NAME____BOX NUMBER______________

Problem 1 (30) _______________

Problem 2 (35) _______________

Problem 3 (35) _______________

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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-°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

(ΔT/^{o}R) = 1.8(ΔT / K)

(ΔT/^{o}R) = (ΔT/^{o}F)

(ΔT / K) = (ΔT/^{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

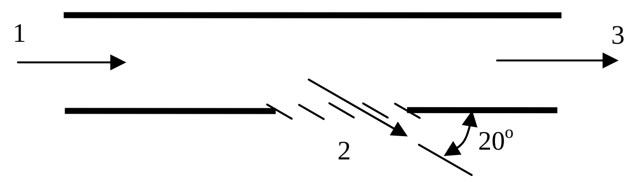
1 Btu/lbm = 25037 ft^2/s^2

1 ft·lbf /lbm = 32.174 ft^2/s^2

Problem 1 (30 points)

(a) A simple air duct with a side exhaust is shown below along with the direction of the velocity vectors at each inlet or outlet. The cross-sectional areas at 1 and 3 are identical, $A_{c1} = A_{c3} = 0.5\ m^2$. The velocity at 2, V_2, makes a 20° angle with the opening in the side of the duct $A_2 = 0.5\ m^2$. Measurements indicate that the flow is steady with velocities $V_1 = 10$ m/s and $V_3 = 3$ m/s.

Assume that air behaves like an incompressible substance under these conditions.



….. Determine the ratio of the volumetric flow rate at 2 to the volumetric flow rate at 1, $\dot{V}_2/\dot{V}_1$.

….. Determine the ratio of the velocity at 2 to the velocity at 1, V_2/V_1.

(b) A scuba tank containing air accidentally falls into a campfire. The volume of the rigid walled tank is $0.30\ m^3$. Before it fell on the fire, the pressure and temperature of the air in the tank were 600 kPa and 27°C, respectively.

….. Determine the mass of air in the tank, in kg, and the amount of air, in kmol.

….. Determine the final pressure of the air in the tank if its temperature reaches 500°C after a few minutes in the fire.

Problem 2 (35 points)

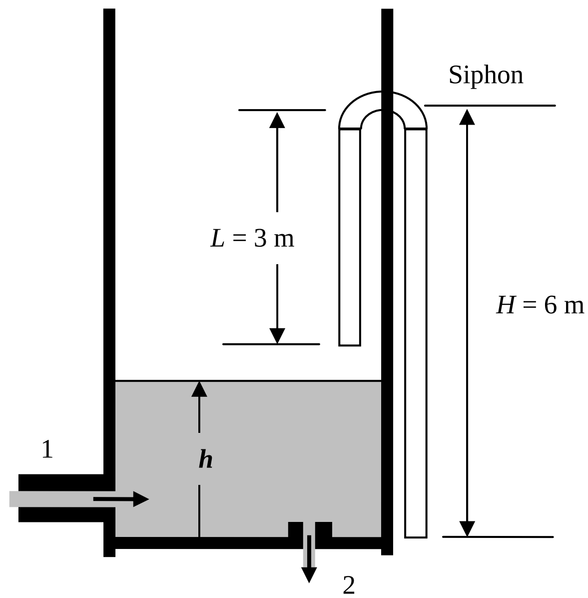
The tank shown below handles gasoline which has a density of 680 kg/m^3. The tank is a vertical cylinder with a diameter D of 2 meters. Normally gasoline flows into the tank at Inlet 1 with a specified mass flow rate and leaves the tank at Outlet 2.

A siphon is built into the side of the tank to prevent an overflow if there is a sudden change in the flow conditions for the tank. The siphon is simply a bent tube with one end inside the tank and the other outside the tank as shown. It will *not* start operating ("kick in") until the level of the gasoline in the tank exceeds the level of the siphon elbow by at least 0.1 meters, i.e. $h > H + 0.1$ m. Once it "kicks in", the siphon will stop working ("break") if the water level drops below the siphon inlet, i.e. $h < H$.

Under normal conditions, the mass flow rate of gasoline into the tank is 700 kg/min, and the gasoline level in the tank is h = 4.0 meters.

(a) For some unknown reason, the outlet at 2 becomes totally blocked and the level begins to rise.
…..Determine how long it will take for the siphon to start working ("kick in").
….. SET UP, but do not solve the differential equation that describes the *rate of change* of the gasoline level h during the transient to the *new* steady-state conditions after the siphon starts working.
…..Determine the new steady-state height h of the gasoline in the tank under these conditions.

(b) After some time, the operator notices the siphon is discharging gasoline and stops the flow of gasoline into the tank; however, the tank will continue to drain until the siphon "breaks." How long will it take for the siphon to "break" (stop working)?



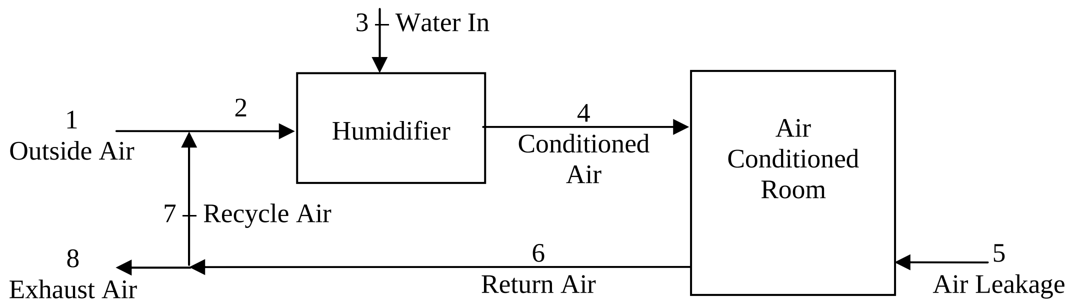
Siphon mass flow rate

$$\dot{m}_{\text{siphon}} = \left(300 \frac{\text{kg}}{\text{min} \cdot \text{m}^{1/2}}\right)\sqrt{h}$$

<u>Problem 3</u> (35 points)

In the winter, a major problem is the low relative humidity when dry outside air is heated. The schematic drawn below shows an air-handling system designed to humidify outside air for ventilation and heating purposes. Conditioned air is supplied to the room from the humidifier. Outside air is mixed with some recycle air before it enters the humidifier where water is added to achieve the desired conditioned air conditions.

DEVELOP THE NECESSARY EQUATIONS to calculate the unknown flow rates and compositions. DO NOT SOLVE THE EQUATIONS. For full credit, you must clearly identify the unknowns and the set of equations you would use to solve for the unknowns.



Stream		Mass Flow Rate kg/min	Composition (Mass Fractions)	
			Water	Dry Air
1	Outside Air		0.004	
2	Mixed Air			
3	Water In		1.000	0.000
4	Conditioned Air	600	0.011	
5	Air Leakage		0.004	
6	Return Air	650	0.009	
7	Recycle Air		0.009	
8	Exhaust		0.009	