Ph.D. Qualifying Examination

Fluid Mechanics

Fall 2008

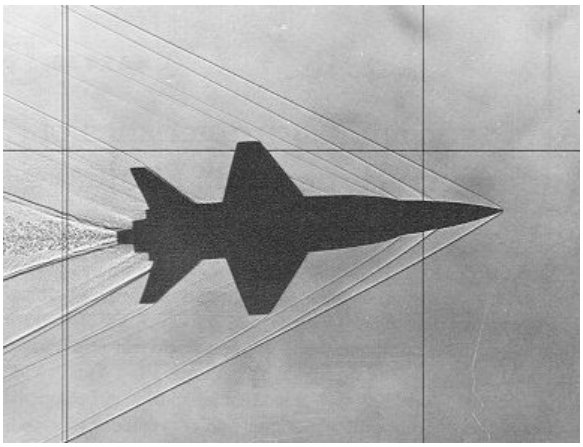
Notes:

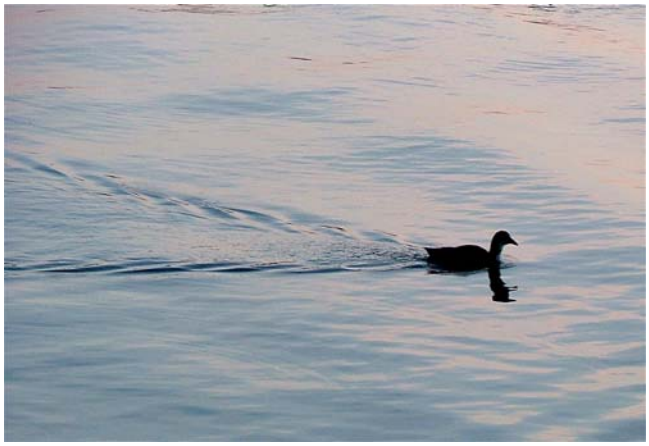
- Time allowed: 2.5 hours.
- Part 1 of exam (20%) is closed book and closed-notes, no calculator (turn it in before beginning work on part 2
- Part 2 of exam (80%) is open book (1 textbook), open notes, and calculator allowed.
- State your assumptions, methods, and procedures. Show your work on these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

Fluids Fa08 Part 1 (20%) closed book and closed-notes, no calculator

Work 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.

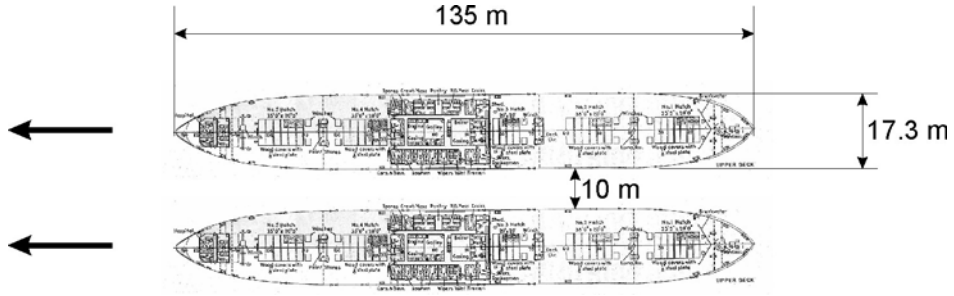
3. In many cases, scale models are tested in wind tunnels or water tanks to predict the performance of larger apparatus. Consider the case where the Reynolds number is the same for a model airplane and the life-size counterpart. Can the results for the model be used in all cases? Explain.

4. The Bernoulli equation is a very useful relation, but it has some limitations. Is it reasonable to apply the equation through a propeller? Explain.

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

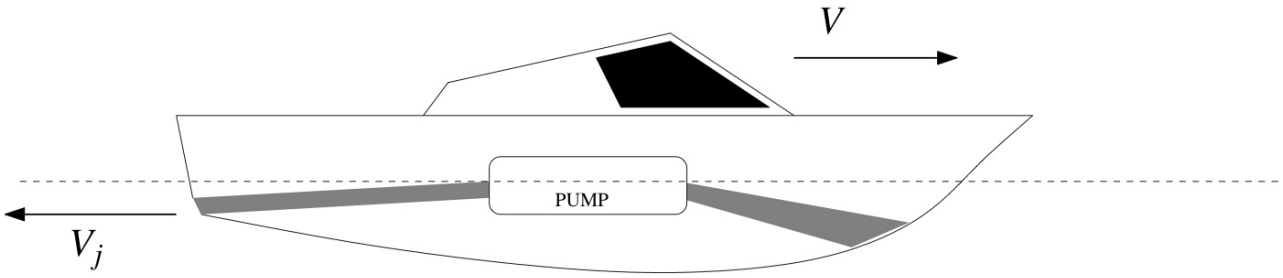
Fluids Fa08 Part 2 (80%) open book (1 textbook), open notes, calculator allowed

1. 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.



Fluids Fa08 Part 2 (80%) open book (1 textbook), open notes, calculator allowed

2. A waterjet-powered boat moves with velocity V with respect to a body of water with density ρ. The velocity of the jet with respect to the boat is V_j and can be considered horizontal. The pump has a volumetric capacity Q. If the drag on the boat is kV^2, where k is a constant, write an expression for the velocity of the boat. State any assumptions.



Fluids Fa08 Part 2 (80%) open book (1 textbook), open notes, calculator allowed

3. A turbine flowmeter measures flow in a pipe with a free-wheeling rotor whose rotation rate is picked off by a magnetic sensor. The flow rate Q depends on rotor angular velocity Ω, rotor radius R, and fluid kinematic viscosity ν.
   a. Perform a dimensional analysis of this system. Identify a Reynolds number among your dimensionless groups, noting the velocity scale used.
   b. A prototype meter rotates at 500 rpm for a flow rate of 0.8 m^3/s. For a 1:4 scale model determine the rotor angular velocity and flow rate if it is properly scaled.