For each multiple choice question, please circle the correct answer(s). Ask the proctor during the exam if you don’t understand the question.

1. Can the Bernoulli equation \( \frac{P}{\rho} + \frac{V^2}{2} + gz = \text{const} \) be used to obtain a good (within a factor of 3) estimate of:
   a. The pressure rise along a streamline that goes through a shock wave.
   b. The pressure drop in water flow through a pipe.
   c. The pressure in the center of the eye of a hurricane given the pressure at the edge of the eye.
   d. The lift produced by the wing of a commercial passenger aircraft.
   e. The pressure fluctuations in front of a speaker operated at 256 Hz.

2. The steps required to use a computational fluid dynamics package to simulate a flow include:
   a. Creating a grid or mesh of nodes throughout the domain of interest.
   b. Specifying initial and boundary conditions.
   c. Performing a control volume analysis using a large control volume that encompasses the domain of interest.
   d. Specifying a velocity profile such as a linearly decreasing velocity profile along a slice through the interior of the domain of interest.
   e. Updating values such as \( u \) and \( v \) at each of the nodes until differential equations of motion are nearly satisfied throughout the domain of interest.
   f. Using the Bernoulli equation at selected points within the domain of interest.

3. For which of the following applications would integral (control volume) analysis be more appropriate than differential analysis?
   a. Determining the drag on an object in a wind tunnel given only the upstream flow conditions.
   b. Determining the force necessary to support a fire hose while in use given the nozzle output flow conditions.
   c. Determining the drag and lift on an airfoil in a wind tunnel given conditions everywhere on the boundaries of the wind tunnel test section.
   d. Providing guidance for ways to modify wing geometry to increase lift or reduce drag, again given conditions everywhere on the boundaries of the wind tunnel test section.

4. If you wished to solve for the pressure on the front bumper of your car as you travel at 55 mph, which of the following equations could be useful:
   a. \( \frac{P}{\rho} + \frac{V^2}{2} + gz = \text{const} \)
   b. \( \rho \left( \frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} + w \frac{\partial u}{\partial z} \right) = -\frac{\partial \rho}{\partial x} + \mu \left( \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} \right) \)
   c. \( \rho \left( \frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} + w \frac{\partial u}{\partial z} \right) = -\frac{\partial \rho}{\partial x} \)
   d. \( \frac{\Delta p}{\rho V^2} = f \left( \frac{\rho V D}{\mu} \right) \)
5. Use of the Buckingham Pi theorem provides:
   a. the number of relevant dimensionless groups
   b. dimensionless groups
   c. the physical meaning of the dimensionless groups
   d. the function $f$ in $\Pi_1 = f(\Pi_2, \Pi_3, ..)$

6. Consider the velocity field $\vec{V} = x\hat{i}$
   a. For an incompressible fluid, this field satisfies conservation of mass
   b. The acceleration of a particle in this field increases with $x$
   c. The pressure of an incompressible, inviscid fluid in this field increases with $x$

7. The pressure, $p$ [kPa], in an organ pipe depends on the frequency of the note $\nu$ [Hz], the density, $\rho$ [kg/m$^3$], viscosity, $\mu$ [kg/m-s], speed of sound, $c$ [m/s], length, $L$ [m] and specific heat ratio $c_p/c_v$ [-]. Which of the following are possible dimensionless groups
   a. $\frac{\rho L^2 \nu}{\mu}$
   b. $\frac{c\nu}{L}$
   c. $\frac{\rho Lc}{\mu}$
   d. $\frac{p}{\nu\mu}$
   e. $\frac{pc\nu}{\rho L^2 \mu}$
In the figure shown, water ($\rho = 1000 \text{ kg/m}^3$) discharges from a nozzle into the atmosphere. The free jet strikes a stagnation tube as shown. The pressure at point 1 is 110 kPa absolute, and flow losses are negligible. Find:

a) The mass flow in kg/s
b) The height, $H$ in meters, that the liquid rises in the stagnation tube

\[ \frac{P_1}{\rho} + \frac{V_1^2}{2} + gZ_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2} + gZ_2 \]

\[ \frac{P_1 - P_2}{\rho} = \frac{1}{2} (V_2^2 - V_1^2) \]

**MASS:** \[ \rho A_1 V_1 = \rho A_2 V_2 \quad \Rightarrow \quad V_2 = \frac{A_1}{A_2} V_1 \]

\[ \frac{2(P_1 - P_2)}{\rho} = V_1^2 \left[ (\frac{A_1}{A_2})^2 - 1 \right] \quad \Rightarrow \quad V_1 = \sqrt{\frac{2(P_1 - P_2)}{\rho} \left[ (\frac{A_1}{A_2})^2 - 1 \right]} \]

\[ V_1 = \sqrt{\frac{2(110,000 - 101,300) \text{ N/m}^2}{(1600 \text{ kg/m}^3) \left[ (\frac{12}{4})^4 - 1 \right]}} = 0.47 \text{ m/s} \]

\[ \dot{m} = \rho A_1 V_1 = (1600 \text{ kg/m}^3)(\frac{\pi}{4})(0.12 \text{ m})^2(0.47 \text{ m/s}) = 5.3 \text{ kg/s} = \dot{m} \]

\[ \dot{Z} = H = \frac{P_1 - P_3}{\rho g} + \frac{V_2^2}{2g} = \frac{(110,000 - 101,300) \text{ N/m}^2}{(1600 \text{ kg/m}^3)(9.81 \text{ m/s}^2)} + \frac{(0.47 \text{ m/s})^2}{2(9.81 \text{ m/s}^2)} = 0.91 \text{ m} = H \]