ES201 - Examination I **Fall 2016-2017**

NAME____ Campus Mailbox _______________

INSTRUCTOR (Circle One): Richards (5th Period) Richards (6th Period) Livesay (5^{th} Period)

Lui (5th Period) Lui (6th Period) Cunningham (5th Period) Cantwell (6^{th} Period)

Problem 1 (35) ________________

Problem 2 (30) ________________

Problem 3 (35) ________________

____

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 or accounting principles MUST clearly identify the system and show a clear, logical progression from the basic principle(s).**
   - **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 and how you used the given information in the process.
   - **Always crunch numbers last on an exam**. The final numerical answer is worth the least amount of points. (Especially if all we 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 point/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**
Standard Acceleration of Gravity: g	= 9.810 m/s^2	= 32.174 ft/s^2
Universal Ideal Gas Constant: R_u	= 8.314 kJ/(kmol-K)	= 1545 (ft-lbf)/(lbmol-ºR) = 1.986 Btu/(lbmol-ºR)
WATER (Liquid): Density ρ	= 1000 kg/m^3	= 62.4 lbm/ft^3 = 1.94 slug/ft^3
AIR: Molecular weight M	= 28.97 kg/kmol	= 28.97 lbm/lbmol
AIR: Specific gas constant R	= 0.287 kJ/(kg-K)	= 53.3 (ft-lbf)/(lbm-ºR) = 0.0686 Btu/(lbm-ºR)

Problem 1 (35 points)

A desalination plant operates at steady-state conditions and produces pure water vapor and brine from seawater.

Sea water enters the plant with a mass flow rate of 100,000 kg/hr and a density of 1025 kg/m^3. Brine exits the plant with a mass flow rate of 14,630 kg/hr and a density of 1200 kg/m^3. Water vapor leaves the plant at a pressure of 120 kPa and temperature of 105^{o}C. The water vapor can be modeled as an ideal gas with

$$R_{water} = 0.4614 \text{ kJ/(kg-K)}; \quad R_u = 8.314 \text{ kJ/(kmol-K)}; \quad M_{water} = 18.02 \text{ kg/kmol}.$$

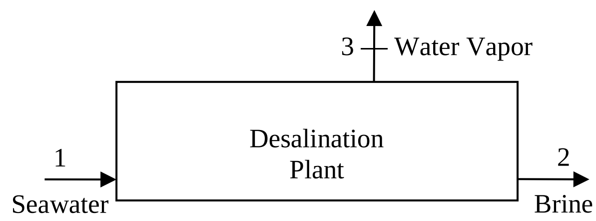
Determine the following information for the desalination plant:

(a) the mass flow rate of **water vapor**, in kg/hr.

(b) the volumetric flow rate of **water vapor** leaving the plant, in m^3/hr.

(c) the volumetric flow rate of **brine**, in m^3/hr.

(d) the average velocity of the **brine**, in *m/s*, if the cross-sectional area of the brine pipe is 0.5 m^2. [*Note the units for velocity*.]



Problem 2 (30 points)

To shape the head of a steel bolt, a cylindrical steel rod is placed into a die. A punch then moves downward at constant velocity V_P to forge the head. The bolt head remains cylindrical during the entire process, as shown below. The density of the steel is constant and uniform during the entire process.

Determine the following:

(a) the time rate-of-change of the bolt head diameter (dD/dt) in terms of the punch velocity (V_P), the instantaneous bolt-head diameter (D), and the instantaneous bolt-head thickness (h).

(b) the time rate-of-change of the bolt-head thickness (dh/dt) if the velocity of the punch is $V_P = 1$ m/s.

(c) the final bolt-head thickness (h_f) in terms of the punch diameter (D_P), the steel-rod diameter (D_0), and the initial height of the rod above the lower die cavity (h_0).

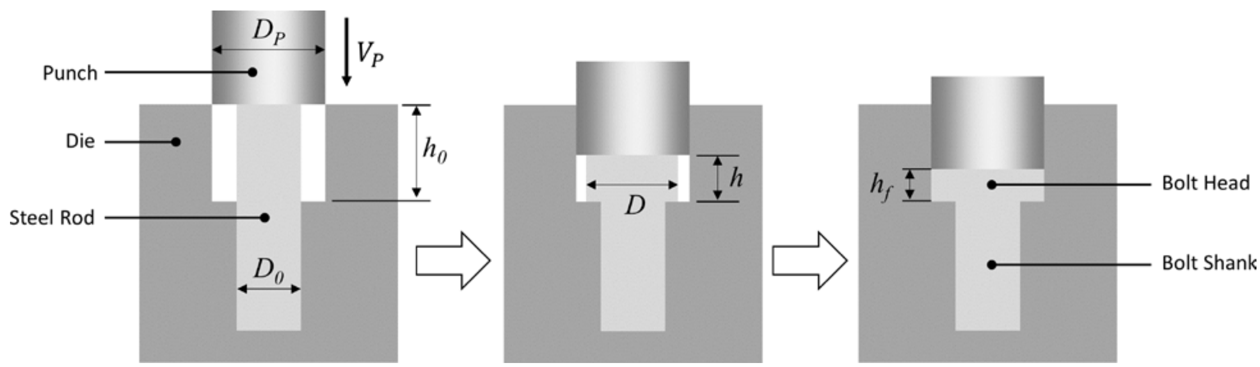


Figure (i) Figure (ii) Figure (iii)

Problem 3 (35 points)

A tank with a concrete basin is shown in the figure and is filled with water to a height *h*. Openings to fill and drain the tank are located in the concrete basin (see figure).

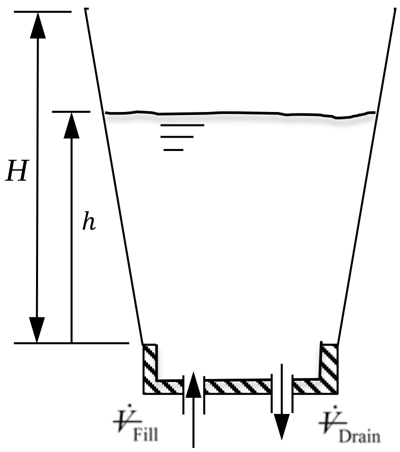
The volume of water in the tank $\mathcal{V}_{\text{water}}$ depends on the height *h* of water in the tank:

$$\mathcal{V}_{\text{water}} = \mathcal{V}_{\text{base}} + wh^2 \qquad \text{where} \qquad \mathcal{V}_{\text{base}} = 144 \text{ ft}^2 \text{ and } w = 100 \text{ ft.}$$

The volumetric flow rate of the water draining from the tank also depends on the height *h*:

$$\dot{\mathcal{V}}_{\text{Drain}} = K_{\text{Drain}}\sqrt{h} \qquad \text{where} \qquad K_{\text{Drain}} = 20.0 \text{ ft}^{3/2}\text{/s .}$$

Assume water is incompressible with a density of 62.4 lbm/ft^3.



(a) Develop a symbolic equation for *dh/dt*, the time rate-of-change of the water level in the tank when $\dot{\mathcal{V}}_{\text{Fill}}$, $\dot{\mathcal{V}}_{\text{Drain}}$ and *h* are all known.

(b) If the tank is initially empty but $\dot{\mathcal{V}}_{\text{Fill}} = 50 \text{ ft}^3\text{/s}$ and the drain is open, determine the steady-state height *h* of the liquid in the tank, in ft.

(c) If the height of the water is *h* = 14 ft and only the drain is open, i.e. $\dot{\mathcal{V}}_{\text{Fill}} = 0$, determine how long it will take, in seconds, for the tank to drain to *h* = 3 ft.

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

$(T/K) = (T/{}^oR) / 1.8$

$(T/K) = (T/{}^oC) + 273.15$

$(T/{}^oC) = [(T/{}^oF) – 32]/1.8$

$(T/{}^oR) = 1.8(T/K)$

$(T/{}^oR) = (T/{}^oF) + 459.67$

$(T/{}^oF) = 1.8(T/{}^oC) + 32$

Temperature Differences

$(\Delta T/{}^oR) = 1.8(\Delta T/K)$

$(\Delta T/{}^oR) = (\Delta T/{}^oF)$

$(\Delta T/K) = (\Delta T/{}^oC)$

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 $kg \cdot m/s^2$ = 0.22481 lbf

1 lbf = 1 $slug \cdot ft/s^2$ = 32.174 $lbm \cdot ft/s^2$ = 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 = "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