ES201 - Examination I   Winter 2002-2003   Richards

NAME____BOX NUMBER_______________

Problem 1 (25) ________________

Problem 2 (25) ________________

Problem 3 (50) ________________

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.**
   - 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.
   - **Always crunch numbers last on an exam**. The final numerical answer is worth the least amount of points. (Especially if all I would have to do is plug in the numbers into a well-documented solution.)
2) Useful Rule of Thumb (Heuristic): (100 point exam)/(50 min) = 2 points/minute. That means a 10 point problem is not worth more than 5 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	
Ideal Gas Constant: R_u	= 8.314 kJ/(kmol-K)	= 1545 (ft-lbf)/(lbmol-^{o}R)	Air	28.97
		= 1.986 Btu/(lbmol-^{o}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

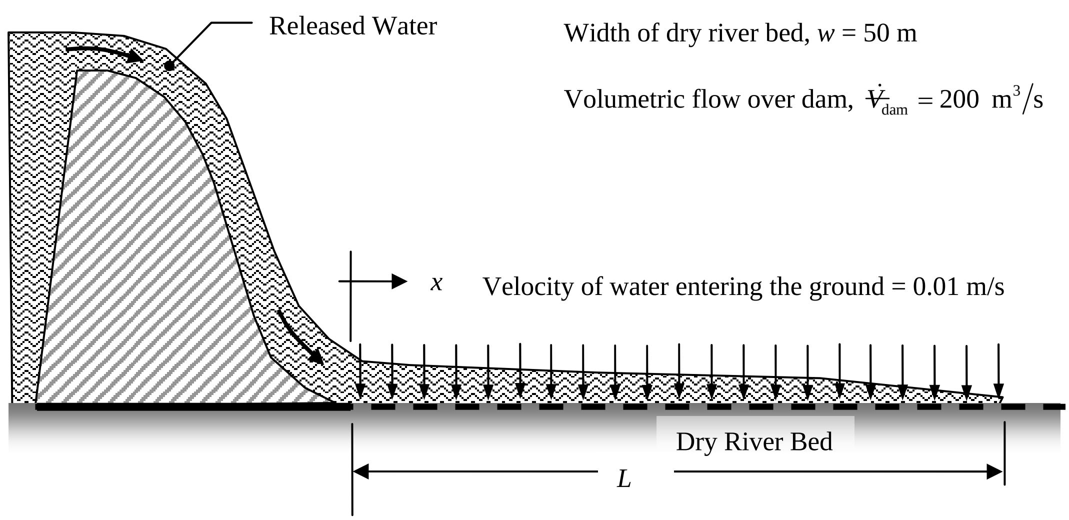
1 Btu/lbm = 25037 ft^2/s^2

1 ft·lbf /lbm = 32.174 ft^2/s^2

Problem 1 (25 points)

Consider the hydraulic dam shown in the figure. Water is released from the dam and flows steadily over the top of the dam into a dry river bed at a volumetric flow rate of 200 m^3/s. The river bed is 50 m wide. The river bed absorbs water, and the velocity of the water entering the ground is V_{ground} = 0.01 m/s (see the arrows in the diagram).

Determine the extent of the river bed, the length L, that will be affected by the released water, i.e. how far (L) will the released water flow before it is completely absorbed by the river bed?



Problem 3 (50 Points)

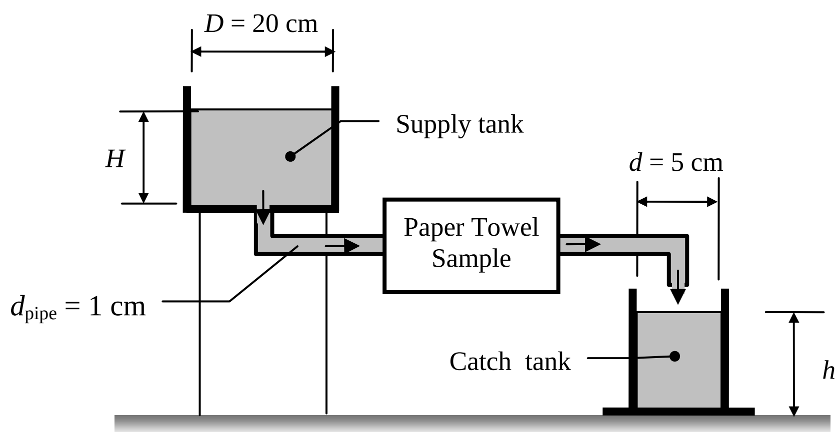
One of the important characteristics of paper towels is their ability to absorb liquid. The experimental setup shown in the figure is used to measure the absorption (storage) rate of liquid for paper towel material. The apparatus is designed so that any water stored in the sample holder is assumed to be absorbed by the paper towel.

To run the test, a dry towel sample is placed in the sample holder. Then water is allowed to drain from the supply tank into the sample holder. Excess liquid not absorbed by the towel material drains to the catch tank. The absorption (storage) rate data is developed by monitoring the liquid levels H and h as a function of time.

(a) Develop an expression for the *rate of storage* of liquid in the paper towel sample (*dm/dt*), in terms of the relevant information. A symbolic solution in terms of the problem variables is desired.

(b) When the towel material saturates, it will stop absorbing (storing) liquid. How will *dH/dt* and *dh/dt* be related when the towel saturates?

(c) Determine the time it takes to drain the liquid in the supply tank from H = 10 cm to 5 cm when the sample holder is *empty*. Under these conditions the volumetric flow rate out of the supply tank is given by the expression: $\dot{\forall}_{\text{supply}} = \left(0.30\ \text{cm}^{2.5}/\text{s}\right)\sqrt{H}$.



Problem 2 (25 points)

A glycerol plant operates at steady-state conditions and treats a glycerol solution (1) by feeding it into an extraction tower with an alcohol solvent (3). Two streams leave the extraction tower: a raffinate stream (2) and an extract stream (4). The extraction tower involves four compounds: glycerin, salt (NaCl), butyl alcohol, and water.

The extract stream (4) is fed into a distillation tower. No salt enters the distillation tower, and the distillation process involves only three compounds: glycerin, butyl alcohol, and water. A distillate stream (5) and a bottoms stream (6) leave the distillation tower. Detailed information about the known flow rates and mass compositions is shown in the table.

DEVELOP A *SUFFICIENT* SET OF EQUATIONS to determine the unknown flow rates and compositions. YOU DO NOT NEED TO SOLVE THE EQUATIONS. For full credit, you must clearly identify the unknowns you are solving for and the set of equations you would use to solve for the unknowns.

Stream		$\dot{m}_i$	Composition (Mass %)			
		lbm/h	Glycerin	Salt (NaCl)	Butyl Alcohol	Water
1	Glycerol Solution	1000	10.00	3.00	----------	87.00
2	Raffinate		1.00		1.00	
3	Solvent	1000	----------	----------	98.00	2.00
4	Extract			0.00		
5	Distillate		----------	----------	95.00	5.00
6	Bottoms		25.00	----------	----------	75.00