**ES201 -** Examination I　　　　Fall 2005-2006　　　　$5^{th}/6^{th}$ hours

NAME________________________________________________SECTION_______________
BOX NUMBER__________

Problem 1 ( 30 ) ________________

Problem 2 ( 35 ) ________________

Problem 3 ( 35 ) ________________

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Total (100) ________________

**INSTRUCTIONS**

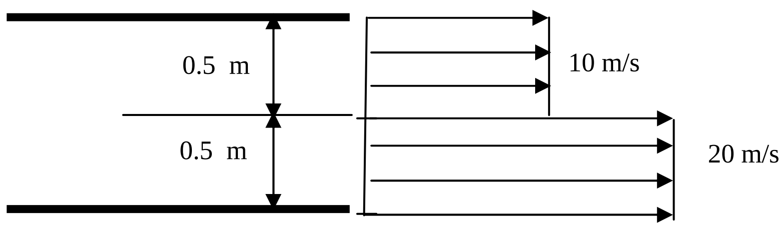
- **Closed book/notes exam. (Unit conversion page provided)**
- **Help sheet allowed. (8-1/2 x 11" sheet of paper, one side)**
- **Laptops may be used; however, no pre-prepared worksheets or files may be used.**

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 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.)

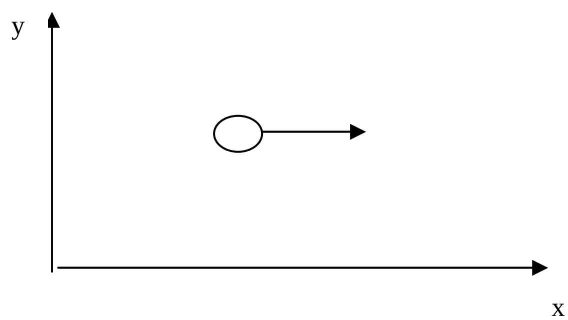
| USEFUL INFORMATION | SI | USCS | Molar Mass | |
|---|---|---|---|---|
| Ideal Gas Constant: $R_u$ | = 8.314 kJ/(kmol-K) | = 1545 (ft-lbf)/(lbmol-$^o$R) | Air | 28.97 |
| | | = 1.986 Btu/(lbmol-$^o$R) | $O_2$ | 32.00 |
| Standard Acceleration of Gravity: $g$ | = 9.810 m/s$^2$ | = 32.174 ft/s$^2$ | $N_2$ | 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 |

## Problem 1

A. (4 pts) Find the volume flowrate of the fluid flowing out of the channel with the velocity profile shown below. The duct is 1 meters high and 2 meters wide (into the page).




B. (4 pts) What is the momentum (in lbf-s) of a 1 lbm particle moving to the right at 1 ft/s?



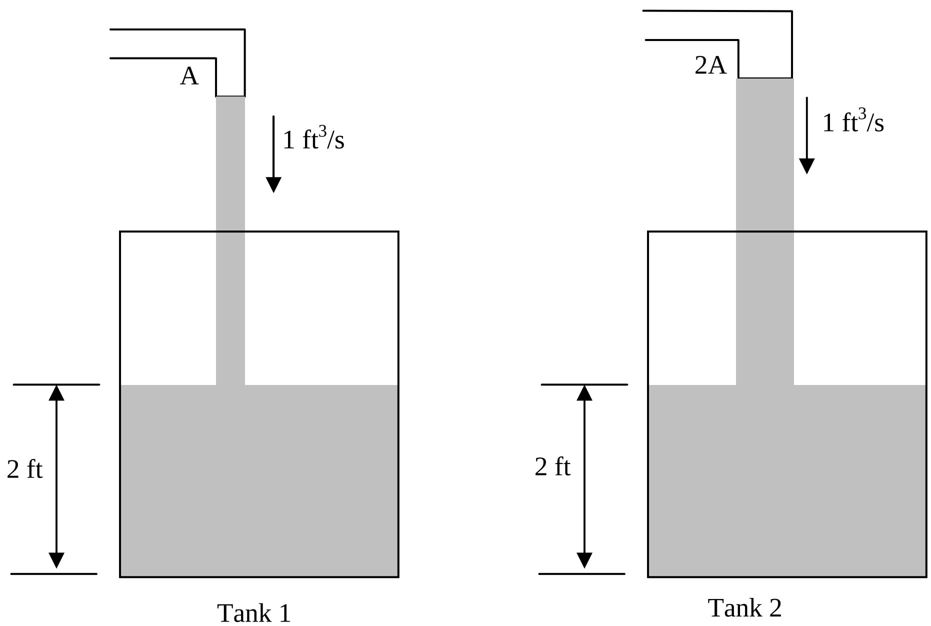

C. (2 pts) What is the momentum of the same particle on the moon ($g_{moon} = 1/6\ g_{earth}$)?

i. 6 times as much as on earth
ii. 1/6 as much as on earth
iii. The same as on earth
iv. Zero
v. None of the above

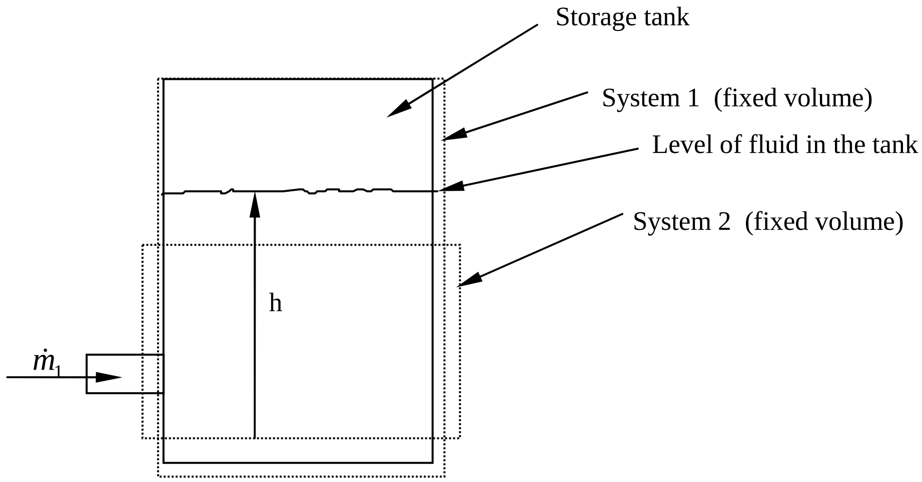
Two tanks with identical geometry are being filled as shown. The volumetric flow rate entering each tank is the same and is equal to 1 $ft^3/s$ and at the instant shown both tanks have 2 ft of water in them. The area of the inlet for tank 2 is twice the area of the inlet for tank 1. You may assume that the liquid is incompressible. Answer the following questions (Circle the best answer.)

D. (2 pts) The velocity of the fluid going into tank 2 is equal to:
   i) velocity of fluid into tank 1
   ii) 2*( velocity of fluid into tank 1)
   iii) 0.5*( velocity of fluid into tank 1)

E. (4 pts) Which tank will have 3 ft of fluid in it first?
   i) They will have 3 ft of fluid at the same time
   ii) Tank 1
   iii) Tank 2

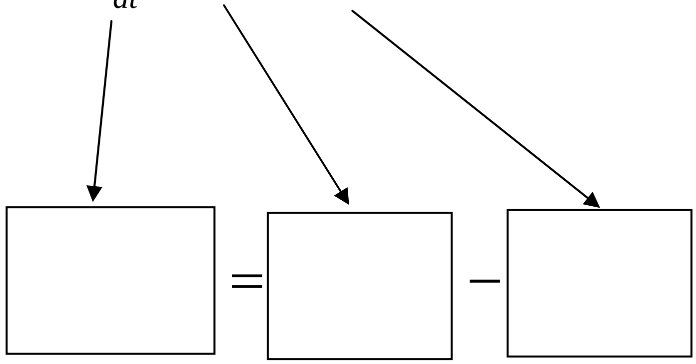


F. (8 pts) For the two systems shown below determine the terms in the conservation of mass equation, that is fill in the boxes. Assume the cross sectional area of the tank is $A_{tank}$. Express you answers in terms of $\dot{m}_1$, $A_{tank}$, ρ, h (and its derivative). You may assume that the liquid used in filling the tank is incompressible.



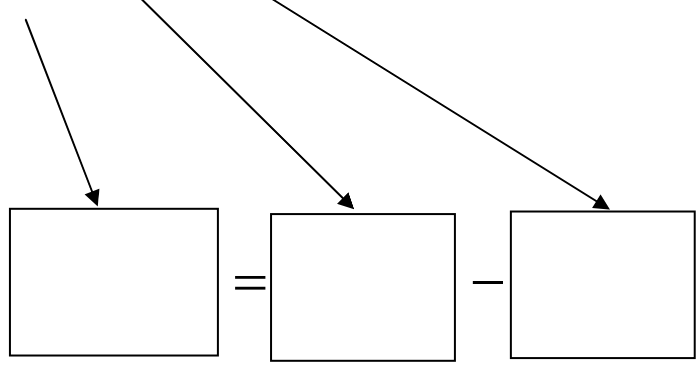

**System 1**
Conservation of Mass:

$$\frac{dm_{sys}}{dt} = \sum \dot{m}_{in} - \sum \dot{m}_{out}$$




**System 2**
Conservation of Mass:

$$\frac{dm_{sys}}{dt} = \sum \dot{m}_{in} - \sum \dot{m}_{out}$$



G. (6 pts) Air is to flow through the duct system shown below. What is the volumetric flow rate into the system? You may assume that the air behaves as an incompressible gas in this case, and that the duct has a width *w* into the page.

i) $2wV_{in}\cos\theta$

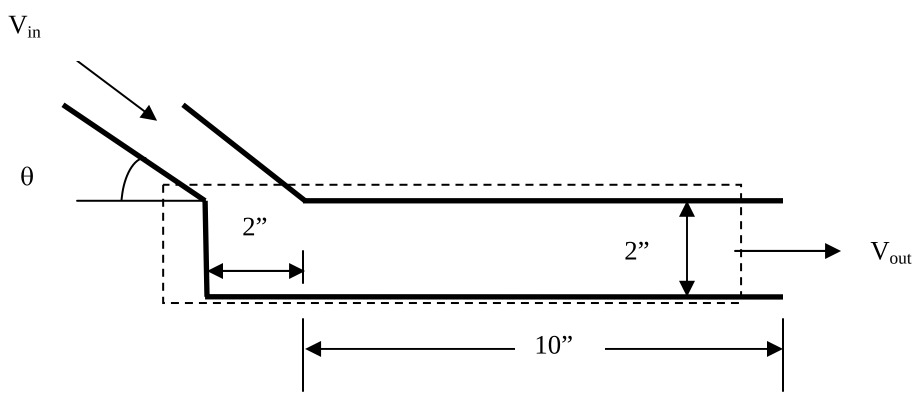
ii) $2wV_{in}\sin\theta$

iii) $2wV_{in}/\cos\theta$

iv) $2wV_{in}/\sin\theta$

v) $2\rho wV_{in}\sin\theta$

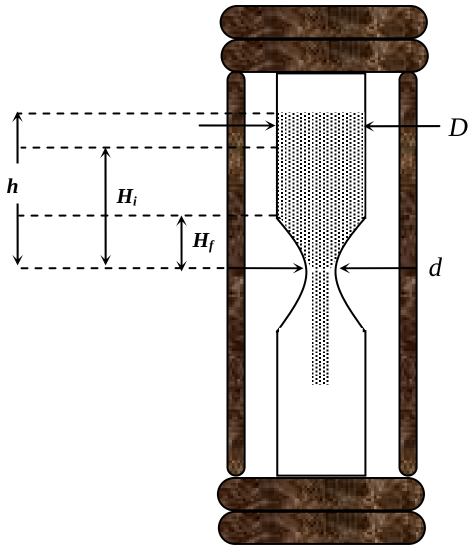
vi) None of the above



**Problem 2 (35 pts)**

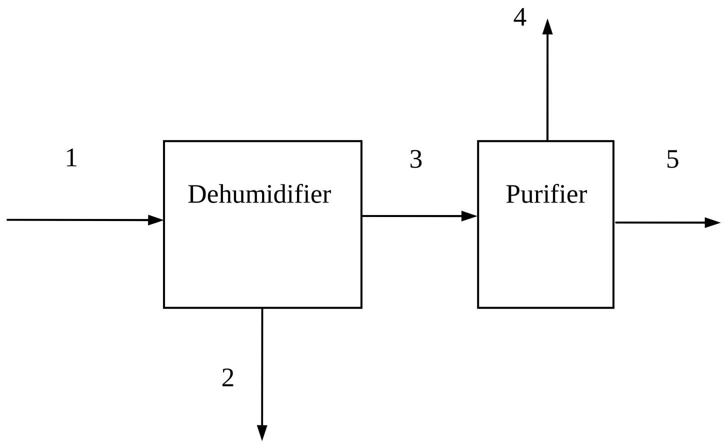
To make a good cup of Keemun tea, one should use 1 to 1½ teaspoons of loose lea tea per 8 fluid oz of boiling water and steep for 3 to 4 minutes to taste. To make sure one steeps for the correct length of time, many people use hour glasses like the one shown in the figure. The hourglass is filled with sand, which can be modeled as an incompressible substance. The top and bottom portions of the hourglass are cylindrical with diameter $D$, whereas the skinny portion has diameter $d$. If the sand passing through the skinny portion has velocity $\sqrt{2gh}$ ,

a) Find an expression for the length of time $t_{drop}$ required for the level of sand to drop from $H_i$ to $H_f$. (You may assume that $H_f$, $H_i$, $D$, $d$, and $g$ are given.)
b) Once the level of sand drops below $H_f$, how would you modify your analysis of part a)? A qualitative description will suffice.



**Problem 3  (35 pts)**

An air-cleaning device consists of two separate stages and is depicted in the following figure.  In the first stage, moist and polluted air (Stream 1) is passed through a dehumidification process such that liquid water (Stream 2), contaminated with dirt, is condensed out.  In the second stage, the drier and cleaner air (Stream 3) is then passed into an electrostatic purifier where dirt is precipitated and ejected out (Stream 4).  The purified air (Stream 5) leaves the system.




a) Assume the dirt to water ratio is 0.2 in Stream 2 by weight.  Develop a sufficient set of independent equations that could be used to determine the unknowns in the table.  *Do not solve the equations!*  For full credit, you <u>must</u> clearly identify <u>both the equations</u> you would solve and the <u>unknowns</u> in your equation set.

b) The desirable mass composition of the product stream is 99% dry air and 1% water.  Determine the equivalent composition in terms of mole fractions.  ($M_{air}$ = 29 kg/kmol and $M_{water}$ = 18 kg/kmol)

| Stream | Mass flow rate (kg/sec) | Mass fraction | | |
|---|---|---|---|---|
| | | Dirt | Water | Air |
| 1 | 100 | 0.01 | 0.02 | 0.97 |
| 2 | | | | --- |
| 3 | | | | |
| 4 | | 1.00 | --- | --- |
| 5 | | --- | 0.01 | 0.99 |

## 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$^2$