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SECTION :	'A'
SUBJECT:	FLUID MECHANICS II
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EXAM:-	FINAL TERM (SUMMER 2020)
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QUESTION: 01

PART: a

DRAG:- Drag can be defined as' when a body which is fully immersed in homogenous fluid is subjected to two kinds of forces arising from relative motion between body and fluid. these two forces are called drag and lift. Depending upon whether force is parallel or at right angle to motion

(OR) 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.

1. **PRESSURE DRAG:-** (F_p) :- Pressure drag is measured to be equal to the integration of components in direction of motion of all pressure forces exerted on surface of body.

it's given as

$$F_p = C_p \rho \frac{V^2}{2} A \qquad (C_p \text{ depends upon shape})$$

FRICTION DRAG (F_f): Friction drag is determined to be equal to integration of components sheer stress along the surface of body in direction of motion.

Given as

$$F_f = C_f \rho \frac{V^2}{2} BC \qquad (C_f = \text{depends upon Viscosity}).$$

FRICTION DRAG COEFFICIENT:

Friction drag co-efficient is used for characterization of friction drag which is caused sheer stress. It puts the wall sheer stress in relation to flow velocity of undisturbed external flow.

For Laminar Boundary Layer:

We know that in case of laminar flow.

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

Now by solving it, we get

$$\tau_0 = \frac{\mu U \beta}{\delta} \quad - (1)$$

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

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

$$\frac{u}{U} = f\left(\frac{y}{\delta}\right)$$

$$\eta = y/\delta$$

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

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

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

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

Now experimentally

$\beta = 1.63$ $\alpha = 0.135$, putting values in (1)

so

$$\frac{\delta}{x} = \sqrt{\frac{2 \times 1.63}{0.135}} \times \frac{1}{\sqrt{R_x}} = \frac{4.91}{\sqrt{R_x}} \rightarrow$$

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

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

Now we have

$$F_f = \beta \int_0^L \tau_0 \, dx \Rightarrow$$

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

$$R_x = \frac{xU\rho}{\mu}$$

Thus we have

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

where

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

Now Equating Both so,

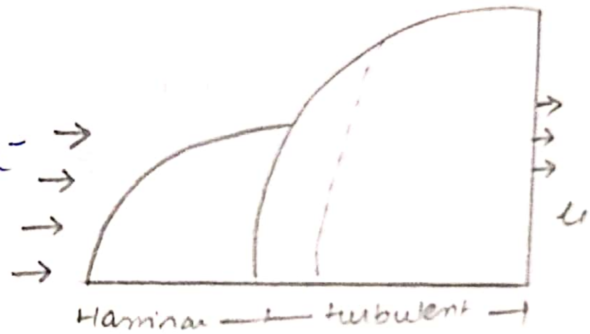
$$C_f = 1.328 \sqrt{\frac{\mu}{\rho L U}} = \frac{1.328}{\sqrt{R_x}}$$

→ R is based on characteristic length of whole plate

→ The laminar Boundary layer will remain laminar if R_x is ~~abs~~ 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 ~~flows~~. Thus we have

$$\tau_0 = \rho f \frac{V^2}{8}$$

V = average velocity

To obtain relation b/w avg and maximum we have

$$\frac{V}{U_{max}} = \frac{1}{1+1.33\sqrt{f}} \qquad F = 0.023$$

$$\frac{V}{U_{max}} = \frac{1}{1+1.33\sqrt{0.023}}$$

$$U = 1.235\,V$$

$$V = \frac{U}{1.235}$$

$$F = \frac{0.316}{\left[\left(\cancel{\frac{17}{v}}\right)\left(\frac{19}{1.235}\right)\right]^{1/4}}$$

$$F = \frac{0.316}{(Rh)^{1/8}} \qquad Rh = \left(\frac{Dv}{\nu}\right)$$

$$D = 2\delta$$

$$\tau_0 = \frac{f\rho v^2}{8}$$

$$\tau_0 = \frac{0.316}{\left[\left(\frac{17}{\nu}\right)\left(\frac{0}{1.235}\right)\right]^{1/4}} \cdot \frac{\rho}{8}\left(\frac{v}{1.235}\right)^2$$

$$\tau_0 = \frac{0.023\ \rho v^2}{\left(\frac{2\delta}{\nu}\right)^{1/4}} \quad -①$$

As we have general equation

$$\tau_0 = \rho v^2 \times \frac{d\delta}{dx} \quad -②$$

eq ① and ②

$x = 0 \qquad \delta = 0$

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

$$\alpha = 0.0972$$

$$\delta = \frac{0.377}{(Rn)^{1/5}} \cdot x$$

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

Now $F_f = B\int_0^c \tau_0\, dx$

$$F_f = 0.0735\ \frac{\rho v^2}{2} \left(\frac{\nu}{UL}\right)^{1/5} BL$$

$$= C_f \cdot \frac{\rho v^2}{2}\ BL$$

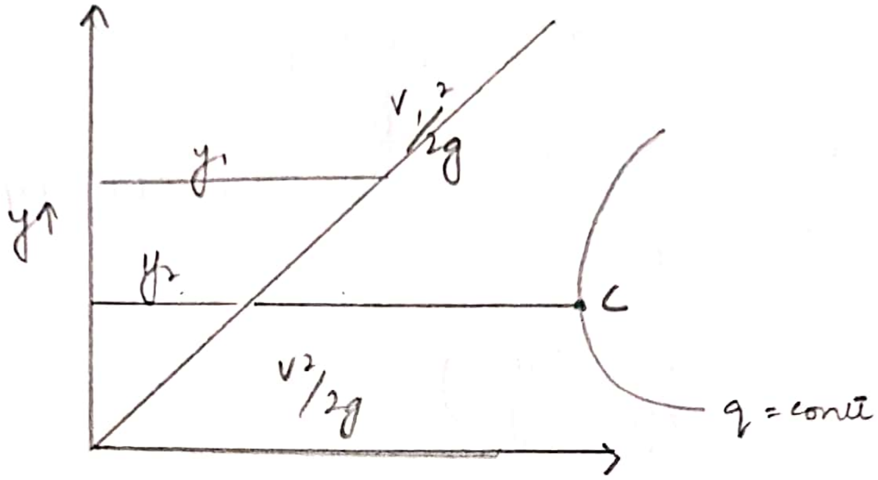
~~F_f~~ = " equating b/s

$$CF = \frac{0.0735}{(R)^{1/5}} \qquad (500{,}000 < R < 10^7)$$

For $R > 10^7$

$$CF = \frac{0.455}{(\log R)^{2.52}}$$

PART: (b)



This represent specific Energy Equation:
For a particular value of q, there are two possible values of "y" for given "E". The equation is cubic with three roots with third being negative, giving no value.

Thus two alternative depth represent two different regimes.
(1) slow and deep on upper portion
(2) Fast and shallow on lower portion.

Point represent dividing point b/w two regimes of flow.

Thus for given "q", value of E is minimum and flow at this point is critical flow. Depth of flow at this point is critical depth. and velocity at this point is critical velocity.

Thus relation of critical depth can be found as:

(7) We know

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

We have for minimum specific Energy

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

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

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

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

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

As we know

$$q = vy \qquad v_c^2 = gy^3$$

OR $$v_c = \sqrt{gy_c}$$

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

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

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

$$= 3/2\, y_c \quad \text{or} \quad y_{cr} = 2/3 \text{ Constant}$$

	sub-critical	critical	super-critical
Depth of flow	$y > y_c$	$y = y_c$	$y < y_c$
velocity slope	$V < V_c$ mild slope $S_o < S_c$	$V = V_c$ critical slope	$V > V_c$

QUESTION: 02

Given Data:-

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

Slope of Bed $(S_o) = 0.0008$

$n = 0.0219$

Width of Bed $= 7802mm = 7.802\ m$

Required:-

Depth of Rectangular Channel $(d) = ?$

Critical Depth $= ?$

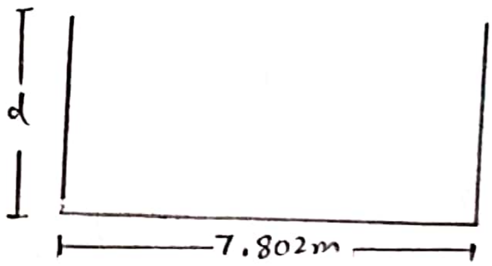
Flow sub critical or super-critical $= ?$

Critical velocity $= ?$

Solution:-

Finding area $= 7.802\ (d)$

$A = 7.802d$



Finding perimeter:

$d + 7.802 + d$

$P = 7.802 + 2d$

Finding Hydraulic radius $(R_h) = A/P$

$$= \frac{7.802}{7.802 + 2d}$$

Now By using Manning Equation

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

Now by putting values:
we have

$$3.5 = \frac{1}{0.0219} \times 7.802d \times \left(\frac{7.802d}{2d + 7.802}\right)^{2/3} \times (0.0008)^{1/2}$$

By calculation we get

$d = 0.56\ m$

So putting value of D

Area $= 7.802(0.56)$

$= 4.36\ m^2$

Now perimeter

$= 7.802+2(0.56)$

$= 8.92\ m$

Hydraulic radius $(R_h) = \frac{4.36}{8.92} = 0.488\ m$

Now finding critical Depth.

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

As $q = Q/B$

putting values

$q = 3.5/7.802 = 0.44\ m^2/sec$

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

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

$0.55 > 0.27$

Critical velocity

$V_{cr} = \sqrt{g \times y_{cr}} = \sqrt{9.81 \times 0.270}$

$V_{cr} = 1.62\ m/sec$

QUESTION: 03

Given Data:-

length = 800mm = 0.8 m
Width = 200mm = 0.2 m
G_s = 0.89
Velocity (undisturbed) = 5 m/sec
Viscosity = $0.93 \times 10^{-4} m^2/sec$

Required:-

Friction Drag = ?

Solution:-

As we know

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

At $x = L$

$R = \frac{LU}{\nu}$ (putting values)

$= \frac{0.8 \times 5}{0.93 \times 10^{-4}} = 43010.75$

at $R < 500,000$

So $C_f = \frac{1.328}{\sqrt{R}} = \frac{1.328}{\sqrt{43010.75}} = 0.0064$

Now

$F_f = C_f \rho \frac{v^2}{2} BL$ (putting values)

$= 0.0064 \times 890 \times \frac{(5)^2}{2} (0.2)(0.8)$

$F_f = 11.39N$

$S = \frac{\rho_{oil}}{\rho_{water}}$

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

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

$= 890 kg/m^3$