M.E. (Water Resources and Hydraulic Engineering) Examination, 2025

(2nd Semester)

Design of Water Resources System

(Paper IX)

Time: Three hours | Full Marks: 100

Answer any ***four*** questions

1. (a) Derive a relationship between the capital recovery factor, where A is the capital recovery and F is the future sum of money at the end of the n^{th} year, and i is the interest rate per annum.

   (b) Intermittent flooding has occurred along a reach of the river that has a capacity of 13 cumec. A study shows that the annual average cost of increasing the capacity by lining and strengthening could be approximated by $C = 100Q - (400 + 4Q^2)$ where C is in thousands of Rupees and Q is the increased capacity in thousands of m^3/s. The average annual benefits in thousands of Rupees would be $B = -1050 - 230Q - 0.8Q^3$. These expressions apply in the range from 12 to 28 cumec. What is the optimum capacity? Making reasonable assumptions, estimate the first cost of this project.

   (c) Estimate project costs and residual flood damages for the four flood damage reduction plans as follows:

Flood Mitigation Plan	Initial Investment Cost	Annual O&M cost	Average Annual damage
	(Lakh of Rs.)	(Lakh of Rs.)	(Lakh of Rs.)
No Action	0	0	1450
Plan A	5640	572	210
Plan B	4820	485	300
Plan C	4730	271	375
Plan D	3890	185	570

   Determine the Benefit-Cost ratio and net benefits for each plan for a 100-year period of analysis and a discount rate of 8%. Which plan is best from an economic perspective?

   4+7+14=25

2. (a) What are the recommended design floods for (i) spillways of dams, (ii) vegetated waterways, (iii) field diversions, and (iv) permanent barrages?

   (b) Derive the relationship between the risk, reliability, and return period for a structure of designed flood magnitude.

   (c) A flood of 4000 cumec in a certain river has a return period of 40 years. (i) What is its probability of exceedance? (ii) What is the probability that the flood of 4000 cumec or

[Turn over

greater magnitude may occur in the next 20 years? (iii) What is the probability of the occurrence of the flood magnitude less than 4000 m^3/s?

(d) Analysis of annual flood peak data of a river, covering the period 1997 to 2024, yielded a mean of 8520 m^3/s. A proposed water control project on this river near this location is to have an expected life of 40 years. The policy decision of the project allows an acceptable reliability of 85%. (i) Using Gumbel's method, recommend the flood discharge for this project, and (ii) if a safety factor for a flood magnitude of 1.3 is desired, what discharge is to be adopted? What would be the corresponding safety margin?

4+5+6+10=25

Reduced mean in Gumbel's extreme value distribution

N = sample size

N	0	1	2	3	4	5	6	7	8	9
10	0.4952	0.4996	0.5035	0.5070	0.5100	0.5128	0.5157	0.5181	0.5202	0.5220
20	0.5236	0.5252	0.5268	0.5283	0.5296	0.5309	0.5320	0.5332	0.5343	0.5353
30	0.5362	0.5371	0.5380	0.5388	0.5396	0.5402	0.5410	0.5418	0.5424	0.5430
40	0.5436	0.5442	0.5448	0.5453	0.5458	0.5463	0.5468	0.5473	0.5477	0.5481
50	0.5485	0.5489	0.5493	0.5497	0.5501	0.5504	0.5508	0.5511	0.5515	0.5518
60	0.5521	0.5524	0.5527	0.5530	0.5533	0.5535	0.5538	0.5540	0.5543	0.5545
70	0.5548	0.5550	0.5552	0.5555	0.5557	0.5559	0.5561	0.5563	0.5565	0.5567
80	0.5569	0.5570	0.5572	0.5574	0.5576	0.5578	0.5580	0.5581	0.5583	0.5585
90	0.5586	0.5587	0.5589	0.5591	0.5592	0.5593	0.5595	0.5596	0.5598	0.5599
100	0.5600									

Reduced SD in Gumbel's extreme value distribution

N	0	1	2	3	4	5	6	7	8	9
10	0.9496	0.9676	0.9833	0.9971	1.0095	1.0206	1.0316	1.0411	1.0493	1.0565
20	1.0628	1.0696	1.0754	1.0811	1.0864	1.0915	1.0961	1.1004	1.1047	1.1086
30	1.1124	1.1159	1.1193	1.1226	1.1255	1.1285	1.1313	1.1339	1.1363	1.1388
40	1.1413	1.1436	1.1458	1.1480	1.1499	1.1519	1.1538	1.1557	1.1574	1.1590
50	1.1607	1.1623	1.1638	1.1658	1.1667	1.1681	1.1696	1.1708	1.1721	1.1734
60	1.1747	1.1759	1.1770	1.1782	1.1793	1.1803	1.1814	1.1824	1.1834	1.1844
70	1.1854	1.1863	1.1873	1.1881	1.1890	1.1898	1.1906	1.1915	1.1923	1.1930
80	1.1938	1.1945	1.1953	1.1959	1.1967	1.1973	1.1980	1.1987	1.1994	1.2001
90	1.2007	1.2013	1.2020	1.2026	1.2032	1.2038	1.2044	1.2049	1.2055	1.2060
100	1.2065									

3. (a) Derive the parameters for the best hydraulic sections for a triangular channel in terms of depth of flow for a channel.

(b) Establish the co-relationship between the non-dimensional shear stress τ_x and the boundary Reynold's number Re_x using dimensional analysis method.

(c) Design a drainage system considering a trapezoidal section to accommodate a peak flow rate of 4.5 m^3/s has a longitudinal slope of 0.042%. The lining of the channel is to be unfinished concrete. Consider(i) permissible shear stress of the bottom of the channel = 30 Pa and (ii) a section with side slope of 2.5:1, Assume n=0.011, angle of repose = 35^0. Any data, if needed, please assume as per CPHEEO Manual.

6+7+12=25

4. (a) How does the provision of a drop in a manhole help in preventing backwater during sewage flow? Justify with equation and draw a schematic diagram.

(b) A manhole is to be placed at a location where the slope of a 760 mm diameter pipe changes from 0.5% to 0.2%. The roughness height of the concrete pipe is estimated as 1 mm and the design maximum flow rate is 0.485 m^3/s. If the inflow and outflow pipes are located directly opposite to each other, determine the minimum drop in the pipe invert that must be provided at the manhole. Assume average friction factor 'f'=0.0141, average Manning's roughness coefficient 'n' =0.0101 and coefficient of head loss due to bend 'k' = 0.15. Assume any data if required as per CPHEEO Manual

6+19=25

5. (a) Consider the pipe network shown in the figure. the Hardy Cross method can be used to calculate the pressure distribution in the system, where the friction loss h_f, is estimated using the equation $h_f = rQ^n$ and all pipes are made of ductile iron. What value of r and n would you use for each pipe in the system? The pipeline characteristics are as follows:

Pipe	L (m)	D (mm)
AB	1000	300
BC	750	325
CD	800	200
DE	700	250
EF	900	300
FA	900	250
BE	950	350

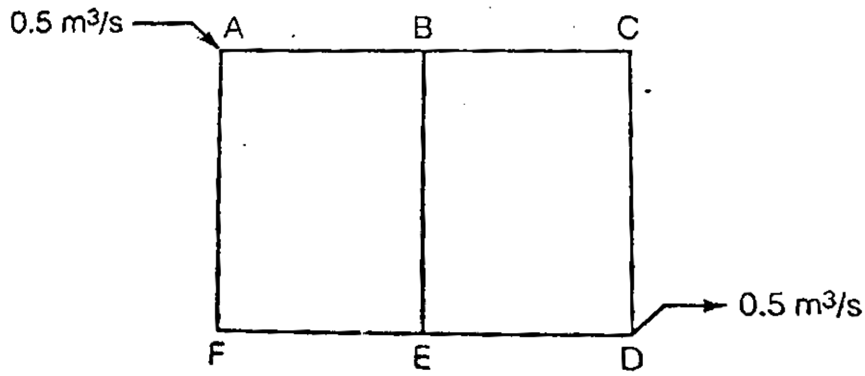


Fig. Two-loop pipe network

Assume that the flow in each pipe is hydraulically rough.

(b) The performance curve for a variable speed pimp operating at 600 rpm is given by

$$h_p = 6 - 0.05Q^2 \text{ w}$$

here h_p is the head added by the pump in m and Q is the flow rate in m^3/min. This pump is installed in a system where energy consideration requires a system curve given by

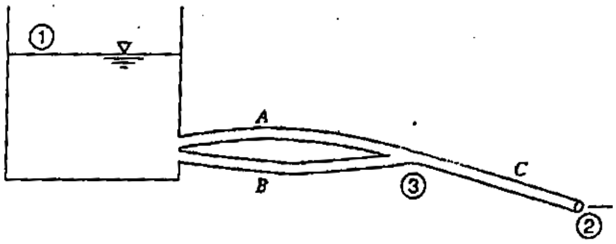
$$h_p = 3 + 0.042Q^2.$$

Find the flow rate in the system when the pump is operating at 600 rpm and compare this with the flow rate when the pump is operating at 1200 rpm.

17+8=25

6. (a) The three-pipe system shown in the figure has the following characteristics:

Pipe	D (m)	L (m)	f
A	0.2032	457.2	0.020
B	0.1524	609.6	0.025
C	0.254	914.4	0.030



Elevation at level 1: 61 m; level 2: 25 m; level 3: 43 m

Find the flow rate of water in each pipe and the pressure at point 3. Neglect minor losses.

(b) Water flows at a velocity of 2 m/s in a 300 mm new ductile-iron-pipe. Estimate the head loss over 500 m using; i) the Hazen Williams Formula ii) the Manning's formula and iii) the Darcy Weisbach equation. Compare your results. Calculate the Hazen William's roughness coefficient and Manning's coefficient that should be used to obtain the same head loss as the Darcy Weisbach equation.

17+8=25

7. (a) What do you mean by NPSH? State the difference between $NPSH_{(available)}$ and $NPSH_{(required)}$.

(b) What is Specific speed. Show that it is a dimensionless parameter.

(c) A pump is placed in a pipe system in which the energy equation (system curve) is given by

$$h_p = 15 + 0.03Q^2$$

Where, h_p is the head added by the pump in meters and Q is the flow rate through the system in lps. The performance curve of the pump is

$$h_p = 20 - 0.08\,Q^2$$

What is the flow rate through the system? If the pump is replaced by two identical pumps in parallel, what would be the flow rate in the system? If the pump is replaced by two identical pumps in series, what would be the flow rate in the system?

(d) The characterestics of axial flow pump delivering water are followes

Q (m^3/s)	0	0.040	0.069	0.092	0.115	0.138	0.180
H (m)	5.6	4.20	4.35	4.01	3.38	2.42	0

When two such pumps are connected in parallel, the flow rate through the system is the same as when they are connected in series. Determine the flow rate that a single pump would deliver if connected to the same system. Assume the system characteristic to be purely resistive (no static lift).

2.5+2.5+12+8=25

8. (a) Briefly describe the design procedure of well field design.

   (b) An urban housing is to be developed in an unconfined sand aquifer with a transmissivity 1465 m^2/day, saturated thickness of 30 m, and specific yield of 0.2. A service demand of 5000 people is required from the wellfield, and the diameter of each well is to be 20 cm. If the drawdown in the aquifer is not to exceed 3.5 m when the wellfield is operational, develop a proposed layout for the wells. There are no nearby surface-water bodies.

5+20=25

9. (a) Briefly describe the working function of collectorwell with diagram.

   (b) A radial water collector is to be designed for extraction of 18000 m^3/day from the groundwater stored in riverbed which has an aquifer extending up to 13 m below the bed with width limited to actual riverbed itself, which is 600 m wide. Along duration pump test indicates a transmissibility of 3.6 ×106 lpd/m for the saturated thickness of 12 m when the water table is 1 m below the riverbed and storage coefficient of 33 % for the aquifer as confirmed by laboratory tests. The water table goes down by 4.2 m over a period of 250 days during which period the summer rain fall amounts tom40 cm.

5+20=25

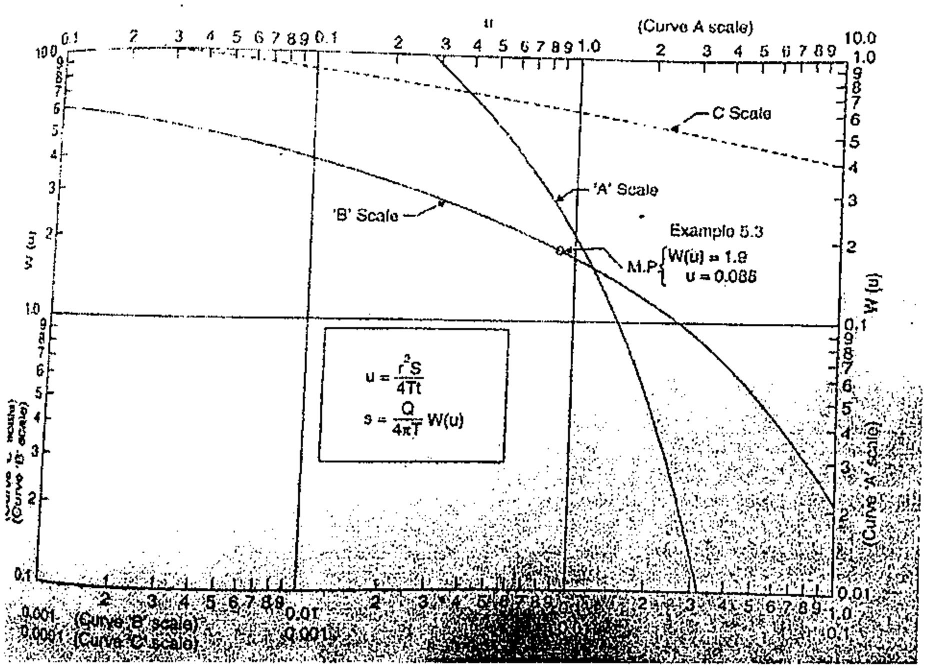


Table 5.1 Values of $W(u)$ for values of u (abridged after Wenzel, 1942)

u	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0
$\times 1$	0.219	0.049	0.013	0.0038	0.0011	0.00036	0.00012	0.000038	0.000012
$\times 10^{-1}$	1.82	1.22	0.91	0.70	0.56	0.45	0.37	0.31	0.26
$\times 10^{-2}$	4.04	3.35	2.96	2.68	2.47	2.30	2.15	2.03	1.92
$\times 10^{-3}$	6.33	5.64	5.22	4.95	4.73	4.54	4.39	4.26	4.14
$\times 10^{-4}$	8.63	7.94	7.53	7.25	7.02	6.84	6.69	6.55	6.44
$\times 10^{-5}$	10.94	10.24	9.84	9.55	9.33	9.14	8.99	8.86	8.74
$\times 10^{-6}$	13.24	12.55	12.14	11.85	11.63	11.45	11.29	11.16	11.04
$\times 10^{-7}$	15.54	14.85	14.44	14.15	13.93	13.75	13.60	13.46	13.34
$\times 10^{-8}$	17.84	17.15	16.74	16.46	16.23	16.05	15.90	15.76	15.65
$\times 10^{-9}$	20.15	19.45	19.05	18.76	18.54	18.35	18.20	18.07	17.95
$\times 10^{-10}$	22.45	21.76	21.35	21.06	20.84	20.66	20.50	20.37	20.25
$\times 10^{-11}$	24.75	24.06	23.65	23.36	23.14	22.96	22.81	22.67	22.55
$\times 10^{-12}$	27.05	26.36	25.96	25.67	25.44	25.26	25.11	24.97	24.86
$\times 10^{-13}$	29.36	28.66	28.26	27.97	27.75	27.56	27.41	27.28	27.16
$\times 10^{-14}$	31.66	30.97	30.56	30.27	30.05	29.87	29.71	29.58	29.46
$\times 10^{-15}$	33.96	33.27	32.86	32.58	32.35	32.17	32.02	31.88	31.76

Example: For $u = 3.0 \times 10^{-4}$, $W(u) = 7.53$.