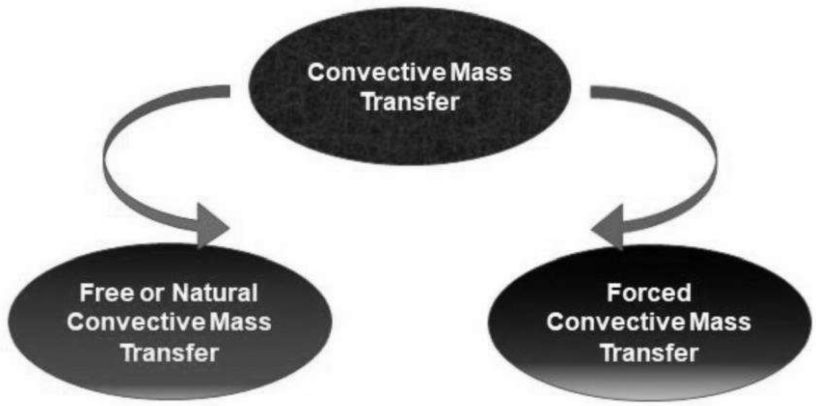
**Covective Mass Transfer**

**Definition:**

Mass transfer between surface and liquid / gas due to concentration difference.




**Terms used in Connective mass Transfer:**

**Sherwood number: [ HMT Data Book Pg.No. 112]**

The ratio of concentration gradient at the boundary by diffusion to concentration gradient at the boundary by convection

$$S_h = \frac{h_m L}{D_{ab}} \text{ (for plates) and } S_h = \frac{h_m d}{D_{ab}} \text{ (for Tubes)}$$

Where,

$h_m$ = Mass transfer coefficient (m/sec); L = Length (m); d = Diameter (m);
$D_{ab}$ = Diffusion Coefficient ($m^2$/sec)

**Schmidt number: [ HMT Data Book Pg.No. 112]**

The ratio of Molecular diffusivity of momentum to the molecular diffusivity of mass.

$$S_c = \frac{v}{D_{ab}} = \frac{\mu}{\rho D_{ab}}$$

Where,

$v$ = Kinematic viscosity ($m^2$/sec), $D_{ab}$ = Diffusion Coefficient ($m^2$/sec)

Reynolds number: [ HMT Data Book Pg.No. 112]

The ratio of Inertia force to viscous force

$$R_e = \frac{uL}{v} \text{ (for plates) and } R_e = \frac{ud}{v} \text{ (for Tubes)}$$

Where,

u = Velocity (m/sec); $v$ = Kinematic viscosity ($m^2$/sec) ; L = Length (m); d = Diameter (m)

**It used to classify the type of flow**

| Flat Plate | Tubes |
|---|---|
| if $R_e < 5 \times 10^5$ flow is laminar<br>if $R_e > 5 \times 10^5$ flow is turbulent | if $R_e < 2000$ flow is laminar<br>if $R_e > 2000$ flow is turbulent |

Lewis number: [ HMT Data Book Pg.No. 112]

The ratio heat diffusivity to mass diffusivity

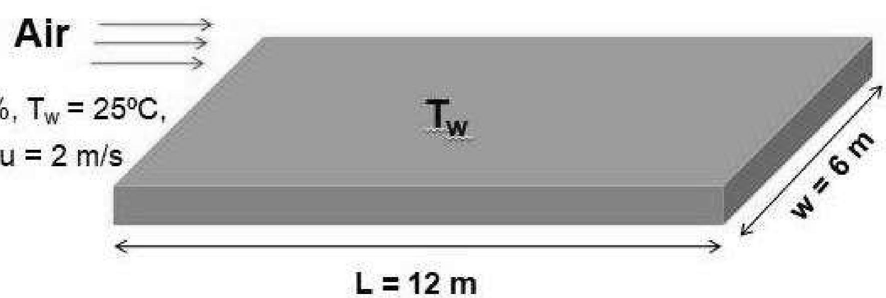
$$L_e = \frac{S_c}{P_r}$$

Where,

Pr = Prandtl Number

**Problem 1:**

Air at 25°C, 50% R.H, flows over a swimming pool at a surface temperature of 25°C of 12 m x 6 m. The velocity of air in the length direction is 2m / sec. Determine the (a) mass transfer coefficient (b) mass rate of water evaporation




**Given :**

$T_\infty$ = 25°C, $\phi$ = 50%, $T_w$ = 25°C,

L = 12 m, w = 6 m, u = 2 m/s

**Solution:**

Since velocity is given in the problem, it is a convection mass transfer.

**Step 1: Determination of film temperature ($T_f$)**

$$T_f = \frac{T_w + T_\alpha}{2} = \frac{25 + 25}{2} = 25^\circ C$$

**Step 2: Taking properties of air, [ from HMT Data book, Pg.No. 34]**

**Corresponding to $T_f = 25^{o}C$,**

$$v = 15.53 \text{ x } 10^{-6} \frac{m^2}{s}$$

$$P_r = 0.702$$

**Step 3: Determination of type of flow:**

$$R_e = \frac{uL}{v} = \frac{2 \text{ x } 12}{15.53 \text{ x } 10^{-6}} = 1545396 > 5 \text{ x } 10^5$$

**Since greater than $5 \text{ x } 10^5$, the flow can be assumed as turbulent or Laminar - turbulent**

Here we assume the flow is Laminar – turbulent.

**Step 4: Determination of Diffusion coefficient, [ from HMT Data book, Pg.No. 181]**

**Corresponding to the medium, (water – air) at $T_f = 25^{o}C$**

$$D_{ab} = 25.83 \text{ x } 10^{-6} \text{ m}^2/\text{s}$$

**Step 5: Determination of Schmidt Number ($S_c$),**

$$S_c = \frac{v}{D_{ab}} = \frac{15.53 \text{ x } 10^{-6}}{25.83 \text{ x } 10^{-5}} = 0.60123$$

**Step 6: Determination of Sherwood Number ($S_h$), From HMT data book, Pg.No. 177,**

$$S_h = [0.037 {R_e}^{0.8} - 871] {S_c}^{0.33}$$

$$S_h = [0.037 \text{ x } 1545396 - 871] 0.60123^{0.33}$$
$$= 2059.4906$$

**But we know that, [ HMT Data Book Pg.No. 112]**

$$S_h = \frac{h_m L}{D_{ab}} = 2059.4906$$

**Step 7: Determination of mass transfer coefficient ($h_m$),**

$$h_m = \frac{S_h D_{ab}}{L} = \frac{2059.49 \text{ x } 2.583 \text{ x } 10^{-5}}{12}$$
$$= 4.43305 \text{ x } 10^{-3} \frac{m}{s}$$

**Step 8: Mass of flow rate evaporated ($\dot{m}_w$),**

$$\dot{m}_w = h_m A(\rho_{aw} - \varphi\rho_{a\infty})$$

**Where,**

$\rho_{aw}$ = Density of water vapor at $T_w$ = $\frac{1}{v_g}$

$\rho_{a\infty}$ = Density of water vapor at $T_\infty$ = $\frac{1}{v_g}$

**From steam tables, corresponding to $T_w = T_\infty = 25^0C$,**

$$v_g = 43.402\ \frac{m^3}{kg}$$

$$\rho_{aw} = \frac{1}{v_g} = 0.02304\ \frac{m^3}{kg}$$

∴ **Mass of flow rate evaporated**

$$\dot{m}_w = 4.43305 \text{ x } 10^{-3} \text{x } (12 \text{ x } 6)(0.02304 - 0.5 \text{ x } 0.02304) = 3.6769 \text{ x } 10^{-3}\ \frac{kg}{sec}$$