

**Ph.D. Qualifying Examination**  
*Fluid Mechanics*

**2023**

Notes:

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

**Part 1 (closed book, closed notes, 20 pts.)**

a) Consider a laboratory water-tunnel test of a 1/20 scale model of a container ship. The Reynolds number of the experiment is matched to the design Reynolds number of the ship. What else must be considered when translating the results of the test to the full-scale ship design?

b) Consider the same experiment. If the design speed of the ship is 10 knots (1 knot = 1852 km/hr), how fast must the water-tunnel flow be? Is it realistic?

c) Explain why helium weather balloons, which are used to measure atmospheric conditions at high altitude, are normally released while filled to only 10%-20% of their maximum volume.

d) An old parlor trick uses an empty thread spool and a playing card. The playing card is placed against the bottom of the spool. Contrary to intuition, when one blows downward through the central hole in the spool, the card is not blown away. Instead, it is “sucked” up against the spool. Explain.

e) A steel needle can be made to float on the surface of water even though it is denser than the water. Explain why.

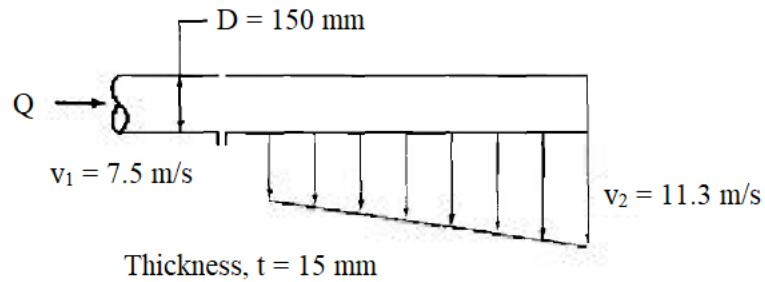
## Part 2 (open book, open notes)

### Problem 1 (20 pts.)

Water is discharged from a narrow slot in a 150 mm diameter pipe. The resulting horizontal two-dimensional jet is 1 m long and 15 mm thick, but of nonuniform velocity. The pressure at the inlet section is 30 kPa (gage).

Calculate

- the volume flow rate at the inlet section and
- the forces required at the coupling to hold the spray pipe in place. Neglect the mass of the pipe and the water it contains.

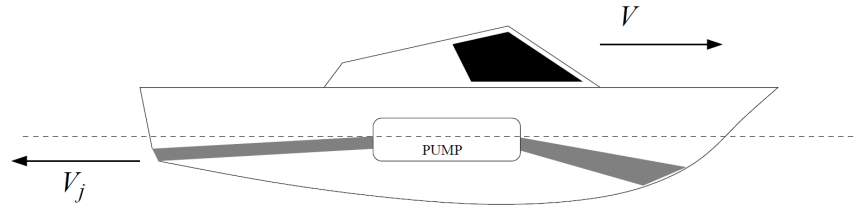


**Problem 2 (20 pts.)**

The inlet contraction and test section of a laboratory wind tunnel are shown. The air speed in the test section is  $U = 22.5$  m/s. A total-head tube pointed upstream indicates that the stagnation pressure on the test section centerline is 6.0 mm of water below atmospheric. The corrected barometric pressure and temperature in the laboratory are 99.1 kPa (abs) and 23°C. Evaluate the dynamic pressure on the centerline of the wind tunnel test section. Compute the static pressure at the same point. Qualitatively compare the static pressure at the tunnel wall with that at the centerline. Explain why the two may not be identical.

**Problem 3 (20 pts.)**

A waterjet-powered boat moves with velocity  $V$  with respect to a body of water with density  $\rho$ . The velocity of the jet with respect to the boat  $V_j$  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.



**Problem 4 (20 pts.)**

Find the weight (kN) of a gate that opens just as liquid depth reaches  $h = 2$  m. The gate is constructed from one-quarter ( $90^\circ$  section) of a circular pipe of radius  $R = 80$  cm. The width of the gate into the page (or length of the pipe section) is  $w = 4$  m. The liquid has specific gravity  $SG = 1.20$ .

