



13.012 Marine Hydrodynamics for Ocean Engineers  
Fall 2003 Quiz #2

Student name: \_\_\_\_\_

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This is a closed book examination. You are allowed 2 one-sided sheets of 8.5" x 11" paper with notes.

For the problems in Section A, fill in the answers where indicated by \_\_\_\_\_, or in the provided space. When a list of options is presented ([...], [...], [...] etc), circle all the options (all, none, one or more) that apply.

For part B problems: BE SURE TO SKETCH THE PROBLEM, STATE YOUR ASSUMPTIONS AND SHOW YOUR WORK! Use the provided exam booklet.

Use the following constants unless otherwise specified:

Gravity: $g = 10 \text{ m/s}^2$	water density: $\rho_w = 1000 \text{ kg/m}^3$	kinematic viscosity: $\nu_w = 1 \times 10^{-6} \text{ m}^2/\text{s}$
Seawater density: $\rho_w = 1025 \text{ kg/m}^3$	kinematic viscosity: $\nu_{sw} = 1 \times 10^{-6} \text{ m}^2/\text{s}$	
Air density: $\rho_a = 1 \text{ kg/m}^3$	kinematic viscosity: $\nu_a = 1 \times 10^{-5} \text{ m}^2/\text{s}$	

Assume the fluid is incompressible unless otherwise defined.

Give all answers in SI units (kg, m, s). All numerical answers MUST have the proper units attached.

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**Part A:** (30%) Each question #1-6 carries equal weight

- 1) A fishing lure is designed to be towed on the end of a line, fully submerged underwater. The action of towing causes this lure to wiggle its tail like a fish at some frequency,  $f$ , and amplitude,  $a$ . The lure has a length  $l$ , and body diameter  $d$ . It is used for trolling (ie dragged behind the boat at a constant speed) at speed  $U$ . The relevant non-dimensional parameters used for analyzing the drag force on the lure, in terms of the given parameters and fluid properties, are

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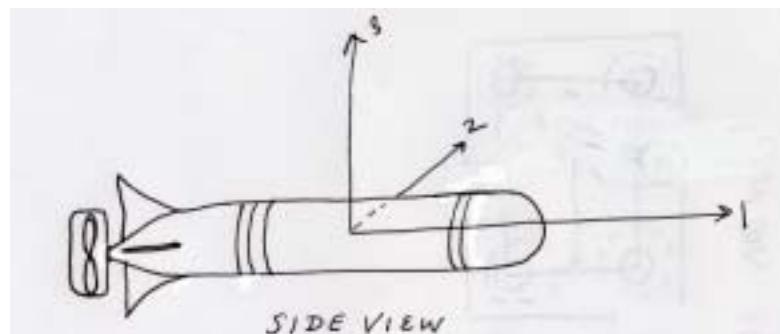
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Note: you may have a lesser or greater number of pi (non-dimensional) groups than spaces.

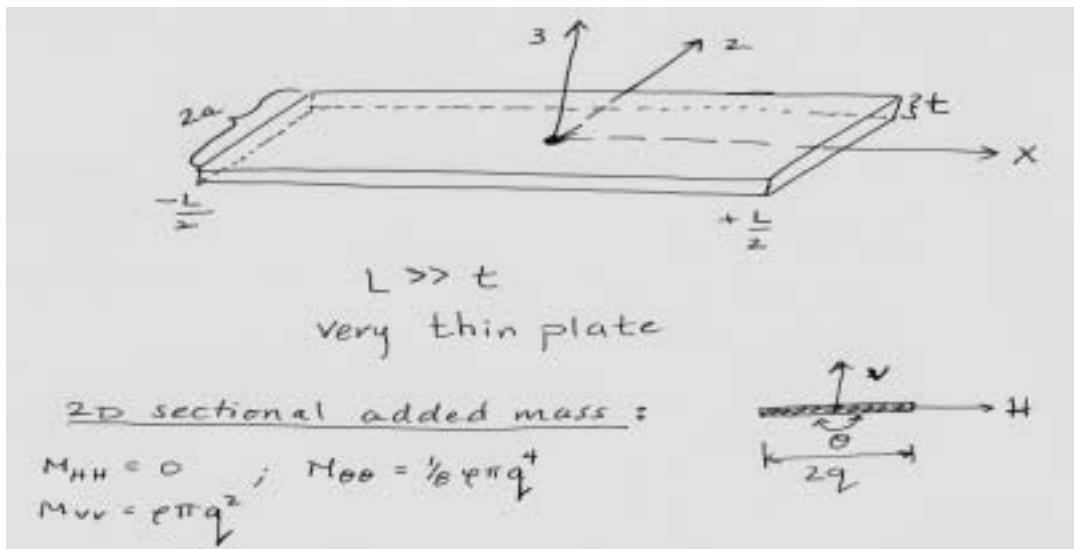
- 2) The Froude number is a ratio of \_\_\_\_\_ effects to \_\_\_\_\_ effects, and is written as  $Fr = \frac{\text{_____}}{\text{_____}}$  in terms of flow velocity, V, ship length, L, fluid properties,  $\rho$  or  $\mu$ , or physical constant, g. Froude number is important in problems with bodies [on] [just below] [far below] the free surface. (Mark all that apply).
- 3) The advance ratio for a propeller is determined as a ratio of \_\_\_\_\_ to \_\_\_\_\_ such that  $J = \frac{\text{_____}}{\text{_____}}$ , given propeller diameter, D, rotation speed, n, inflow (or ship) velocity, V, torque, Q, thrust, T, or fluid properties,  $\rho$  or  $\mu$ .
- 4) You are asked to determine which added mass coefficients are zero in the added mass matrix for the AUV drawn below. The vessel is symmetric top-down and left-right (side view looks identical to top view).



Mark an “X” where the added mass is non-zero and an “O” when the added mass is zero.


- 5) A model propeller is tested in a water tunnel at free stream velocity of 3 m/s. The model propeller has a diameter of 25.4 cm. At its maximum efficiency point, it is operating at 1200 rpm and generating 100 N thrust. The maximum thrust available for a geometrically similar, full-scale propeller, with diameter ten times that of the model operating on a ship moving at 10 m/s, is \_\_\_\_\_ N.

- 6) Given a very thin and long flat plate, drawn below, with length, L, width, 2a, and negligible thickness, and the two-dimensional added mass coefficients for such a cross section:



$$M_{33} = \underline{\hspace{2cm}} \quad M_{22} = \underline{\hspace{2cm}} \quad M_{66} = \underline{\hspace{2cm}}$$

$$M_{55} = \underline{\hspace{2cm}}$$

- 7) (**Bonus +5 points**) A sphere with diameter 5 cm impacts the still free surface of a tank of water at 20 m/s. The **TWO** non-dimensional parameters that are the most important governing parameters *at the instant that the sphere impacts* the water are [Reynolds Number] [Froude Number] [Strouhal Number] [Cavitation Number] [Weber Number] [Drag Coefficient].

**Part B:**

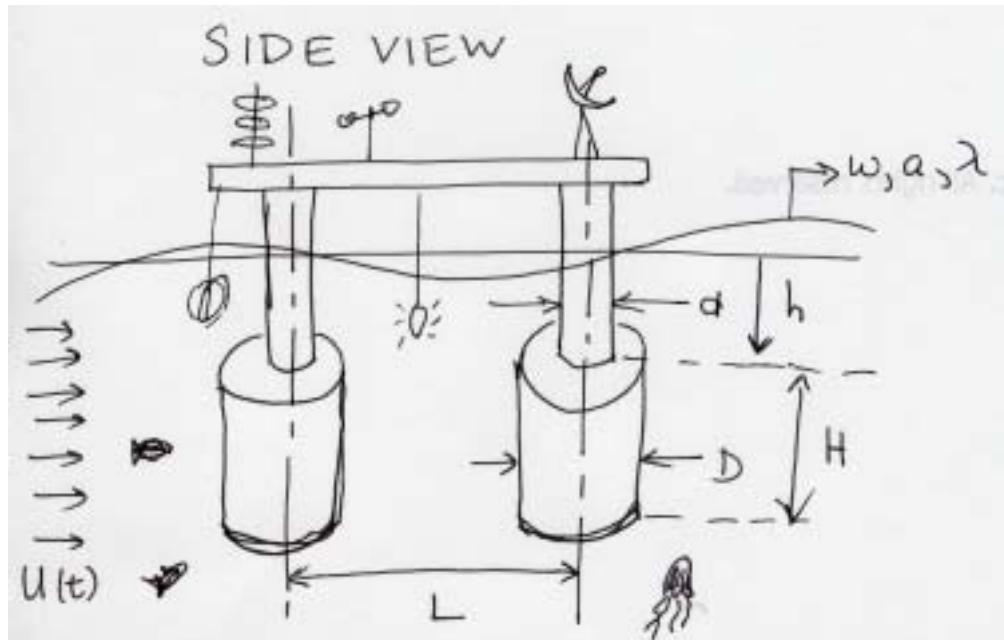
**Problem 1: (15%)**

An underwater cable with uniform mass per unit length  $m^* = 85 \text{ kg/m}$  in the ocean can be modeled as an elastically mounted cylinder aligned perpendicularly to the current (cylinder length along the y-axis, current in x-direction). The cylinder is free to vibrate only in the direction transverse to the flow (vertically, in the z-direction). The cylinder is 10 cm in diameter.

- a) An engineer notices that data from an accelerometer mounted on the pipeline indicates that the cable was vibrating consistently at 5 Hz all day on Monday. Determine the velocity of the current in that region on Monday.
- b) Calculate the *steady* drag (per unit length of the cable) due to vortex shedding using the data from part a. (Give value in Newtons/meter.)
- c) What is the frequency of the unsteady drag (x-direction) force, in terms of the vortex shedding frequency. How does this compare with the frequency of the lift (vertical) force?

Problem 2: (50%)

A semi-submersible offshore platform used as an ocean observatory for instrumentation is installed in the Atlantic Ocean. In this region the current is unsteady,  $U(t)$ , and surface waves are prevalent. The platform is supported by four legs, each of which can be modeled as a smaller diameter cylinder, diameter  $d$ , that extends a depth  $h$  into the water, above a larger diameter cylinder, diameter  $D=4*d$ . At its equilibrium position, the total depth of the platform below the average free surface is  $H+h$ , where  $H = 2*h$ . The platform is square and each leg is a distance  $L = 10*D$  apart.



- a) In this region of the ocean, long swells are persistent in one direction perpendicular to one side of the platform, in addition to a significant, unsteady current. It can be assumed that the incoming deep water waves have a wavelength much longer than the diameter of the legs, and that the amplitude of these waves is  $0.6*d$ .

**Give the expression for the total x-force on one leg of this platform using the appropriate form of Morrison's equation in terms of given body geometry, relevant fluid properties, current and wave conditions.**

**Do you expect this force to be identical on all of the legs? If not which leg(s) would feel the greater force? Explain...**

- b) Determine the natural frequency of this platform in heave in terms of the given body geometry, and physical constants,  $\rho_w$  and  $g$ . The added mass of each leg in heave can be modeled as twice the added mass of a sphere with a diameter equivalent to that of the larger cylinder. All submerged instrumentation can be ignored.
- c) Determine the heave excitation force on this structure due to the incoming waves only.
- d) Write the basic form of the equation of motion for this structure in heave given the forcing term found in part d.

**Do you expect the platform will heave with the *same* or *different* frequency from the heave excitation force? Why?**

- e) In order to obtain accurate data from the instruments on the platform, the heave amplitude and must be minimized and the heave period needs to be long. One way to mitigate the effects of the waves on the structure's motion in heave is to minimize the heave excitation force. **How do you think this can best be achieved? What do you estimate that will do to the natural frequency of the platform? Do you think this is a sensible design?**