# Drag Definitions &Types

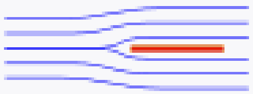
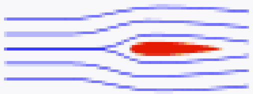
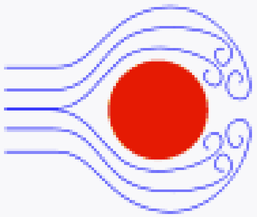
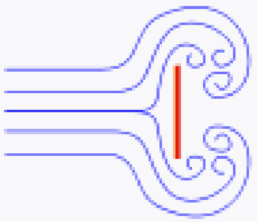
# Drag Types

## Skin or wall drag

The fluid (passes parallel to a surface, see figure) will exert a force on the solid in the direction of flow. This force is called skin or wall drag.

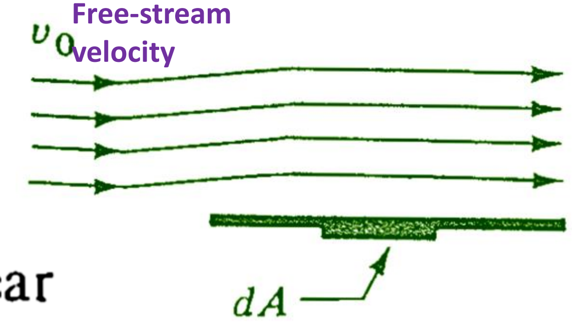
## Form drag

As the fluid changes its direction (not parallel) a round a solid surface as shown in figures additional frictional losses takes place called form drag.

| Shape and flow | Form Drag | Skin friction |
| --- | --- | --- |
|  | 0% | 100% |
|  | ~10% | ~90% |
|  | ~90% | ~10% |
|  | 100% | 0% |

# Look to the following figure

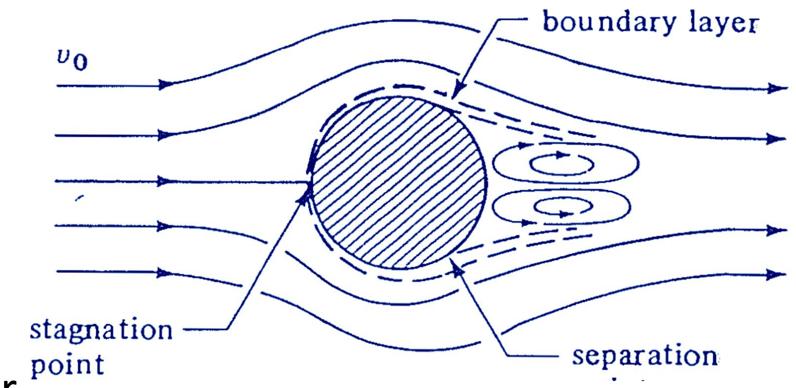
- A fluid is flowing parallel to a smooth solid flat surface as shown in figure. The force $dF$ in newtons on an element of area $dA$ $m^2$ of the plate is the wall shear stress $\tau_w$ times the area $dA$ or $\tau_w\, dA$.




- The total force is the sum of the integrals of these quantities evaluated over the entire area of the plate.

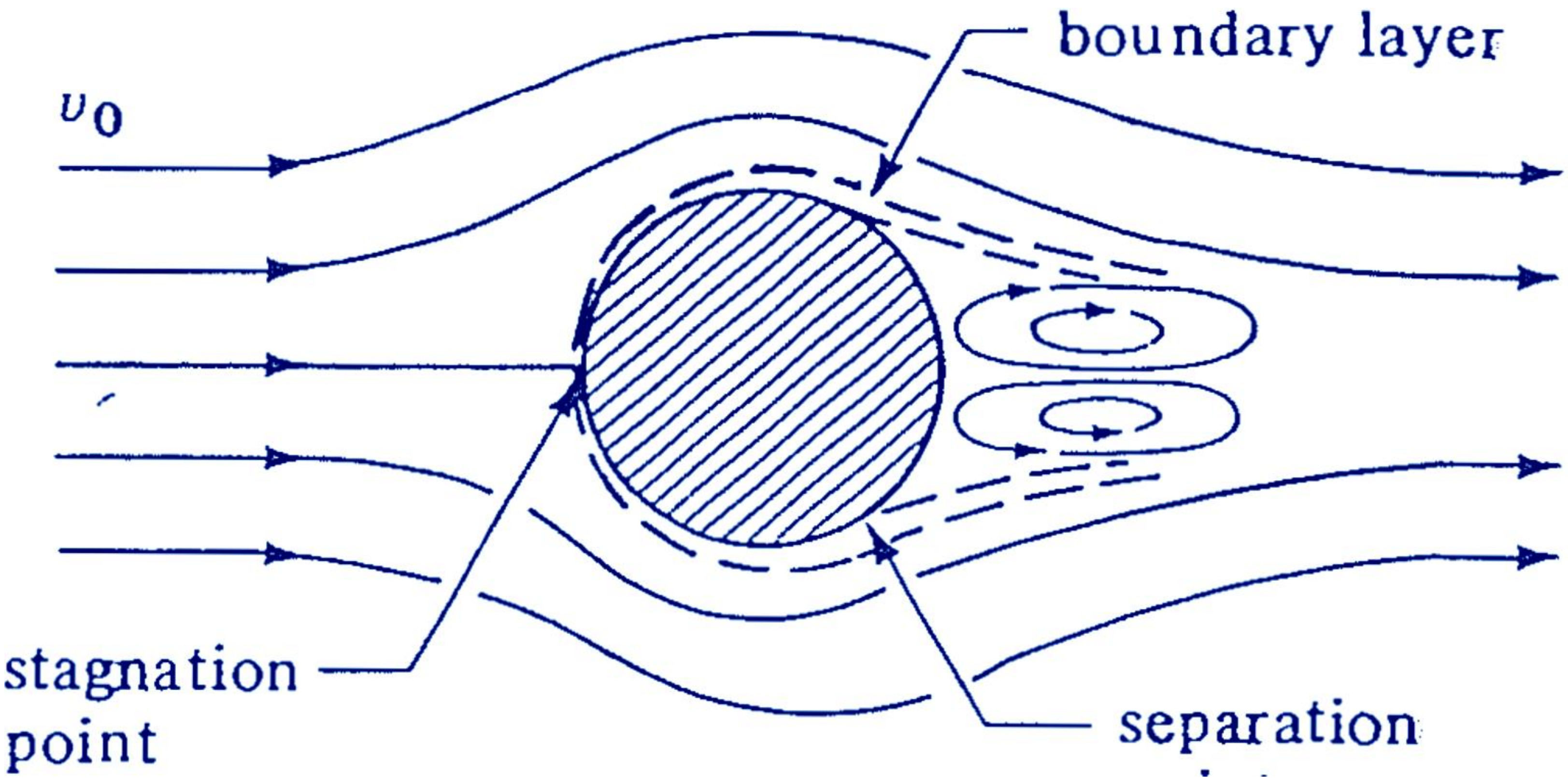
- **Note**: the transfer of momentum to the surface results in a tangential stress or skin drag on the surface.

# Flow past immersed sphere

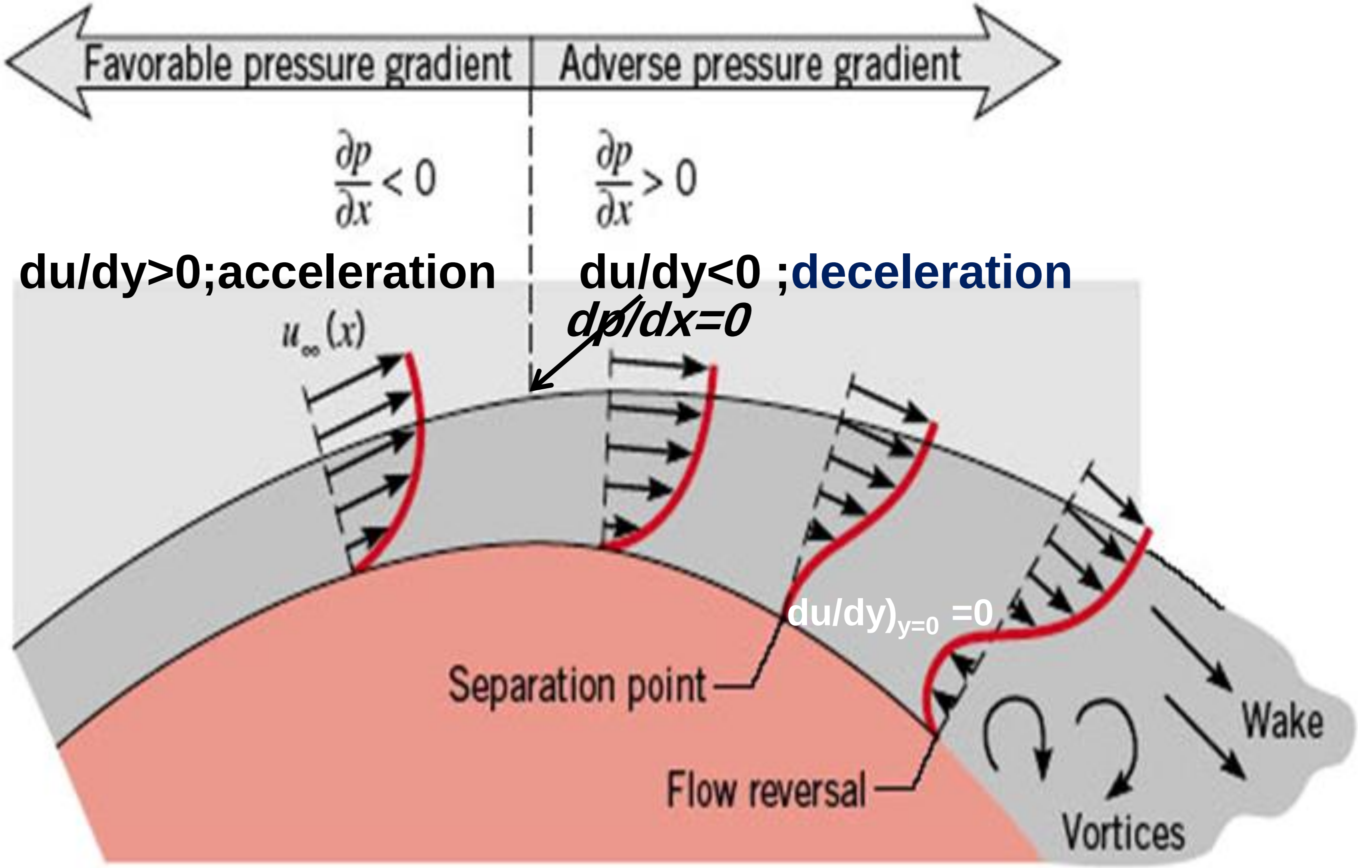



- Lines called *streamlines* represent the path of fluid elements around the suspended body.
- The dash line represents a thin boundary layer around the immersed sphere. In this B.L velocity and pressure are not constant.
- Velocity at the edge of the B.L and above is similar to the bulk fluid velocity.
- At the front center of the body, called the *stagnation point*, the fluid velocity will be zero and boundary-layer growth begins at this point and continues over the surface until it separates.
- ***Skin Friction:*** The tangential stress on the body because of the velocity gradient in the boundary layer is the skin friction.
- ***Form drag:*** Outside the B.L the fluid changes the direction around the sphere and accelerates near the front and then decelerates.
  Because of these effects, an additional force is exerted by the fluid on the body. This is called form drag, to be added to the skin friction in the B.L.

# Flow past immersed sphere



# Separation point



# Notes

- The point of separation depends on
    a) the shape of object
    b) leading edge
    c) condition of flow
    d) velocity , regime of flow, Re
- In general, the geometry of the immersed solid plays a significant role in the amount of the total drag force excreted on the body.

# Drag Coefficient

- Correlations of the geometry and flow characteristics for solid objects suspended or held in a free stream (immersed objects) are similar in concept and form to the friction factor–Reynolds number correlation given for flow inside conduits.

- Based on flow inside conduits the drag coeff. is defined as the ratio of the drag force per unit area (shear stress) to the product of density times the velocity head.

- In a similar manner for flow past immersed objects, the drag coefficient $C_D$ is defined as the ratio of the total drag force per unit area to $\rho v_0^2/2$.

$$C_D = \frac{F_D/A_p}{\rho v_0^2/2}$$

Projected area

where $F_D$ is the total drag force in N, $A_p$ is an area in $m^2$, $C_D$ is dimensionless, $v_0$ is free-stream velocity in m/s, and $\rho$ is density of fluid in $kg/m^3$.

# Total drag force

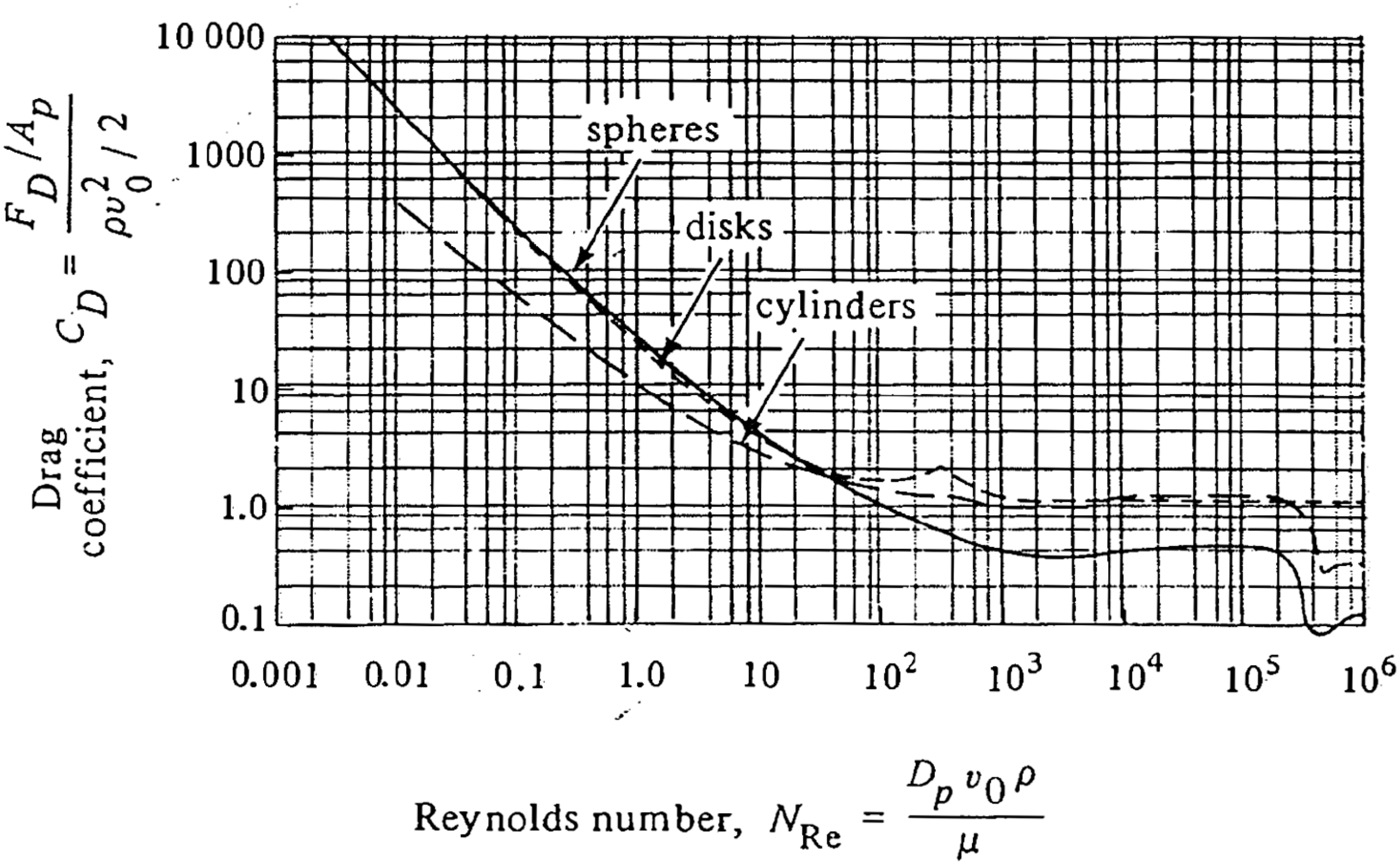
$$F_D = C_D \frac{v_0^2}{2} \rho A_p$$

The Reynolds number for a given solid immersed in a flowing liquid is

$$N_{Re} = \frac{D_p v_0 \rho}{\mu} = \frac{D_p G_0}{\mu}$$

where $G_0 = v_0 \rho$.

# Flow Past Sphere, Long Cylinder, and Disk




These curves have been determined experimentally.

# Stokes' Law

- For a sphere , Re < 1.0

$$F_D = 3\pi\mu D_p v_0$$

# Example

Air at 37.8°C and 101.3 kPa absolute pressure flows at a velocity of 23 m/s past a sphere having a diameter of 42 mm. What is the drag coefficient $C_D$ and the force on the sphere?

# Solution

- From Appendices (see text), for air at 37.8°C, $\rho$ = 1.137 kg/m$^3$ and $\mu$ = 1.90 × 10$^{-5}$ Pa · s. Also, $D_p$ = 0.042 m and $v_0$ = 23.0 m/s. firstly, find Reynolds No.

$$N_{\text{Re}} = \frac{D_p v_0 \rho}{\mu} = \frac{0.042(23.0)(1.137)}{1.90 \times 10^{-5}} = 5.781 \times 10^4$$

- From previous figure, obtain $C_D$

for a sphere, $CD = 0.47$.

- Then find drag force

$$F_D = C_D \frac{v_0^2}{2} \rho A_p = (0.47) \frac{(23.0)^2}{2} (1.137)(\pi) \frac{(0.042)^2}{4} = 0.1958 \text{ N}$$