M.E. (Water Resources and Hydraulic Engineering) Examination, 2018

(First Year-2nd Semester)

Design of Water Resources System

Time: Three hours Full Marks: 100

Answer any ***four*** questions

1. (a) Explain the behaviour and responsibilities of different types of valves that may be used in a pressurized system.

   (b) Derive the expression of the velocity of propagation of the pressure wave for the water hammer in case of an elastic pipe where the pipe is subjected to circumferential stress but negligible longitudinal stress. Assume proper notations.

   (c) A steel pipe 1.6 km long place on a uniform slope has a 0.5 m diameter and a 5 cm wall thickness. The pipe carries water from a reservoir and discharges it into the air at an elevation 50 m below the reservoir free surface. A valve installed at the downstream end of the pipe allows a flow sure at the valve and at the midlength of the pipe. Neglect longitudinal stresses. Use $K_{water} = 2.17\times10^9$ N/m^2 and $E_p = 1.9\times10^{11}$ N/m^2.

5+10+10=25

2. (a) Define reliability of a hydraulic system. What is safety margin?

Consider that load and resistance are independent exponentially distributed random variables with Probability Distribution Functions (PDFs) as

Load: $f_L(l) = \lambda_1 e^{-\lambda_1 l}$ $\quad l_1 \le l \le l_2$

Resistance: $f_R(r) = \lambda_2 e^{-\lambda_2 r}$ $\quad r_1 \le r \le r_2$

Furthermore, $l_1 < r_1 < l_2 < r_2$ and $f_L(l) > f_R(r)$. Derive the expression for the failure probability.

(b) In the design of storm sewer systems, the rational formula

$$Q_L = CIA$$

is used frequently, in which Q_L is the surface inflow resulting from a rainfall event of intensity 'I' falling on the contributing drainage area of A, and C is the runoff coefficient. On the other hand, Manning's formula for full pipe flow, is that,

$$Q_C = 0.311\, n^{-1} S^{1/2} D^{8/3}$$

Is used commonly to compute the flow carrying capacity of storm sewers, in which D is the pipe diameter, n is the Manning's roughness, and S is the pipe slope.

Consider that all the parameters in rational formula and Manning's equation are independent random variables with their mean and standard deviation given below. Compute the reliability of a 915 mm pipe.

Parameter	Mean	Std.Dev.	Distribution
C	0.825	0.057575	Normal
I(mm/hr)	4.000	0.6	Normal

A(ha)	10.000	0.5	Normal
n	0.015	0.00083	Lognormal
D(m)	3.000	0.03	Normal
S(m/m)	0.005	0.00082	Lognormal

(7+18)=25

3. (a) The pipe system shown in fig. below connects two reservoirs that have an elevation difference of 20 m. This pipe system consists of 200 m of 500 mm concrete pipe–A, that branches into 400 m of 200 mm pipe-B and 400 m of 400 mm pipe-C in parallel. Pipes B and C join into a single 500 mm pipe that is 500 m long pipe-D. For f = 0.030 in all pipes, what is the flow rate in each pipe of the system?

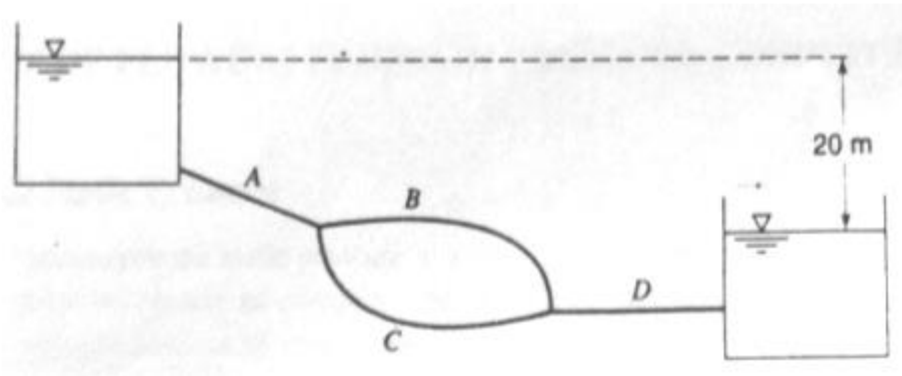


Fig. Pipe system

(b) Using Buckingham pi theorem, establish a relation between three dimensionless groups such as head co-efficient, flow co-efficeint and Reynolds number. What is Affinity law?

15+10=25

4. Water at 20^0C is being pumped from a lower to an upper reservoir through a 200 mm pipe in the system. The water surface elevations in the source and destination reservoirs differ by 5.2 m, and the length of the steel pipe connecting the reservoirs is 21.3 m. The pump is to be located 1.5 m above the water surface in the source reservoir, and the length of the pipeline between the source reservoir and the suction side of the pump is 3.5 m. Express the head loss due to pipe friction in terms of flow rate. The performance curves of the 885 rpm homologous series of pumps being considered for this system are given below. Assume f = 0.040 and neglecting local head losses.

Q (m^3/s)	h_p (m)	η (%)	Q (m^3/s)	h_p (m)	η (%)	Q (m^3/s)	h_p (m)	η (%)
0	10	0	0.18	12	30	0.214	13.5	55
0.245	12.5	76	0.277	13.5	70	0.305	8.5	70
0.345	6.5	57	0.370	4.5	38			

(i) Estimate the operating point of Q and h_p from the pump-system characteristics curve.

(ii) Estimate the brake Horsepower (BHP) to be required in the pipeline system.

(iii) What specific-speed pump should be selected at the operating point condition?

(iv) Estimate the available net positive suction head at the operating point condition. Assume atmospheric pressure = 101 kPa; saturated vapour pressure of water =2.34 kPa; specific weight of water =9.80 kN/m^3. 13+4+4+4 =25

5. (a) Design a trapezoidal drainage channel to accommodate a peak flow rate of 1.5 m^3/s on a slope of 0.65%. Local regulations require that the side slope of the channel be no greater than 3:1 (H : V). A filed investigation has indicated that the native soil is non-cohesive and has a 50-perentile grain size of 50 mm. Use gravel mulch lining. Assume n = 0.022 and the permissible shear stress on the gravel mulch lining = 28 Pa. Assume angle of repose = 36.8^0

(b) Differentiate between cohesive and non-cohesive materials. Using Buckingham pi theorem, establish a relation between the critical shear stress (τ_c) and shear velocity (u*).on non-cohesive bottom sediments.

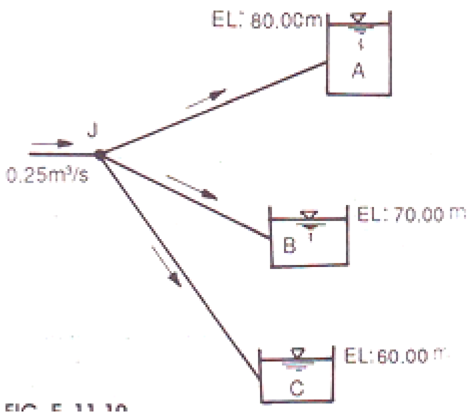
15+10=25

6. (a) Show the energy grade line through manholes with equations to avoid backwater effects.

(b) A fully developed 55 km^2 city will have land uses that are 70% residential, 20% commercial, and 10% industrial. The residential development will be 20% large lots (6 persons/ha), 70% small single-family lots (75 persons/ha), and 10% multistory apartments (2500 persons/ha). The average wastewater flow rates can be taken as 168 L/d/person for large and single family lots, 150 L/d/person for apartments, the average commercial flow rate as 50,000 l/d/ha, and the average industrial flow rate as 90,000 L/d/ha. When the sewer is first installed, the average wastewater flow rate will be 30% of the average flow rate expected when the area is fully developed. Infiltration and inflow is estimated 1600 L/d/ha for the entire area. Estimate the maximum and minimum flow rates to be handled by the main sewer.

(c) What are the components of flows in sanitary sewers and discuss them with their empirical equations. 5+14+6 = 25

7. (a) A Water Supply main trifurcates at a junction point J into three branches each feeding a separate reservoir. The details of the pipes and the reservoir are as follows:



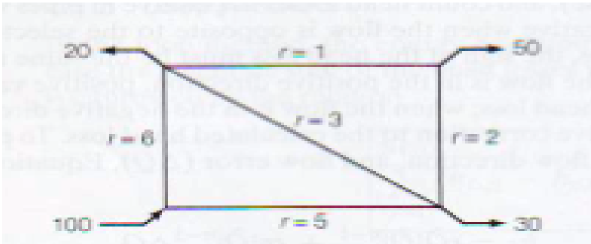
Pipe	Diameter (mm)	Length (m)	f	Feeding to reservoir elevation (m)

JA	200	2000	0.02	A=80
JB	300	2500	0.03	B=70
JC	400	3000	0.04	C=60

If the inflow from the main at the junction is 0.250 m^3/s, determine the delivery into each reservoir.

(b) State the difference between $NPSH_A$ and $NPSH_R$

(c) A pipe network is shown in figure given below in which Q and h_f refers to a discharge and head losses respectively. Determine the head losses and discharges for this pipe network. The head loss h_f is given by $h_f = rQ^2$. Consider correction to be done up to second trial. Assume f= 0.03. All dimensions are in SI unit.



12+3+10=25

TABLE 2.2 Table of Standard Normal Probability, $\Phi(z) = P(Z \leq z)$

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990
3.1	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9993	0.9993
3.2	0.9993	0.9993	0.9994	0.9994	0.9994	0.9994	0.9994	0.9995	0.9995	0.9995
3.3	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997
3.4	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9998

NOTE: $\Phi(-z) = 1 - \Phi(z)$, $z \geq 0$.