Skin friction:

When the boundary layer eq:

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \nu\frac{\partial^2 u}{\partial y^2} \quad - (A)$$

is integrated, the velocity distribution can be deduced, and the position of the point of separation can be determined.

Point of separation:-

The point of separation is defined as the limit between forward and reverse flow in the layer in the layer in the immediate neighbourhood of the wall, mathematically,

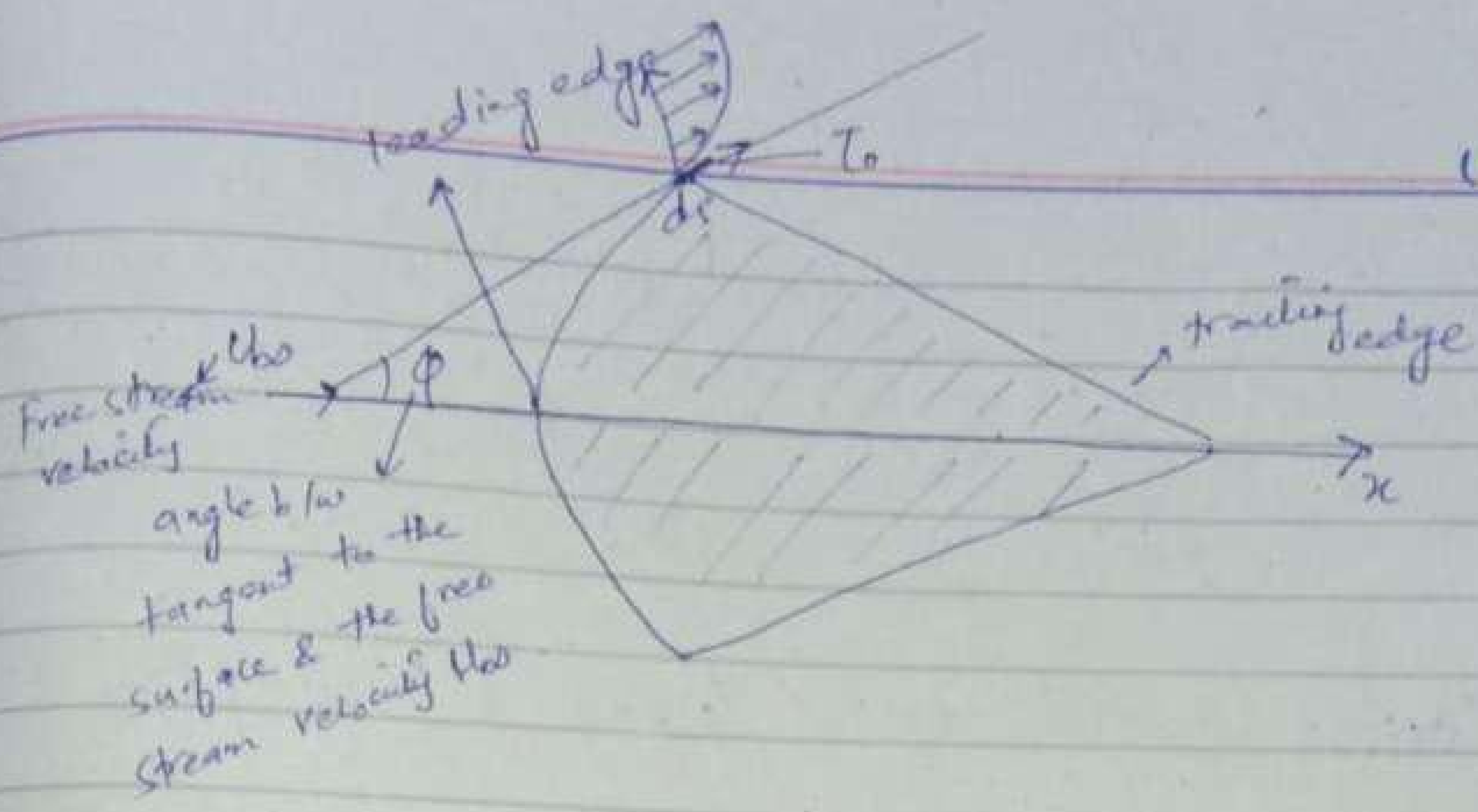
$$\left(\frac{\partial u}{\partial y}\right)\bigg|_{y=0} = 0 \quad - (1)$$

This turn permits us to calculate the viscous drag (skin friction) around the surface by a simple process of integrating the shearing stress at the wall over the surface of the body. The shearing stress at the wall is

$$\tau_0 = \mu\left(\frac{\partial u}{\partial y}\right)_{y=0} \quad - (2)$$

Viscous drag for the case of two dimensional flow becomes

$$D_f = b\int_0^l \tau_0 \cos\phi \, ds \quad - (3)$$



ds: Small distance measured along the surface.

In (3) 'b' denotes the height of the cylinder. The process of integration is to be performed over the whole surface, from the stagnation (where velocity of the fluid is zero) point at the leading edge to the trailing edge, assuming that there is no separation

Since

$$\cos\phi \, ds = dx$$

where 'x' is measured parallel to the free stream velocity. We can also write (3) as

$$D_f = b\mu \int_{x=0}^{l} \left(\frac{\partial u}{\partial y}\right)_{y=0} dx$$

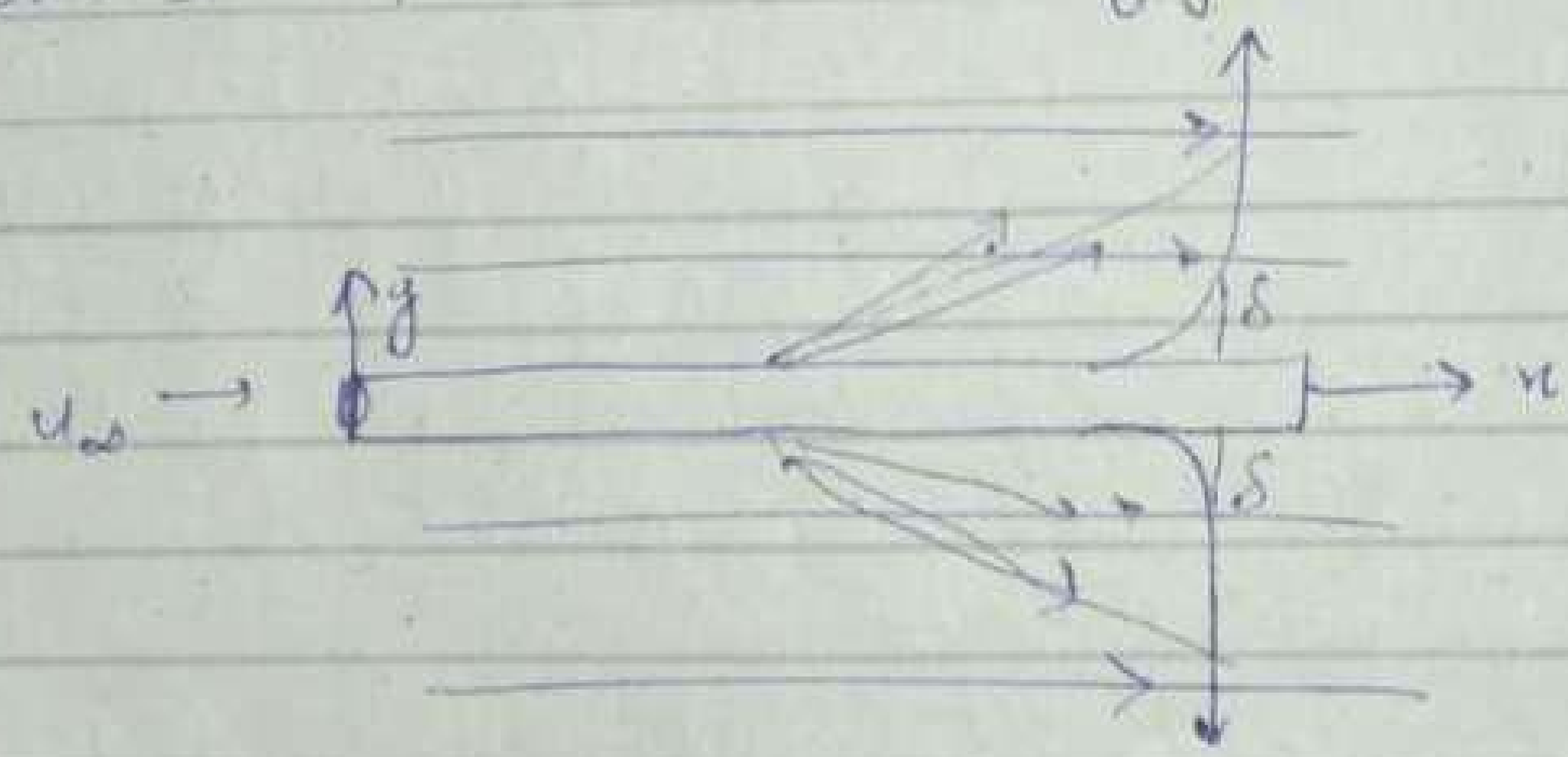
In order to calculate skin friction, it is necessary to know the velocity gradient

$\left(\frac{\partial u}{\partial y}\right)_{y=0}$ at the wall, which can be achieved only through the differential eq. of the boundary layer given in (A). we will practise this for a problem given as belows

Problem: Boundary layer along a flat plate

Statement:-

Let the leading edge of the plate be at $x=0$, the plate being parallel to the x-axis and infinitely long down stream as shown in fig.



Sol:- we shall consider a steady flow with a free-stream velocity u_∞, which is parallel to the x-axis. The velocity potential flow is constant in this case and therefore

$$\frac{dp}{dx} = 0$$

The boundary layer eq. for this case becomes:

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \quad (1)$$

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \nu \frac{\partial^2 u}{\partial y^2} \quad (2)$$

B.C:

$$\left.\begin{aligned} u = v &= 0 \quad \text{at } y = 0 \\ u &= U_\infty \quad \text{at } y \to \infty \end{aligned}\right\} \quad (3)$$

from this model we have to calculate velocity distribution & boundary layer thickness also skin friction + drag force