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x ———— x ———— x ————

QNo: 1 Part (A)

Drag:-

A body which is immersed in a homogeneous Fluid may be subjected To Two Kind of forces arising from relative motion b/w body and fluid. These forces are termed as drag and lift. If The forces Parallel to The motion Then. its

is turned as drag force
These are two components.

→ Pressure Drag (FP):

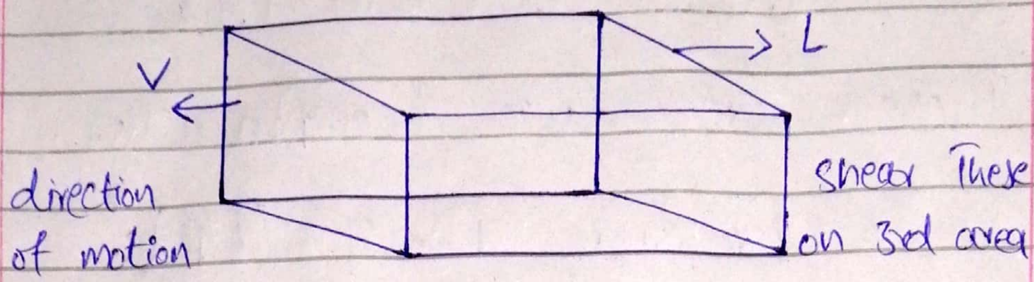
It is equal to integration of components in direction of components in direction of motion of all Pressure forces exerted on surface of body.

$F_P = C_P \rho V^2/2\ A$ where C_P depends on shapes.

Friction Drag (Ff):

It is equal to integration of components of shear stress along surface of body in direction of motion.

$F_f = C_f \rho V^2/2\ BL$



→ Friction Drag of boundary layer

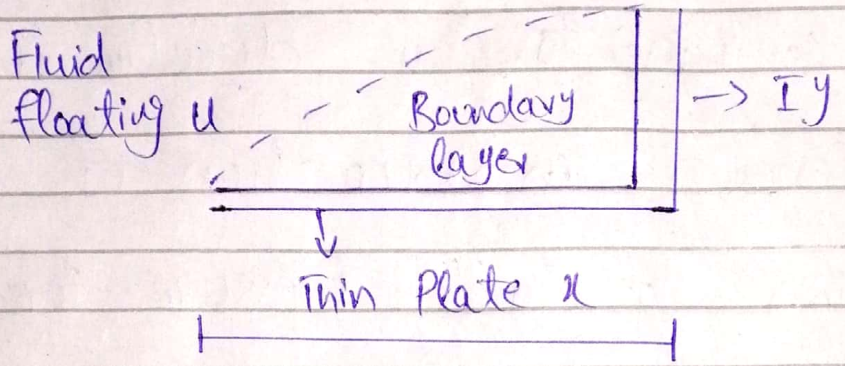
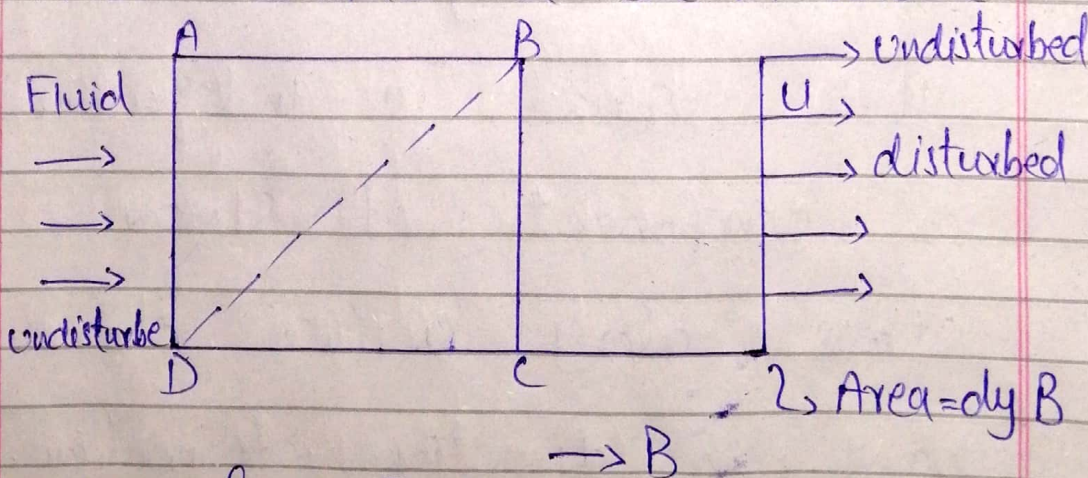


Fig shows growth of boundary layer along one site of smooth plastic inside The fluid.

Now consider a Control volume.



where δ is Thickness of boundary layer and u is undisturbed velocity

Thus $-F_x$ = drag (rate in momentum in x-direction)

$\Delta P = P_{out} - P_{in}$

Thus according to momentum.

$\Sigma F = d/dt\,(P) = dm/dt$

where $dm/dt = \rho Q$ Thus

$F = \rho Q v$

$F = \rho A . V . V$

$F = \rho A V^2$

$DA \longrightarrow \rho u\,(UB\delta)$

$BL \longrightarrow \rho B \int u^2 - dy$

$\Delta B \longrightarrow \rho u\,(UB\delta - B \int_0^{\delta} u - dy)$

Putting value

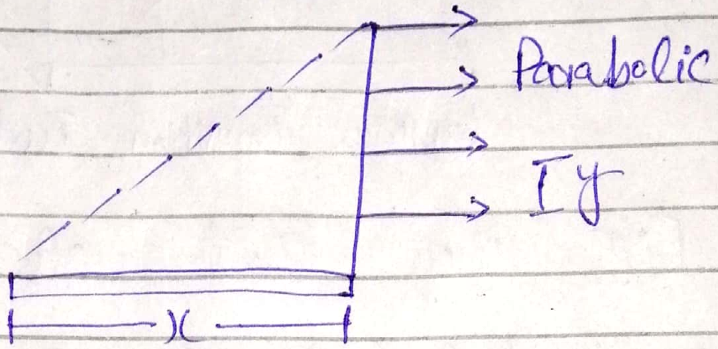
$F_x = \rho B u^2 \delta \alpha$ "where α is friction of boundary layer"

Now to find load wall shear stress. $\tau_0 = dF_x / B.dx$ - area

$F_x = \rho B u^2 \delta \alpha$

$\tau_0 = \rho u^2 \alpha \, d\delta/dx$ is general equation of shear stress.

→ Laminar Boundary Layer:



Assume.

$\eta = y/\delta$ or $y = \eta\delta$

Thus $u/U = f(\eta)$ or $u = U f(\eta)$

In case of laminar flow.

$\tau_0 = \mu (du/dy)$

$= \mu/\delta \, (du/d\eta) = \mu/\delta \left[df/d\eta \, (\eta) \right]$

Solving the equation.

$\tau_0 = \mu U \beta / \delta \longrightarrow (1)$

As general equation is $\tau_0 = \rho u^2 \alpha \, d\delta/dx$.

Equating both equations.

$\mu B/\delta = \delta v^2 \alpha \, d\delta/dx$

or

$$\delta d\delta = \mu B/\rho u \alpha \; dx$$

Integrating The equation.

$$\delta^2/2 = \mu B/\rho u \alpha \; x + C$$

Now at $x = 0$, $\delta = 0$ Thus $C = 0$

$$\delta^2/2 = \mu B/\rho u \alpha \; x$$

or

$$\delta = \frac{\sqrt{2 \mu B x}}{\sqrt{U \alpha}} \text{ or } \sqrt{\frac{2B}{\alpha}} \cdot \frac{\sqrt{\mu x}}{\sqrt{u}}$$

x ing and ÷ ing by 'x'

$$\delta = \sqrt{\frac{2B}{\alpha}} \cdot \sqrt{\frac{\mu x}{\rho u}} \cdot \frac{x}{\sqrt{x} \cdot \sqrt{x}}$$

where;

$$\alpha = 0.135$$
$$B = 1.63$$
$$Rx = \rho u x / \mu$$

$$\delta = \frac{4.91 \cdot x}{\sqrt{Rx}} \text{ or } \delta/x = 4.91/\sqrt{Rx}$$

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Now; $\tau_0 = \mu u B/\delta$.

Thus Putting value.

$$\tau_0 = 0.332 \ \mu u/x \sqrt{R_x}$$

where R_x is local Reynold number.

Now;

$$F_f = B\int_0 \frac{\tau_0 \, dx}{\text{stress}}$$

Putting values.

$$F_f = 0.664 \ B\sqrt{\rho \mu L U^3}$$

As general equation is.

$F_f = C_f \ \rho v^2/2 \ BL \rightarrow$ equating both equation.

$$C_f = 1.328\sqrt{\frac{\mu}{\rho w}}$$

$$= 1.328/\sqrt{R}$$

x ——— x ——— x

→ Turbulant Boundary layer:-

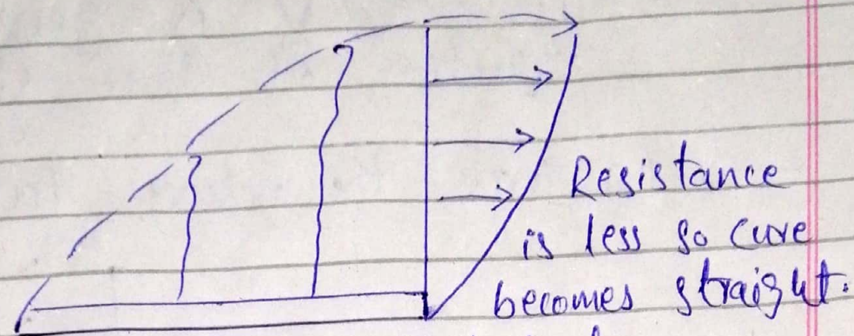


Fig show That velocity distribution is Turbulant boundary layer shows a much gradient near wall and flatter Through out rearing layer.

The shear stress is greater in Turbulant Than in laminar layer.

As we Know.

$\tau_0 = f \rho v^2/8$ "where v denots average, velocity of pipe."

Now we have obtained an approximate relation b/w v and v by using Pipe factor equation at.

$V/U_{max} = 1/1+1.33\sqrt{f}$

using friction factor of 0.028 from chart which is middle critical value.

So $u = 1.235V$

Now we have

$\tau_0 = f\rho V^2/8$

As we know.

$f = 0.316/0.25$

Thus $\tau_0 = 0.316/(DV/\nu)^{1/4} \; \rho V^2/8$

where $V = u/1.235$

$$\tau_0 = \frac{0.316}{\left(\frac{D}{\nu}\left(\frac{u}{1.235}\right)\right)^{1/4}} \cdot \frac{\rho}{8}\left(\frac{V}{1.235}\right)^2$$

$D = 2\delta$

Thus $\tau_0 = 0.023\, \rho u^2 / (\delta u/\nu)^{1/4}$

we have.

$\tau_0 = \rho u^2 \alpha \, d\delta/dx$

Equating both & integrating for boundary condition of.

$x = 0 , \delta = 0 .$

$$\delta = \left(\frac{0.0287}{\alpha}\right)^{4/5} \left(\nu/ux\right)^{1/5} x$$

For $\alpha = 0.0972$

$$\delta/x = 0.377/(Rx)^{1/5}$$

Putting values in equation.

$$\tau_0 = 0.0587 \rho u^2/x \left(\nu/ux\right)^{1/5}$$

Now; $F_f = B \int^L \tau_0 \, dx$

$$F_f = 0.0735 \rho \frac{u^2}{2} \left(\nu/uL\right) BL$$

As $F_f = C_f \rho v^2/2 \; BL$

equating both.

$C_f = 0.0735 / R^{1/5}$

R is less than 10^7 for $500{,}000 < R < 10^7$

for $R > 10^7$

$C_f = 0.455 / (\log R)^{2.58}$ (Ans)

x ——— x ——— x

Q No: 1 (Part B)

Sol:- As specific energy.

$$E = y + v^2/2g$$

→ The flow Q per unit width b can be expressed as.

$$q = Q/b$$

Now average velocity will be.

$$V = Q/A = qb/by = q/y$$

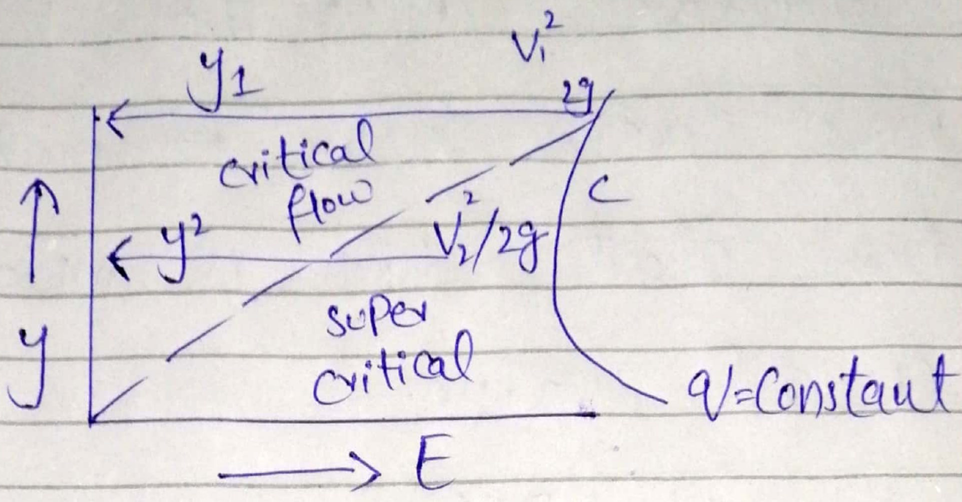
Thus, The point at which specific energy is least among it is called critical depth point.

$$E = y + V^2/2g \Rightarrow V + \frac{1}{2g}(q^2/y^2)$$

$$(E-y) = \frac{1}{2g}(q^2/y^2) \quad \text{or}$$

$$(E-y)\,y^2 = q^2/2g$$

Thus plot of E vs Y will be parabolic for particular q, There will be two kind of possible values of y, for a given E.



The equation is cubic with three roots with third root being negative. Point C represents dividing point b/w two regime of flows. Thus for given q_1 and value of E is minimum & flow at that point is critical flow. Depth of flow at that point is critical depth y_c & velocity at that point is critical velocity V_c.

Thus $E = y + 1/2g \, (q^2/y^2)$

for minimum specific energy =

$$dE/dy = 0$$

Thus; $\frac{dE}{dy} = 1 - \cancel{2}/\cancel{2}g \, (q^2/y^3) = 0$

$\Rightarrow q^2/gy^3 = 1 \Rightarrow q^2 = gy^3$

$q^2/g = y^3 = (q^2/g)^{1/3} = y_{cr}$

Now;

$$q^2 = gy^3$$

&

$$q = Vy = V^2y^2 = gy^3$$

or

$$V^2 = gy_{cr}$$

$$V_{CR} = \sqrt{gy_{cr}} \quad \text{(Ans)}$$

x ———— x ———— x

Q No: (2)

Given:

Depth of Rectangular channel (d) = ?

Flow rate $(Q) = 3.5\ m^3/sec$

Slope of Bed $(S_o) = 0.0008$

$n = 0.0219$

width of Bed = 7395 mm
= 7.395

Critical Depth = ?

Flow Sub-Critical or Super-Critical = ?

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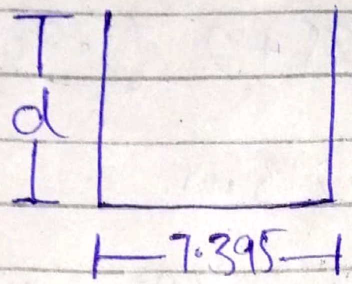
Sol:-

$$\text{Area} = 7.395 \times d$$
$$= 7.395d$$



$$\text{Perimeter} = d + 7.395 + d$$
$$= 7.395 + 2d$$

$\longrightarrow$ Hydraulic Radius = $(R_h) = A/P$

$$= \frac{7.395d}{7.395 + 2d}$$

By using Manning Equation.

$$Q = 1/n \; A R_h^{2/3}, S_o^{1/2}$$

Putting values.

$$3.5 = \frac{1}{0.0219} \times 7.395d \times \left(\frac{7.395\cancel{d}}{2\cancel{d} + 7.395}\right)^{2/3} \times (0.008)^{1/2}$$

$$3.5 = 45.66 \times 7.395d \; (0.008)^{1/2}$$

$$3.5 = 4.063 \times 7.395d$$

$$d = 1.909 \text{ m}$$

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Area $= 7.395\,(1.909)$

$= 14.71\ m^2$

Perimeter $= 7.395 + 2\,(1.909)$

$= 21.213\ m$

Hydraulic Radius $(R_h) = 14.71/21.213$

$= 0.693\ m$

Finding critical depth:

$y_{cr} = (q^2/g)^{1/3}$

As $q = Q/B$

$= 3.5/7.395$

$= 0.47\ m^3/sec$

$\Rightarrow y_{cr} = \left((0.47)^2/9.81\right)^{1/3}$

$= 0.282$

As $y > y_{cr}$

$1.909 > 0.282$

So flow is sub-critical

x ———— x ———— x

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Q No: (3)

Given;

Friction Drag = (F_D) = ?

width (B) = 200mm = 0.2m

Length (L) = 800mm = 0.8m

Specific Gravity (S) = 0.89

undisturbed velocity (U) = 5m/sec

Kinematic velocity (ν) = $0.93 \times 10^{-4} m^2/sec$

Sol;

checking whether flow is laminar or not By Reynold no.

$$R = Du/\nu$$

For smooth flat plate

$$D = L \quad , \quad \nu = u$$

So; $R = Lu/\nu$

$$= 0.8 \times 5 / 0.93 \times 10^{-4} = 43010$$

$43010 < 500{,}000 \rightarrow$ laminar

By using formula:

$F_f = C_f \cdot \rho \cdot V^2/2 \cdot BL$

where;

$C_f = 1.328/\sqrt{R} = 1.328/\sqrt{43010}$

$= 0.0064$

$\rho = \rho_{oil}/\rho_{water} \Rightarrow 0.89 = \rho_{oil}/1000$

$\rho_{oil} = 0.89 \times 1000$

$\rho_{oil} = 890\ kg/m^3$

$\Rightarrow F_f = C_f \cdot \rho \cdot V^2/2 \cdot BL$

$= 0.0064 \times 890 \times (5)^2/2 \times 0.2 \times 0.8$

$F_f = 11.39\ N$

x ——→ x ——→ x