will also illustrate the relationship between celerity, group velocity, wave length, and frequency for simple linear waves. We will be able to study the effect of water depth by changing the lengths of the waves compared to the water depth of the tank.

2. **Background:** The main data recording instrument in this lab is the acoustic wave gage. There are two wave gages fixed to the wall of the 120-ft tank at a distance of about 40 ft apart. The other major component used in this lab is the wavemaker. The wavemakers used in both the 120-ft and 380-ft tanks are a dual flap design, requiring a control for each flap. Using the control system on the wavemaker computer, the system can generate either regular or irregular waves.

3. **Procedure:** There are three stations that need to be manned during this experiment. Each station will be involved for each test run and every student is expected to experience each station at some point during the lab period.

- **Wavemaker**
  The group running the wavemaker is responsible for running the waves down the tank. This is to teach you how to set and operate the wavemaker. One of the lab staff will assist in the operation of the equipment. The wavemaker operators must be certain that the data run for each wave frequency is long enough for the manual timers to get *at least* three measurements. Keep in mind, the longer the wavemaker is run, the longer it takes for the tank to settle down before the next run.

- **Manual Timers**
  The manual timers will record the time it takes for a single wave to travel the distance between the gages so as to measure the wave celerity.
  (a) Start at the wave gage nearest the wavemaker with a stopwatch in hand.
  (b) Pick a wave approaching and start your watch as the wave passes in front of you. Follow the wave along the tank until it passes the second gage, at which time you stop the watch. *Be sure to wait and pick a wave once the full size waves are fully established. Otherwise your wave may disappear before you reach the second wave gage!*

Each group member should “run” with at least one wave. Find the average time it took for a wave to travel the distance between the gages and record that time.

- **Data Collection**
  The group running the data collection will start the run before the waves reach the first wave gage and collect a long enough set of data that the second wave gage has collected enough full-size waves for analysis. The data collection group will then run the Computer Lab MATLAB code to analyze the collected data for wave amplitude and frequency. This data, along with the average time from the Manual
Timers group, should be recorded on the board. In addition, the data collection
group will make an estimate of the group velocity using the data collected from
both wave gages.

(a) Identify a wave from the first wave gage that has a particular wave energy
(typically chosen by selecting the wave that has 50% of the maximum wave
height).

(b) Using the data cursor, identify the time this wave passes the first wave gage.

(c) Looking at the data from the second wave gage, find the wave with the same
energy level (i.e. when the gage reads 50% of the maximum wave height) and
find the time that wave reaches the second wave probe.

(d) The time interval between the two points can be used to determine the group
velocity (distance/time). See Figure 10.1.

![Wave Record - 1.0 Hz](image)

Figure 10.1: Determining the Group Velocity using “Energy Envelopes”

**Deliverables: Tables and Plots**

1. Create a table with the tank information, including the tank dimensions (length, width, height), the operating water depth, and the distance between the wave gages.

2. Create a table for each wave run with the following data:

   (1) Programmed wave frequency and wave height (for wavemaker)

   (2) Is this run considered deep water, shallow water, or in-between?

   (3) Average wave run time from manual timers

   (4) Calculated wave frequency, wave amplitude, wave celerity from manual timer runs, group velocity from wave time histories, and the ratio of the group velocity to the wave celerity from the experimental data. Include a brief description of particle motions (circular, elliptical, mainly back-and-forth)

   (5) Calculated wave period, wave celerity, group velocity, and ratio of the group ve-

   locity to the wave celerity from the wave frequency and water depth information.
3. Sample plots of the time histories from each wave gage (only for one regular wave run) showing how the group velocity was determined.

4. **Wave Velocity Plot**: A plot of the wave velocity for all data points (wave celerity and group velocity versus wave frequency with the data plotted as individual points). On this same plot, include a line for both the wave celerity and group velocity predicted using the deep water theoretical wave equations. *Be sure to use different line styles for these lines.*

**Sample data collection tables**

<table>
<thead>
<tr>
<th>Tank Length</th>
<th></th>
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<tbody>
<tr>
<td>Tank Width</td>
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<tr>
<td>Tank Depth</td>
<td></td>
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<tr>
<td>Distance between Wave Probes</td>
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</tbody>
</table>

Table 10.1: General Information

<table>
<thead>
<tr>
<th>Run #</th>
<th>Wave Height</th>
<th>Period</th>
<th>Freq.</th>
<th>Wave Height</th>
<th>Period</th>
<th>Freq.</th>
<th>Water Depth?</th>
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Table 10.2: Regular Wave Conditions

<table>
<thead>
<tr>
<th>RW title</th>
<th>Wave Run Time</th>
<th>Distance</th>
<th>Wave Celerity</th>
<th>Group Velocity</th>
<th>Velocity Ratio</th>
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Table 10.3: Regular Wave Velocities

Be sure you have all the required deliverables for the regular wave runs:

- Tank dimensions and intended wave conditions (wave height and period)
- Sample plots of time histories (both probes)
- Measured/calculated wave celerity and group velocity equations for one regular wave condition
- Plot with measured data points for velocities and theoretical curves