ES201 - Examination I   Winter 2003-2004   Adams / Richards

NAME______________________________________ BOX NUMBER______________

Circle Instructor/Section: Richards – 4th Period   Adams – 4th Period   Adams – 6th Period

Problem 1 (16) ______________

Problem 2 (24) ______________

Problem 3 (36) ______________

Problem 4 (24) ______________

Total (100) ______________

INSTRUCTIONS

- **Closed book/notes exam. (Unit conversion page provided)**
- **Help sheet allowed. (8-1/2 x 11" sheet of paper, one side)**
- **Laptops may be used; however, no pre-prepared worksheets or files may be used.**

1) Show all work for complete credit.
   - **Start all problems at the ANALYSIS stage**, but clearly label any information you use for your solution.
   - **Problems involving conservation principles MUST clearly identify the system and show a clear, logical progression from the basic principle(s).**
   - **Don't expect us to read your mind** as to how or why you did something in the solution. Clearly indicate how you arrived at your answer and how you used the given information in the process.
   - **Always crunch numbers last on an exam**. The final numerical answer is worth the least amount of points. (Especially if all we would have to do is plug in the numbers into a well-documented solution.)
2) Useful Rule of Thumb (Heuristic): (100 point exam)/(90 min) ≈ 1 point/minute. That means a 10 point problem is not worth more than 10 minutes of your time (at least the first time around).
3) Please remain seated until the end of class or everyone finishes. (Raise your hand and I'll pick up your exam if you have other work you need or want to do.)

USEFUL INFORMATION	**SI**	**USCS**	Molar Mass [kg/kmol; lbm/lbmol]	
Ideal Gas Constant: R_u	= 8.314 kJ/(kmol-K)	= 1545 (ft-lbf)/(lbmol-°R)	Air	28.97
		= 1.986 Btu/(lbmol-°R)	O_2	32.00
Standard Acceleration of Gravity: g	= 9.810 m/s^2	= 32.174 ft/s^2	N_2	28.01
Density of liquid water	= 1000 kg/m^3	= 62.4 lbm/ft^3	H_2	2.016
		= 1.94 slug/ft^3	CO_2	44.01

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

Problem 1 (16 points)

(a) (3 pts) In this course, what is meant by a system?

(b) (3 pts) In this course, what is meant by a property being conserved?

(c) (2 pts each) By considering conservation of mass, indicate whether each of the following systems is possible or impossible.

Proposed System	**Circle the correct answer**	
An open system with inlet mass flow but no outlet mass flow.	Possible	Impossible
A steady-state open system with inlet mass flow but no outlet mass flow.	Possible	Impossible
A closed system with inlet mass flow but no outlet mass flow.	Possible	Impossible
A closed system undergoing a finite time process with no accumulation of mass	Possible	Impossible

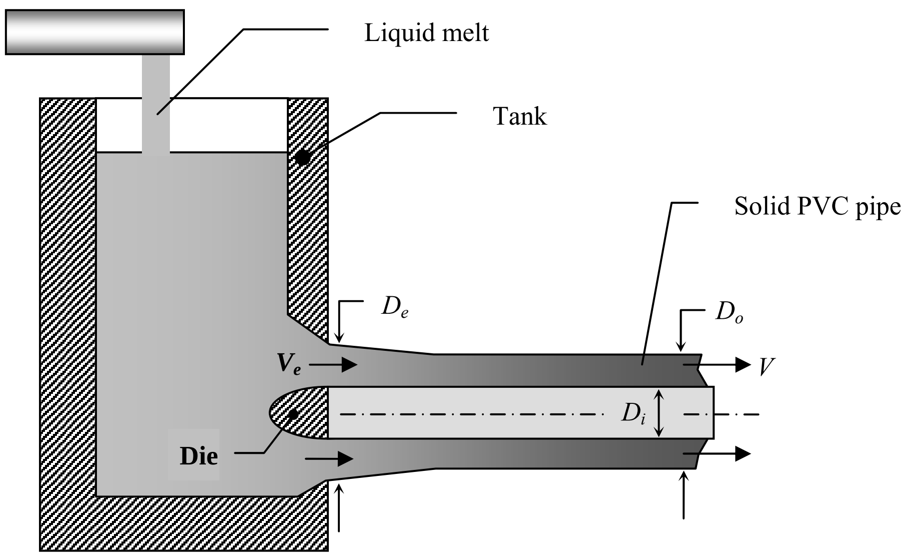
(d) (2 pts) A pressure gage reads 225 kPa. What is this pressure in lbf/ft^2?

Problem 2 (24 pts)

PVC pipe is manufactured using a steady-state extrusion process as shown in the figure. A liquid melt with density ρ_m is fed into the tank and the PVC pipe is extruded through a die in the side of the tank. As the extrusion travels to the right, the PVC material solidifies. Solid PVC has a density of ρ_s. The finished PVC pipe has inner and outer diameter of D_i and D_o, respectively, and travels to the right with a velocity of V.

(a) Determine the volumetric flowrate of liquid melt that must be supplied to the tank. Express your answer in terms of ρ_m, ρ_s, D_i, D_o and V.

(b) The extrusion passing through the die in the side of the tank is not solidified, but still in the liquid state. As a result, the pipe wall thickness is larger in this region. If the outer diameter of the pipe extrusion at the die (tank) exit is D_e as shown in the figure, find the velocity V_e of the liquid PVC material at this location. Express your answer in terms of the other problem variables as required.



Problem 3 (36 pts)

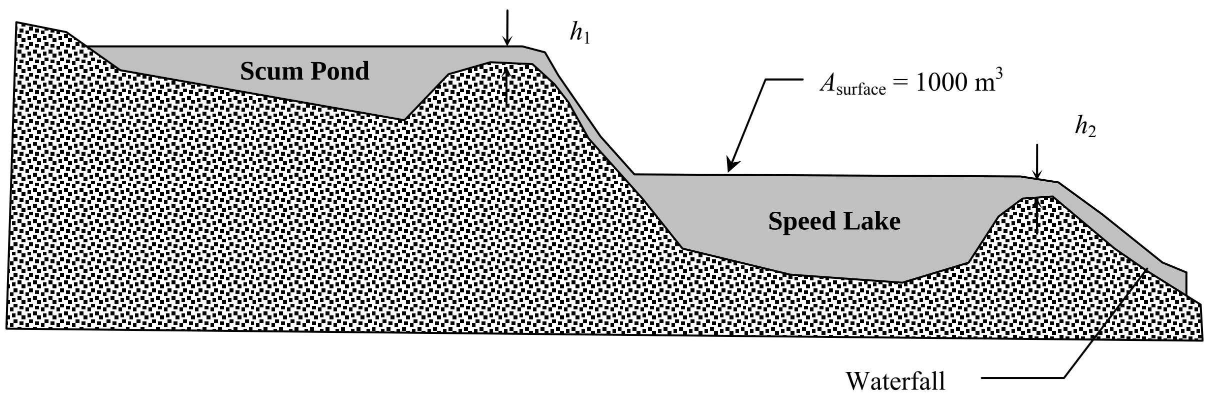
A new waterfall is to be installed at one end of Speed Lake. The water level in Speed Lake is to be held constant by feeding it with water from Scum Pond. The volume flow rates into and out of Speed lake are given by the equations $C_1\sqrt{h_1}$ and $C_2\sqrt{h_2}$, respectively, where C_1 = 700 $m^{5/2}$/hr and C_2 = 1400 $m^{5/2}$/hr.

At the design conditions which produce a pleasing waterfall, h_2 = 0.50 m and the surface area of Speed Lake is $A_{surface}$ = 1000 m^2. By design, the surface area, $A_{surface}$, of Speed Lake is a constant for all values of $h_2 \geq 0$.

(a) Determine the required height h_1 to keep the water level in Speed Lake constant at the design conditions.

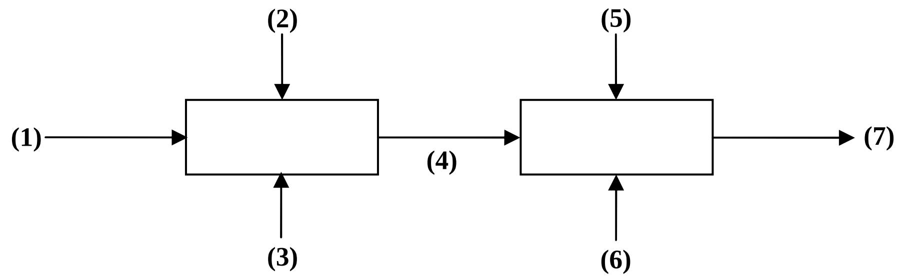
(b) During long dry periods, evaporation from the surface of Speed Lake may also be important. If 50,000 kg/hr of water evaporates from the surface of Speed Lake, calculate the new height h_1 required to match the design conditions.

(c) If the flow into Speed Lake from Scum Pond is suddenly stopped, determine the *time rate of change* of the water level, h_2, in Speed Lake immediately *after* the flow from Scum Pond is stopped. You may neglect evaporation and assume Speed Lake was at design conditions, h_2 = 0.50 m, when the inlet flow stopped.



Problem 4 (24 pts)

Salad dressing[1] is made in a two stage mixing process as shown in the figure below. A sugar solution is mixed with pure water and crushed herbs in the first stage. The exiting stream is mixed with vinegar and olive oil in the second stage. Known flow rates and compositions are listed in the table.



Stream		Mass flow rate (lbm/h)	Composition (mass percent)				
			Sugar	Herbs	Vinegar	Oil	Water
1	Sugar solution		0.3	---	---	---	0.7
2	Herbs		---	1.0	---	---	---
3	Water		---	---	---	---	1.0
4	Mixture						
5	Vinegar		---	---	1.0	---	---
6	Oil		---	---	---	1.0	---
7	Dressing	500	0.10	0.09			

a) It is desired to have equal amounts (by mass) of water, oil and vinegar in the dressing. What are the required mass fractions of vinegar, oil and water in the exit stream (7)?

b) Derive a set of equations that could be used to solve for all unknown mass flowrates as well as the mixture composition of stream (4). **You do not have to solve these equations**; however, for full credit you must clearly label your equations and unknowns to show that it is a complete set.

[1] Crushed herbs include basil, thyme, rosemary and just a hint of saffron. Of course, only the finest red wine vinegar and extra virgin olive oil go into any ConAps salad dressing.