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Section ※ C

Subject ※ Fluid Mechanics.

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Ans; 01 "a"; Drag Force;

In commonly used context drag force is the force that is exerted on a solid body moving with respect to a fluid due to the movement of the fluid. Therefore a drag force is the resistance force caused by the motion of a body through a fluid like water or air.

Mathematically;

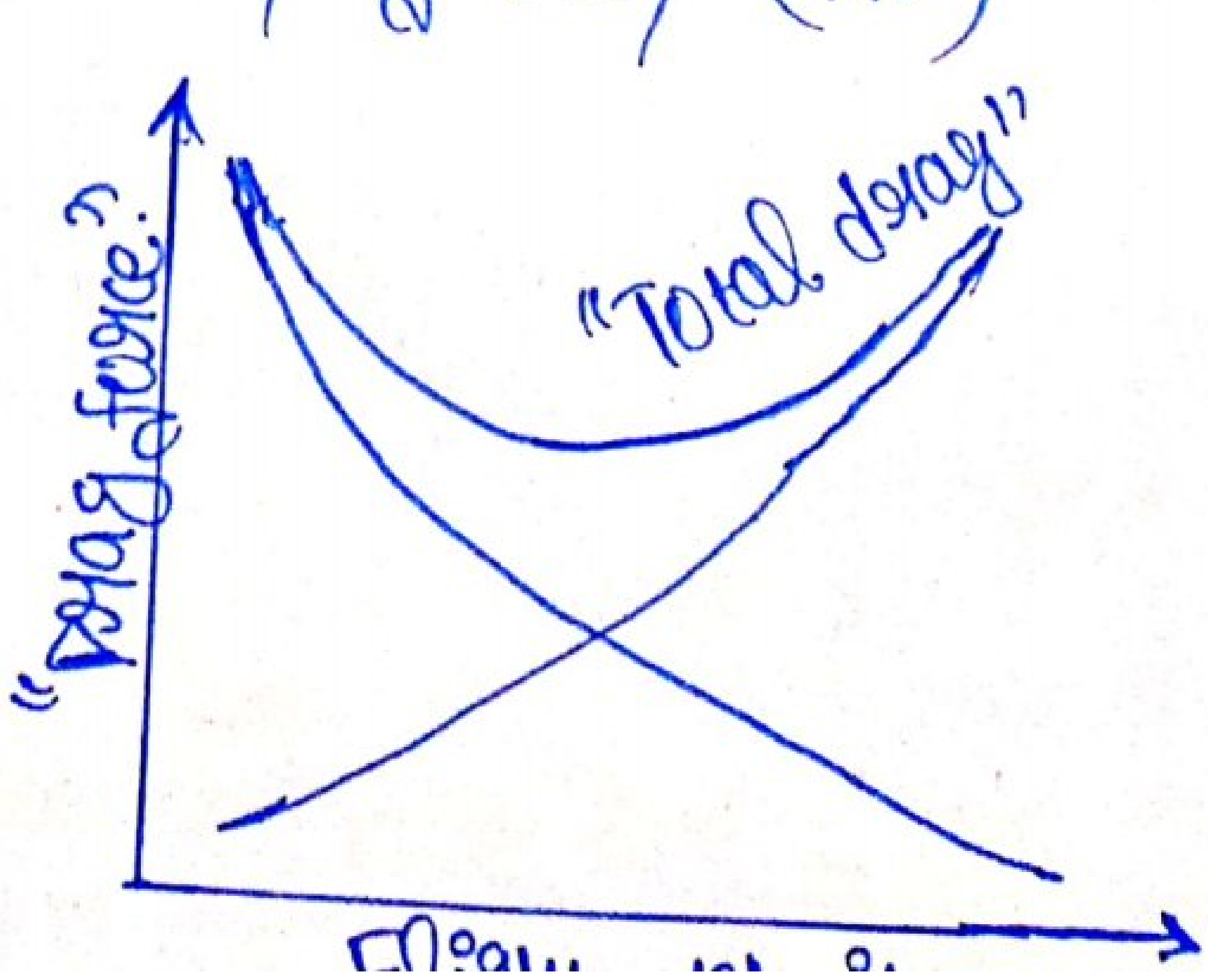
$$\text{“}D = \frac{C_d \times \rho \times V^2 \times A}{2}\text{”}$$

D = Drag Force.

C_d = Drag coefficient.

ρ = Density of medium (kgm^{-3})

V = Velocity of Body (ms^{-1})



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Components;

Drag forces on submerged body can have two components.

- Pressure drag ; F_p.
- Friction drag ; F_f.

"i"; Pressure drag ; F_p:

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

Mathematically;

$$F_p = C_p \cdot \rho \cdot \frac{V^2}{2} \cdot BL.$$

"ii"; Friction drag ; F_f:

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

Mathematically;

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

Ans; 01 : "b" "Derivation";

As;

$$\text{Specific energy, } E = y + \frac{V^2}{2g}.$$

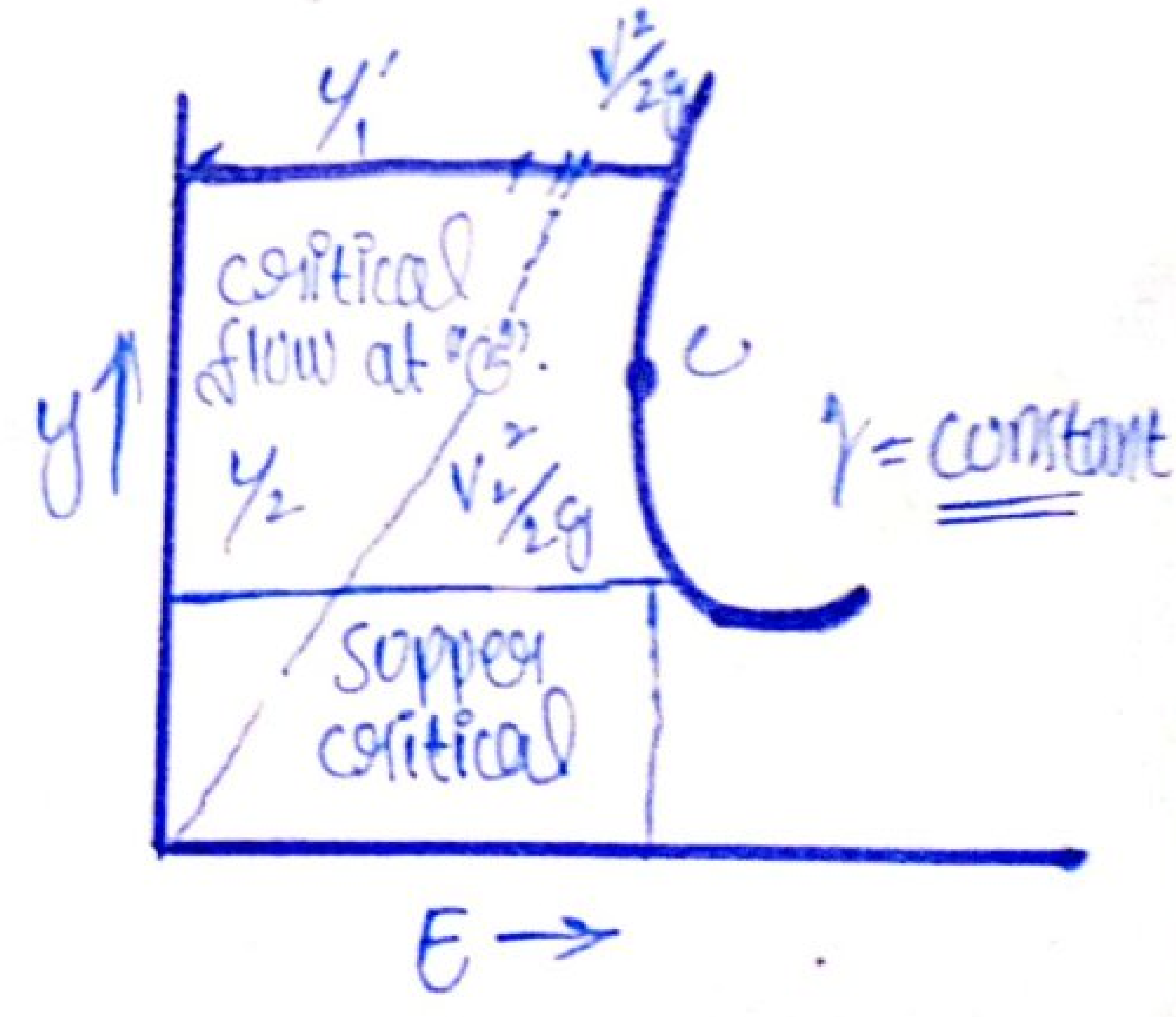
$$= y + \frac{1}{2g}\left(\frac{q^2}{y^2}\right) \because \left(V = \frac{q}{y}\right)$$

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

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

Thus plot of E and 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 root being negative. Point "c" represents dividing point between two regions of flow.



Thus for given "q" and value of "E" is minimum and flow at that point is critical flow.

Depth of flow at that point is critical depth "y_c". and velocity at that point will be critical velocity "V_{cr}".

Thus;

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

For minimum specific energy $dE/dy = 0$

Therefore;

$$dE/dy = 1 - \frac{2}{2g}\left(\frac{q^2}{y^3}\right) = 0$$

$$= 1 - q^2/gy^3 = 0$$

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

$$q^2 = gy^3$$

$$q^2/g = y^3$$

$$\boxed{y_{cr} = \left(q^2/g\right)^{1/3}}$$ "Critical depth".

Now;

$q^2 = gy^3$ and "$q = Vy$" $\Rightarrow$

$$V^2 \cancel{y^2} = g y^{\cancel{3}}$$

$$V^2 = g y_{cr}$$

or $\boxed{V_{cr} = \sqrt{g y_{cr}}}$ "critical velocity."

Ans; 02; "Rectangular channel";

Given;

- Discharge "Q", $= 3.5 m^3/s$
- Bed slope, $S_o = 0.0008$
- $n = 0.0219$
- Width (Bed) $b = 7766$ mm

Required;

- Depth = ?
- Critical depth = y_c = ?
- Critical velocity = V_c = ?
- Flow is critical or sub-critical = ?

Sol; "Manning Equation";

$$Q = \left(\frac{1}{n} R_h^{2/3} \cdot S_o^{1/2}\right) A \quad \text{— (i)}$$

$$\text{Area} = 7.766 \times d$$

$$\text{Perameter} = d + 7.766 + d$$

$$\text{Hydraulic radius}, R_h = \frac{\text{Area}}{\text{perameter}} = \frac{7.766 * d}{d + 7.766 + d}$$

By putting values in eq (i);

$$3.5 = \left(\frac{1}{0.0219}\right)\left(\frac{7.766 * d}{2d + 7.766}\right)^{2/3}(7.766d)(0.0008)^{1/2}$$

$$\frac{3.5\times 0.0219}{(0.0008)^{1/2}} = \left(\frac{7.766d}{2d+7.766}\right)^{2/3}(7.766d)$$

$$\left(\frac{3.5\times 0.0219}{(0.0008)^{1/2}}\right)^{3/2} = \frac{60.310d^2}{2d+7.766}$$

$$4.4612 = \frac{60.310d^2}{2d+7.766}$$

$$4.4612(2d+7.766) = 60.310d^2$$

$$8.922d + 34.645 = 60.310d^2$$

$$60.310d^2 - 8.922d - 34.645 = 0$$

By using Quadratic formula;

we get;

$\boxed{d = 0.834\,m}$ Depth of channel;

Now; Critical Depth, y_{cr};

Using equation;

$$y_{cr} = \left(\frac{q^2}{g}\right)^{1/3} \quad \text{—— ("ii")}$$

Here; q = Discharge per unit width

$$q = Q/b$$

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$$q = Q/b = 3.5/7.766$$

$$\boxed{q = 0.451}$$ By putting in "ii":

$$y_{cr} = \left(\frac{(0.451)^2}{9.81}\right)^{1/3}$$

$$\boxed{y_{cr} = 0.275\ m}$$

Critical velocity, V_{cr};

We know that;

$$V_{cr} = \sqrt{g y_{cr}} = \sqrt{(9.81)(0.275)}$$

$$\boxed{V_{cr} = 1.642\ m/s}$$

Now; $V = Q/A = 3.5/7.766(0.834)$

$$\boxed{V = 0.540\ m/s}$$

$y = 0.834m$, $y_{cr} = 0.275m$, $V = 0.540 m/s$, $V_{cr} = 1.642\ m/s$

As; $y > y_{cr}$

$V < V_{cr}$

Flow is sub-critical flow;

"Ans;03"; **Given Data;**

Width of Smooth plate ; $B = 200mm = 0.2m$
Length of Smooth plate ; $L = 800mm = 0.8m$
Oil with specific gravity ; $S = 0.89$
Undisturbed velocity; $u = 5 m/s$
Kinematic velocity , $\nu = 0.93 \times 10^{-4} m^2/s$

Required Data;

Friction Drag on one side of a Smooth plate
$F_d = ?$

Sol;

Check the Flow;

As;

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

$$R = \frac{Lu}{\nu} = \frac{0.8(5)}{0.93 \times 10^{-4}}$$

$$R = 43010 < 500,000$$

Thus flow is laminar,

Now;

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

$$C_f = 6.403 \times 10^{-3}$$

$$\boxed{C_f = 0.0064}$$

Now;

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

$$= (0.0064)(Soil \times \gamma_{water})\left(\frac{(5)^2}{2}\right)(0.2)(0.8)$$

$$= (0.0064)(0.89 \times 1000)\left(25/2\right)(0.2)(0.8)$$

$$\boxed{F_f = 11.392}$$ Ans.