# M.E. WATER RESOURCES AND HYDRAULIC ENGG.(EVENING)

## SECOND YEAR SECOND SEMESTER - 2024

## DESIGN OF WATER RESOURCES SYSTEM

**(Paper – X)**

Time : Three Hours Full Marks : 100

Answer any *four* questions.

1.(a) Derive the parameters for the best hydraulic sections for a semi- circular channel in terms of depth of flow for a channel.

(b) Prove that bottom width, 'b' to depth, 'y' ratio of the best hydraulic section as

$$\frac{b}{y} = 2(\sqrt{m^2 + 1} - m)$$

(c) Design a Drainage System considering a trapezoidal Section to accommodate a peek flow rate of 25 $m^3/s$ has a longitudinal slope 0.0015. The lining of the channel is to be float – finished concrete. Consider (i) permissible shear stress of the bottom of the channel =34 Pa, and (ii) a section with side slope of 1.75:1 (H:V). Assume n = 0.013, angle of repose = 39° . Any data if needed please assume.

7+6+12=25

2.(a) A city has an area of 7.5 ha with the following population in the years as follows

| Year | Population |
|---|---|
| 1991 | 1,20,000 |
| 2001 | 1,60,000 |
| 2011 | 1,95,000 |
| 2021 | 2,20,000 |

Forecast the population of the city by (i) Arithmetical progression method (ii) Geometrical progression method (iii) Incremental increase method. Estimate the average and peak flow of waste water for a separate and combined sewerage project laying through a conveyer system for the period of 2024, 2039 and 2054 considering water supply of 135 lpcd.

[ Turn over

Assume rainfall intensity = 60 mm/h, runoff coefficient = 0.72 and groundwater infiltration = 5000 L/ha/d as per the guide line given in the CPHEEO manual.

(b) Find out the intensity vs. duration curve (ID Curve) for 6 months, 1 year and 2 years storm frequency. Analysis of the frequency of storms stated intensities and durations during 30 years for which rainfall data were available for a given town.

| **Duration In mins** | **Intensity (mm/hr)** | **30** | **35** | **40** | **45** | **50** | **60** | **75** | **100** | **125** |
|---|---|---|---|---|---|---|---|---|---|---|
| | | No of storm intensity or more for a period of 30 years | | | | | | | | |
| **5** | | | | | | 100 | 40 | 18 | 10 | 2 |
| **10** | | | | 90 | 72 | 41 | 25 | 10 | 5 | 1 |
| **15** | | | 82 | 75 | 45 | 20 | 12 | 5 | 1 | |
| **20** | | 83 | 62 | 51 | 31 | 10 | 9 | 4 | 2 | |
| **30** | | 73 | 40 | 22 | 10 | 8 | 4 | 2 | | |
| **40** | | 34 | 16 | 8 | 4 | 2 | 1 | | | |
| **50** | | 14 | 8 | 4 | 3 | 1 | | | | |
| **60** | | 8 | 4 | 2 | 1 | | | | | |
| **90** | | 4 | 2 | | | | | | | |

**15+10=25**

(a) Water flows at a rate of 0.040 $m^3/s$ from reservoir 1 to reservoir 2 through three pipes connected in series ($f = 0.022$) as shown in **Figure 1** Neglecting minor losses, determine the difference in water surface elevation.

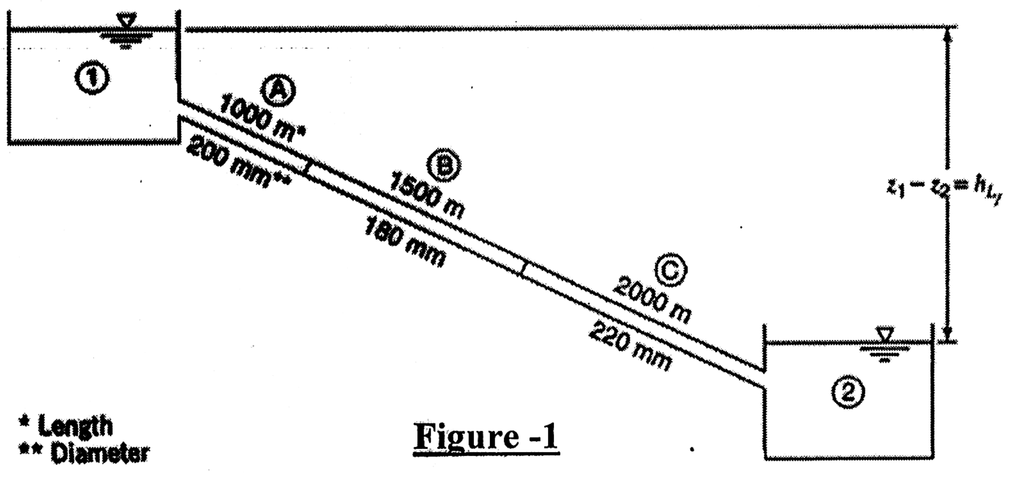



**Figure -1**

(b) The pipe system shown in **Figure 2** connects two reservoirs that have an elevation difference of 20 m. This pipe system consists of 250 m of 400 mm concrete pipe (pipe A), that branches into 350 m of 150 mm pipe (pipe B) and 450 m of 250 mm pipe (pipe C) in parallel. Pipes B and C join into a single 350 mm pipe that is 550 m long (pipe D). For f = 0.032 in all the pipes, what is the flow rate in each pipe of the system?

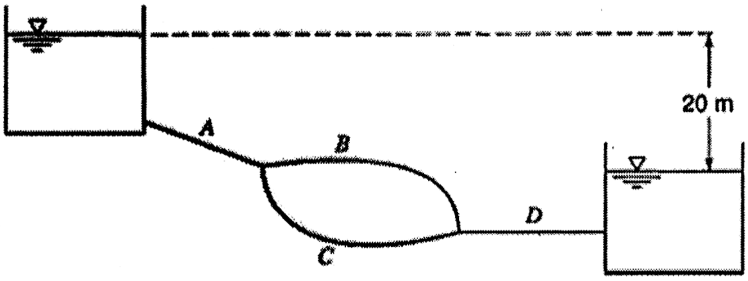



Figure 2

**10+15=25**

4. (a) Water at 15⁰C is pumped from reservoir A (EL 6 m) to reservoir B (EL- 15 m. A 300 mm diameter suction pipe (from reservoir A to pump) is 31 m long and the discharge pipe (from pump to reservoir B) is 250 mm in diameter and 450 m long. Assume that the friction factor for each pipe is 0.015. The suction pipe has an entrance loss coefficient of Ki =1.0 and a check valve loss coefficient of KV= 2.5. The discharge pipe has two gate valves KgV = 0.2 fully open. The pump has the head-discharge curve and efficiency curves. The pump is operated at 1600 rpm.

| Q ($m^3/s$) | $h_P$ (m) | Efficiency (%) |
|---|---|---|
| 0 | 37 | 0 |
| 0.03 | 38 | 27 |
| 0.06 | 37 | 50 |
| 0.09 | 35 | 70 |
| 0.114 | 32 | 81 |
| 0.143 | 28 | 80 |
| 0.171 | 22 | 70 |
| 0.200 | 15 | 50 |

(i) What is the flow rate?

(ii) Find the power required to drive the pump.

(b) A pump is to be selected that will pump water from a well into a storage reservoir. In order to fill the reservoir in a timely manner, the pump is required to deliver 7.5 L/s when the water level in the reservoir is 5 m above the water level in the well. Find the head that must be added by the pump. The pipeline system is shown in **Figure 3**. Assume that the local loss coefficient for each of the bends is equal to 0.35 and that the temperature of water is 22°C.

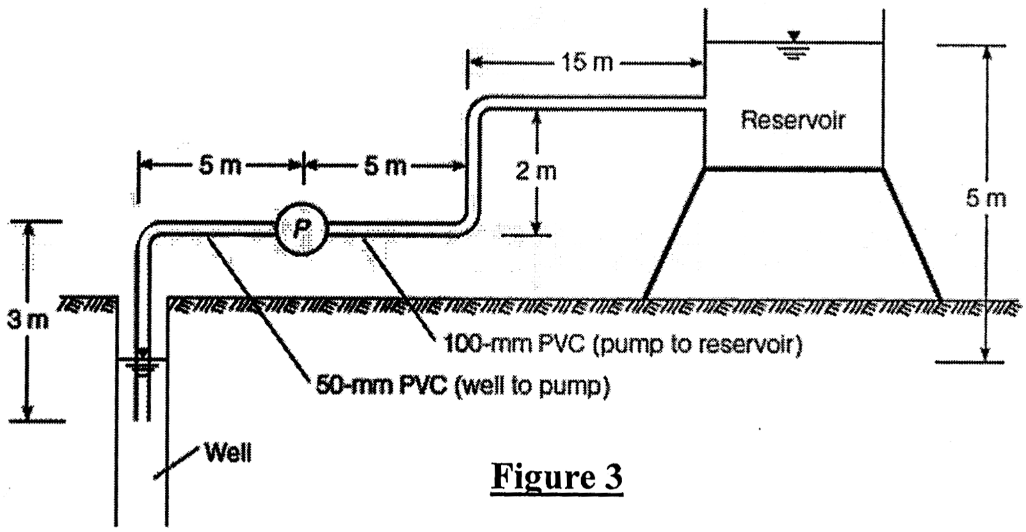



**Figure 3**

**18+7=25**

5. (a) Define waterhammer.

(b) Derive the following expression of the velocity of propagation of the pressure wave ($C$) for the water hammer in the case of an elastic pipe.

$$C = \sqrt{\frac{K}{\rho} \Big/ \left(1 + \frac{K}{E}\frac{d}{t}\right)}$$

where, $K$ is the bulk modulus of elasticity, $\rho$ is the density of water, $E$ is Young's modulus of elasticity, $d$ is the pipe internal diameter and $t$ is the pipe wall thickness. Assume that the pipe is subjected to circumferential stress but negligible longitudinal stress.

Then derive a relationship between maximum water hammer head ($h_m$) and static head ($h_{static}$).

(c) A cast iron pipe with a 20 cm diameter and 15 mm wall thickness is carrying water when the outlet is suddenly closed. Use bulk modulus of elasticity of water = $2.17\times10^9$ N/m$^2$ and Young's modulus of elasticity for the pipe material is $16\times10^{11}$ N/m$^2$. If the design discharge is 40 L/s, calculate the water hammer pressure rise for (i) rigid pipe walls, (ii) consider stretching of pipe walls, neglecting the longitudinal stress and (iii) pipeline that is anchored at the upstream end only.

**2+(12+2)+9=25**

6. (a) Briefly describe the design procedure of well field design.
   (b) An urban field to be developed in an unconfined sand aquifer with a transmissivity 1495 m2/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**

7. (a) Briefly describe the working function of infiltration gallery with diagram.
   (b) A radial water collector is to be designed for extraction of 22700 m3/day from the subsurface water stored in riverbed which has an aquifer extending up to 12 m below the bed with width limited to actual riverbed itself, which is 600 m wide. A long duration pump test indicates a transmissibility of 2500 m2/day 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 tom 60 cm.

**5+20=25**

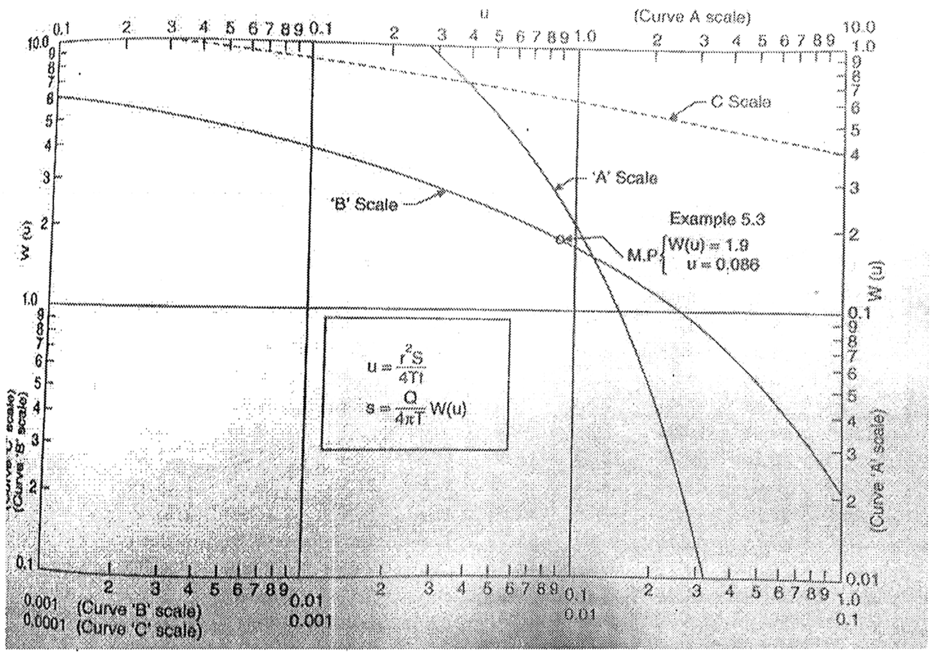


**Table 5.1 Values of $W(u)$ for values of $u$ (abridged, after Wenzel, 1942)**

| $u$ | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 | 9.0 |
|---|---|---|---|---|---|---|---|---|---|
| × 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 $u = 3.0 \times 10^{-4}$, $W(u) = 7.53$

8. (a) The performance curve for a variable -speed pump operating at 600 rpm is given by

$$h_p = 6 - 0.05\, Q^2$$

where $h_p$ 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 considerations require a system curve given by

$$h_p = 3 + 0.042\, Q^2$$

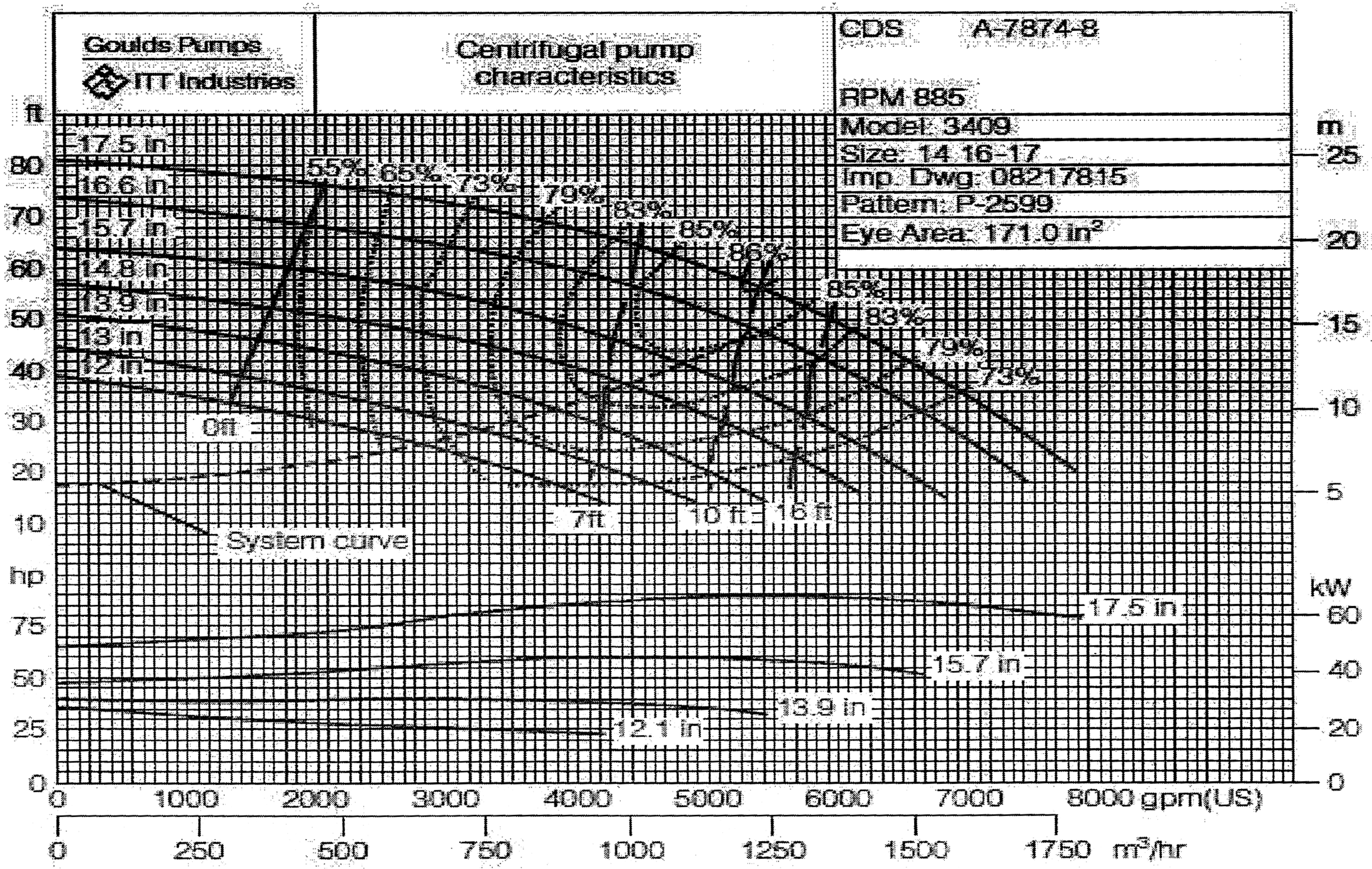
Find the flow rate in the system when pump is operating at 600 rpm and compare this with theflow rate when pump is operating at 1200 rpm.

(b) Define $(NPSH)_{available}$ and $NPSH)_{required}$. Represent them in head vs. Pump capacity curve. Label the critical point.

**20+5=25**

9. Water at 20°C is being pumped from a lower to an upper reservoir through a 200mm pipe in the system shown in Figure 2.20. The water-surface elevations in the source and destination reservoirs differ by 5.2 m, and the length of the steel pipe (ks = 0.046 mm) 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. The performance curves of the 885rpm homologous series of pumps being considered for this system are given in Figure 2.19. If the desired flow rate in the system is 315 L/s (= 5000 gpm), what size and specific-speed pump should be selected? Assess the adequacy of the pump location based on a consideration of the available net positive suction head. The pipe intake loss coefficient can be taken as 0.1.

**25**


Goulds Pumps
ITT Industries
Centrifugal pump characteristics
CDS A-7874-8
RPM 885
Model: 3409
Size: 14 16-17
Imp. Dwg: 08217815
Pattern: P-2599
Eye Area: 171.0 in²
ft
m
17.5 in
16.6 in
15.7 in
14.8 in
13.9 in
13 in
12 in
55% 65% 73% 79% 83% 85% 86% 85% 83% 79% 73%
0ft
7ft
10 ft
16 ft
System curve
hp
kW
17.5 in
15.7 in
13.9 in
12.1 in
0 1000 2000 3000 4000 5000 6000 7000 8000 gpm(US)
0 250 500 750 1000 1250 1500 1750 m³/hr