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Section: A

Subject: Advanced Fluid Mechanics

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Exam : Final Term (Summer)

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Question: 01

Part: a

DRAG:-

Drag can be defined as "When a body which is fully immersed in homogeneous fluid is subjected to two kinds of forces arising from relative motion between body and fluid. These two forces are called "Drag" and left depanding upon whether force is parallel or at right angle to motion.

Drag is the force acting opposite to the relative motion of any object moving w.r.t surrounding fluid.

Components:-

Drag forces on Submerged body can have following two Components.

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1. Pressure Drag:- (C_P)

Pressure drag is measured to be equal to the integration of component in direction of motion of all pressure forces exerted on surface of body.

it's given as,

$$F_P = C_P \rho \frac{V^2}{2} A$$ (C_P depends upon shape)

2. Friction DRAG:-(C_F)

Friction drag is determined to be equal to integration of components, shear stress along the surface of body in direction of motion.

it's Given as,

$$F_F = C_f \rho \frac{V^2}{2} BL$$ (C_f:- depends upon viscosity)

Friction DRAG COEFFICIENT:-

Friction drag Coefficient is used for characterization of friction drag which is caused shear stress it put the wall shear stress in relation to flow velocity of undisturbed external flow.

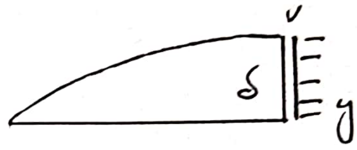
For Laminar Boundary Layer:-

We know that in case of laminar flow.

$$\tau_0 = \mu \left(\frac{du}{dy}\right)_{y=0} \Rightarrow \frac{\mu}{\delta}\left(\frac{du}{d\eta}\right) = \frac{\mu V}{\delta}\left[\frac{df(\eta)}{d\eta}\right]_{\eta=0}$$

Now by solving it, we get

$$\tau_0 = \frac{\mu V \beta}{\delta} \rightarrow ①$$



$$\frac{u}{U} = \frac{F(y)}{\delta}$$

$$\eta = y/\delta$$

$$\frac{u}{V} = f(\eta)$$

$$u = U(F(\eta))$$

Now Equating:

$$\Rightarrow \tau_0 = \rho u^2 \alpha \frac{d\delta}{dx}$$

So

$$\delta\, d\delta = \frac{\mu \beta}{\rho U \alpha} dx$$

By Solving;

$$\frac{\delta^2}{2} = \frac{\mu \beta}{\rho U \alpha} x + c$$

Now at $x=0$, $\delta=0$, $c=0$

$$\delta = \sqrt{\frac{2\mu\beta x}{\rho U \alpha}} = \sqrt{\frac{2\beta}{\alpha}} \cdot \frac{x}{\sqrt{R_x}}$$

$$R_x = \frac{x U \rho}{\mu}$$

Now experimentally

$\beta = 1.63$ $\alpha = 0.135$

Putting values in ①

So,

$$\frac{\delta}{x} = \sqrt{\frac{2 \times 1.63}{0.135}} \times \frac{\circ}{\sqrt{R_x}} = \frac{4.91}{\sqrt{R_x}} \rightarrow$$

$$\tau_0 = 0.332 \frac{\mu U}{x} \sqrt{R_x}$$

R_x may be called the "local Reynolds Number"
it should be noted that R_x increases linearly in downstream direction.

Now we have,

$$F_P = B \int_0^L \tau_0 \, dx \Rightarrow$$

$$\tau_0 = 0.332 \frac{\mu U}{2} (\sqrt{R_x})$$

$$R_x = \frac{x U \rho}{\mu}$$

Thus we have

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

where

$$F_F = C_f \frac{\rho U^2}{2} B L$$

Now Equating Both

$$C_F = 1.328 \sqrt{\frac{\mu}{\rho L U}} = \frac{1.328}{\sqrt{R_x}}$$

R is based on characteristic length of whole plate.

The laminar boundary layer will remain laminar if R_x is of about 500,000

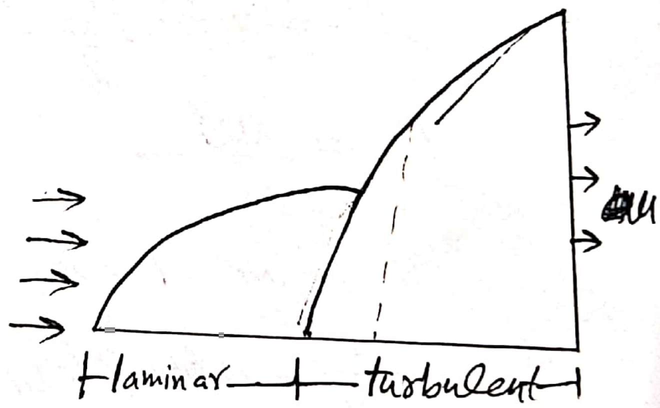
For Turbulent Boundary Layer:-

Velocity distribution at Boundary layer is shown in figure, which is steeper near walls and thicker throughout remainder of layer

The shear stress is greater in turbulent than in laminar. Thus we have

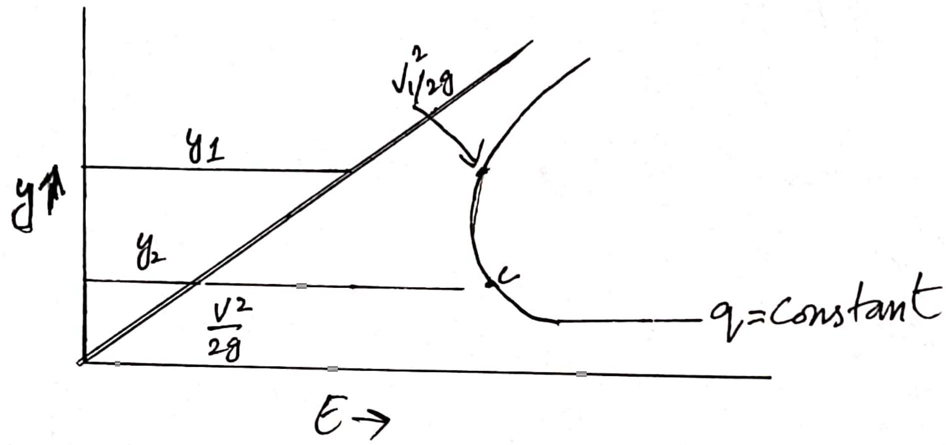
$$\tau_o = \rho f \frac{V^2}{8}$$

V = average velocity



Question: 01

Part: b



This is Specific energy eqn :-
For particular q, there will be two kind of possible values of y for given E. The eqn is cubic with three roots with third being negative giving no values. Thus two alternative depths represents two totally different flow regimes - slow & deep on upper portion & Fast & shallow on lower portion.

Point represent dividing point between two regins of flow.

Thus for given "q" values of E is minimum & flow at this point is critical flow Depth of flow at this point is critical depth y_c & velocity at this point is critical velocity.

Thus relation of critical depth can be found as

$$E = y + \frac{1}{2g}\left(\frac{q^2}{y^2}\right)$$

for minimum Specific energy

$$\frac{dE}{dy} = 0$$

$$\frac{dE}{dy} = 1 - \frac{2}{2g}\left(\frac{q^2}{y^3}\right)$$

$$\frac{dE}{dy} = 1 - \frac{q^2}{gy^3}$$

$$1 = \frac{q^2}{gy^3} = q^2 = gy^3$$

$$y_{cr} = \left(\frac{q^2}{g}\right)^{1/3}$$

As $q = Vy$, $V_c^2 = gy^3$

OR $V_c = \sqrt{gy_c}$

$$y_c = \frac{V_c^2}{g}$$

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Now $\frac{y_c}{2} = \frac{V_c^2}{2g}$

$E_{min} = y_c + \frac{V_c^2}{2g}$

$E_{min} = y_c + \frac{y_c}{2}$

$\frac{3}{2} y_c$ OR $y_{cr} = \frac{2}{3}$ Constant.

	Subcritical	Critical	Supercritical
Depth of flow	$y > y_c$	$y = y_c$	$y < y_c$
velocity Slop	$V < V_c$ mild slope $S_o < S_c$	$V = V_c$ critical slope	$V > V_c$

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Q.No(02)

Answer.No(02)

Given data:-

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

Slope of Bed (S_o) = 0.0008

$n = 0.0219$

Width of Bed = ~~782~~ 7829mm = 7.829 m

Required:-

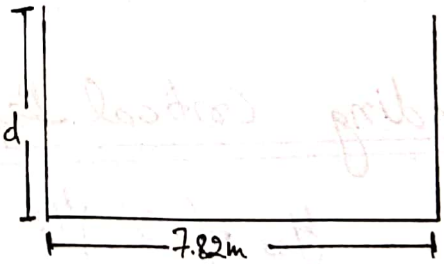
Depth of Rectangular channel (d) = ?

Critical depth = ?

Flow Subcritical or Super Critical = ?

Solution:-

As we know that;



⇒ Area = $7.82 \times d$

$= 7.82d$

⇒ Perimeter:

$= d + 7.80 + d$

$= 7.82 + 2d$

⇒ Hydraulic Radius (R_h) = A/P

$= \dfrac{7.82}{7.82+2d}$

By using Manning Equation

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

<u>Putting Values:</u>

$$= 3.5 = \frac{1}{0.0219} \times 7.82d \times \left(\frac{7.82d}{2d+7.82}\right)^{2/3} \times (0.0008)^{1/2}$$

By solving, we get.

$$\boxed{d = 0.55\,m}$$

So,

$$\text{Area} = 7.82d$$
$$= 7.82(0.55)$$
$$= 4.301\,m^2$$

$$\text{Perimeter} = 7.82 \times 2(0.55)$$
$$= 8.602\,m$$

Hydraulic Radius (R_H) =

$$\frac{4.301}{8.602} = 0.5\,m$$

<u>Finding Critical Depth:-</u>

$$y_{cr} = \left(\frac{q^2}{g}\right)^{1/3}$$

As, $q = Q/B$

$$= 3.5/7.82$$
$$= 0.44\,m^2/sec$$

$$\Rightarrow y_{cr} = \left(\frac{(0.44)^2}{9.81}\right)^{1/3}$$
$$= 0.27$$

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As $y > y_{cr}$ → So flow is Sub-critical

$0.55 > 0.27$

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Question # 03

Answer # 03

Given data:-

Friction drag

$d = 200mm = 0.2m$

$l = 800mm = 0.8m$

$G_s = 0.89$

Kinamatic Viscosity $= 0.93 \times 10^{-4} m^2/sec$

Required data:-

To find friction drag

Solution:-

As we know that

$V = 0.93 \times 10^{-4} m/s$

$$R = \frac{LU}{V} = \frac{0.8 \times 5}{0.93 \times 10^{-4}}$$

$R = 43010.75$

which is less than $R < 500{,}000$

Now $$C_f = \frac{1.328}{\sqrt{R}}$$

$= 6.40 \times 10^{-3} = 0.0064$

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$$F_f = C_f \, \rho \, \frac{V^2}{2} \, BL$$

Putting Values.

$$\Rightarrow F_f = 0.0064 \times 0.925 \times 1000 \times \left(\frac{5}{2}\right)^2 \times 0.2 \times 0.89$$

$$\boxed{F_f = 13.172}$$