Equation Sheet for ME 405





Room ventilation : <i>Note</i> : No <i>j</i> subscript, well-mixed conditions. E.g., for the	
simple foom sketched here with a source and wall adsorption, dc $Q + k A$ $S + Q c$	$\underbrace{\mathcal{Q}_s}_{V, c(t)}$ $\underbrace{\mathcal{Q}_e}_{c}$
$V\frac{dc}{dt} = Q_s c_s + S - Q_e c - k_w A_s c \rightarrow \frac{dc}{dt} = B - Ac, A = \frac{Q_e - W_w A_s}{V}, B = \frac{S + Q_s v_s}{V},$	
$\frac{c_{ss} = \frac{B}{A}}{l}, \frac{c_{ss} - c(t)}{c_{ss} - c(0)} = \exp(-At).$ If also <i>desorption</i> : $\dot{m}_{wall loss} = k_w A_s (c - c_d).$	$\mathcal{N}^{k_w A_s c}$
Modify as necessary for other configurations. Students must be able to generate	
equations for A and B for any given room ventilation configuration. Examples:	
Infiltration: $N_{inf} = 0.315 + 0.02/30 + 0.0105 I_{outside} - I_{inside} $ [U in mph, I in F, N in I/h]	
Recirculated and make-up air: $N = Q/V$, $Q_r = (1-f)Q$, $Q_m = fQ$, $Q = Q_r + Q_m$. Air cleaners: $c_{out} = (1-\eta)c_{in}$.	
Effectiveness coefficient: $e = t_N / t_{age,P}$, $t_N = V / Q$, $t_{age,P} =$ time for a fluid particle to go from air supply to point P.	
Room effectiveness coefficient: $e_{\text{room}} = \frac{t_N}{t_{\text{room,avg}}}$, $t_N = \frac{V}{Q}$, $t_{\text{room,avg}} = \frac{\int_0^\infty t \left(1 - \left[\frac{c_E}{c_{E,ss}}\right] - \left[\frac{c_E}{$	where E is at the room exhaust.
Clean rooms: Same equations as above, but specify maximum particle concentratio	ons according to <i>Class</i> of clean room.
Make-up air operating costs : <u>heating</u> $DD_h = (1 \text{ day}) \sum_{365 \text{ days}} (T_{\text{bal}} - \overline{T_{\text{outdoor}}})^+$, <u>cooling</u>	$DD_c = (1 \text{ day}) \sum_{365 \text{ days}} (\overline{T_{\text{outdoor}}} - T_{\text{bal}})^+,$
Engineering equation (be careful to use these units): $\$_{\text{heating}} = 0.154 \frac{DD_h t_{\text{operating}} C_{fu} Q}{q_{fu}}$, where $DD_h = [^{\circ}F$ heating days],
$t_{\text{operating}} = [\text{h/wk}], C_{fu} = \text{unit fuel cost } [\text{unit}], q_{fu} = \text{unit fuel energy } [\text{BTU/unit}], Q = 0$	= make-up air [ACFM, ft ³ /min].
Tunnel ventilation: Note: We consider only balanced, steady-state, uniformly distrib	uted transverse tunnel ventilation.
Source: $S = (EF)_c n_c v_c L$, where $(EF)_c = \text{emission factor per car [mg/(car·km)]}, n_c =$	= traffic density [cars/km],
v_c = car speed [km/hr], and L = tunnel length [km] (sometimes [m] – must convert; b	be careful of units, as always!)
Concentration : We get a first-order ODE as a function of x (distance down the turn $c_{\max} = \frac{B}{A}$, $\frac{c_{\max} - c(x)}{c_{\max} - c(0)} = \exp(-Ax)$, where $A = \frac{k + q_m}{U}$, $B = \frac{s + q_m c_m}{U}$, $q_m = \frac{Q_m}{A_c L}$,	hel): $\left \frac{dc}{dx} = \frac{B - Ac}{a_c L} \right $, with solution $q_e = \frac{Q_e}{A_c L} = q_m$, $s = \frac{S}{A_c L}$, $k = \frac{k_w A_s}{A_c L}$.
Hood design: Particles – match <i>capture velocity</i> to actual velocity. Vapors – use <i>con</i>	<i>trol velocity</i> and tables as needed.
<u>Canopy hoods with periodic surging</u> : $V_h = \text{hood volume}, Q_s(t) \text{ and } Q_w(t)$ are source a	and hood volume flow rates, respectively,
and T is the time period between surges. $V_s = \int_0^T Q_s dt$, $V_w = \int_0^T Q_w dt$ To avoid spille	over, $V_s < V_h$ and $V_s < V_w$.
<u>Gaseous air cleaners in series and parallel</u> : <i>Note</i> : Some books use <i>E</i> instead of η for air cleaner removal efficiency.	
Parallel : $\eta_{\text{overall}} = 1 - \sum_{j=1}^{m} f_j \left[1 - \eta_j \right]$ for <i>m</i> cleaners, where f_j = volume fraction through	gh cleaner j , $f_j = \frac{Q_j}{Q_{\text{total}}}$.
Series: $\eta_{\text{overall}} = 1 - \prod_{j=1}^{m} \left[1 - \eta_j \right]$ for <i>m</i> cleaners, where the volume flow rate of air through the second	ough each cleaner is the same.
Exhaust Duct System Design: For major losses (long, straight sections of duct), use	the Darcy friction factor, <i>f</i> ,
$h_{L,\text{major}} = f \frac{L}{D} \frac{V^2}{2g}, f = 8 \left[(8 / \text{Re})^{12} + (A + B)^{-1.5} \right]^{1/12}, \text{ where } A = \left\{ -2.457 \cdot \ln \left[\left(\frac{7}{\text{Re}} \right)^{12} + \left(\frac{1}{2} + \frac{1}{2} \right)^{12} + \left(\frac{1}{2} + \frac{1}{2} \right)^{12} \right] \right\}$	$\left. + 0.27 \frac{\varepsilon}{D} \right]^{16}$ and $B = \left(\frac{37530}{\text{Re}}\right)^{16}$.
Non-circular ducts: hydraulic diameter, $D_h = \frac{4A_c}{p}$, where $A_c = \text{cross-sectional}$ area of the duct, $p = \text{wetted}$ perimeter.	
For minor losses (elbows, transition sections,), $h_{L,\text{minor}} = \sum C_0 \frac{V^2}{2g} (C_0 = K_L)$. Use tables and charts provided.	
Energy equation in pressure form: $P_1 + \alpha_1 (VP)_1 + \rho g z_1 + \delta P_{fan,u} = P_2 + \alpha_2 (VP)_2 + \rho g z_1$	$z_2 + \rho g h_L$, where $VP = \rho V^2 / 2$ and Δz is
negligible in air. Operating point is volume flow rate $Q = VA_c$ where <i>required</i> fan pr	essure = <i>available</i> fan pressure.

$$\begin{aligned} & \operatorname{Particles} \left[c_{\operatorname{purper}} - \frac{m}{R_{point}} \right] \left[\frac{m}{R_{point}} - \rho_{no} - \rho_{no}$$