M.E. (Water Resources & Hydraulic Engg.) Examination, 2024

(2nd Semester)

DESIGN OF WATER RESOURCES SYSTEM

(Paper – X)

Time : Three Hours | Full Marks : 100

Answer any ***four*** questions.

1. (a) The facility plan for a development recommended that the minimum and maximum flows to be considered for the design of a proposed collection system are 5037 m^3/day and 15319 m^3/day respectively.
   i. What size of trunk sewer should be used to carry these flows?
   ii. To ensure self-cleansing at all times, at what slope should the sewer be laid?
   iii. What is the minimum depth of flow? Assume self-cleansing velocity = 0.6 m/s (CPHEEO manual) & concrete pipe sewer (n = 0.012)

   (b) Water flows at a rate of 3.3 m^3/s in a circular concrete sewer of diameter 1900 mm and longitudinal slope 1.00%. Estimate the normal depth of flow and the average velocity in the sewer. Check whether the velocity is satisfying or not as per the guideline given in CPHEEO Manual. Assume the necessary data (if required).

18+7=25

2. (a) A lined (straight) triangular channel is to be constructed on a slope of 0.032% to handle a design flow rate of 4.4 m^3/s. The lining of the channel is to be smooth asphalt. Determine the dimensions of the most efficient channel.

   (b) Determine the coefficient of variation of the loading and the capacity for the following parameters. Assume a uniform distribution to define the uncertainty of each parameter:

Parameter	Mode	Range
C	0.75	0.70–0.80
i	7.5 in/hr	7.2–7.8 in/hr
A	12 ac	11.9–12.1 ac
n	0.015	0.0145–0.0155
D	5 ft	4.96–5.04 ft
S_0	0.001 ft/ft	0.0009–0.0011 ft/ft

Figure: 1

(c) A new 60-m-long pipe segment is to be designed to accommodate a peak flow rate of 1.9 m^3/s. The new pipe segment is to be an extension of an existing upstream pipe segment that has a diameter of 645 mm. At the upstream end of the new pipe segment, the crown elevation matches the crown of the existing pipe and just meets the minimum-cover requirement of 1.1 m. Local regulations require a minimum full-flow (self-cleansing) velocity of 1.1 m/s, a maximum velocity less than 4.6 m/s. The ground elevation at the upstream and downstream ends of the pipe segment are 10.04 m and 9.89 m, respectively. Determine the diameters and corresponding slopes that could be used in the new pipe segment. Assume any data if required.

12+7+6=25

3 (a) A water pump is discharging at a rate of 0.25 m^3/s. The diameters of the discharge and suction nozzles are 300 and 350 mm respectively. The reading on the discharge gage located 0.25 m above the centreline of the impeller is 150 kN/m^2; the reading on the suction gage located at the centreline of the impeller is 20 kN/m^2. Determine (i) the total dynamic head, (ii) the power input require by the pump, and (iii) the power input to the motor. Assume the efficiency of the pump and motor are 65 and 90 percent, respectively.

(b) Design a sustainable arsenic and iron removal plant for a community with a population of 7,000. The raw water contains arsenic at 0.312 mg/L and iron at 3.44 mg/L. Include a detailed flow diagram of AIRP with design calculation, specifying the equipment and operational considerations necessary to meet BIS 10500:2012 drinking water standards for arsenic (<0.01 mg/L) and iron (<1.0 mg/L).

7+18=25

4. (a) Using Buckingham pi theorem, establish a relation between three dimensionless group such as head coefficient, flow co-efficient and Reynolds number.
(b) Determine the relationship between the Hazen Williams roughness coefficient and Manning's roughness coefficient.
(c) Reservoirs A, B, and C are connected as shown in Figure 2. The water elevations in reservoirs A, B, and C are 100 m, 80 m, and 60 m, respectively. The three pipes connecting the reservoirs meet at the junction J, with pipe AJ being 900 m long, BJ 800 m long, CJ 700 m long, and the diameter of all pipes equal to 850 mm. If all pipes are made of ductile iron and the water temperature is 20◦C, find the flow into or out of each reservoir.

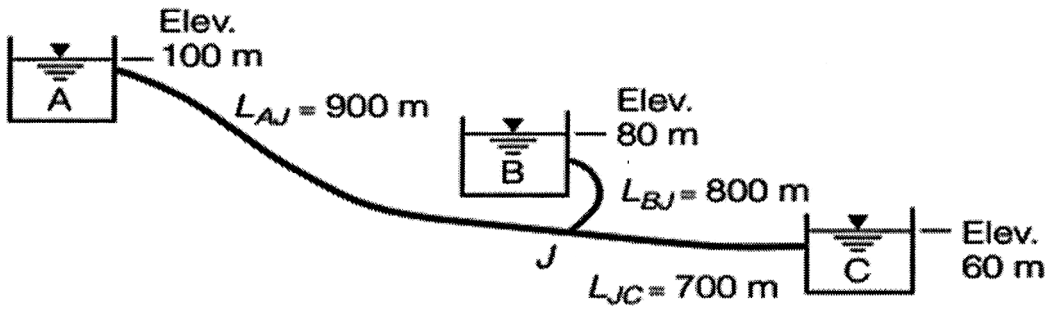


Figure. 2

8+7+10=25

5. (a) Define water hammer.

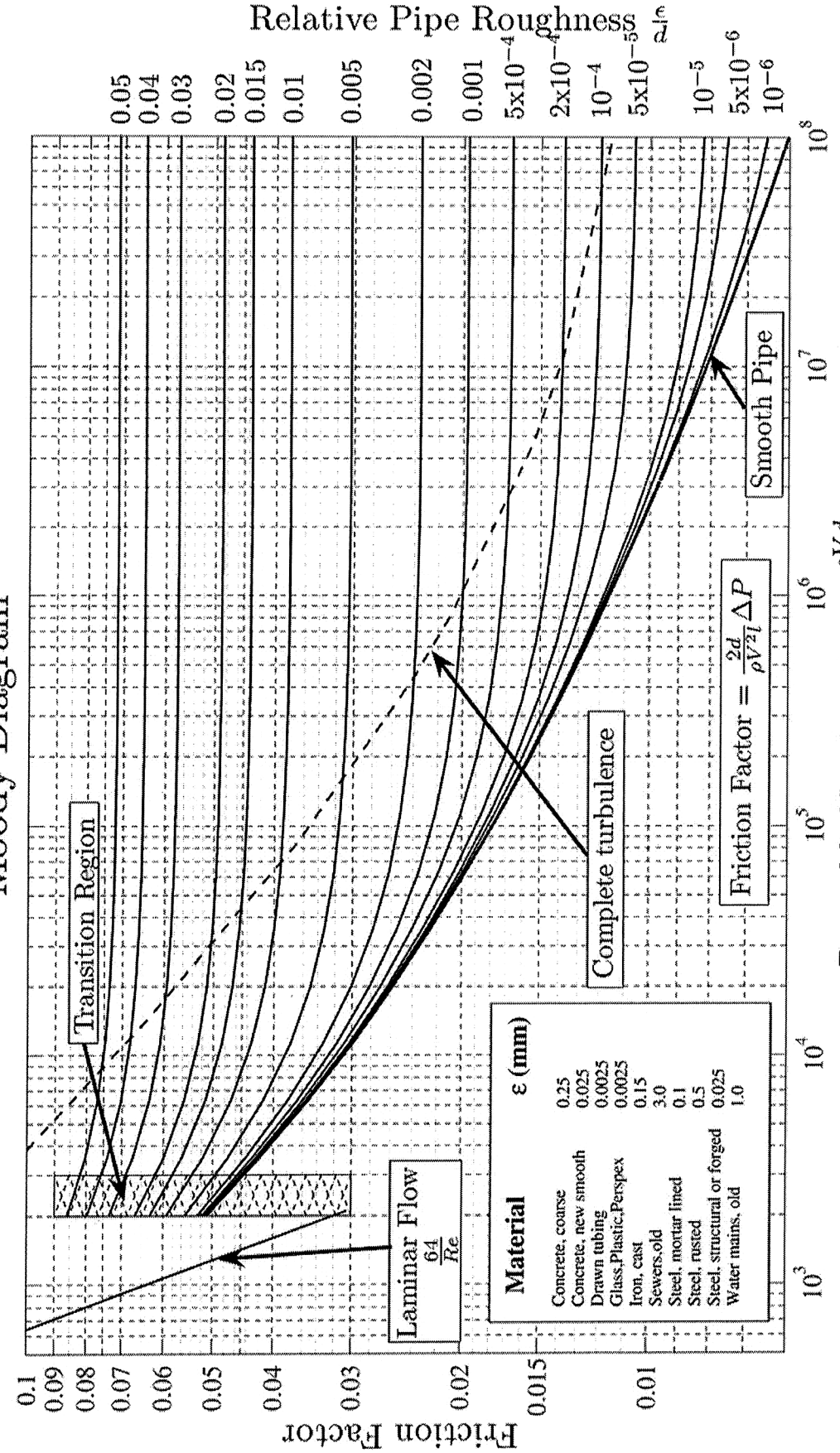
(b) Derive the expression of the velocity of propagation of the pressure wave for the water hammer in the case of an elastic pipe where the pipe is subjected to circumferential stress but negligible longitudinal stress. Assume proper notations.

Then derive a relationship between the maximum water hammer head and static head.

(c) Why surge tanks are used and where?

(d) A 500 mm diameter steel pipe 1500 m long placed on a uniform slope and a 5 mm 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 rate of 0.85 m^3/sec. If the valve is completely closed in 1.4 seconds, calculate the maximum water hammer pressure and stress at the valve and at the middle length of the pipe. Neglect the longitudinal stress. The Young's modulus of elasticity of steel is 1.9×10^{11} N/m^2 and the bulk modulus of elasticity of water is 2.17×10^9 N/m^2.

2+12+3+8=25


Moody Diagram
Relative Pipe Roughness $\frac{\epsilon}{d}$
0.05
0.04
0.03
0.02
0.015
0.01
0.005
0.002
0.001
$5\text{x}10^{-4}$
$2\text{x}10^{-4}$
10^{-4}
$5\text{x}10^{-5}$
10^{-5}
$5\text{x}10^{-6}$
10^{-6}
Transition Region
Laminar Flow $\frac{64}{Re}$
Complete turbulence
Friction Factor = $\frac{2d}{\rho V^2 l}\Delta P$
Smooth Pipe
Material ε (mm)
Concrete, coarse 0.25
Concrete, new smooth 0.025
Drawn tubing 0.0025
Glass,Plastic,Perspex 0.0025
Iron, cast 0.15
Sewers,old 3.0
Steel, mortar lined 0.1
Steel, rusted 0.5
Steel, structural or forged 0.025
Water mains, old 1.0
Friction Factor
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.015
0.01
10^3
10^4
10^5
10^6
10^7
10^8
Reynolds Number, $Re = \frac{\rho V d}{\mu}$

6. (a) What is net positive suction head (NPSH)?

(b) Water is being pumped from reservoir A to reservoir F through a 30 m long PVC pipe of diameter 150 mm (see the figure below). There is an open gate valve located at C; 90° bends (threaded) located at B, D, and E, and the pump performance curve is given by

$$H_p = 20 - 4713Q^2$$

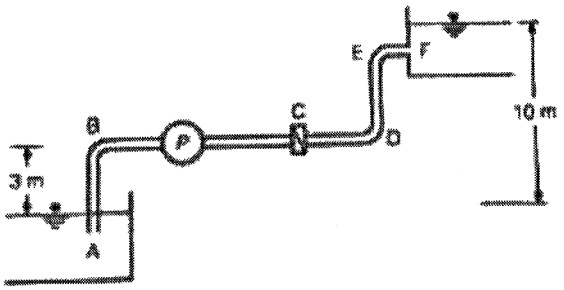
where H_p is the head added by the pump in 'm' and Q is the flow rate in m^3/s. The specific speed of the pump is 3000. Assuming that the flow is turbulent, and the temperature of the water is 20^0C,

i) Write the energy equation between the upper and lower reservoirs, accounting for entrance, exit and local losses between A and F.

ii) Calculate the flow rate and velocity in the pipe.

iii) If the required net positive suction head at the pump operating point is 3 m, assess the potential for cavitation in the pump (it may be assumed that the head loss in the pipe is negligible between the intake and the pump) and

iv)Use the affinity laws to estimate the pump performance curve when the motor on the pump is charged from 800 rpm to 1600 rpm.



3 + 22=25

7. (a) Describe parallel and series pump operation and draw a neat sketch to show the H-Q curve for two similar pumps when they are connected in series and also in parallel.

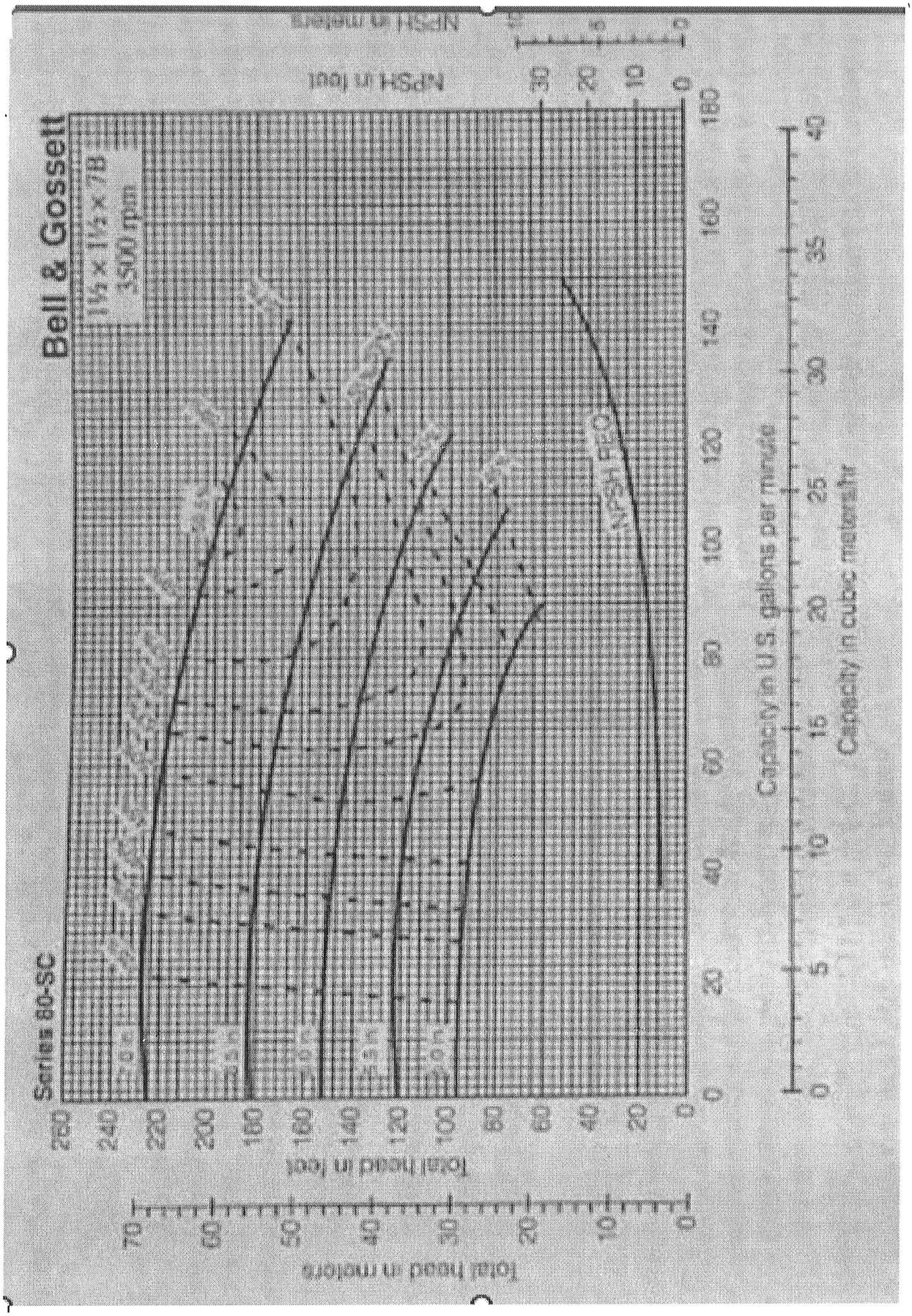
(b) The characteristics of an axial flow pump running at 1450 rpm is as follows:

Q (m^3/s)	0	0.046	0.069	0.092	0.115	0.138	0.180
H (m)	5.6	4.2	4.35	4.03	3.38	2.42	0

When two such pumps are connected in parallel the flow rate through the system is same as when they are connected in series. At what speed should a single pump run in order to deliver the same volume? Assume the system characteristic to be purely resistive

5+20=25

8. Water is to be pumped out of a well and stored in an above-ground reservoir. The water surface in the well is 3 m below the ground surface, water is to be pumped through a 100-m long 50-mm diameter galvanized iron line and exit 19.3 m above the ground, and water is to be delivered to the upper reservoir at a rate of at least 370 lpm when the reservoir is empty. The sum of the local loss coefficients in the system is 1.8. A local pump salesman suggests a pump model with performance curves shown in figure below. Determine if this pump will meet the demands of the project and, if so, the pump size that is required. What is the maximum height that the pump can be placed above ground?


Bell & Gossett
Series 80-SC
1½ x 1½ x 7⅞
3500 rpm
Total head in feet
Total head in meters
Capacity in U.S. gallons per minute
Capacity in cubic meters/hr
NPSH in feet
NPSH in meters

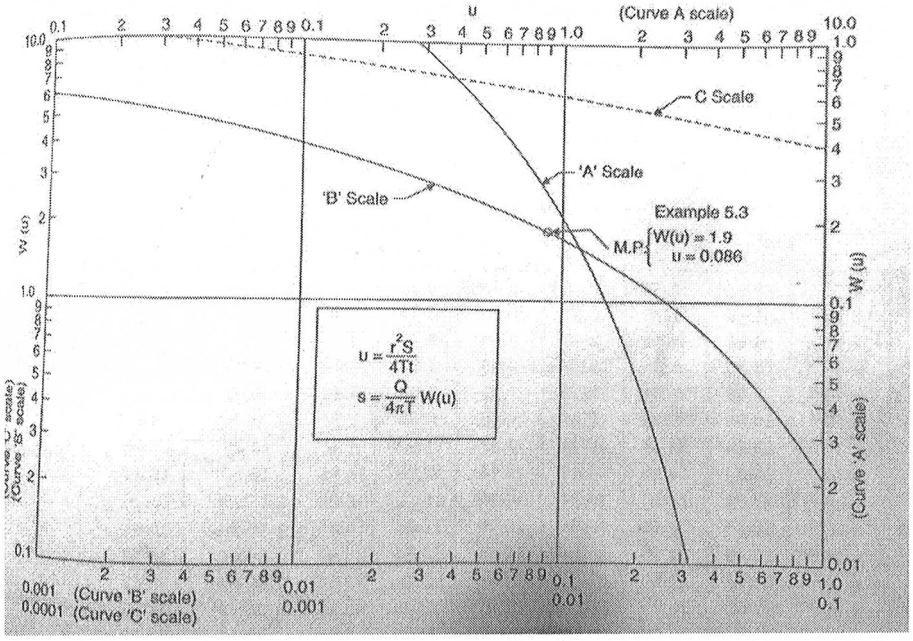
9 (a) Briefly describe the working function of infiltration gallery with diagram.

(b) A radial water collector is to be designed for extraction of 15000 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 $\times 10^6$ 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.

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	14.35	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 $u = 3.0 \times 10^{-4}$, $W(u) = 7.53$



5+20=25

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

(b) A small municipal wellfield is to be developed in an unconfined sand aquifer with a hydraulic conductivity of 50 m/d, saturated thickness of 30 m, and specific yield of 0.2. A service demand of 81.0 L/s is required from the wellfield, and the diameter of each well is to be 60 cm. If the drawdown in the aquifer is not to exceed 3 m when the wellfield is operational, develop a proposed layout for the wells. There are no nearby surface-water bodies.

4+21=25