EAS 361 Midterm Exam 31 October 2006

Print Your Name: _____

Sign Your Name: _____

This exam booklet contains

1. This cover sheet.
2. A short list of potentially useful formulas and data.
3. Five questions of increasing difficulty.

**Choose either problem 2 or problem 3**, and do all remaining problems.

**Do not open the exam booklet until you are instructed to do so.**

You will have 1 hour and 15 minutes to complete the exam.

# Universal Cheat Sheet

**Properties of Water at 20 °C:**

$$\rho = 999\ \frac{\text{kg}}{\text{m}^3} = 1.94\ \frac{\text{slugs}}{\text{ft}^3} \qquad \mu = 1.12 \times 10^{-3}\ \frac{\text{N}\cdot\text{s}}{\text{m}^2} = 2.34 \times 10^{-5}\ \frac{\text{lb}_\text{f}\cdot\text{s}}{\text{ft}^2}$$

**Properties of Air at 1 atm and 20 °C:**

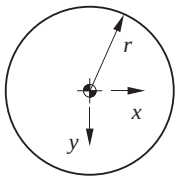
$$\rho = 1.23\ \frac{\text{kg}}{\text{m}^3} = 2.38 \times 10^{-3}\ \frac{\text{slugs}}{\text{ft}^3} \qquad \mu = 1.79 \times 10^{-5}\ \frac{\text{N}\cdot\text{s}}{\text{m}^2} = 3.74 \times 10^{-7}\ \frac{\text{lb}_\text{f}\cdot\text{s}}{\text{ft}^2}$$

$$R_\text{air} = 286.9\ \frac{\text{J}}{\text{kg}\cdot\text{K}} = 1716\ \frac{\text{ft lb}_\text{f}}{\text{slug}^\circ\text{R}}$$

**Basic Constants**

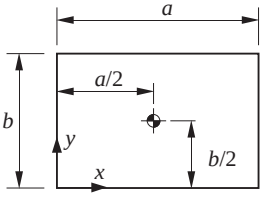
$$R_u = 8.314\ \frac{\text{kJ}}{\text{kmol}} = 1545\ \frac{\text{ft}\cdot\text{lb}_\text{f}}{\text{lbmol}\cdot\text{R}} \qquad g_c = 32.174\ \frac{\text{lb}_\text{m}\,\text{ft}}{\text{lb}_\text{f}\,\text{s}^2}$$

**Properties of Sections:**




$I_{xc} = I_{yc} = \dfrac{\pi r^4}{4}$

$I_{xyc} = 0$




$I_{xc} = \dfrac{1}{12}ab^3 \quad I_{yc} = \dfrac{1}{12}ba^3$

$I_{xyc} = 0$

**Properties of Objects:**

Sphere: $V = \dfrac{\pi D^3}{6}, \quad A = \pi D^2$

**Capillary Rise in a Tube:**

$$h = \frac{2\sigma\cos\theta}{\gamma R}$$

1. **[10 points]** Complete the column labeled "*Find*" in the following table. The first column in the table gives the definition of a dimensionless quantity. The second column gives the dimensions of all but one of the quantities in the dimensionless quantity.

   The answer for each row is the correct dimension in the F-L-T-$\Theta$ or M-L-T-$\Theta$ system of primary dimensions. A sample solution is given below.

   Each row of the table is worth 5 points. **Be sure to show your work**. Answers given without any justification will be given zero points. Even if you see the solution by inspection, provide a simple mathematical justification (or proof that your answer is correct) in the space at the bottom of the page.

   The expression $[V] = \mathrm{L/T}$ is read, "The dimensions of $V$ are length divided by time.

   **Example:**

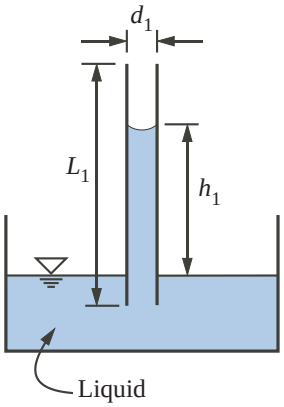
| Definition | Given | Find |
|---|---|---|
| $\mathrm{Re} = \dfrac{V\ell}{\nu}$ | $[V] = \mathrm{L/T}$, $[\ell] = L$ | $[\nu] = \mathrm{L^2/T}$ |

   **Assignment:**

| Definition | Given | Find |
|---|---|---|
| $\mathrm{Pr} = \dfrac{\nu}{\alpha}$ | $[\nu] = \mathrm{L^2/T}$, | $[\alpha] =$ |
| $\mathrm{We} = \dfrac{\rho V^2 \ell}{\sigma}$ | $[\rho] = \mathrm{M/L^3}$, $[V] = \mathrm{L/T}$, $[\ell] = L$ | $[\sigma] =$ |

Choose either problem 2 or problem 3. Clearly indicate which problem you wish to have graded.

2. A tube of diameter $d_1$ and length $L_1$ is held vertically so that the lower end is immersed in a pan of liquid. The top surface of the pan and the upper end of the tube are open to the atmosphere.



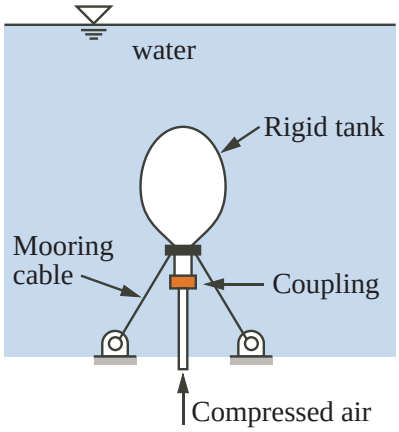

   a. **[3 points]** What is the name of the physical property associated with the movement of liquid up the tube?

   b. **[3 points]** Another tube with diameter $d_2$ and length $L_1$ is placed parallel to, but not touching or near to the first tube. Both the second tube and the first tube are now held vertically. If $d_1 > d_2$, how does $h_2$ compare to $h_1$?

   c. **[9 points]** Justify your answer to part (b).

Choose either problem 2 or problem 3. Clearly indicate which problem you wish to have graded.

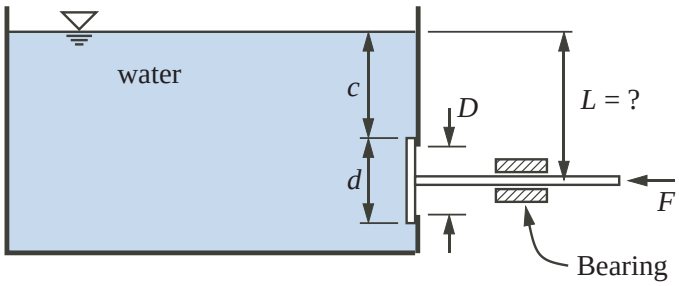
3. A perfectly rigid, air-filled tank is held underwater by mooring cables. The tank is connected to a supply of compressed air by a coupling that provides negligible structural support to the tank. As the pressure in tank is increased, its walls do not flex so that the volume of tank is always constant.




   a. [**5 points**] As the pressure in the tank is increased, how does the tension on its mooring cables change?

   b. [**10 points**] Justify your answer to part (a).

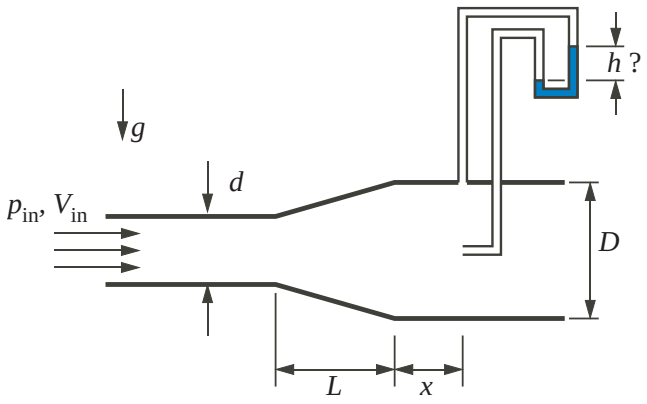
4. A round stopper of diameter $d$ prevents water from leaking through a hole of diameter $D$. The rod that actuates the stopper is held in place by a slider bearing.



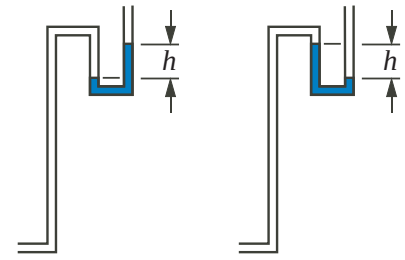

   a. [**8 points**] Neglecting friction in the bearing, what force $F$ is necessary to open the stopper?

   b. [**12 points**] The stopper and rod are to be redesigned to reduce the load on the bearings. Where should the axis of the push rod be located so that there is no side load on the bearings? Assume that the attachment point between the push rod and the stopper is to be moved without moving the position of the stopper relative to the tank. In other words, the dimension $L$ is to be changed to eliminate side loads in the bearing. Assume that the stopper is perfectly rigid.

5. A horizontal round pipe of diameter $d$ is connected to a larger pipe of diameter $D$ by a gradual transition of length $L$. Air flows from left to right through the duct. A piezometer is located on the centerline of the duct and a distance $x$ downstream of the duct transition. A water-filled U-tube manometer connects the piezometer to a static pressure tap on the wall of the duct. The static pressure tap is aligned with the open end of the piezometer.




a. **[3 points]** Which of the following two configurations of the water in the manometer is correct?




b. **[17 points]** What is the value of $h$ if $p_{in}$, $V_{in}$, $d$, $D$, and $L$ are known? Assume that the velocity is uniform across the duct at any cross section. Start with basic equations governing the flow and develop a formula for $h$.