B.TECH. 4TH SEMESTER EXANIMATION, 2014

Answers to Short / Objective Questions

; Code: 011410, Hydraulics & open ~~clas~~ channel Flow

Sem.

i) — (b)

ii) — (c)

iii) — (c)

iv) — (a)

v) — (a)

vi) — (c)

vii) — (b)

viii) — (d)

(ix) — (b)

(x) — (d)

I/.

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Model Answer

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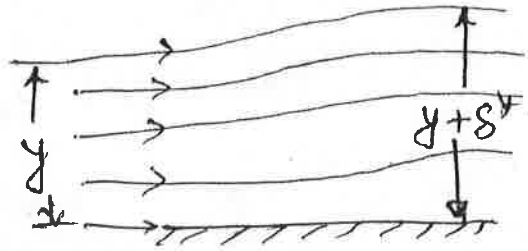
Sets (I) / (II)

Solution of Q2. The displacement thickness, δ^*, may be defined as the distance measured perpendicular to the boundary by which the free stream is displaced on account of formation of boundary layer.



displacement thickness can be written as

$$\delta^* = \int_0^{\delta} \left(1 - \frac{u}{U_\infty}\right) dy \qquad \text{—— (1)}$$

Momentum Thickness, θ, may be defined as the distance, measured perpendicular to the boundary of the solid body, by which the boundary should be displaced to compensate for reduction in momentum of the flowing fluid on account of formation of B.L.

The momentum Thickness, θ, can be written as

$$\theta = \int_0^{\delta} \frac{u}{U_\infty}\left(1 - \frac{u}{U_\infty}\right) dy \qquad \text{- - - (2)}$$

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Sets (I) / (II)

$$Re_L = \frac{UL}{\nu} = \frac{5*4}{1.47*10^{-5}} = 1.36*10^6 > 5*10^5$$

Flow is turbulent at rear side.

$$Re_x \frac{Ux}{\nu} = 5*10^5 \Rightarrow x = \frac{\cancel{5}*\cancel{10^5}*1.47*\cancel{10^{-5}}}{\cancel{5}} = 1.47\ m$$

Hence B.L. is laminar on 1.47 m length of the plate.

$$\delta = \frac{5*x}{\sqrt{Re_x}} = \frac{5*1.47}{\sqrt{5*10^5}} = 0.01039\ m$$
$$= 1.039\ cm.$$

$$c_f = \frac{0.664}{\sqrt{Re_x}} = 0.000939$$

$$\tau_o = c_f \frac{\rho U^2}{2} = 0.000939*\frac{1.208*5^2}{2}$$
$$= 0.01418\ N/m^2$$

Force on 1.47m Length (on both sides) will be

$$F = 2*(2*1.47)\, C_f \frac{\rho U^2}{2}$$

$$C_f = \frac{1.328}{\sqrt{Re_x}} = 0.001878$$

$$F = 2*(2*1.47)*0.001878*\frac{1.208*5^2}{2}$$

$$F = 0.1667\ N.$$

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Sets (I) / (II)

Soln of Q3

$$\frac{Q^2}{g} = \frac{A_c^3}{T_c} = B^2 y_c^3$$

$$B = \sqrt{\frac{Q^2}{g}}\, y_c^{-3/2} \; ; \quad P = B + 2y = \sqrt{\frac{Q^2}{g}}\, y_c^{-3/2} + 2y$$

For minm P, $\frac{dP}{dy} = \sqrt{\frac{Q^2}{g}}\left(-\frac{3}{2} y^{-5/2}\right) + 2 = 0$

$$y^{+5/2} = \frac{3}{4}\sqrt{\frac{Q^2}{g}} \Rightarrow \sqrt{\frac{Q^2}{g}} = \frac{4}{3} y^{5/2} \Rightarrow \frac{Q^2}{g} = \frac{16}{9} y^{10/2}$$

$$B^2 = \frac{16}{9} y_c^2 \; ; \text{ Hence } B = \frac{4}{3} y_c$$

$$E_c = y_c + \frac{V_c^2}{2g} = \frac{3B}{4} + \frac{27}{64} B^5 \times \left(\frac{1}{2} \times \frac{16}{9} \frac{1}{B^4}\right)$$

$$= \left(\frac{3}{4} + \frac{3}{8}\right) B = \frac{9}{8} B$$

$$\boxed{B = \frac{8}{9} E_c}$$

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Sets ~~(I)~~ / (II) ✓

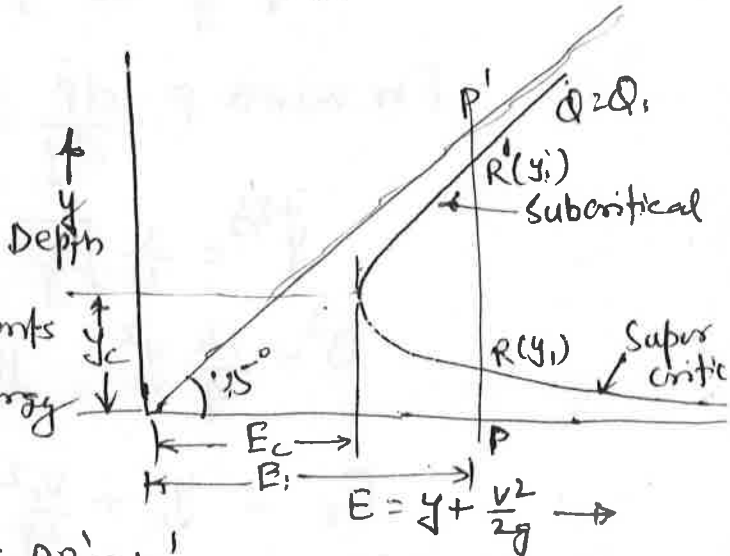
Sol^n of Q4

$$E = y + \frac{V^2}{2g} = y + \frac{Q^2}{2gA^2}$$

For a channel of known geometry, $E = f(y, Q)$

Now, Keeping $Q = \text{const.} = Q_1 \Rightarrow E = f(y)$

By drawing a curve betn E Vs y as show in figure.



The ordinate PP' represents the condition for a sp. energy E. The depth of flow can be either $PR = y_1$ or $PR' = y_1'$. These two depth y_1 and y_1' depths are known as alternate depths. The intercept P'R' or P'R represents the velocity head.

For given Q_1 as the sp. energy is increased the difference betn two depths increases. On other hand, if E is decreased, the difference will decrease at $E = E_c$, the two depth will merge with each other. This is the minimum sp. energy and the critical point for flow, so it is known as critical flow cond

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Sol^n of Q.4 Continue **Sets (I) / (II)**

$$E = E_c = 1.2\ m$$

$$y_c = \frac{2}{3} E_c = 0.8\ m$$

$$q_m = \left(g y_c^3\right)^{1/2} = \left(9.81 * (0.8)^3\right)^{1/2} = 2.241\ m^3/s/m$$

$$Q = qB = 2.241 * 2.0 = 4.482\ m^3/s$$

$$R = \frac{2 * 0.8}{2 + 1.6} = 0.4444\ m$$

Conveyance $K = \frac{1}{n} A R^{2/3} = \frac{1}{0.015} 1.6 * (0.4444)^{2/3} = 62.12\ m^3/s$

$$S_0 = \left(\frac{Q}{K}\right)^2 = \left(\frac{4.482}{62.12}\right)^2 = 5.206 \times 10^{-3}$$

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Sets (I) / (II)

Sol^n of Q5

$$\frac{dy}{dx} = \frac{S_o - S_f}{1 - \frac{Q^2 T}{g A^3}}$$

$\frac{dy}{dx} \rightarrow$ Water surface profile variation with r. to x.

$S_o \rightarrow$ Bottom Slope $= \frac{dz}{dx}$

$S_f \rightarrow$ Energy Slope $= \frac{dH}{dx}$

$\frac{Q^2 T}{g A^3} \rightarrow F_r^2$ = Froude No.

For wide rectangular channel $q^2 = \frac{1}{n^2} y_o^{10/3}$

At critical depth $\frac{q^2}{g} = y_c^3$

At critical Slope, $S_o = S_c$ and $y_o = y_c$

$$g\, y_c^3 = \frac{1}{n^2} y_c^{10/3}$$

$$S_c = \frac{g n^2}{y_c^{1/3}} = \frac{g n^2 g^{1/9}}{q^{2/9}} = \boxed{\frac{g^{10/9} \cdot n^2}{q^{2/9}} = S_c}$$

If $S_o > S_c$, the flow is supercritical, slope is steep.
If $S_o < S_c$, the flow is subcritical, slope is mild.

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Soln. of Q6

Sets (I) / (II)

$A = 4.0y$, $V = \frac{15}{A}$, $P = (4+2y)$, $E = y + \frac{V^2}{2g}$

$$S_f = \frac{n^2 V^2}{R^{4/3}} = \frac{(0.016)^2 V^2}{R^{4/3}}$$

$$\phi = \frac{Qn}{\sqrt{S_0}\, B^{8/3}} = \frac{15 * 0.016}{\sqrt{0.0009} * (4)^{2.67}} = 0.198425$$

corresponding value of $\frac{y_0}{B} = 0.5$ and $y_0 = 2.0$ m.

$$y_c = \left[\frac{(15.0/4)^2}{9.81}\right]^{1/3} = 1.128 \text{ m}$$

If $y_1 = 2.6$ m, $y_1 > y_0 > y_c$ Hence Water Surface Profile is M_1.

The depth down stream of A would be higher than 2.6 m.

y (m)	A (m²)	R (m)	V (m/s)	E (m)	ΔE (m)	S_f	$\bar{S}_f$	$S_0 - \bar{S}_f$	Δx	x
2.6	10	1.13	1.44	2.71		0.0004522				0
2.8	11	1.16	1.36	2.84	0.1387	0.0003915	0.000422	0.000478	290	290
2.88	12	1.18	1.30	2.97	0.121633	0.0003479	0.00037	0.00053	229	520

By interpolation depth at section B 500m from A is $2.80 + [(0.08/230) * 210] = 2.873$ m.

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Soln of Q7.

Sets (I)/(II)

By momentum Eqn $P_1 + M_1 = P_2 + M_2$

$$\rho g \frac{m}{3} y_1^3 + \frac{\rho Q^2}{m y_1^2} = \rho g \frac{m}{3} y_2^3 + \frac{\rho Q^2}{m y_2^2}$$

$$\frac{Q^2}{m^2}\left(\frac{1}{y_1^2} - \frac{1}{y_2^2}\right) = \frac{g}{3}\left(y_2^3 - y_1^3\right)$$

Here $m = 1$.

$$Q^2\left[\frac{1}{(0.6)^2} - \frac{1}{(1.2)^2}\right] = \frac{9.81}{3}\left(1.2^3 - (0.6)^3\right)$$

$$2.0833\, Q^2 = 4.94424$$

$$\boxed{Q = 1.541 \ m^3/s}$$

$$F_1^2 = \frac{2Q^2}{g^2 m^2 y_1^5} = \frac{2 \times (1.541)^2}{(9.81)^2 (0.6)^5} = 6.227$$

$$\boxed{F_1 = 2.494}$$

Similarly $F_2^2 = \dfrac{2Q^2}{g^2 m^2 y_2^5} = 0.1944$

$$\boxed{F_2 = 0.441}$$

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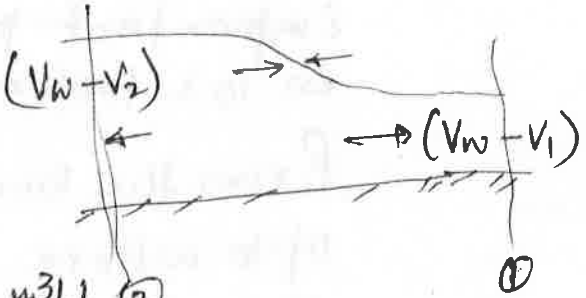
Solution of Q 8 **Sets (I) / (II)**

$q_1 = 1.5 \ m^3/s/m = V_1 y_1$

$y_1 = 0.75 m$

$V_1 = \frac{1.5}{0.75} = 2.0 \ m/s$

$q_2 = V_2 y_2 = 1.33 \times 1.5 = 1.995 \ m^3/s/m$



$y_2 (V_w - V_2) = y_1 (V_w - V_1)$

$y_2 V_w - 1.995 = 0.75 V_w - 1.5$

$V_w (y_2 - 0.75) = 0.495 \quad \text{--- (1)}$

Now, we know,

$$(V_w - V_1)^2 = \frac{g}{2}\left[\frac{y_2}{y_1}(y_1 + y_2)\right]$$

$$\left[\frac{0.495}{y_2 - 0.75} - 2\right]^2 = \frac{9.81}{2} \cdot \frac{y_2}{0.75}(0.75 + y_2)$$

By Trial & Error, $y_2 = 0.85 m$ and $V_w = 4.95 m/s$.

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Solution of Q.9. **Sets (I) / (II)**

(i) Boundary Layer Thickness (BLT) is very important parameter that must be determined in B.L. Problem. It is defined as the distance from the boundary to the point vertically upward upto where the velocity differs by 1% from the free stream velocity. The condition for B.L.T, δ;

$$y = \delta \text{ for } u = 0.99U_\infty .$$

(ii) Specific force

Steady-state momentum equation takes a simple form if the tangential force and body force are both zero.

$$F_1 + m_1 = F_2 + M_2 = \text{Const} = P_s$$

P_s is known as specific force and represent the sum of the pressure force and momentum flux per unit weight of the fluid at a section. Specific force is function of depth of flow, channel geometry and discharge.

$$P_s = \frac{P+M}{\gamma} = A\bar{y} + \frac{Q^2}{gA} = \text{Constant} .$$

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Solution of Q.9 **Sets (I) / (II)**

(iii.) Factors Affecting 'n'

The Manning's n is essentially a coefficient representing the integrated effects of a large number of factors contributing to the energy loss in a reach.

These are: → Surface roughness
→ Vegetation
— Cross-section irregularity
— irregular alignment of channel

The chief among these are the characteristics of the surface.

(iv.) Hydraulically efficient channel is one which, for a given slope, roughness coefficient and area of flow, carries the maximum flow rate. The conveyance of a section of a given area increasing with decrease in its perimeter. Hence, a channel section having minimum perimeter for a given area of flow provides the maximum value of conveyance and hence maxm discharge.

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Hence a channel with the slope, roughness and area of flow fixed, a minimum perimeter section will represent the hydraulically efficient section.

(v) Unsteady flow occurs in an open channel when the discharge or depth or both vary with respect to time at a section. These changes may be due to natural causes, planned action or accidental happening. Depending upon the curvature of water surface, this can be classified as gradually varied unsteady flow and rapidly varied unsteady flow. Unsteady flow causes are heavy rainfall in a catchment, snow melt which give rise to floods in rivers, stream etc. Operation of control gates in hydraulic structure opening or closing of gate of turbine etc.