Ph.D. Qualifying Examination

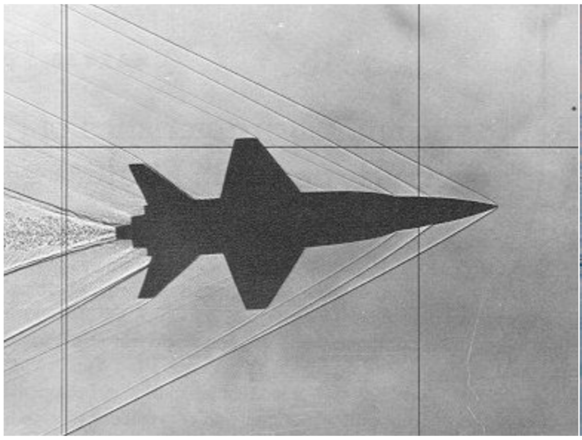
Fluid Mechanics

Fall 2018

Notes:

- Time allowed: 2.5 hours.
- Part 1 of exam (20%) is closed book and closed-notes, no calculator (turn it in before beginning work on part 2)
- Part 2 of exam (80%) is open book (1 textbook), open notes (one notebook), and calculator allowed.
- State your assumptions, methods, and procedures. Show your work on these exam sheets. (Add additional sheets, if needed.)
- Laptops, cell phones, tablets are not allowed.

Fluids Part 1 (20%): closed book and closed-notes, no calculator
Provide answers to 4 of 5 problems (on additional pages). Clearly indicate which problem should not be graded.




1. These two pictures (NASA X-15 in a supersonic wind tunnel and a duck in shallow water) have at least one prominent feature in common, although arising from two physically different systems of governing equations. Name it and describe it.

2. In many cases, physical models are derived using the concept of a `control volume'. Define a control volume.

3. Define Prandtl number, describe its physical meaning, provide two examples of problems where it is relevant.

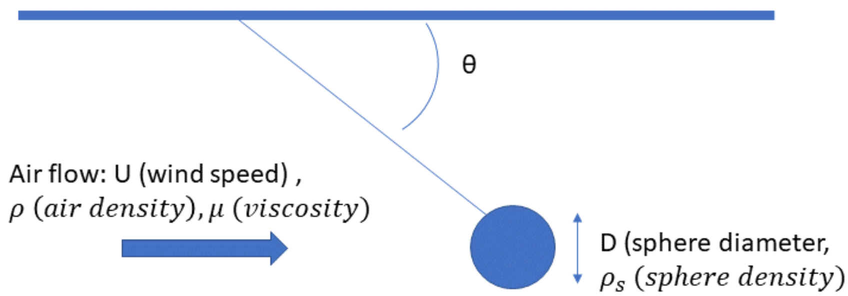
4. For a wing, what is tip vortex? Explain its underlying cause.

5. Describe the mechanism that leads to boundary layer separation.

Part 2 (80%) open book (1 textbook), open notes, calculator allowed

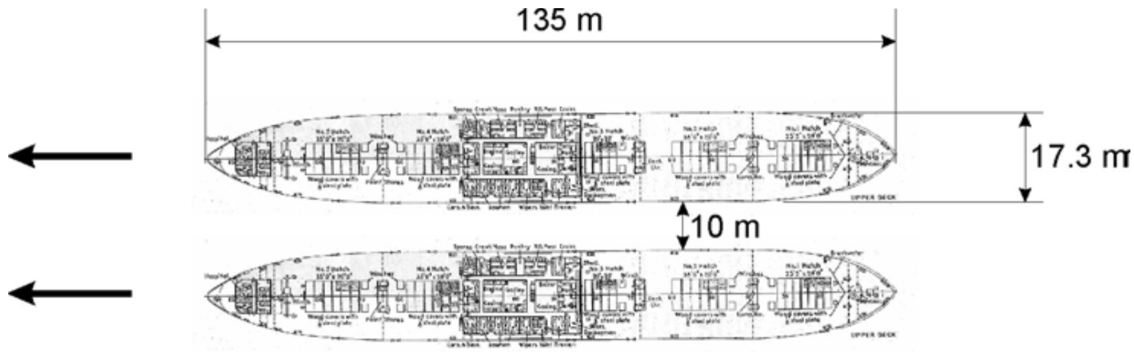
Problem 1.

A heavy sphere (diameter D, density ρ_s) attached to a string hangs at an angle θ with the horizontal when immersed in a stream of air with velocity U, density ρ, and dynamic viscosity μ. Derive an expression for θ as a function of the sphere and flow properties. Neglect the string drag.



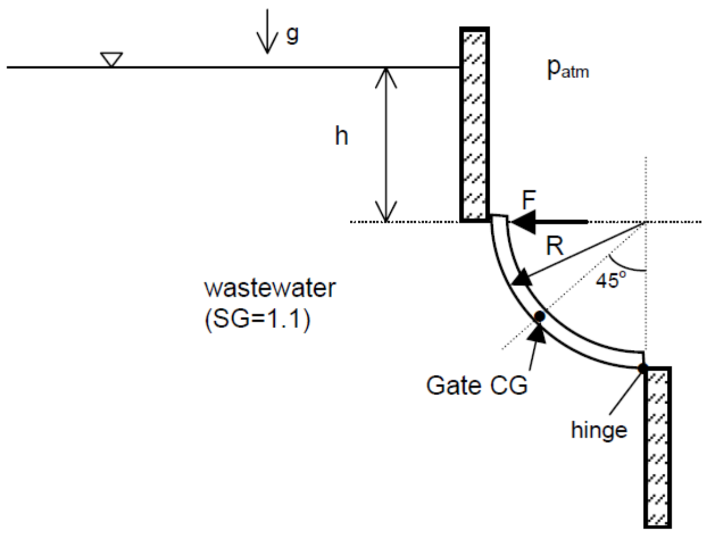
Problem 2

It is known that sea-going vessels traveling next to each other on parallel or near-parallel courses exhibit a force of attraction, which led to multiple collisions. Estimate this force of attraction for two World War II era Liberty ships (135 m length, 17.3 m beam, 8.5 m draft) steaming parallel to each other at 8 knots and separated by 10 m of water. Disregard the effects due to the shape of the bow and stern. Note: 1 knot = 1852 meters/hr.



Problem 3.

A thin, quarter-circle gate (radius *R*= 1.5 m) in a wastewater (SG = 1.1) reservoir is *L*=5 m long (into the page). Its mass is 5,000 kg; the gate center of gravity is halfway along the arc as shown. What horizontal force *F* (kN) is required to keep the gate closed when *h*= 2 m (see sketch)?



Problem 4

A nozzle for a spray system is designed to produce a flat radial sheet of water. The sheet leaves the nozzle at $V_2 = 10$ m/s, covers an arc of 180°, and has thickness $t = 1.5$ mm. The nozzle discharge radius is $R = 50$ mm. The water supply pipe is 35 mm in diameter and the inlet pressure p_1 is 150 kPa (abs). Evaluate the force exerted by the nozzle on the coupling. Gravity direction is normal to the plane of the schematic.