

5 Mass Transfer - 131 to 140

1. Write down the main equations governing boundary layer model of heat/mass/momentum transfer with appropriate boundary conditions.
2. Reduce the boundary layer equations to conserved property form in each of the following cases
 - (a) Mass transfer without heat transfer & chemical reaction
 - (b) Mass transfer with heat transfer but without chemical reaction
 - (c) Mass transfer with heat transfer & chemical reaction
3. Using consequences of the Reynolds flow model, derive boundary conditions for the Boundary layer flow model for each conserved property equation. Hence, explain the nature of coupling between momentum and mass transfer equations.
4. List the main assumptions made in the Stefan-flow and Couette-flow models of innterface mass transfer. Derive each model from the boundary layer flow model.
5. A solid cylinder of naphthaline ($C_{10}H_8$) of 5 cm dia and 60 cm long is fixed in a wind-tunnel. Air flows across the cylinder at 10 m/s. Both the air and naphthaline are at 20°C. Determine the reduction in the weight of the cylinder after 1 hour. Given $p_{sat,C_{10}H_8} = 6.95 \text{ N/m}^2$, $D_{C_{10}H_8-air} = 6.14 \times 10^{-6} \text{ m}^2/s$
6. Air at 25°C and 60 % RH flows with a velocity of 7 m/s over a 5 cm dia porous cylinder containing water at 95°C. Calculate the cylinder surface temperature and the rate at which water must be supplied to keep the cylinder outer surface wet. Given: $D = 0.15 \text{ m}^2/\text{hr}$, $\nu = 0.097 \text{ m}^2/\text{hr}$, $\alpha = 0.155 \text{ m}^2/\text{hr}$, $k_m = 0.037 \text{ W/m}^2\text{-K}$.
7. In the previous problem, allow for fluid property variations and re-evaluate the water replenishment rate using the Couette flow model and the recommended empirical corrections.
8. Consider combustion of a 100 μm ethanol (C_2H_5OH) droplet ($\rho_l = 790 \text{ kg/m}^3$) in stagnant dry air at 1 atm and 300 K. Assuming $T_l =$

$T_w = T_{bp} = 78^\circ\text{C}$, estimate (a) initial burning rate and (b) burning time. Take $Cp_m = 1680 \text{ J/kg-K}$, $h_{fg} = 838 \text{ kJ/kg}$, $\Delta h_c = 27.6 \text{ MJ/kg}$.

9. In the previous problem, if the relative velocity between the droplet and air is 65 m/s , estimate the droplet burn time. Evaluate Nusselt number using

$$Nu = 2 + 0.555 Pr^{0.33} \left[\frac{Re}{1 + 1.232/(Re Pr^{1.33})} \right]^{0.5}$$

Also plot the variation of $r_w/r_{w,i}$ vs time (Hint: Numerical Integration is required).

10. Repeat the previous problem, if $p = 10 \text{ atm}$ and $T_\infty = 800 \text{ K}$. Neglect flame radiation.