1. (15 pts) Two air cleaners (efficiencies $\eta_1$ and $\eta_2$) are connected in parallel as sketched. The volume flow rate is split unevenly between the two cleaners such that 25% of the flow goes through cleaner 1 and 75% of the flow goes through cleaner 2.
   (a) Calculate the mass concentration of the cleaned air, i.e., develop an expression for $c_{\text{out}}$ as a function of $c_{\text{in}}$, $\eta_1$, and $\eta_2$ only.
   (b) Consider the simplification where both cleaners have the same efficiency, $\eta_1 = \eta_2 = \eta$. Calculate $c_{\text{out}}$ as a function of $\eta$ for this simplified case and discuss. Is it what you would have expected?

2. (15 pts) A closed, sealed room contains no general ventilation system, and infiltration of fresh air into the room is negligible. Wall adsorption is also negligible. The air in the room is well mixed. A source of contaminant ($S$) is inside the room, but an air cleaner with removal efficiency $\eta_{\text{cleaner}}$ and volume flow rate $Q_{\text{cleaner}}$ cleans the air, as sketched.
   (a) Showing all your work, write an ordinary differential equation for mass concentration in the room in standard form. Write expressions for coefficients $A$ and $B$.
   (b) Generate an expression for the steady-state mass concentration $c_{\text{ss}}$ of the contaminant in the room in terms of the other variables.

3. (15 pts) A sealed tank of volume 2.0 m$^3$ has nothing inside but dry air at STP and a small balloon filled with 23.0 grams of water, which rests on the bottom of the tank. At time $t = 0$, the balloon breaks, and all the water evaporates into the tank.
   (a) Calculate the mol fraction of water vapor in the tank when the system reaches steady state. Give your answer in PPM.
   (b) Calculate the relative humidity of the air in the tank (in percent) when the system reaches steady state.

4. (20 pts) This problem is designed to give you some practice with the Runge-Kutta technique. You may use Matlab, Excel, or any other computer program you desire. (Sample R-K files for both Excel and Matlab are provided on the course website.) Consider the following ODE:

\[
\frac{dy}{dt} = B(t) - A(t)y
\]

where

\[
A(t) = 2.5 + 7.6 \cdot \cos(15\pi t) \quad B(t) = 15 + 2.5 \cdot \sin(15\pi t)
\]

The initial condition is $y(0) = 2.5$. Plot $y$ as a function of time for $t$ between 0 and 3 s, and calculate the value of $y$ at $t = 3$ s. Depending on the computer program you use, you may need to experiment with different resolutions ($\Delta t$ or number of time steps) to make sure you are resolving time accurately enough.

**Note:** There is another page.
5. (15 pts) In an industrial process, chlorobenzene is produced as a byproduct inside a pressurized tank. The air inside the tank is at 80. °C and 200. kPa. The safety officer of the company orders a detector to be installed inside the tank. The detector is to be adjusted to set off an alarm when the chlorobenzene concentration exceeds 10% of its lower explosion limit. Use the Internet to obtain the latest MSDS data for this chemical, and answer the following questions:
(a) At what mol fraction (in PPM) of chlorobenzene should the alarm be set?
(b) At what mass concentration (in units of g/m³) will the alarm sound? (Be careful of units – give answer in g/m³.)
(c) Does this concentration exceed the PEL? Comment about safety issues in this situation.

6. (20 pts) An open drum contains a small amount of liquid isopropyl alcohol at the bottom. Assume the air in and above the container is stagnant, the height of the drum is \( z_2 - z_1 = 0.613 \) m, the drum’s cross-sectional area \( A = 0.35 \) m², \( T = 19.7^\circ\text{C} \), and \( P = 101.3 \) kPa.
(a) Calculate the evaporation rate of isopropyl alcohol from the drum in grams per hour. \textit{Hint:} You will need to interpolate in Appendix A-8 to find the vapor pressure of this volatile liquid at the given temperature. \textit{Note:} To help the TA grade this problem more easily, put a box around each of these quantities: \( P_{v,j}, M_j, D_{aj}, P_{a1}, P_{aw} \), and of course 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 isopropyl alcohol 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 \textit{physically}. 

\[ \text{THIS IS PHIL, OUR NEW VICE PRESIDENT OF MARGINAL LEGAL ACTIVITIES.} \]

\[ \text{HE'LL BE LEADING THE EFFORT TO MAKE OUR USER INTERFACES SO CONFUSING THAT PEOPLE HAVE TO PAY US FOR TRAINING.} \]

\[ \text{WE ALREADY DO THAT UNINTENTIONALLY. SURE, BUT WE CAN'T ALWAYS RELY ON LUCK} \]