M.E. (Water Resources & Hydraulic Engg.) (6 Semester) Examination, 2025

(1st Semester)

FREE SURFACE FLOW

Paper Code: PG/WRS/PE/T/113A

(Paper - Program Elective 1)

Time: Three Hours | Full Marks :100

Answer any five questions

1. a) Explain the transition of flow in a width constriction, considering changes in width, and describe how subcritical and supercritical flow behavior changes during this transition.
   b) What do you mean by choking of a free surface flow
   c) A rectangular channel is 4.0 m wide and carries a discharge of 20 m^3/s at a depth of 2.0 m. At certain section it is proposed to build a hump. Calculate the water surface elevations at upstream of the hump and over the hump height is (a) 0.33 m, and (b) 0.20m (assume loss of energy in the hump)

   5+3+12=20

2. a) What is Specific Energy in open channel flow?

   b) How is open channel flow classified based on different criteria?

   c) If y_1 and y_2 are alternate depth in a triangular channel Show that

$$\frac{4y_1^4 y_2^4}{\left(y_1^2+y_2^2\right)\left(y_1+y_2\right)} = y_c^5$$

   Where y_c =critical depth show further the specific energy E is given by

$$\frac{E}{y_1} = \frac{\eta^4+\eta^3+\eta^2+\eta+1}{\left(1+\eta^2\right)\left(1+\eta\right)}$$

   where $\eta = y_2/y_1$

   2+3+15=20

3. a) Deduce an expression of velocity distribution against shear velocity in the cone of fully turbulent flow of hydraulically smooth and rough boundaries.

   b) The bottom sediment of an open channel consists mainly of coarse sand with a medium grain size of 1.5mm and a specific gravity of 2.65. If the temperature is 20°C. Estimate the permissible shear stress at the bottom of the channel.

   10+10=20

4. a) The velocity distribution in a rectangular channel of width B and depth of flow y_0 was approximated as $v= k_1 \sqrt{y}$, in which k_1 is a constant. Calculate the average velocity for the cross section and correction co-efficient α and β, respectively.

   b) Define the terms average velocity for the cross section and correction coefficient.

   (c) What is the principle of conservation of energy, and how does it apply to fluid mechanics?

   10+5+5=20

5. a) Water ($\nu=1.1x\ 10^{-6}$ m²/s at 20°C) flows in a channel (Ks=2.5 mm) of bottom width 4.2 m and side slope 1.50 H: 1 V at a depth of 1.2 m and a slope of $1.3x10^{-4}$. Find the mean velocity of flow and indicate whether the boundary is smooth, rough or in transition.

   b) Deduce an expression for equivalent/composite roughness of an open channel section.

   12+8=20

6. a) Establish a relationship between the depths of flow upstream and downstream of hydraulic jump in terms of upstream Froude number (F_1) in case of horizontal rectangular channel.

   b) In a hydraulic jump taking place in a horizontal apron below an Ogee shaped weir the discharge per unit width is 2.5 $m^3/s/m$ and the energy loss is 2.75 m. Estimate the depths at the toe and heel of the jump

   c) A spillway discharges a flood flow at a rate of 9.5 m^3/s per metre width. At the upstream horizontal apron, the depth of flow was found to be 0.55 m. What tailwater depth is needed to form a hydraulic jump? If a jump is formed, find its (a) type of jump (b) head loss (c) energy loss as a percentage of the initial energy.

   8+8+4=20

7. Describe critical and steep type GVF profiles with neat sketches.

   b) In a rectangular channel three reaches 1, 2 and 3 in series, with reach A being upstream of reach B, have the following characteristics.

Reach	Width	Discharge	Bed slope	Manning's coefficient
	(m)	(m^3/s)	(m/m)	(-)
1	3.3	12.0	0.0005	0.018
2	3.0	12.0	0.0160	0.011
3	2.7	12.0	0.0100	0.014

   Sketch the resulting water-surface profiles due to changes in the channel characteristics as above. The length of the reaches can be assumed to be sufficiently long for the GVF profiles to develop fully.

   8+12 = 20

8. a) Find out the GVF differential equation by direct integration method.
   b) Derive the following relationship required for the Standard Step Method from the differential energy equation of GVF. Assume proper notations, if required.

9+11 = 20

9. a) Derive the basic differential equation of GVF.
   b) In a wide river the depth of flow at a section is 3 m, bed slope is 1 in 5000 and discharge intensity is 3 m^3/s per meter width. If the Chezy formula with C = 70 is used, estimate the slope of the water surface relative to the bed at that section of the river.
   c) Find out the basic equation to calculate the water surface elevation in the case of GVF using the Direct Step Method.

8+5+7 = 20

TABLE 3A. 1 Values of ϕ For Trapezoidal Channels

$$\phi = \left[\frac{nQ}{S_0^{1/2} B^{8/3}}\right], \qquad \eta_0 = (y_n / B)_s$$

η_0	Values of ϕ			
	$m = 0.00$	$m = 0.50$	$m = 1.00$	$m = 1.25$
0.100	0.019079	0.020428	0.021390	0.021785
0.105	0.020581	0.022112	0.023207	0.023659
0.110	0.022118	0.023845	0.025086	0.025599
0.115	0.023690	0.025627	0.027024	0.027603
0.120	0.025294	0.027457	0.029021	0.029671
0.125	0.026930	0.029334	0.031078	0.031803
0.130	0.028597	0.031256	0.033193	0.034000
0.135	0.030294	0.033224	0.035365	0.036259
0.140	0.032019	0.035237	0.037595	0.038582
0.145	0.033772	0.037293	0.039882	0.040968
0.150	0.035551	0.039393	0.042227	0.043416
0.155	0.037357	0.041536	0.044627	0.045927
0.160	0.039188	0.043721	0.047084	0.048501
0.165	0.041043	0.045947	0.049597	0.051137
0.170	0.042922	0.048215	0.052166	0.053835
0.175	0.044824	0.050523	0.054790	0.056596
0.180	0.046748	0.052872	0.057470	0.059419
0.185	0.048694	0.055261	0.060205	0.062304
0.190	0.050660	0.057689	0.062995	0.065251
0.195	0.052648	0.060157	0.065840	0.068260

η_0	Values of ϕ			
	$m = 0.00$	$m = 0.50$	$m = 1.00$	$m = 1.25$
0.200	0.054655	0.062663	0.068741	0.071331
0.205	0.056682	0.065208	0.071696	0.074465
0.210	0.058727	0.067791	0.074705	0.077661
0.215	0.060791	0.070412	0.077770	0.080919
0.220	0.062873	0.073070	0.080889	0.084239
0.225	0.064972	0.075766	0.084063	0.087622
0.230	0.067088	0.078499	0.087291	0.091067
0.235	0.069220	0.081268	0.090574	0.094575
0.240	0.071369	0.084074	0.093911	0.098146
0.245	0.073533	0.086916	0.097303	0.101779
0.250	0.075713	0.089795	0.100749	0.105476
0.255	0.077908	0.092709	0.104250	0.109235
0.260	0.080117	0.095659	0.107805	0.113057
0.265	0.082341	0.098645	0.111415	0.116943
0.270	0.084578	0.101666	0.115079	0.120892
0.275	0.086829	0.104722	0.118799	0.124905
0.280	0.089094	0.107813	0.122572	0.128981
0.285	0.091371	0.110939	0.126401	0.133121
0.290	0.093661	0.114100	0.130284	0.137325
0.295	0.095963	0.117295	0.134222	0.141593
0.300	0.098278	0.120525	0.138215	0.145925
0.310	0.102942	0.127087	0.146366	0.154784
0.320	0.107651	0.133786	0.154737	0.163901
0.330	0.112404	0.140620	0.163329	0.173280
0.340	0.117199	0.147589	0.172142	0.182920

η_0	Values of ϕ			
	$m = 0.00$	$m = 0.50$	$m = 1.00$	$m = 1.25$
0.600	0.252330	0.374808	0.482159	0.530843
0.610	0.257818	0.385301	0.497329	0.548183
0.620	0.263321	0.395925	0.512751	0.565834
0.630	0.268840	0.406678	0.528425	0.583796
0.640	0.274373	0.417563	0.544353	0.602071
0.650	0.279921	0.428578	0.560536	0.620662
0.660	0.285483	0.439724	0.576976	0.639569
0.670	0.291058	0.451001	0.593673	0.658796
0.680	0.296646	0.462410	0.610628	0.678343
0.690	0.302247	0.473950	0.627844	0.698212
0.700	0.307861	0.485622	0.645321	0.718406
0.710	0.313487	0.497427	0.663061	0.738925
0.720	0.319124	0.509363	0.681064	0.759773
0.730	0.324773	0.521432	0.699332	0.780949
0.740	0.330433	0.533634	0.717867	0.802458
0.750	0.336104	0.545968	0.736668	0.824299
0.760	0.341786	0.558436	0.755739	0.846475
0.770	0.347478	0.571038	0.775080	0.868988
0.780	0.353180	0.583773	0.794691	0.891839
0.790	0.358892	0.596643	0.814576	0.915030
0.800	0.364614	0.609647	0.834733	0.938564
0.810	0.370345	0.622785	0.855166	0.962441
0.820	0.376085	0.636059	0.875875	0.986664
0.830	0.381834	0.649467	0.896862	1.01123