1. (15 pts) A noisy machine is installed in a workplace that has a very high ceiling. The machine is near the floor and close to the center of one of the building walls. Both the wall and the floor are hard, reflective surfaces. The equipment manufacturer claims that the free-field sound pressure level is 75 dB at a distance of 10 meters.
(a) Calculate the sound power level of this machine in dB to the nearest integer value of dB.
(b) If a worker stands 0.5 m from the machine, estimate the sound pressure level on his ears in dB to the nearest integer value of dB.
(c) Repeat for a distance of 1.5 m away.
(d) For the conditions of Part (b), approximately how long would OSHA permit this worker to stand there without hearing protection?

2. (25 pts) Industrial buildings often have air quality monitors to measure whether OSHA standards for contaminant concentrations in the indoor air environment are satisfied. Consider a building in which an indoor air monitoring device records the mol fraction \( y \) of a particular contaminant every 5 minutes in units of PPM. The sketch below (not to scale) shows several such readings at times around time \( t \), i.e., at \( t = t_i, t = t_{i-1}, t = t_{i+1}, \) etc. The data points are separated by equal time spacing, \( \Delta t \), which for this example is 5 minutes.

(a) Use the trapezoidal rule of integration to derive a simple expression for the running 15-minute average at time \( t = t_i \). Your expression should contain only \( y_i, y_{i-1}, y_{i-2}, \) and \( y_{i-3} \). Assume \( \Delta t = 5 \) minutes. The time increment should cancel out of your final expression.
(b) Examine the mol fraction record on the spreadsheet “hw_04_Problem_02_post.xls” which can be downloaded from the course website. Apply your equation from Part (a) to calculate the running 15-minute time average throughout the day. Note: You will not be able to calculate a running 15-minute average for the first few data points for obvious reasons. On the same plot, plot both the instantaneous record and the running 15-minute average.
(c) Calculate the overall time average mol fraction for this contaminant over the whole day. For this particular pollutant, the OSHA PEL values are PEL-TWA = 55 PPM, PEL-STEL = 115 PPM, and PEL-C = 150 PPM. Determine if the air in this building on this day satisfies OSHA standards. Explain why or why not. (Be sure to check all the criteria.)
3. (10 pts) Jed’s job at the local concrete batching plant consists of loading large mixers with raw materials. The environmental health officer at the plant estimates that Jed loads approximately 18,000 kg of raw materials per hour, on average. She is concerned about Jed’s health, since he breathes in the small particles all day long, and does not use a respirator or face mask. She uses AP-42 emission factors (Appendices A.2 to A.7 of the Heinsohn-Cimbala textbook) as a quick estimate of the emission rate of particles.

(a) Estimate $m_{\text{particles}}$, the emission rate (in g/hr) of particles produced by loading the mixer with raw materials.

(b) The environmental officer estimates that the steady-state dust mass concentration in the plant is equal to $c_{\text{ss}} = \frac{m_{\text{particles}}}{Q}$, where $Q$ is the ventilation volume flow rate. In the room where Jed works, the ventilation rate is approximately 2200 SCFM. What is the steady-state dust mass concentration (in units of mg/m$^3$) to which Jed is exposed?

4. (25 pts) Cory likes to sit and relax in the sauna at a local health club. The air temperature in the sauna is 60$^\circ$C, and the relative humidity is 25%. The globe temperature is estimated to be 40$^\circ$C. There is not much air movement in the sauna, but natural convection generates an average air speed of about 0.50 m/s in the air near Cory’s body. Consider Cory to be an average healthy male with 1.8 m$^2$ of skin at 35$^\circ$C, seated and at rest in the sauna, with only a swimming suit on ($K = 0.9$).

(a) Estimate Cory’s heat stress index (HSI) in percent.

(b) Should Cory stay in the sauna very long? Explain.

5. (15 pts) Consider air that is at standard atmospheric pressure and 100% relative humidity.

(a) Compare the mol fraction of water vapor (in PPM) at 35$^\circ$C and at 0$^\circ$C.

(b) Why do people say the “warm air holds more moisture than does cold air”? Is this statement true?

(c) By what factor (on a molar basis) does air at 35$^\circ$C hold more water than does air at 0$^\circ$C?

6. (10 pts) The following mixture of three vaporous contaminants exists in a workplace:

- acetic acid vapor at 5 PPM
- toluene vapor at 50 PPM
- phenol vapor at 1 PPM.

(a) Is this mixture considered “safe” for 8-hour exposure by OSHA standards? Why or why not?

(b) Suppose that only the toluene level could be controlled somewhat; the mol fraction of the other two chemicals cannot be controlled. Calculate the mol fraction of toluene that would make this mixture border-line safe according to OSHA standards. Explain.