ExES202 - Fluid & Thermal Systems — Winter 2006-2007
Exam I — Olson & Richards

Name______________________________ Box Number____________________

Problem 1 (22) __________________

Problem 2 (20) __________________

Problem 3 (44) __________________

Problem 4 (24) __________________

TOTAL (100) __________________

NOTE:

(1) Closed book/notes; however, you may use a single-sided, hand-written equation page you prepared.

(2) For maximum credit,
... solve problems symbolically first showing logic and reasoning for solution,
... substitute numbers into the equations clearly showing any required unit conversion factors
... then and only then crunch numbers on your calculator.
If I only have to punch your numbers into a calculator to get a correct answer (including units) you will receive full credit. **Don't make me guess what you are doing and why you chose to do this.**

Unless told differently in a specific problem use the following information where appropriate:

Useful Information		
	SI	**USCS**
Density of water @ T_{room}	**1000 kg/m^3**	**62.4 lbm/ft^3**
Acceleration of gravity	**9.81 m/s^2**	**32.2 ft/s^2**
Std Atmospheric Pressure	**101.3 kPa (abs)**	**14.7 psia**

Problem 1 (22 points)

Part (a) (4 points)

Does the velocity field shown below satisfy continuity (conservation of mass) for an incompressible flow? Show your reasoning.

$$V_x = 2x \qquad \text{and} \qquad V_y = 3xy$$

Part (b) (4 points)

Find the velocity field (V_x and V_y) associated with the stream function $\psi = 5x + y$.

Part (c) (4 points)

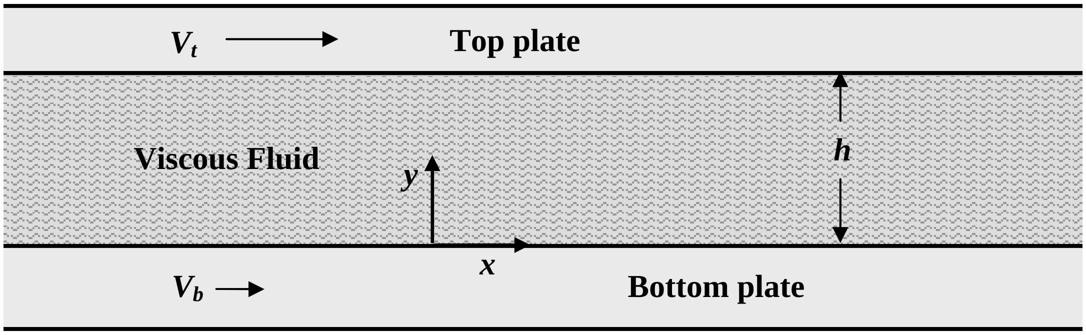
Is the following flow irrotational? Show your reasoning.

$$V_x = 2y \qquad \text{and} \qquad V_y = -2x$$

Problem 1 (continued)

Part (d) (10 points)

Consider two (infinitely long) flat plates with a viscous fluid between the plates (see sketch). Each plate moves to the right with a different velocity.



The top plate moves to the right at a velocity V_t, the bottom plate moves to the right at a velocity V_b, the height of the gap is h, and the viscosity of the fluid is μ. The flow is steady and incompressible, with no pressure gradient in the x-direction. Under these conditions, the Navier-Stokes equations reduce to a single equation:

$$\mu \frac{d^2 V_x}{dy^2} = 0$$

Using the given information, determine the velocity profile $V_x(y)$ in the viscous fluid.

Problem 2 (20 points)

We wish to measure the pressure of a gas in a jar by using the two-fluid manometer shown in the figure. The manometer contains a red fluid and a blue fluid.

Assume we know the following information:

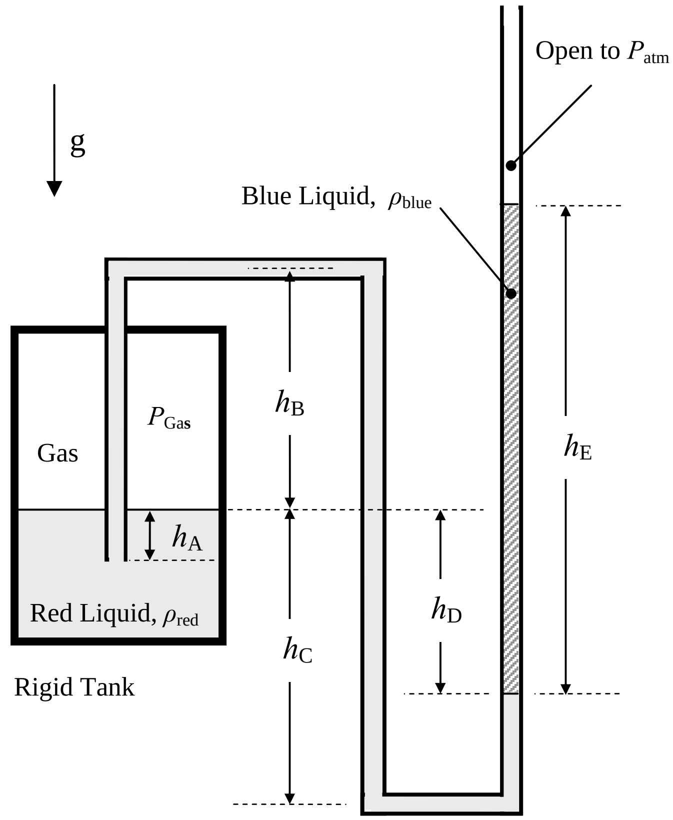
Distances: h_A, h_B, h_C, h_D, h_E (see figure)

Acceleration due to gravity: g

Density of two fluids: ρ_{red} and ρ_{blue}

Atmospheric pressure: P_{atm}

Determine the pressure P_{Gas} of the gas trapped above the red liquid. Your answer should be an equation with symbols.



Problem 3 (44 points)

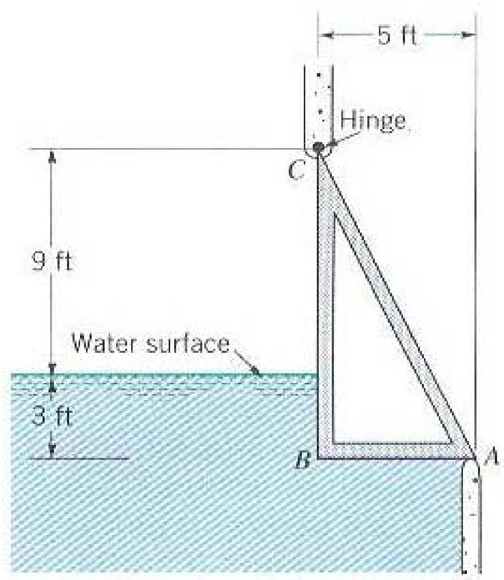
A gate having the cross section shown in the figure is 4 ft wide (into the paper) and is hinged at *C*. Both sides of the gate are vented to the atmosphere.

The gate weighs 18,000 lbf, and its mass center is 1.67 ft to the right of the plane *BC*. The hinge at *C* is frictionless, and the wall at *A* can only support a vertical reaction force.

The density of water is 62.4 lbm/ft^3.

(a) Sketch *and* label the pressure distributions acting on the gate.

(b) Determine the vertical reaction of the wall on the gate at *A* when the water level is 3 ft above the base. For full credit, you must draw a complete free-body diagram.



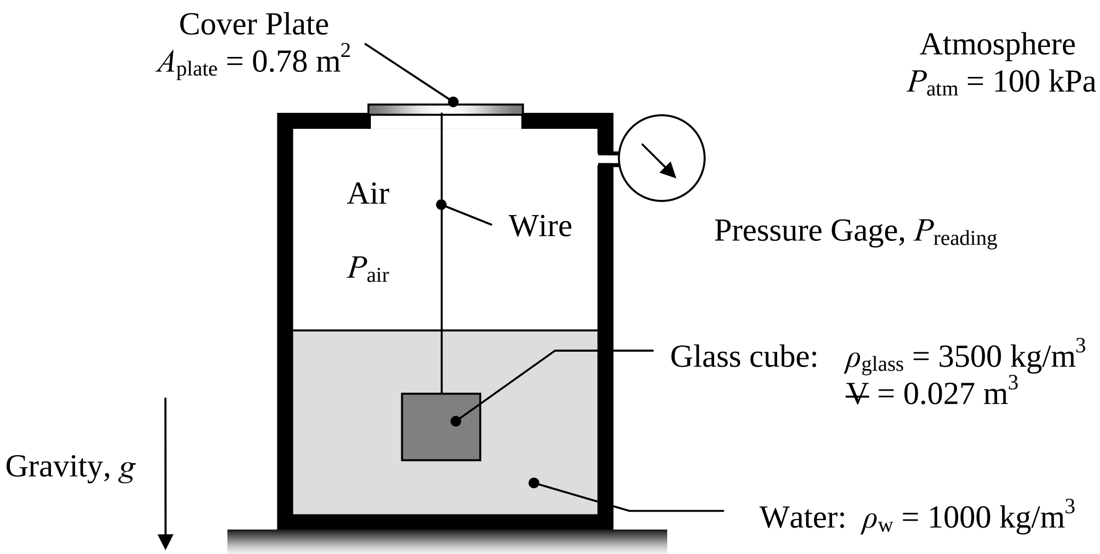
Problem 4 (24 points)

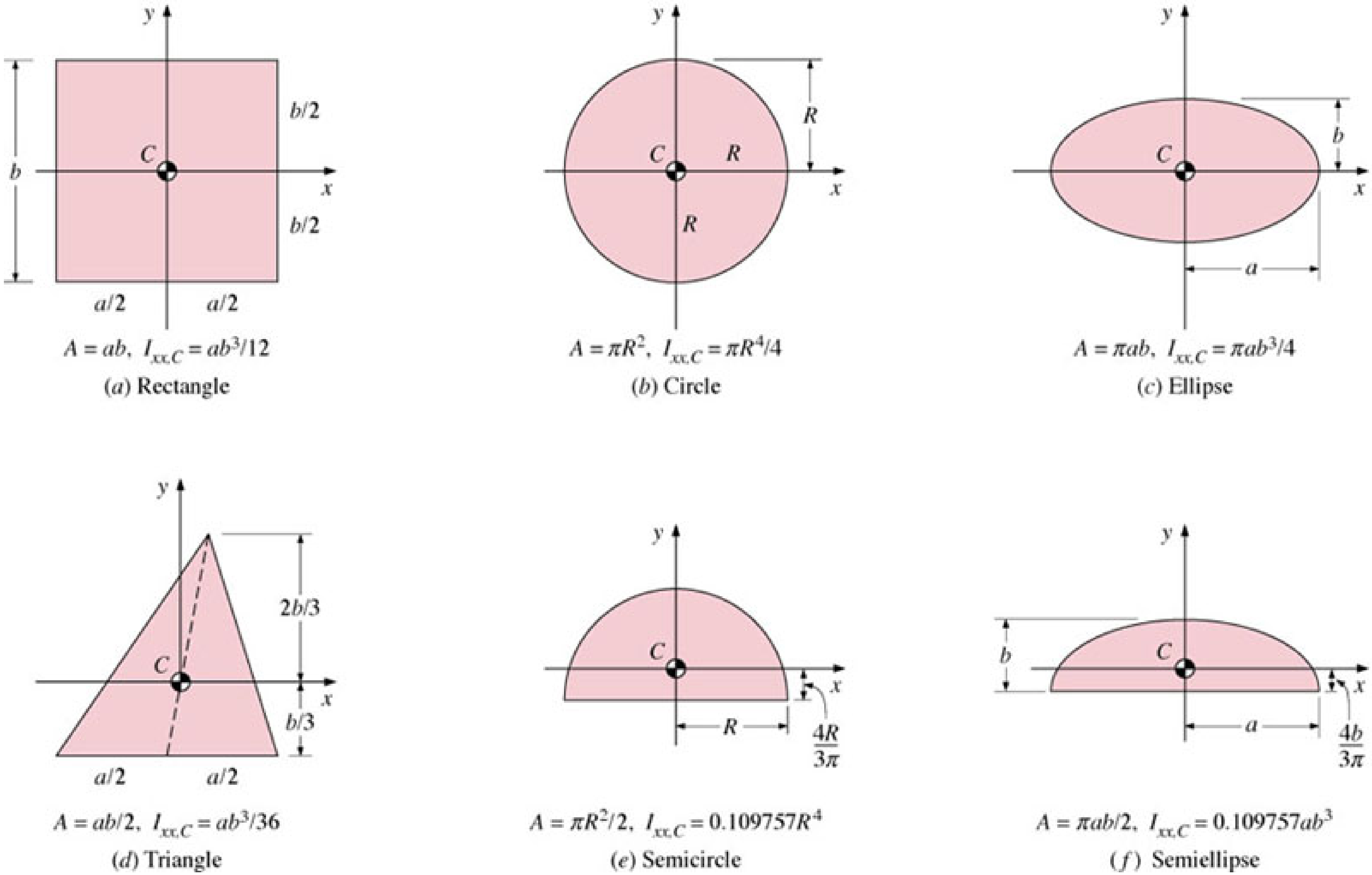
An improvised safety valve is "pops" open when the air pressure in the tank gets too large.

The valve consists of a glass cube hanging by a wire from a small cover plate. The cover plate rests loosely over an opening in the tank, and the glass cube is submerged in water. The wire and cover plate have negligible mass. The figure shows the cover plate in the closed position.

When the valve "pops" open, the cover plate is blown off the tank and air escapes.

What is the reading on the pressure gage, $P_{reading}$, when the air pressure in the tank is just large enough to "pop" the cover plate? [**A clear, complete symbolic solution will get full credit! A numerical answer is not required.]**





Cengel & Turner, Fig 11-6 –

Length

1 ft = 12 in = 0.3048 m = 1/3 yd

1 m = 100 cm = 1000 mm = 39.37 in = 3.2808 ft

1 mile = 5280 ft = 1609.3 m

Mass

1 kg = 1000 g = 2.2046 lbm

1 lbm = 16 oz = 0.45359 kg

1 slug = 32.174 lbm

Temperature Values

$(T/K) = (T/{}^{o}R) / 1.8$

$(T/K) = (T/{}^{o}C) + 273.15$

$(T/{}^{o}C) = [(T/{}^{o}F) – 32]/1.8$

$(T/{}^{o}R) = 1.8(T/K)$

$(T/{}^{o}R) = (T/{}^{o}F) + 459.67$

$(T/{}^{o}F) = 1.8(T/{}^{o}C) + 32$

Temperature Differences

$(\Delta T/{}^{o}R) = 1.8(\Delta T / K)$

$(\Delta T/{}^{o}R) = (\Delta T/{}^{o}F)$

$(\Delta T / K) = (\Delta T/{}^{o}C)$

Volume

1 m^3 = 1000 L = 10^6 cm^3 = 10^6 mL = 35.315 ft^3 = 264.17 gal

1 ft^3 = 1728 in^3 = 7.4805 gal = 0.028317 m^3

1 gal = 0.13368 ft^3 = 0.0037854 m^3

Volumetric Flow Rate

1 m^3/s = 35.315 ft^3/s = 264.17 gal/s

1 ft^3/s = 1.6990 m^3/min = 7.4805 gal/s = 448.83 gal/min

Force

1 N = 1 kg·m/s^2 = 0.22481 lbf

1 lbf = 1 slug·ft/s^2 = 32.174 lbm·ft/s^2 = 4.4482 N

Pressure

1 atm = 101.325 kPa = 1.01325 bar = 14.696 lbf/in^2

1 bar = 100 kPa = 10^5 Pa

1 Pa = 1 N/m^2 = 10^{-3} kPa

1 lbf/in^2 = 6.8947 kPa = 6894.7 N/m^2

[lbf/in^2 often abbreviated as "psi"]

Energy

1 J = 1 N·m

1 kJ = 1000 J = 737.56 ft·lbf = 0.94782 Btu

1 Btu = 1.0551 kJ = 778.17 ft·lbf

1 ft·lbf = 1.3558 J

Energy Transfer Rate

1 kW = 1 kJ/s = 737.56 ft·lbf/s = 1.3410 hp = 0.94782 Btu/s

1 Btu/s = 1.0551 kW = 1.4149 hp = 778.17 ft·lbf/s

1 hp = 550 ft·lbf/s = 0.74571 kW = 0.70679 Btu/s

Specific Energy

1 kJ/kg = 1000 m^2/s^2

1 Btu/lbm = 25037 ft^2/s^2

1 ft·lbf /lbm = 32.174 ft^2/s^2