MIE 340, Fluid Mechanics, Spring 1998
FINAL EXAM : **NAME_____**

OPEN BOOK, OPEN NOTES – 4 Problems

During this exam, <u>use the following values for these fluid properties</u>:

Density of water = 1000 kg/m^3
Density of air = 1.2 kg/m^3
Density of mercury = 13550 kg/m^3
Acceleration of gravity = 9.8 m/s^2
Atmospheric Pressure = 100,000 Pa
Viscosity of water = 1.0e-3 kg/(m s)
Viscosity of air = 1.8e-5 Ns/m^2

Hints:

(1) Answer the questions.
(2) Use the values stated above.
(3) Check your answers.
(4) Check your signs.
(5) Check your assumptions afterwards.
(6) Relax – You know this stuff.

Statement & Signature:

Short Answer Questions:

(1a) If you want to test a 1/20 scale model of a airplane in a water tunnel, how much faster does the water tunnel speed have to be than the airplane operating speed?

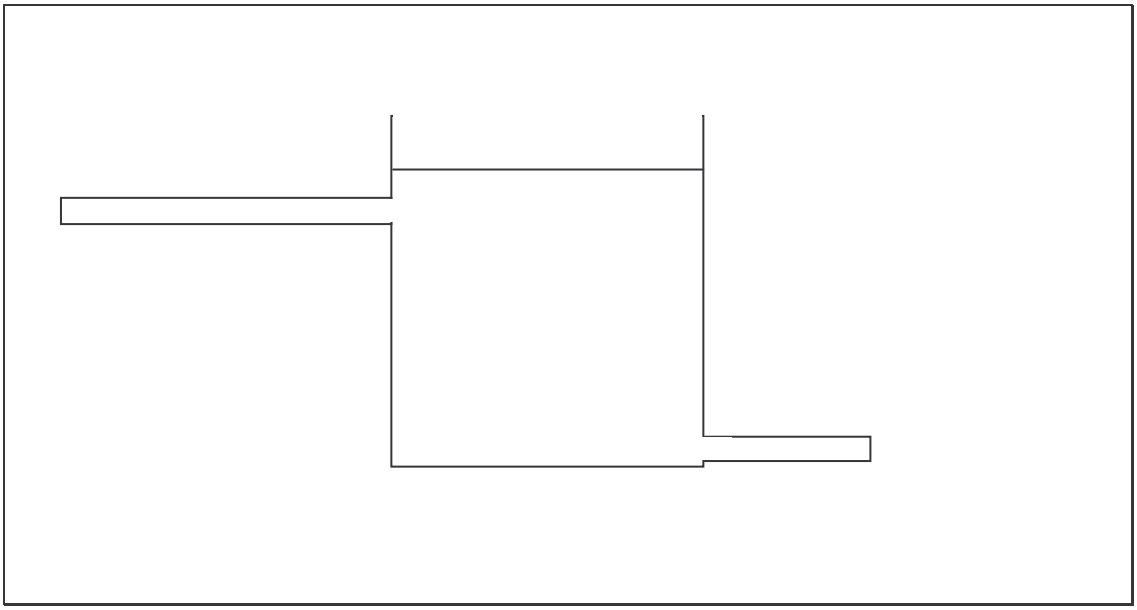
(1b) What is the mathematical definition of vorticity? Describe what it is physically and where it comes from. Does a vortex (tornado) contain lots of vorticity?

(1c) What is the gage pressure at the bottom of a 1km vertical pipe that is closed at the bottom and filled with water?

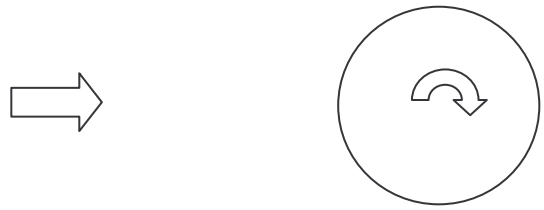
(1d) Roughly how fast does an object need to go through air in order for the air to begin acting like a compressible fluid? Explain your reasoning.

2. The large open water tank shown below has two outlets. The left outlet has a 1cm diameter steel pipe attached that is 15m long. The left pipe is horizontal and 10cm below the water surface. The right outlet has a 1cm diameter steel pipe attached that is 5m long and has an exit velocity of 5m/s. It runs horizontally from the bottom of the tank. Assume the water surface level does not change and the pipes discharge into the air.

(a) Use the right pipe to determine the height of the surface.
(b) Determine the velocity of the left pipe.
(c) Determine the pressure drop in each pipe.
(d) What is the <u>horizontal</u> force (magnitude *and* direction) required to hold the entire system in place?



3. The flow around a rotating cylinder is described by the streamfunction $\psi_z = U\sin\theta(r - \frac{R^2}{r}) + \Omega R^2 \ln\frac{r}{R}$, where U (the translational speed of the cylinder), Ω (the rotation rate), and R (the radius) are constants.



(a) Calculate the expression for the velocity vector, $\mathbf{v} = \begin{pmatrix} v_r \\ v_\theta \\ v_z \end{pmatrix}$ in terms of R, U and Ω.

(b) Plot the velocity vector on the <u>surface</u> of the cylinder at 45 degree intervals (θ = 0, $\pi/4$ $\pi/2$, $3\pi/4$, π, $5\pi/4$, $3\pi/2$, $7\pi/4$ radians). [Assume U=1.0, R=1.0 and $\Omega = \sqrt{2}$].

(c) There is a sideways force on the cylinder due to the rotation. Is the force upwards or downwards? Explain why (and mention the relevant equations).

(d) The nondimensional coefficient of lift C_L for a rotating cylinder is a function of U, R and Ω. What is the simplest functional relationship for the coefficient of lift in terms of these quantities.

(e) If the coefficient of lift is a linear function of the rotation rate derive an equation for the <u>lift force</u> on a spinning cylinder.

4. An advertising billboard is 3m high by 6m wide.

(a) What is the force on the billboard when the wind blows at 5m/s directly perpendicular into the billboard?

(b) What is the force on the billboard when the wind blows at 5m/s directly along the billboard?

(c) What is the force on a scaled down billboard when the wind blows at 5m/s directly along the billboard, and the new billboard is 1/5 the size in both directions (1/25 the area)?