Ocean ENGINEERING

Massachusetts Institute of Technology
2.016 Hydrodynamics
Fall 2005
Surface Waves Kinematics

Friday 14 October 2005, 9-11am
******Ocean Engineering Towing Tank ******

Introduction

This lab is in an investigation into some of the properties of surface gravity waves. The purpose is to gain an understanding of some of the fundamental concepts and relationships of surface wave kinematics by means of an experimental study. The wave-making and wave-detection capabilities of the MIT Towing Tank will be used in conjunction with empirical observations.

Laboratory Setup/Procedures

Equipment

The towing tank is a long rectangular basin of water with a wave-maker at one end and a “beach" at the other. The wave-maker is a hydraulically driven vertical paddle with controllable amplitude and frequency. The “beach" is a region of absorbing material intended to prevent the reflecting of waves from this end of the tank.

You will be using wave probes to measure the amplitude, or height, of the passing waves. The wave probes are a “resistance" type probe, which produce a voltage proportional to the submerged length. This voltage can be logged by a computer at a prescribed sampling rate. As waves pass the probe, the computer will display the height of the free surface as a function of time. The data will be recorded to a disk.

Visual measurements will also be taken for corroboration of the methods and equipment. A stop watch and tape measure will be provided for such measurements.

Objectives

To measure the basic surface wave properties in terms of wave amplitude, period, wavelength, phase velocity, and group velocity.

Measurements

<u>Towing Tank personnel will provide instructions for the operation of the wave-maker and data collection system. Please follow their instructions.</u>

The class will be broken into three groups (A, B, C). The groups will rotate through each running 3-4 wave packets.

First rotation:

Group A: Operates wave paddle/records wave probe data.
Group B: measures group speed/phase speed/wavelength/amplitude by eye/stopwatch/ruler **(Tasks 5 and 6)**
Group C: observes qualitative features of the waves, waves appear/disappear at end/beginning of packet, including surface patterns with glitter/pepper and particle orbits under waves. **(Tasks 3, 4, and 7)**

Second rotation, etc.

Group C then goes to B's Station, B to A, and A to C, and so on.

The post processing of the electronic data can be done on Athena in MATLAB (or even excel) after the lab session. For the group measuring speeds/heights by hand/eye make sure your data makes sense – does your phase speed equal twice the group speed, etc?

<u>FOR ALL GROUPS TO DO:</u>

1. Record the water depth h.

2. Calibrating the wave probes: The calibration of the probes consists of determining the relationship between the voltage read by the computer and the submerged length of the probe. The probes will be calibrated before you arrive. Make sure you write down the calibration data before leaving lab.

<u>BY GROUP (A, B, C):</u>

The following steps (3) through (6) are to be completed for a range of frequencies between 1*hz and* 3*hz, each at a small amplitude and a large amplitude. Plan your runs so that you cover a large range of frequencies first, if time remains you can fill in interim frequencies for better resolution.*

3. **Determine the amplitude, A, and the frequency, $\omega = 2\pi/T$**, where T is the wave period, of the wave using the wave probes and by sight.

   If $\eta(x; t)$ is the free surface elevation, a good definition of the wave amplitude here is $A = (\eta_{max} - \eta_{min})/2$ at some given x. Station someone at the tank window to confirm these measurements by a direct visual measurement of A and T (determine the time it takes for a fixed number of wave crests to pass a given point).

4. **Determine the wavelength, λ,** which is the distance between two crests (or troughs or equal phase points). This value can be found by examining the simultaneous signals from two wave probes a known distance apart.

   (*Think about whether the probes should be close together or far apart?*)

   Also estimate the wavelength by visual observation (this might be easiest with two people).

5. **Determine the wave phase velocity, V_p,** which is the speed at which the wave crests (or constant phase points) move in the direction of propagation.

   This can also be determined from the simultaneous signals of two wave probes a known distance apart.

   Estimate the phase speed using the ruler on the rail of the towing tank, a stopwatch and visual observation.

6. **Determine the wave group velocity, V_g,** which is the speed at which a wave group travels, corresponding to the speed at which the wave energy travels.

   This can be found be measuring the arrival time of a point of constant position within a group at two probes a known distance apart, eg. the "front" or "back" of the group.

   Think whether the probes should be located close together or far apart?

   Also measure the group velocity directly with the tank ruler and stopwatch.

7. **Surface observations and particle orbits:** For any frequency and amplitude wave packet, spread grains of pepper on the free-surface and along the bulk of the water. Observe the motion of the pepper grains as waves are passing to get an indication of the particle motion. What happens to the particles at the surface when a wave crest passes? When a wave trough passes?

Post-Lab Analysis

In your lab report, the final results you present must be in non-dimensional form. Since the wavenumber is $k = 2\pi/\lambda$ and the frequency is $\omega = (gk)^{1/2}$ (where $g = 9.80\ m/s^2$), a good choice is to normalize (divide) length by $1/k$ and time by $(gk)^{-1/2}$. In other words, the non-dimensional length, x', is given by $x' = x / (1/k) = kx$, and the non-dimensional time, t', is given by $t' = t / (gk)^{-1/2} = (gk)^{1/2} * t$. Tables and graphical plots should be used. LABEL ALL AXES!

The lab report should include the specific procedure of the experiments, data analysis, and a discussion of your results.
Besides the discussion and explanation the above measurement steps, the following results are required to be analyzed and discussed in your lab report.

- Relationship between wave length and frequency (from both the wave probe and visual measurements).
- Relationship between phase velocity and frequency.
- Relationship between group velocity and frequency.
- Relationship between phase velocity and group velocity.
- Dependence of the above results on the wave amplitude.
- Also discussion of the observed particle orbits and surface motions.

Plots or tables may be useful in these discussions. In addition to these, you are encouraged to discuss other hydrodynamic issues you have learned from the experiments.

The lab report should be written in a professional way. It should be type-written and should have been edited for grammatical and spelling errors. Although it needs to be complete, conciseness is also emphasized.