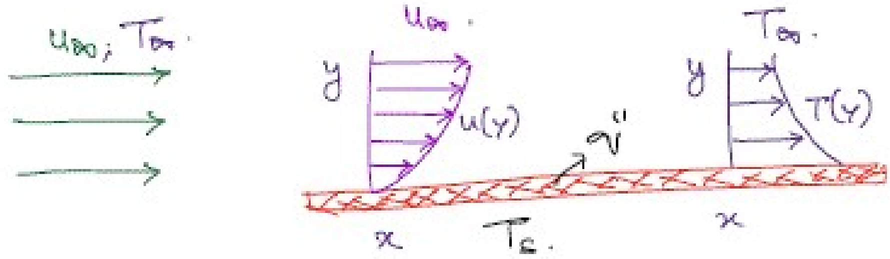
Main purpose:

1) Flow field 2) Temperature in the field. 3) HTC (h).

Consider the process of convection [Cooling / Heating].



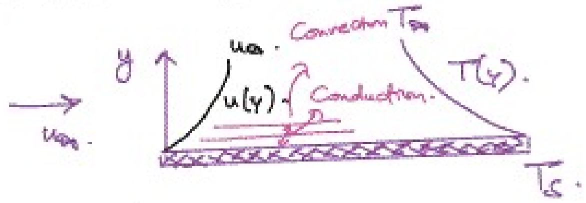
1) Near the wall the fluid is subjected to no slip condition (there is no stagnant sub layer, with no fluid motion).

2) Heat transfer is by conduction in this region.

3) Above the sub layer, viscous forces retard the fluid motion [Convection may occur, but conduction predominate].

4) A carefull analysis of this region using conductive analysis is the basis for convective theory.

Consider the wall,



$$-k_f \cdot \left.\frac{\partial T}{\partial y}\right|_{y=0} = h(T_s - T_\infty).$$

Hence,
$$h = \frac{-k_f \cdot \left.\frac{\partial T}{\partial y}\right|_{y=0}}{(T_s - T_\infty)}$$

But $\left.\frac{\partial T}{\partial y}\right|_{y=0}$ depends on the fluid motion.

(X) The expression shows that in order to determine 'h', we must first determine the temperature distribution in the thin fluid layer on the wall.

Common classification:

1) Based on geometry → External / Internal.
2) Driving mechanism → Natural / Forced.
3) Based on number of phases → Single/multiple.
4) Nature of flow → Laminar/ Turbulent.

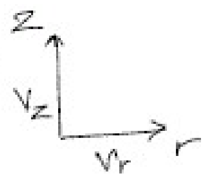
Need for fluid mechanics:

1) Determination of pressure drop [OR] Drag force is a situation of convective heat transfer.
2) Governing equations of fluid flow:
   (a) Mass (b) Momentum (c) Energy.
3) Momentum (Navier stokes equation)
   Cartesian → X, Y, Z
   Cylindrical → r, θ, Z
   Polar (OR) Spherical → r, θ, φ
4) Stokes relation between stress and strain rate → newtonian fluids.
5) Steady state, constant property, incompressible laminar, 2D (OR) 3D.
   ✓ ✗

Continuity equation in 2D:

1) $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0.$ → Cartesian

2) $\frac{\partial V_r}{\partial r} + \frac{V_r}{r} + \frac{\partial V_z}{\partial Z} = 0$ → Cylindrical.



Two momentum equations:

a) Cartesian coordinates: [x,y]

$$X \rightarrow \rho\left[u.\frac{\partial u}{\partial x} + v.\frac{\partial u}{\partial y}\right] = -\frac{\partial p}{\partial x} + \mu\left[\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right]$$

$$Y \rightarrow \rho\underbrace{\left[u.\frac{\partial v}{\partial x} + v.\frac{\partial v}{\partial y}\right]}_{\text{Net out flow}} = \underbrace{-\frac{\partial p}{\partial y} + \mu\left[\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right]}_{\text{Net force.}}$$

Momentum. Pressure. Net viscous.

b) Cylindrical coordinates [r,z]

$$r \rightarrow \rho\left[V_r.\frac{\partial V_r}{\partial r} + V_z\frac{\partial V_r}{\partial z}\right] = -\frac{\partial p}{\partial r} + \mu\left[\frac{\partial^2 V_r}{\partial r^2} + \frac{1}{r}.\frac{\partial V_r}{\partial r} - \frac{V}{r^2} + \frac{\partial^2 V_r}{\partial z^2}\right]$$

$$z \rightarrow \rho\left[V_r.\frac{\partial V_z}{\partial r} + V_z\frac{\partial V_z}{\partial z}\right] = -\frac{\partial p}{\partial z} + \mu\left[\frac{\partial^2 V_z}{\partial r^2} + \frac{1}{r}\frac{\partial V_z}{\partial r} + \frac{\partial^2 V_z}{\partial z^2}\right]$$

Navier stokes equation (comments)

1) They are not easy to solve.
2) Solutions are obtained for simple cases.
3) Solutions are based on correlations based on experimental data.
4) $\tau \propto \frac{du}{dy} \rightarrow \tau = \mu.\frac{du}{dy} \rightarrow \mu = \frac{\tau}{\frac{du}{dy}}$.