13.012 Hydrodynamics for Ocean Engineers
Fall 2004
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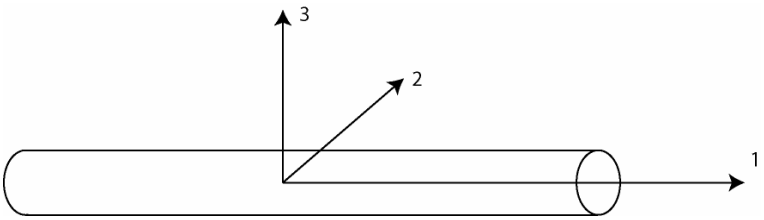
Out: October 19, 2004
Due: October 26, 2004

Determine the 6x6 added mass matrix for the following underwater vehicles, in an infinite fluid with density ρ, in terms of the given variables:

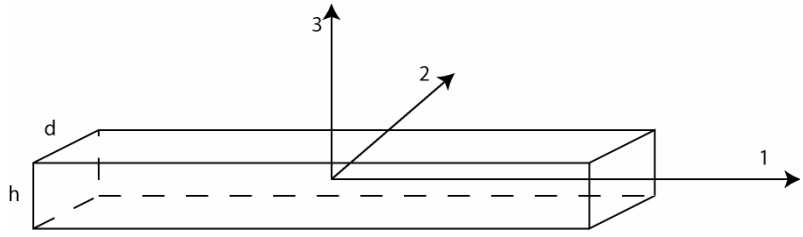
Problem 1

Cylinder length *L*, radius *r*:



Problem 2

Square Cylinder with cross section *h x d* (*h=d*) and length *L*:

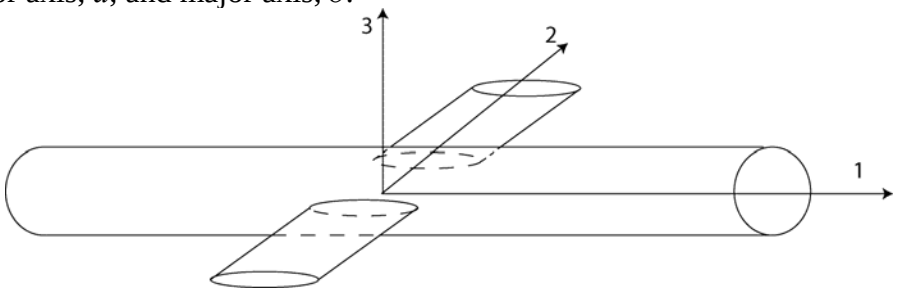


Problem 3

A sphere of volume $\forall = 2\ m^3$ accelerates at $\dot{U} = 5\ m/s^2$ in the ocean with a current that is accelerating at $\dot{V} = -2\ m/s^2$. The horizontal force on the sphere is $F_1 =$ _____N. If the fluid acceleration $\dot{V}$ remains the same, the force F_1 will be zero for $\dot{U} =$ _____ m/s^2.

Problem 4

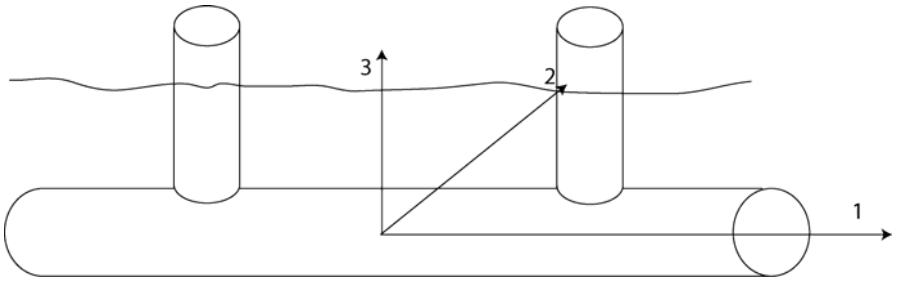
A submarine can be modeled as a cylindrical body (same as in part a), but now with elliptical cross-section control surfaces length *S* at mid span. The elliptical cross-sections have minor axis, *a*, and major axis, *b*.



Problem 3. part b: Find m_{33}, m_{44}, and m_{55} for the submarine in part c given the following dimensions for a submarine in seawater: *L = 100m, r = 8m, S = 10m, a = 1m, b = 4m*. Double check the units!

Problem 5

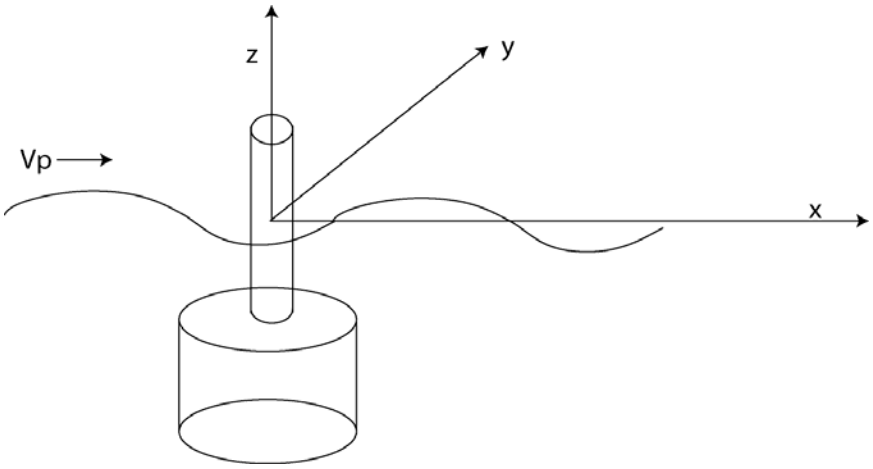
One pontoon for a floating oceanographic instrumentation platform is sketched below. The horizontal float has a length *L = 10 m*, diameter *D = 2 m*, and the vertical struts are located $x = \pm L/4$ from the *z*-axis. The vertical struts have diameter *d = 1m*. In it's equilibrium state, the total draft of the structure is *h = 8m*.



a) Determine the added mass in heave and pitch. Ignore the fact that the vertical struts pierce the surface and consider only the submerged portions of the vessel.
b) From an equilibrium position, the pontoon is pushed down slightly. Determine the vertical restoring force on the pontoon.
c) Determine the natural frequency of the pontoon in heave.

Problem 6

A cylindrical buoy is floating in an oncoming wave train as sketched below:



The frequency and amplitude of the waves is $\omega = 0.5\ rad/s$ and $a = 0.2\ m$. The waves are deep water waves and propagate in the positive x-direction. The centerline of the buoy is positioned at $x=0$. The buoy is constructed as two cylinders stacked on end. The top cylinder has diameter $d = 1\ m$ and the bottom cylinder has diameter $D = 5$ meters. The top cylinder extends 5 meters under the water surface and the total draft of the buoy is 9 meters, in equilibrium position. (Thus the height of the lower, large cylinder is 4 meters)

a) Estimate the added mass of the buoy in heave by using the added mass of a sphere in heave with the same radius as the larger cylinder. Ignore any added mass due to the buoy piercing the free surface.
b) Calculate the heave excitation force acting on the buoy due to the presence of the waves.
c) Determine the natural frequency of the buoy.
d) If the incident waves were near the natural frequency of the buoy what would you expect the heave motion to be compared to when the wave frequency was far away from the natural frequency?