FLOW OVER IMMERSED BODY

When the object is completely surrounded by the fluid and the flows are termed *external flows*.

Lift and drag is also called the *fluid force*.

Theoretical (analytical and numerical techniques) and experimental approached are used to obtain information on the fluid forces developed by external flows.

One of the method to obtain flow data is by *wind tunnel* testing works.
Chapter 1: Boundary Layer

(a) Full scale wind tunnel test
(b) Model scale wind tunnel test
GENERAL EXTERNAL FLOW CHARACTERISTIC

Such as a airplane flying through still air, the fluid far from the body is stationary and the body moves through the fluid with velocity $U$.

Such as the wind blowing past a building, the body is stationary and the fluid flows past the body with velocity $U$.

To simplify the evaluation, we treat the situation as fluid flowing past a stationary body with velocity $U$, called the upstream velocity.

The velocity is assumed a uniform and constant velocity.
Three general categories of bodies are shown below.

1. Two-dimensional objects (infinitely long and of constant cross-sectional size and shape)
2. Axisymmetric bodies (formed by rotating their cross-sectional shape about the axis of symmetry)
3. Three-dimension bodies that may or may not possess a line or plane of symmetry.
LIFT AND DRAG CONCEPTS

The resultant force in the direction of the upstream velocity is termed the *drag*, $D$.

The resultant force normal to the upstream velocity is termed the *lift*, $L$. 
The resultant of the shear stress and pressure distributions can be obtained by integral the effect of these two quantities on the body surface as shown below.

The $x$ and $y$ components are;

\[
dF_x = (pdA)\cos \theta + (\tau_w dA)\sin \theta
\]
\[
dF_y = -(pdA)\sin \theta + (\tau_w dA)\cos \theta
\]

The drag, $D$ is;
\[
D = \int dF_x = \int p \cos \theta dA + \int \tau_w \sin \theta dA
\]

The lift, $L$ is;
\[
L = \int dF_y = -\int p \sin \theta dA + \int \tau_w \cos \theta dA
\]
The widely used alternative is to define dimensionless lift and drag coefficients.

The lift coefficient $C_L$ is defined as:

\[ C_L = \frac{L}{\frac{1}{2} \rho U^2 A} \]

The drag coefficient $C_D$ is defined as:

\[ C_D = \frac{D}{\frac{1}{2} \rho U^2 A} \]

$A$ is a characteristic area of the object.
$
\rho$ is the density of flowing fluid.
$U$ is the upstream velocity.
Typically, $A$ is taken to be frontal area - the projected area seen by a person looking toward the object from a direction parallel to the upstream velocity $U$.

In other situations $A$ is taken to be the platform area – the projected area seen by an observer looking toward the object from a direction normal to the upstream velocity.