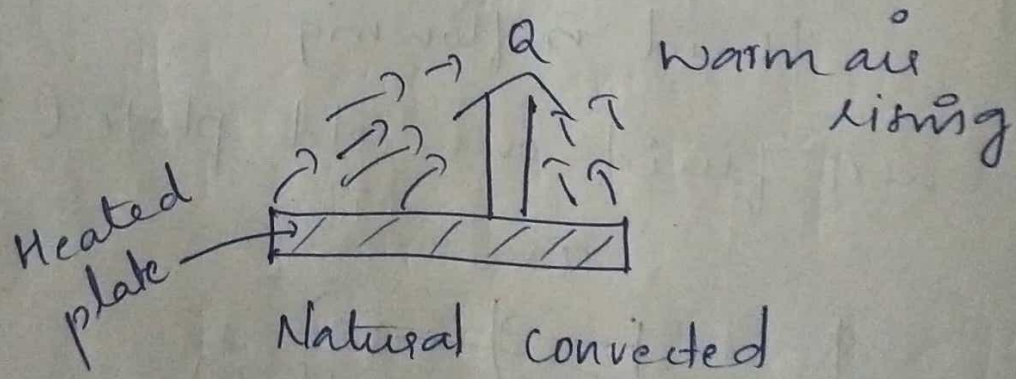
## Types of convection

### 1) Natural or free convection

- Fluid motion is caused by changes in fluid density resulting from temp gradients b/w the solids surface and the main mass of fluid.
- When a fluid is heated or cooled, its density changes and produce a natural circulation in the affected region, which causes itself the rise of warmer fluid and fall of colder fluid
- Therefore energy transfer from hotter region to colder region and such process is repeated as long as the temp diff in the fluid exists




### 2) Forced convection

The fluid is forced to flow over a surface or in a duct by external means such as pump

or a fan
eg: cooling of internal combustion engines, air conditioning, installation, nuclear reactors and condensor tubes etc..

## Dimensional Analysis

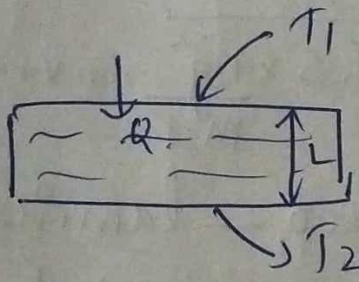
### 1) Dimensionless numbers

- It is defined as ratio of convective heat transfer to conductive heat transfer.

$$Nu = \frac{hL}{K_f}$$

h - convective heat trans. coeff
L - characteristic length
$K_f$ - Thermal conductivity of fluid

Consider a fluid layer of thickness 'L' and temp diff $\Delta T$




$\Delta T = T_2 - T_1$

Acc to Newton's law of cooling

$$Q = hA(t_s - t_f)$$

$$q = \frac{Q}{A} = h(t_s - t_f), \quad q = h\Delta T \text{ —— } (1)$$

Acc to Fourier's law of cond$^n$

$$Q = \frac{-KA\Delta T}{L} = \frac{-KA\Delta T}{L}$$

$$q = \frac{Q}{A} = \frac{-K\Delta T}{L}$$

$$Nu = \frac{q_{conv}}{q_{condu}} = \frac{h\Delta T}{k\frac{\Delta T}{L}} = \frac{hL}{k} = \frac{W \times m}{m^2K \times W/mK}$$

dimensionless.

Note: $Nu = 1$, — Pure conduction

$Nu >> 1$ — effective convection

## Reynold's number

It is defined as ratio of inertia force to viscous force

$$Re = \frac{\rho v^2 L^2}{\mu v L}$$ — inertia force

— visc. force.

$$= \frac{\rho v L}{\mu} = \frac{kg \; m \times m/s}{m^3 \cdot s \times \frac{kg}{m \cdot s}}$$ — dimensionless

$\rho$ — density, $v$ — velocity, $\mu$ — dy. viscosity

conditions: if $Re < 2000$ — laminar flow

$Re > 4000$ — Turbulent flow

$Re$ 2000 - 4000 — Transition flow

## Prandtl number

it is defined as the ratio of kinematic viscosity to thermal diffusivity

or Momentum diffusivity to thermal diffusivity

$$Pr = \frac{\nu}{\alpha} \quad ; \quad \nu = \frac{\mu}{\rho} \qquad \alpha = \frac{k}{\rho C_p}$$

$$= \frac{\mu}{\rho \cdot \frac{k}{\rho C_p}} = \frac{\mu C_p}{k} = \frac{kg \cdot J \; s \; m^2 \; K}{m \cdot s \; kg \cdot K \cdot J}$$

dimensionless

## Biot number

- It is defined as ratio of internal conductive resistance to convective thermal resistance.

$$Bi = \frac{1}{CTR} \frac{CV}{} = \frac{L}{KA} \Big/ \frac{1}{hA} = \frac{L}{KA} \times hA$$

$$= \frac{h L_c}{k_{solid\ body}}$$

$h$ - medium

$k$ - solid body ther condu.

$$L_c = \frac{\text{Volume of given body}}{\text{Area}}$$

## Significance

- For lumped heat capacity method, $Bi \leq 0.1$

  ie conductive resistance is almost 10% of $R_{con}$

  $R_{cond} = 10\% (R_{conv})$

  ie internal temp gradient $\Rightarrow < 5\%$

lumped heat analysis - Temp wrt time - it should change but it should not change wrt to $x$.

$Bi = \infty$ – semi infinite solid

$0.1 < Bi < 100$ – Infinite solid

## Grashoff number

– It is defined as ratio of buoyant to viscous force acting on a fluid

$$G_x = \frac{B.F}{V.F}$$

$$= \frac{g\beta L_c^3 (T_s - T_\infty)}{\nu^2}$$

$\beta$ – Coeff of thermal expansion.

$\nu$ – Kin. viscosity

$g$ – gravit. acceleration

## Stanton number

– Ratio of heat transfer coefficient to heat capacity of fluid

$$S_t = \frac{Nu}{Re \times Pr} = \frac{h}{\rho u C_p}$$

$u$ – velocity

## Dimensional Analysis

- It is a method by which we deduce information about a phenomenon from single premise that the phenomenon can be described by a dimensionally correct equation among certain variables.
- Major advantage - Helps to reduce the no: of independent variables of the problems.
- With the help of dimensional analysis, we can combine the variables of the problem into dimensionless grps such as Reynold's no, Pr: no, etc..
- There are four dimensions namely Mass (M), Length (L), time (t) and temperature (T)