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) Define waterhammer.

   (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 waterhammer head and static head.

   (c) What is flowing at 3 m/s in a pressure penstock 4500 m long? If the celerity of the pressure wave travelling in the pipe due to the sudden complete closure of a valve at the downstream end is given as 1400 m/s, what is the maximum pressure rise? What is the period of oscillation? Show how the pressure changes with time at the middle point of the penstock length. Ignore all frictional losses.

   2+14+9 = 25

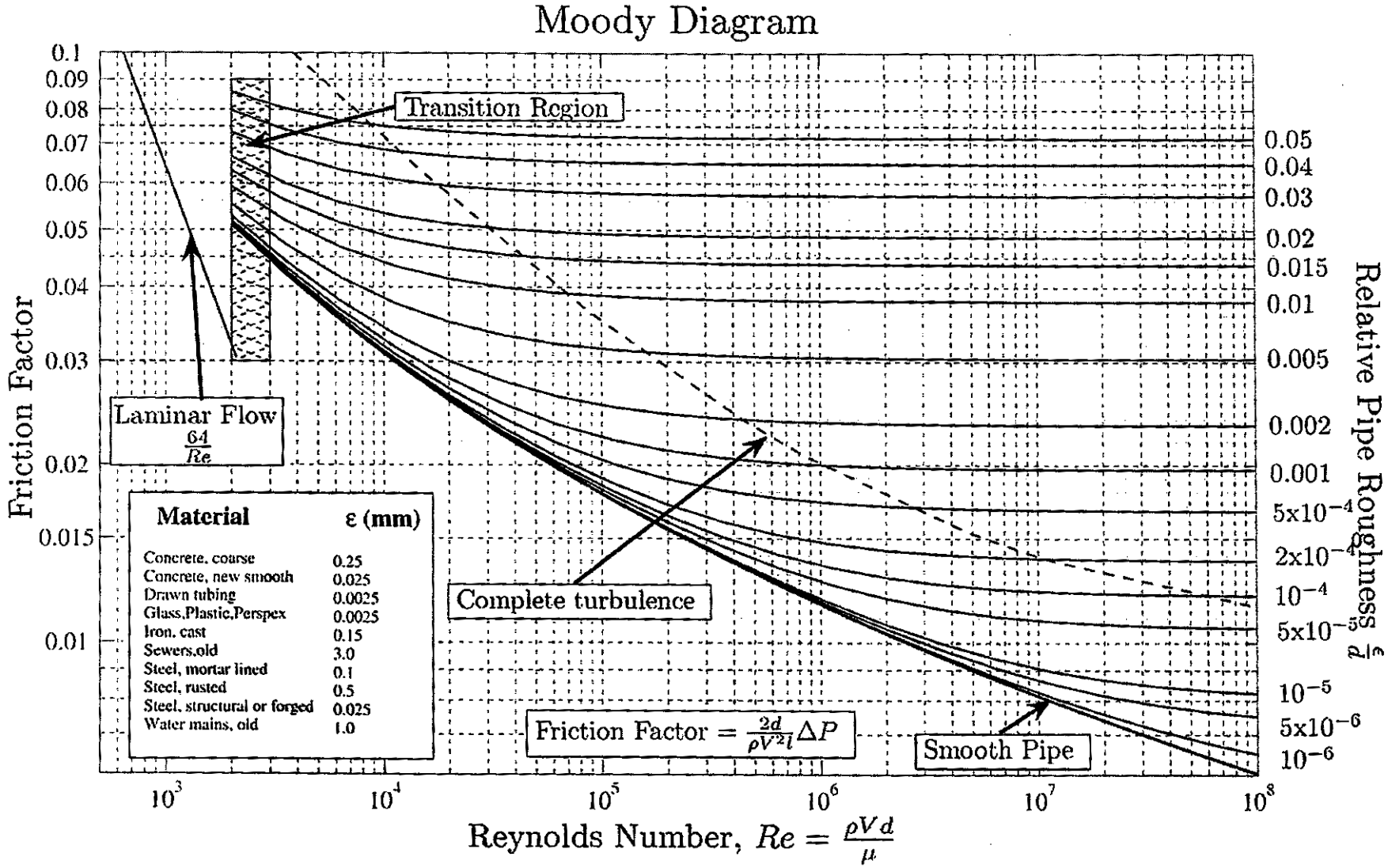
2. (a) Why are surge tanks used and where?

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

   (c) Differentiate between the simple surge tank, orifice tank, and differential surge tank.

   (d) A 500 mm diameter steel pipe 1500 m long placed on a uniform slope and with 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's 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.

   4+4+6+11 = 25


Moody Diagram
Friction Factor
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.015
0.01
Transition Region
Laminar Flow
$\frac{64}{Re}$
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
Complete turbulence
Friction Factor = $\frac{2d}{\rho V^2 l}\Delta P$
Smooth Pipe
0.05
0.04
0.03
0.02
0.015
0.01
0.005
0.002
0.001
5×10^{-4}
2×10^{-4}
10^{-4}
5×10^{-5}
10^{-5}
5×10^{-6}
10^{-6}
Relative Pipe Roughness $\frac{\epsilon}{d}$
10^3
10^4
10^5
10^6
10^7
10^8
Reynolds Number, $Re = \frac{\rho V d}{\mu}$

3. (a) What are the adverse impact of hard water in domestic and industrial use?

(b) How lime-soda ash process can soften hard water? Explain also why re-carbonation is necessary during softening of water?

(c) Hard water is to be softened by lime-soda ash process. Magnesium removal is not deemed necessary. The ionic concentrations of the water sample are furnished below

CO_2	25 mg/L	Ca^{2+}	80 mg/L	Na^{+}	46 mg/L
Mg^{+2}	14 mg/L	HCO_3^{-}	152.5 mg/L	SO_4^{-2}	216 mg/L

(i) Calculate chemical requirements and solids produced in meqv/lt.

(ii) Draw bar diagram for raw water and finished water

(iii) For treatment of 30000 m^3/d water, calculate the daily chemical requirement and the mass of solids produced. Assume that the lime used is 98% pure and the soda ash is 85% pure (Assume acceptable conc. of Hardness as 75 mg/L).

5+7+13=25

4. (a) Design a trapezoidal drainage channel to accommodate a peak flow rate of 0.52 m^3/s on a slope of 0.6%. Local regulations require that the side slope of the channel be no greater than 2.5:1 (H : V). A filed investigation has indicated that the native soil is non-cohesive and has a 50-perentile grain size of 3.5 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 = 36^0

(b) Design the most efficient (straight) lined trapezoidal channel to carry 35 m^3/s on a longitudinal slope of 0.002. The lining of the channel is to be float-finished concrete. Assume n= 0.013. Also estimate the minimum required freeboard.

15+10=25

5. A 5 MLD water treatment plant will be constructed to treat river water and to supply a township.

(a) Design the mechanical rapid mixing unit using the following data

Detention time =30 second

Ratio of tank height to diameter=1.5:1

Ratio of impeller diameter to tank diameter =0.4:1

Rotational speed of impeller = 120 rpm

Velocity gradient = 600 second

Assume any data if required

(b) Calculate filter dimension depth of sand, gravel size gradation and depth, and details of under drainage system of rapid sand filter using the following data:

Quantity of back wash water need = 3% of filter output

Time lost during back washing = 30 minutes

Design rate of filtration =5000 lt/hr-m^2

Length to width ratio = 1.25 -1.33:1

Under drainage system= Central manifold with laterals

Size of perforation = 9 mm

[Assume appropriate design data when required]

12+13=25

6. (a) What are the adverse impact of arsenic on human health?
Briefly discuss problem related to arsenic contamination of groundwater in India.
(b) Suggest action plan to mitigate arsenic contamination problem.

(c) Design a hand pump attached arsenic removal unit. Arsenic concentration in groundwater is 0.35 mg/L. The treated water must conform to desirable limit of IS 10500-2012. The arsenic-safe water will be used for drinking and cooking. The ARU will serve 1000 population.

5+5+5+10=25

7. 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 L/min 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 Figurer 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?

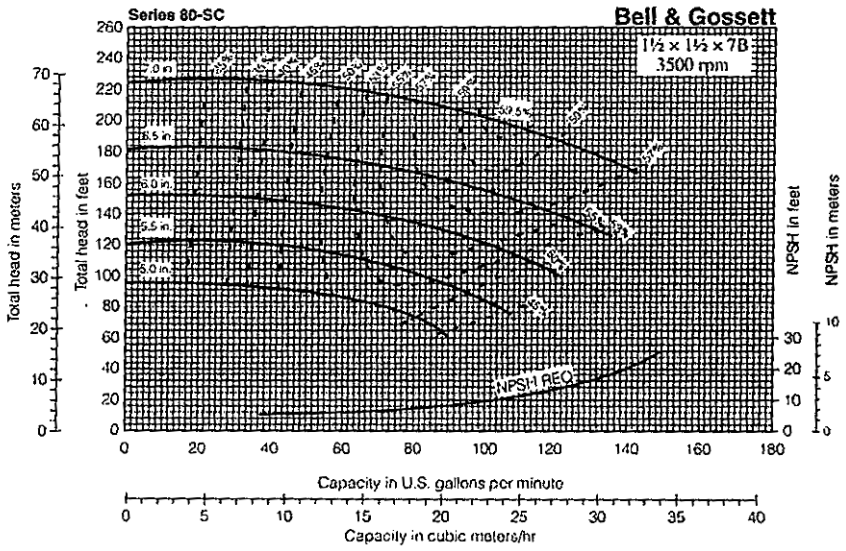


Figure : Pump performance curves

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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 1495 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 well field is operational, develop a proposed layout for the wells. There are no nearby surface-water bodies.

5+20=25