

# Department of Mechanical Engineering

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Massachusetts Institute of Technology

## 2.20 Marine Hydrodynamics, Fall 2007

### Laboratory Assignment B

**Assigned: Wednesday, October 31, 2007**

**Lab time: Wednesday, November 7, 2007 to Friday, November 9, 2007**

**Report Due: Tuesday, November 27, 2007**

### VORTEX-INDUCED VIBRATIONS OF A CYLINDER AND SURFACE WAVE KINEMATICS

This laboratory assignment requires that you do the following:

1. Read through the details of the lab.
2. Perform the Pre-Lab exercise to be turned in at the beginning of lab.
3. Perform the experiment at the time you have signed up.
4. Write a lab report, which is due Tuesday, November 27, 2007. Although the experiments are performed in a group, **the lab report should be individual**. The lab report is expected to be type-written, complete and **concise**.

Lab Assignment B is to be performed at the Towing Tank, Room 48-015, x3-4348 during the time slots for which you have signed up.

Reports are to be done **individually** and are due by 1 pm Tuesday, November 27, 2007.

## Introduction

This lab is designed to help you understand important concepts related to two important phenomena in marine hydrodynamics: Vortex-induced Vibration (VIV) and dispersive surface water waves. In this lab, you are asked to:

1. Observe the VIV phenomenon of flexible cylinders,
2. Observe suppression of the VIV phenomenon,
3. Make quantitative measurements of vortex-induced vibration frequency/amplitude of a free oscillating rigid cylinder
4. Make quantitative measurements of surface wave phase and group speed as a function of wave frequency, and to observe the dispersion phenomenon of surface waves.

## Pre-Lab Preparations

You **must** submit a pre-lab report of the following pre-lab preparations at the beginning of the lab. Although you are encouraged to prepare for the lab as a lab group, your pre-lab report **must** be done individually.

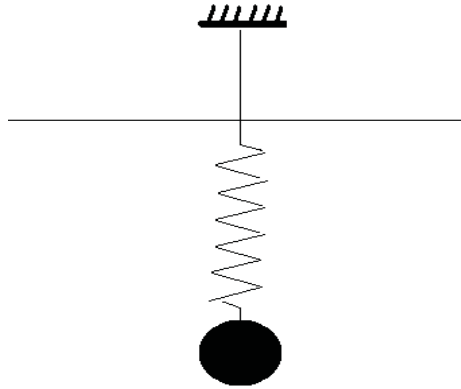
In your final lab report you should include a copy of your pre-lab report (in addition to the one turned in on the day of the lab) along with a short paragraph that connects the pre-lab conclusions to the final report.

*(Time spent on the pre-lab will probably save you many times the effort during and after the lab!)*

1. Read through the entire lab assignment *carefully* so that you have a clear idea of what has to be accomplished. Be familiar with the expected results and calculations so that you can repeat suspicious measurements or reject spurious data during the lab.
2. Pre-read the relevant topics in the course (Reference: Lecture Notes 19, pre-lab recitation presentation, JNN pg. 38-39, 237-260.)
3. Assume we are interested in finding the frequency of vortex shedding ( $f$ ) behind a circular cylinder with diameter  $D$  that moves with a constant speed  $U$  in still water (density  $\rho$

and kinematic viscosity  $\nu$ ). How many dimensionless groups govern this experiment? If everything else is constant, how does frequency of shedding ( $f$ ) vary with the speed  $U$ ? If the cylinder is allowed to oscillate freely in transverse direction, what will happen?

- Write down the equation of motion of a horizontal rigid cylinder (length  $L$ , diameter  $D$ , density  $\rho_s$ ) hung with a vertical spring (spring coefficient =  $k$ ) in water (density  $\rho$ ). How does the added mass affect the natural frequency? How does the drag affect the motion of the cylinder?



- Define basic wave properties, namely wave length, wave number, period, frequency, phase velocity, group velocity, dispersion relation. Make plots/sketches of the: wave length as a function of frequency (dispersion relation); phase velocity as a function of frequency; and group velocity as a function of frequency. How does the water depth affect the wavelength, phase velocity, group velocity for given frequency?
- Think through and plan the lab with your group members. Prepare an action plan for the lab and for tables or graphs. Roughly plot the data you anticipate.

*Be prepared to discuss with the lab staff your action plan when you enter the lab.*

## LABORATORY ASSIGNMENT

### Objectives:

The specific objectives of this laboratory assignment are to:

- Observe the VIV phenomenon and suppression of VIV using hand-towed flexible smooth and straked cylinders
- Measure vortex-induced vibration frequency of a free oscillating cylinder towed at various forward speeds and observe the relation between the amplitude and the frequency of the oscillation

- Measure the frequency, wavelength, phase velocity, and group velocity of various waves generated from the wave maker
- Observe the phenomenon of a long wave overtaking a short wave due to the dispersion effect.

### Equipment:

The towing tank is a long rectangular basin of water, 35m x 2.5m x 1.5m. A motorized carriage above the tank is fitted with a rigid bare cylinder which can be towed at speeds from 0.15 m/s to 1.5 m/s down the length of the tank. The cylinder for measurements in this experiment is rigid and may undergo a harmonic oscillation. At one end of the tank there is a wave-maker and at the other end there is absorbing "beach". 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.

Although the Towing Tank has many instruments/probes for motion/force or wave measurements, we will simply use visual observation and measurements, with the help of a stop watch and measuring tape, in this lab. (Feel free to bring a camera/camcorder.)

### Measurements:

Members of the Towing Tank staff will provide instructions for the operation of the tow carriage and wave maker. Please follow their instructions.

#### 1. Part I: Vortex-Induced Vibration

- (a) Tow a hand-held bare rigid cylinder through the pan at a constant speed. Observe the vortices being shed behind it.
- (b) Tow a hand-held rigid cylinder in the large towing tank and observe the vortex street behind the cylinder. Also take note of what your arm feels
- (c) Tow a hand-held bare flexible bare cylinder through the water at several different speeds to feel and observe the VIV motion of the cylinder. How does the response compare to that of a rigid cylinder? How does the frequency of the motion of the cylinder vary with the forward speed you move?
- (d) Tow a hand-held straked flexible cylinder through the water at several different speeds. How does the response compare to that of the bare cylinder? How might you explain the difference?
- (e) Tow a free oscillating cylinder in the big towing tank at a constant speed. Measure the diameter of the cylinder, towing speed, and vortex-induced vibration frequency and amplitude. Repeat this measurement for 5 ~ 10 different speeds.

#### 2. Part II: Surface Wave Kinematics

- (a) Measure the water depth in the tank.
- (b) Generate a regular wave using wavemaker and measure the wave period, length, phase velocity and group velocity. Repeat this for 5 ~ 10 different frequencies.

- (c) Generate a wave that consists of several wavelengths of a short wave followed by several wavelengths of a long wave and observe the difference between the wave passing a location near the wave maker and that for a location far away from the wave maker.

### **Post-Lab Exercise** (*To be done individually*)

Final results must be primarily presented in tables and graphs. Tables and graphical plots should ALL be in **non-dimensional form**.

The lab report should include names of group members, a copy of your pre-lab preparation, the specific procedure of your group's experiment, data analysis, and a report on the group's discussion of your results.

Besides the above discussion/explanations, a discussion of the following analysis is required in your lab report:

1. Plot non-dimensional frequency of vortex-induced vibration as a function of Reynolds number  $R_e$  (in terms of cylinder diameter) and discuss.
2. Describe the relation between the amplitude and frequency of the vortex-induced vibration and discuss.
3. For free surface waves, plot the wave length, phase velocity, and group velocity as functions of frequency (non-dimensionalize). Compare your results with theory and discuss.

In addition to these, you are encouraged to discuss other hydrodynamic aspects of the experiments. You are also encouraged to design/perform new measurements in addition to those outlined above, with the permission of laboratory staff. Any novel ideas and insightful discussions will be given extra credit in the lab grade.

The lab report should be type-written and edited for grammatical and spelling errors. **Conciseness** is as important as professional quality. Unnecessary length will be regarded as a negative factor in the lab grading.