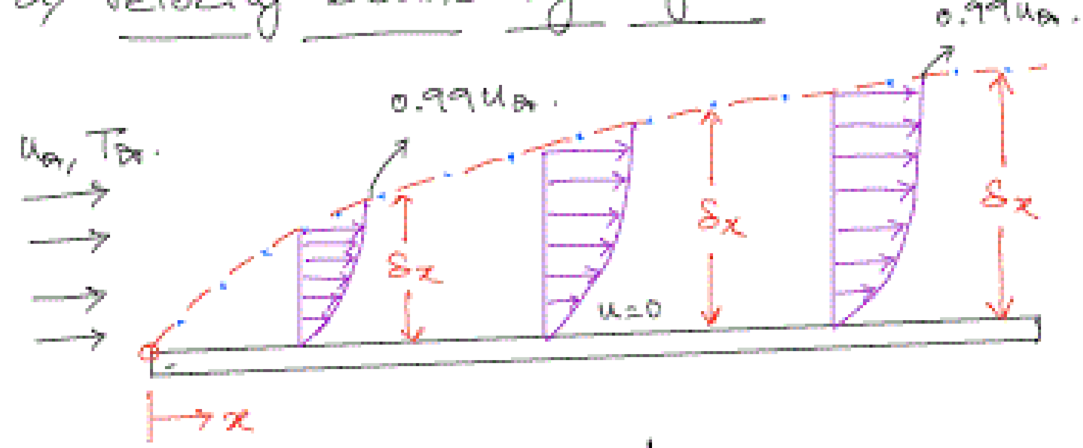
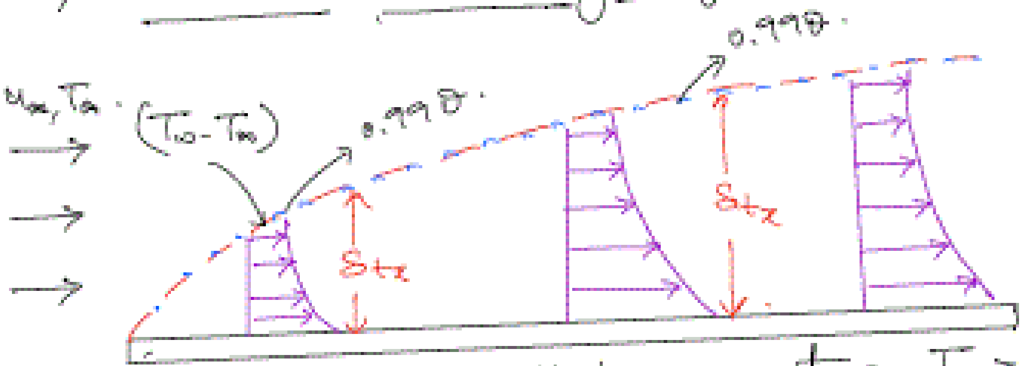
Boundary layer theory:

a) Velocity boundary layer:

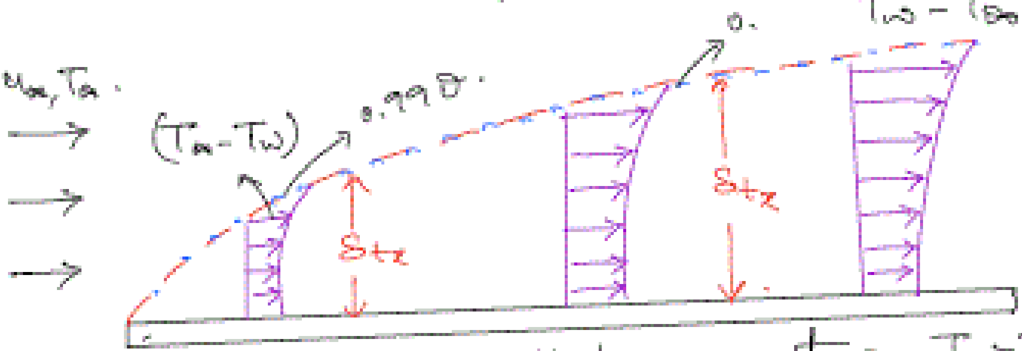


b) Thermal boundary layer:



T_w = Wall temperature $T_w > T_\infty$.

Dimensionless temperature $\theta = \dfrac{T_{w,x} - T_\infty}{T_w - T_\infty}$.



T_w = Wall temperature $T_\infty > T_w$.

Boundary layer characteristics

1) A thin layer, compared to the dimension of the body (0.1mm, 1mm to few cm)

2) Velocity changes in 'x' direction is far greater than in 'y' direction. [Component normal to BL is small]. v.

3) Gradients along the flow are small.

$$\frac{\partial u}{\partial y} >> \frac{\partial u}{\partial x}.$$

4) It simplifies the momentum equation, with terms containing viscous term.

5) Consider the X-momentum equation

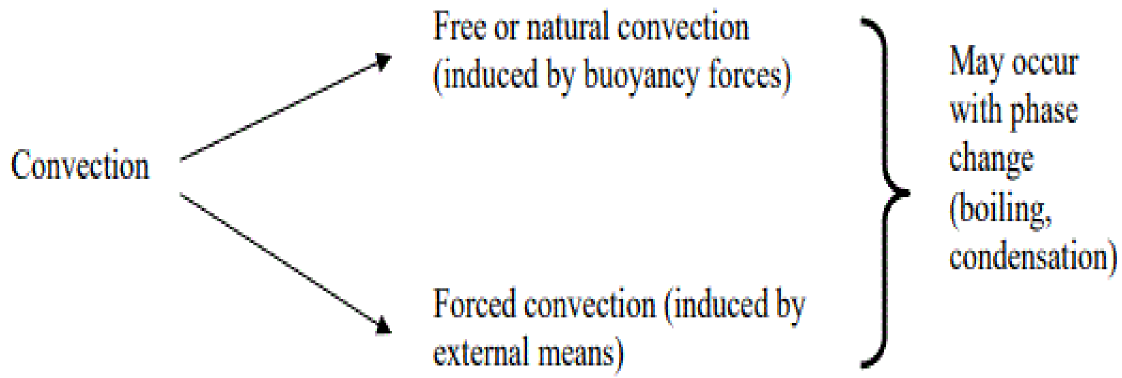
$$X \rightarrow \rho\left[u.\frac{\partial u}{\partial x} + v.\frac{\partial u}{\partial y}\right] = -\frac{\partial p}{\partial x} + \mu\left[\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right]$$

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

$$Y \rightarrow -\frac{\partial p}{\partial y} = 0. \Rightarrow \text{Implies } p(x) \text{ only.}$$

6) Most situations → Correlations based on experimental data.

2.2 Classes of Convective Flows



- extremely diverse
- several parameters involved (fluid properties, geometry, nature of flow, phases etc)
- systematic approach required
- classify flows into certain types, based on certain parameters
- identify parameters governing the flow, and group them into **meaningful non-dimensional numbers**
- need to understand the physics behind each phenomenon

Common classifications:

A. ***Based on geometry:***

External flow / Internal flow

B. ***Based on driving mechanism***

Natural convection / forced convection / mixed convection

C. ***Based on number of phases***

Single phase / multiple phase

D. ***Based on nature of flow***

Laminar / turbulent

h – heat transfer co efficient for various convection processes are tabulated value in (W/m^2K)

Free convection	gases: 2 - 25 liquid: 50 – 100
Forced convection	gases: 25 - 250 liquid: 50 - 20,000
Boiling/Condensation	2500 -100,000

Dimensional analysis:

When more than three parameters influence a problem it becomes very difficult to analyse the effect of each on the problem. It is found desirable to group these parameters into dimensionless parameters so that the number of variables can be reduced to three. In this attempt to formulate dimensionless groups the Π–theorem proposed by Buckingham is useful. The theorem states that if there are *m* physical quantities involved in a problem requiring *n* primary dimensions to express them, then the number of independent dimensionless groups that can be formed is equal to (*m–n*). In case there are seven quantities and four dimensions, it is possible to group these as

$$\pi_1 = f(\pi_2, \pi_3)$$

The dimensional analysis aids in the identification of the groups. This approach provides a method to represent or correlate experimental results. This method does not lead to exact functional relationship and it also does not ensure that all the variables are correctly chosen. Fluid mechanics and Heat transfer studies involve a large number of dimensionless parameters like Reynolds number, Nusselt number etc which have been first identified using this method. Almost all empirical correlations are based on these parameters so identified. The application of the method is illustrated by a problem under the section solved problems.

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