ES201 - Examination I　　　　Fall 2008-2009　　　　$8^{th}/9^{th}$ hours

NAME____　　　　SECTION_______________

BOX NUMBER__________

Problem 1	(40)	________________
Problem 2	(30)	________________
Problem 3	(30)	________________
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.**
- **After the exam, please find a nice restaurant and order yourself something nice.**

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 IN A SEPARATE DRAWING 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 your 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-^oR)	Air	28.97
		= 1.986 Btu/(lbmol-^oR)	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

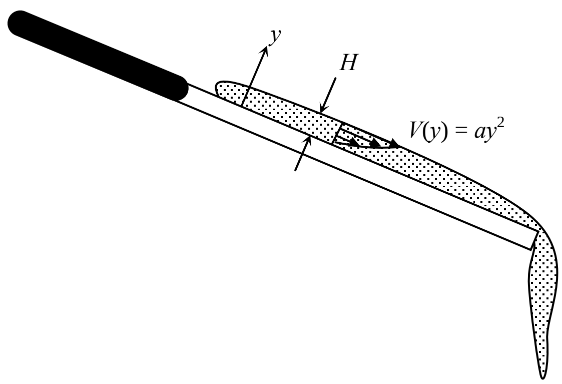
Problem 1 (40 pts)

Answer each of the following unrelated questions.

a) (2 pts) Circle the correct answer. On the earth surface, a 10-pound bag of potatoes weighs

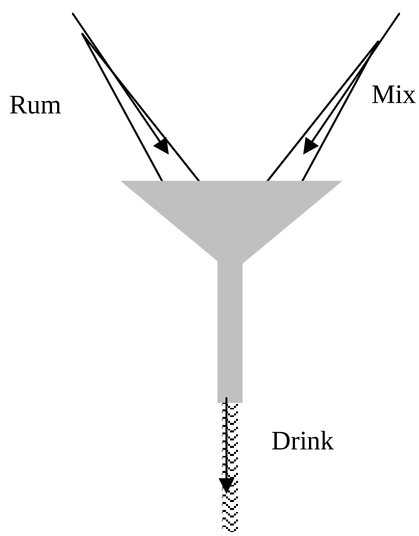
- 10 Newtons
- 10 pound-force
- 321.7 pound-force
- 0.3108 pound-force
- None of the above

b) (8 pts) Honey having a density ρ drips off the Surreal Gourmet's knife with the velocity profile of $V(y) = ay^2$, where a is a constant. The thickness of the honey on the knife is H, and the width of the knife (into the page) is W. Find an expression for the mass flow rate of honey dripping off the knife.

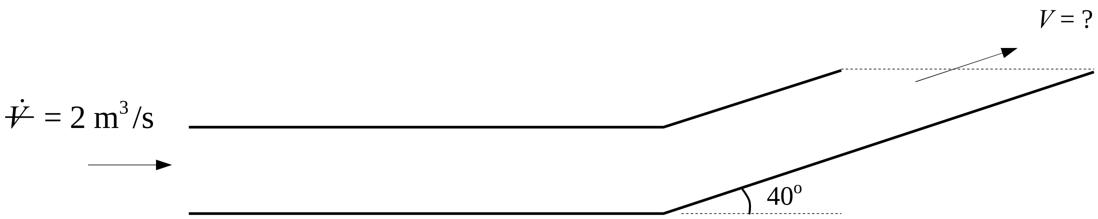


c) (8 pts) Chef Cantu is creating acorn squash foam which can be regarded as essentially air in a vacuum chamber. The volume of the chamber is 0.25 m^3 and it is held at room temperature, T = 22°C. Find the mass of the air in the chamber when the pressure is reduced to P = 12 kPa.

d) (8 pts) Trader Kahiki is making a pitcher of Mai Tais by simultaneously pouring rum and Mai Tai mix into a funnel. The rum is 40% alcohol and 60% water by mass. The Mai Tai mix if 70% water and 30% sugar by mass. The mass flow rates of rum and Mai Tai mix are $\dot{m}_{rum}$ and $\dot{m}_{mix}$, and are both known. Write four independent equations that can be solved to find the composition of the resulting drink (percent water, alcohol and sugar) and its mass flow rate, $\dot{m}_{drink}$. DO NOT SOLVE THE EQUATIONS. Assume steady-state operation.



e) (6 pts) Water from a kitchen sink enters a bent duct at a volumetric flow rate of 2 m^3/sec. The same volumetric flow rate leaves the duct exit, which has an area of 3 m^2. Determine the velocity of the water stream at the exit.



f) (8 pts) Consider the general accounting principle for an extensive property B of any system:

$$\frac{dB_{\text{sys}}}{dt} = \dot{B}_{\text{in}} - \dot{B}_{\text{out}} + \dot{B}_{\text{prod}} - \dot{B}_{\text{cons}}$$

Provide an equivalent mathematical statement to the following scenarios:

a) The system is under steady-state operation.

b) The extensive property B is conserved.

Circle the correct answer in the following two questions:

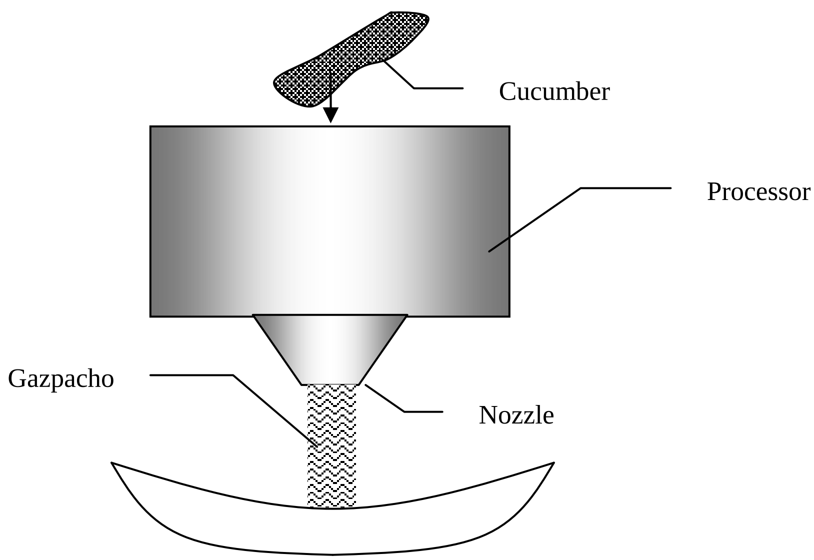
i. Density is an intensive / extensive property.

ii. Volume is an intensive / extensive property.

Problem 2 (30 pts)

The Surreal Gourmet is making his signature Killer Gazpacho by steadily putting N = 5 cucumbers per minute into a food processor. The processed cucumbers leave the food processor and enter a bowl at a rate of $\dot{\forall}_{gaz} = 0.25\,\ell$/min ($\ell$ = 0.001 m^3) through a nozzle of area 2 cm^2. If the gazpacho has a density of ρ_{gaz} = 1000 kg/m^3, then

a) find the mass of each cucumber m_{cuc}, and
b) the velocity of the gazpacho leaving the processor in m/sec.

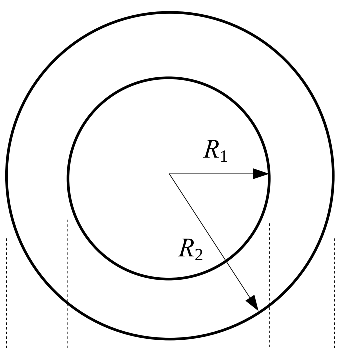


Problem 3 (30 pts)

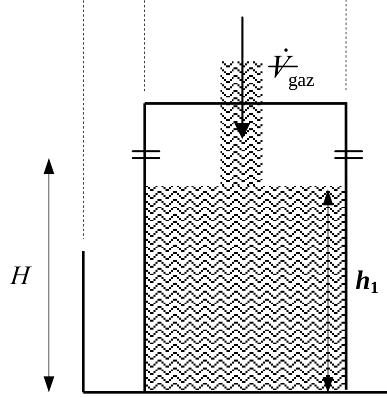
At a cocktail party, the Killer Gazpacho (in Problem 2) is used to fill up a punch fountain, in the form of two concentric cylinders. During the filling process, the inner cylinder will be filled out first. Once the fluid level reaches the over-flow`` holes, the outer cylinder will then be filled.

a) Determine <u>the time it takes to fill up the inner cylinder</u> of the punch fountain, *i.e.* $h_1 = H$. Express your answer in terms of the constant volumetric filling rate $\dot{V}_{gaz}$, the density of the gazpacho ρ_{gaz}, and the cylinder dimensions, H, R_1, and R_2.

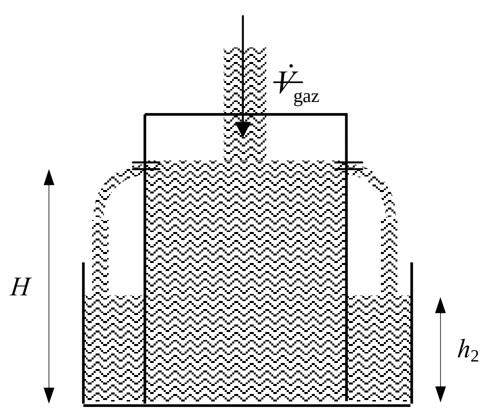
b) After the inner cylinder has been filled, the gazpacho starts filling the outer cylinder. Develop an expression which describes the <u>time rate of change of the liquid level</u> h_2 in terms of the constant volumetric filling rate $\dot{V}_{gaz}$, the density of the gazpacho ρ_{gaz}, and the cylinder dimensions, H, R_1, and R_2.



Plan View



Side View of Part (a)



Side View of Part (b)

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