ES201 - Examination I   Fall 2007-2008 $8^{th}/9^{th}$ hours

NAME____   SECTION_______________

BOX NUMBER__________

Problem 1	(37)	________________
Problem 2	(30)	________________
Problem 3	(33)	________________
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.**
- **Uttering magic words and phrases, such as "Om maddy paddy om" is good showmanship, but unfortunately prohibited.**

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

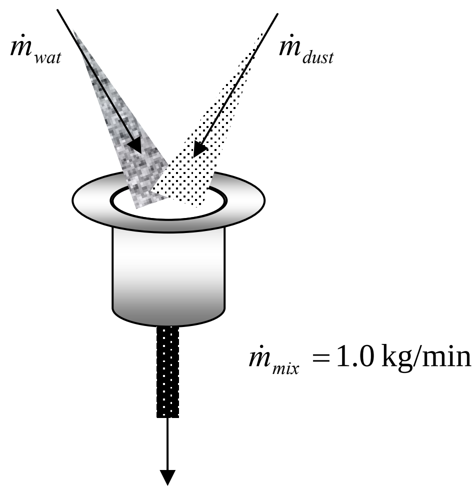
Problem 1 (37 pts)

Answer each of the following unrelated questions.

a) (4 pts) The Great Accountadini is creating balloon animal from a long red balloon. Consider a system consisting of all the air inside the balloon as The Great Accountadini is deforming it. Since the mass is constant, $dm_{sys}/dt = 0$. Is the system therefore steady-state? (Circle one.)

i. Yes ii. No iii. Insufficient information to determine

b) The Great Accountandini simultaneously pours water and magic dust into a hat resting on a table. Unbeknownst to his audience, a mix of water and magic dust flows out of the bottom of the hat at 1.0 kg/min so that the hat/water/dust combination is at **steady-state**. The exit flow is 80% water and 20% dust by mass.



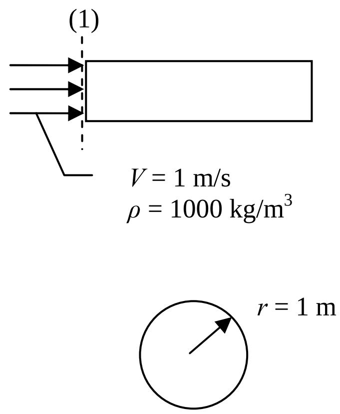
i. (3 pts) What is the minimum number of independent equations that can be written to find the unknown mass flow rates?

- 0
- 1
- 2
- 3

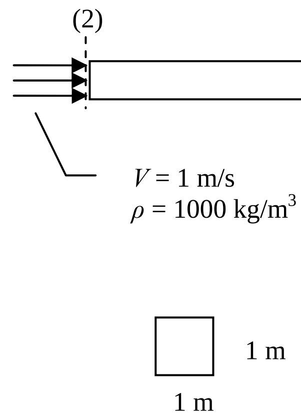
ii. (6 pts) Write the equations.

c) Indicate how the mass flow rates crossing the indicated boundaries (dotted lines) compare to each other

i. (4 pts)



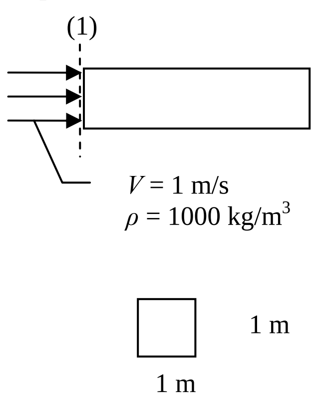
Cross section



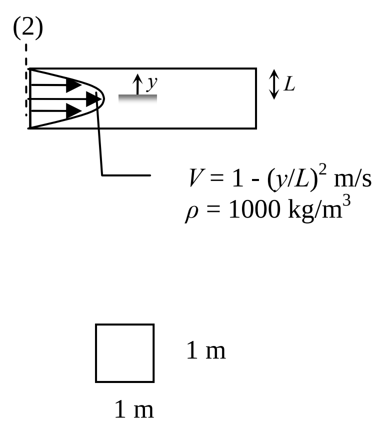
Cross section

- $\dot{m}_1 < \dot{m}_2$
- $\dot{m}_1 > \dot{m}_2$
- $\dot{m}_1 = \dot{m}_2$

ii. (4 pts)



Cross section



Cross section

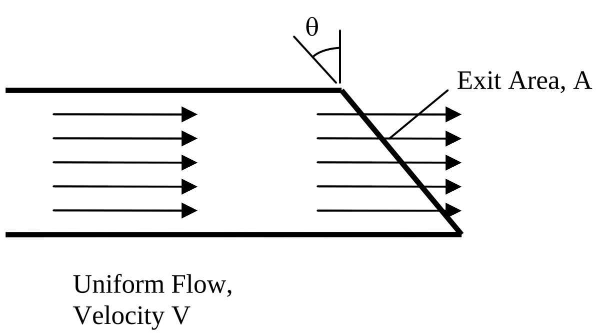
- $\dot{m}_1 < \dot{m}_2$
- $\dot{m}_1 > \dot{m}_2$
- $\dot{m}_1 = \dot{m}_2$

d) (5 pts) An amateur magician (on Earth) holds a five pound rabbit by the ears. The upward force the magician must exert to hold the rabbit is (circle all that are true):

- 5 lbm
- 5 lbf
- 5/32.2 slugs
- 5*32.2 slugs
- None of the above

e) (6 pts) What is the volume of 1 kg of O_2 at a pressure of P=100 kPa and a temperature of 20°C ?

f) (5 pts) A rectangular duct is used to pour water into a tank for a Houdini-type escape trick. The duct geometry is shown below:



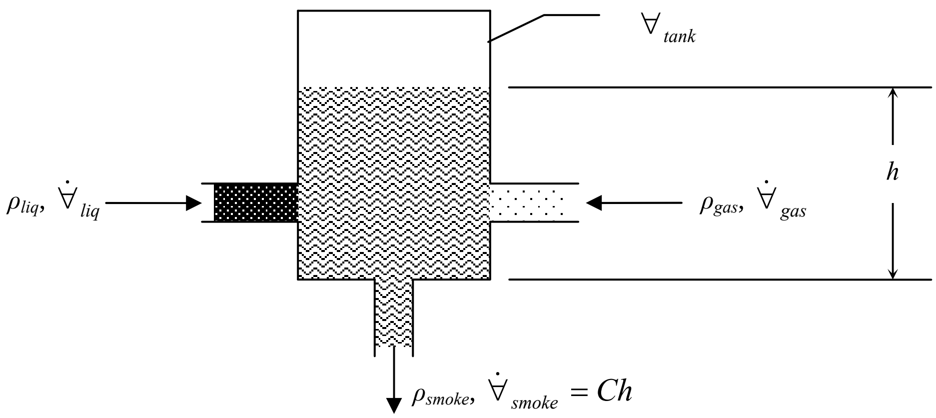
The mass flow rate out of the duct is:

- ρVA
- $\rho VA\cos\theta$
- $\rho VA\sin\theta$
- None of the above

Problem 2 (30 pts)

A machine creates "magic smoke" for The Great Accountadini's act by mixing a liquid and a gas together. The volume of the tank ($\forall_{tank}$) is known, as are the volumetric flowrates of the gas and liquid into the machine ($\dot{\forall}_{gas}$, $\dot{\forall}_{liq}$) and their respective densities (ρ_{gas}, ρ_{liq}). The resulting "smoke" in the tank has a density ρ_{smoke} and exits the machine at a rate proportional to the height of "smoke" in the machine, h. **(Hint: This is not a species accounting problem.)**

a) For steady state operation, find the height of the "smoke" in the machine.
b) At some time Accountandini's inept assistant Carrie Okee plugs the exit, stopping the outflow completely. The "smoke" quickly fills the entire tank. Find an expression for the rate of change of density of the "smoke" in the tank, $d\rho_{smoke}/dt$ valid at anytime *after the tank has filled*.

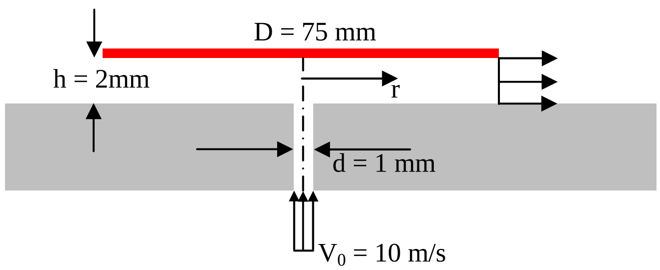


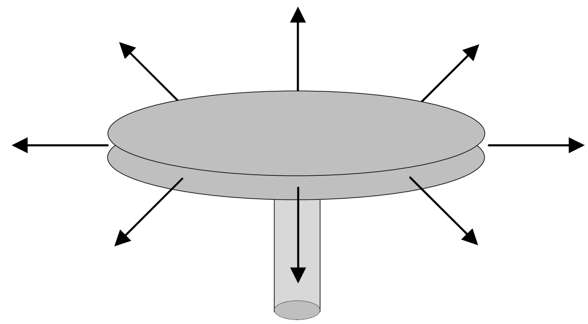
Problem 3 (33 pts)

In his close-up act, The Great Accountadini floats a magic disc over a table. His secret is to use an air hockey table.

The magic disc has a diameter of D = 75mm and is hovering over the table at a height of (h = 2mm). The disc is centered over a single air hole, which has a diameter d = 1 mm with an air flow of uniform velocity of V_0 = 10 m/s. Assume the disc is at steady state and that air is incompressible.

a) What is the velocity of the air as it exits the region between the puck and the table?
b) What is the velocity of the air at any distance, r, from the center of the puck? Is this flow accelerating or decelerating? A symbolic expression is acceptable.





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