1. (20 pts) An open drum contains a small amount of liquid methyl acetate at the bottom. Assume the air in and above the container is stagnant, the height of the drum is \(z_2 - z_1 = 0.513\) m, the drum’s cross-sectional area \(A = 0.45\) m\(^2\), \(T = 26.7^\circ\text{C}\), and the local atmospheric pressure is \(P = 749.5\) mm Hg.

(a) Calculate the evaporation rate of methyl acetate from the drum in grams per hour. **Hint:** You will need to interpolate in Appendix A-8 to find the vapor pressure of this volatile liquid at the given temperature. **Note:** To help the TA grade this problem more easily, put a box around each of these quantities: \(P_v, M_j, D_{aj}, P_a, 1, P_{am}\), and the final answer \(m_j\). Be sure to show all your units in your calculations.

(b) Now suppose everything is the same except that the liquid methyl acetate fills up half the drum instead of just a small amount at the bottom of the drum. Calculate \(m_j\) for this case. Is it less than, greater than, or equal to the value calculated in Part (a)? Briefly explain why physically.

2. (15 pts) Containers of liquid methyl alcohol are filled at a rate of 6 containers per minute. The volume of each container is 1 gallon. Fresh air enters the room at a rate of 15 m\(^3\)/minute, and the exhaust air from the room is sent through a duct to a vapor cleaner that has a removal efficiency of 85%. The temperature is 20\(^\circ\text{C}\).

(a) If the tanks are splash filled, estimate the rate of discharge (emission) of methyl alcohol vapors into the atmosphere in units of grams per minute. Give your result to two significant digits.

(b) Jerry, a young engineer who took ME 405 at Penn State, suggests to his boss that they should modify the filling process such that the tanks are filled by submerged filling instead of splash filling. By approximately what percentage would the emission of methyl alcohol emission be reduced if the boss takes Jerry’s suggestion?

3. (20 pts) In the design of building ventilation systems, especially heating and air conditioning systems, the humidity of the air is of great concern for the comfort of the building’s occupants. We have discussed relative humidity, but you need to be familiar with several other terms used by HVAC designers. Obtain information from any source you like – books, Internet sites, etc., but be sure to list your reference(s).

(a) Define the following four terms, how the temperatures are measured experimentally, and the (qualitative) relationships between the temperatures and the relative humidity: Psychrometrics, Dry Bulb Temperature, Wet Bulb Temperature, and Dew Point Temperature.

(b) Find a good psychrometric chart for water vapor in air, and use it to determine the relative humidity of air with a dry bulb temperature of 96\(^\circ\text{F}\) (35.6\(^\circ\text{C}\)) and a wet bulb temperature of 80\(^\circ\text{F}\) (26.7\(^\circ\text{C}\)).

4. (10 pts) A container of pure isopropyl alcohol is left open on a workbench at \(P = 95.5\) kPa and \(T = 30.5^\circ\text{C}\).

(a) Calculate the partial pressure of the alcohol vapor just above the interface between the liquid alcohol and the air. **Note:** The vapor pressure provided on the SDS is at 20\(^\circ\text{C}\). When your actual temperature is not 20\(^\circ\text{C}\), you must instead use Table A.8 of Heinsohn and Cimbala, which is available on the course website for your convenience. Sometimes you need to interpolate in this table.

(b) Calculate the partial pressure of the air just above the interface between the liquid alcohol and the air.

(c) If a spark were to occur just above the interface, would there likely be an explosion?

*Note: There is another page.*
5. (25 pts) Fred opens a can of paint remover. Just then, he gets a cell phone call and absentmindedly leaves the can open and puts it into a closet of volume 4.00 m³ and goes home. There is no ventilation in the closet (assume it is a sealed container – no air goes in or out). The paint remover consists of 0.600 kg of liquid methanol and 0.400 kg of liquid methylene chloride. Initially, the air in the closet is pure, but the methanol and methylene chloride liquids immediately begin to evaporate. After the container has sat there for a long time, the air in the closet reaches steady-state conditions. The temperature and pressure in the closet are constant at 25.0°C and 101.3 kPa respectively.

(a) Classify each of the liquids as Category 1 or Category 2, according to the definitions in Section 5.2 and in our class notes.

(b) Using Table A.8, interpolate to find the vapor pressure (in mm Hg) for both contaminants at 25.0°C. Note: Do not use the vapor pressure given in the SDS because these are at a different temperature.

(c) At steady-state conditions, calculate the number of mols of each species, including air. (You may neglect air displacement out of the closet and any pressure rise caused by evaporation of the chemicals into the air.)

(d) Determine if the methyl alcohol will evaporate completely, or if some of it will remain as a liquid. Hint: Compare to the maximum possible partial pressure of methyl alcohol in the closet.

(e) Repeat for the methylene chloride.

(f) Summarize your results by listing the final mol fractions for both chemicals (in PPM) in the closet. If there were a spark in the closet, would there likely be an explosion? Why or why not?

6. (10 pts) Consider an office break room with recirculation and an air cleaner as shown in this schematic diagram. Suppose several smokers have gathered in this room, smoking like chimneys for 15 minutes. Suddenly at a time we call $t = 0$, they all leave and get back to work. At this time the mass concentration of smoke in the room is $c(0)$, which is measured. The ventilation system keeps running, but nobody is in the room for the next several hours. Neglecting any adsorption or desorption of smoke into or out of the walls or furniture, write an expression (in terms of the given variables) for the amount of time it takes for the mass concentration of smoke to decrease by a factor of two. In other words, derive an expression for $\Delta t$ such that $c(\Delta t) = c(0)/2$. Hint: There is a very simple solution, and that is why this problem is worth only 10 points.