

TUTORIAL-1

Problems on Flow through Pipes:

1. A closed tank containing water is partly filled with water and air space above it is under pressure of 73.18 Kpa. A 5 cm hose connected to the tank discharges 15 l/s of water to atmosphere on to the roof of a building 3 m above the level of water in the tank (Fig.1.1). Find the amount of head loss in the pipe. (Ans $h_L = 1.5$ m)
2. A reservoir has been built 4 km away from college campus having 5000 inhabitants. Water is to be supplied from reservoir to the campus. It is estimated that each inhabitant will consume 200 litres of water per day, and half of the daily supply is pumped in 10 hours. Calculate the size of the main pipe, if the head loss due to friction in the pipe is 20 m. Assume $f=0.032$. (Ans: $D=0.145$ m)
3. Water flows (at 20°C, $\nu = 1.02 \times 10^{-6}$ m²/s) through a new cast iron pipe at a velocity of 4.2 m/s. The pipe is 400 m long and has a diameter 150 mm. Determine the head loss due to friction. (Ans. $h_f = 54.75$ m).
4. Compute the friction factor for flow having Reynolds number 4×10^6 and relative roughness 0.0001 (rough pipe zone). Use Colebrook equation, Jain's equation and Moody diagram.
5. Two reservoirs containing water at 60°F. The water in the upper reservoir is to be drained to other reservoir at a lower level as shown in Fig.1.2. The total length of the commercial pipe is 30.5 m and diameter is 0.10 m. What will be the flow rate, when water surface elevations of two tanks have to be maintained at levels as shown in Fig.1.2. (Neglect minor loss, use $\nu = 1.21 \times 10^{-5}$ m²/s at 60° F). (Ans. $Q = 0.0373$ m³/s)
6. Find the value of Hazen-William coefficient for the case of where water flows at rate 0.18 m³/s in a 60 cm diameter pipe with head loss of 0.0012 m per m length. If the value of C for the pipe is 100 what will be flow rate using the H-W formula and the nomograph ? (Ans. $C=93.7$, $Q = 0.192$ m³/s)

TUTORIAL-2

Problems on flow through pipes

1. Water flows from an overhead tank shown in Fig.2.1. The pipe line fitted with a nozzle at the end which discharges a jet 6.5 cm diameter. Find the loss coefficient of the nozzle if the flow rate $0.1 \text{ m}^3/\text{s}$ is to be maintained.
2. Determine the discharge through the pipe system connected the two reservoirs shown in Fig.2.2 (Ans. $Q = 4.31 \text{ lit./s}$)
3. A 300 mm diameter cast iron pipe is 30 m long and its connected in series to 250 mm diameter cast iron pipe of 90 m length. If the pipe carries a water discharge of $0.14 \text{ m}^3/\text{s}$ at 20°C , find the equivalent length of pipe in terms of 250 mm diameter pipe. Neglect contraction loss. (Ans : $L^e = 102.37 \text{ m}$)
4. A pipeline system consists of 50 m of 300 mm diameter pipe of $f = 0.025$, 90 bend with K (loss coeff.)= 0.5, 300 mm valve $K = 1.0$, sudden expansion to 400 mm diameter pipe of $f = 0.02$ and 400 mm valve with $K = 1.5$. Convert this pipe system to an equivalent 300 mm diameter pipe of $f = 0.02$ if the velocity in 300 mm pipe is 3.0 m/s . (Ans. $L_e = 89.36 \text{ m}$)
5. A pipe line system shown in Fig.2.3, if the head difference between A and B is 18 m, determine the discharge through each pipe, given that $v = 1 \times 10^{-6} \text{ m}^2/\text{s}$. (Ans. $Q_1 = 0.6 \text{ m}^3/\text{s}$, $Q_2 = 0.165 \text{ m}^3/\text{s}$, $Q_3 = 0.435 \text{ m}^3/\text{s}$, $Q_4 = 0.60 \text{ m}^3/\text{s}$). Use Darcy-Weisbach relation.
6. The difference in water levels between two reservoirs is 180 m and the distance between them is 64 kms. The reservoirs are originally connected by a single pipe designed to carry $27 \times 10^6 \text{ lit/day}$. It was later found necessary to increase the flow by another $9 \times 10^6 \text{ lit/day}$, and it was decided to lay another pipe of same diameter alongside the first pipe over part of the length. Calculate the diameter of the pipes and the length of the second pipe which it was necessary to lay. $f = 0.032$ for each pipe. (Ans. $D = 0.62 \text{ m}$, $L = 37.37 \text{ m}$)
7. Reservoir A delivers to reservoir B through two uniform pipelines AJ:JB of diameters 300 mm and 200mm respectively. Just upstream of the change in section a controlled discharge of 30 l/s is taken off. Length of AJ=3000m; Length of JB=4000m, the effective roughness size (f) of both pipes is 0.015, and gross head is 25 m. Determine the discharge to reservoir B. Neglect the loss at J.(Ans: 32.5 l/s)

TUTORIAL-2

Problems on Flow through pipes

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2. Determine the discharge through the pipe system connected the two reservoirs shown in Fig.2.2 (Ans. $Q = 4.31 \text{ lit./s}$)
3. Two pipes in series having dimensions 900 m long, 45 cm diameter and 450 m long, 37.5 cm diameter. Find the equivalent diameter, if these two pipes are replaced by an one pipe. Total length should remain same and use $C=100$ for all pipes.
4. A looping pipe system shown in Fig.2.3. The total flow rate in AC = flow rate in ABC. Find the length of pipe AC.(Ans. $L_{A-C} = 932 \text{ m}$).
5. Calculate the flow rate through the system and the head H required, if the velocity of pipe 1 (Fig. 2.5) is 1 m/s . use $C = 100$ for all pipe and use Hazen William formula.($Q_1=0.0314, \text{ m}^3/\text{s}$, $Q_2 = 0.0911$, $Q_3 = 0.122$, $Q_4 = 0.0657$ and $Q_5 = 0.0562 \text{ m}^3/\text{s}$ and $H = 5.922 \text{ m}$)
6. The difference in water levels between two reservoirs is 180 m and the distance between them is 64 kms. The reservoirs are originally connected by a single pipe designed to carry $27 \times 10^6 \text{ lit/day}$. It was later found necessary to increase the flow by another $9 \times 10^6 \text{ lit/day}$, and it was decided to lay another pipe of same diameter alongside the first pipe over part of the length. Calculate the diameter of the pipes and the length of the second pipe which it was necessary to lay. $f=0.032$ for each pipe. (Ans. $D=0.62 \text{ m}$, $L=37.37\text{m}$)
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TUTORIAL-3

Problems on Transient Flow through Pipes:

1. Calculate the speed of propagation of pressure wave in a steel pipeline 200 mm in diameter with a wall thickness of 15 mm in the following cases:

i) assuming the pipe is rigid. (Ans. $c=1450$ m/s, $\Delta H_m = 221.7$ m)

ii) assuming the pipe to be anchored at the reservoir with no expansion joints and free to move longitudinally. (Ans. $c=1373.42$ m/s, $\Delta H_m = 210$ m)

iii) assuming the pipe to be provided with expansion joints. (Ans. $c = 1362.25$ m/s, $\Delta H_m = 208.14$ m)

Also, in each case determine the pressure head rise due to sudden valve closure when the initial velocity of flow is 1.5 m/s. (Assume $\nu = 0.3$ and $K=2.1$ Gpa, $E= 210$ Gpa)

2. A valve is suddenly closed at the downstream end of 90 cm diameter pipeline carrying water in such a manner that the velocity decreased from 4 m/s to 1 m/s instantaneously. Estimate the maximum pressure rise at the valve. Assume K for water is 2.2×10^3 Mpa and the pipe is rigid. (Ans $P_{max} = 4.445$ Mpa)

3. A steel pipeline 1600 m long discharges 150 lit./s of water from a reservoir to the atmosphere through a valve at the downstream end. The pipeline is 250 mm in diameter with a wall thickness of 10 mm. The valve is fully closed in 30 seconds. Determine the maximum transient pressure at the valve and 500 m upstream end only. $K=2.1$ Gpa, $E=210$ Gpa and $\nu = 0.3$ (Ans. $\Delta H_m = 15.62$ m, 11.427 m)

4. The velocity of water in a 60 cm diameter, 15 mm thick and 800 m long cast iron pipe ($E=1.04 \times 10^{11}$ N/m²) is changed from 3 m/s to zero in 1.25 sec by closure of a valve. Find the corresponding pressure rise if the closure takes place in i) 3 sec and ii) 0.8 sec respectively. K (water) $= 2.11 \times 10^9$ N/m². (Ans: $P=3.235$ Mpa, i) 1.596 Mpa, ii) 3.235 Mpa)

5. A valve at the downstream end of a 3500 m long pipeline is closed in 4 sec. The pipe carries water flowing at a velocity of 0.8 m/s. Calculate i) the peak water hammer pressure produced by this closure ii) The length of pipe subjected to the above peak pressure. Assume pipe is rigid. (Ans: 1.185 Mpa, $L=530.6$)

TUTORIAL-4

Problems on Pumps:

1. Two homologous pumps A and B are to run at the same speed of 600 rpm. Pump A has an impeller diameter 50 cm and discharges $0.4 \text{ m}^3/\text{s}$ of water under a net head of 50 m. Determine the size of pump B and its net head if it is to discharge $0.3 \text{ m}^3/\text{s}$. (Ans: $D_B = 0.454 \text{ m}$, $H_B = 41.278 \text{ m}$)

2. A centrifugal pump discharges 300 gpm against a head of 55 ft when the speed is 1500 rpm. If the diameter is 12.5 inch and the brake horse power(BHP) is 6.0, what is the efficiency of the pump ? What should be the speed of a geometrically similar pump of 15 inch diameter running at a capacity of 400 gpm ?(Ans: 69.47%, $N = 1158$)

3. Performance characteristics data for a pump having impeller diameter of 14.75 inch are given below. The pump has been tested at speed 1800 rpm.

Discharge, Q (gpm)	3000	2000	1000
Head, H (ft)	200	22	229
Power, hp	175	143	107
Efficiency $\eta\%$	87	79	54

- i) Obtain the performance characteristics data if the same pump is operated at speed of 1400 rpm.
- ii) Obtain the performance characteristics data if the impeller diameter is changed to 14.0 inch
- iii) Obtain the performance characteristics data if both speed and diameter are changed to 1400 rpm and 14.0 in respectively.

3. Water is pumped from a sump tank through pipe system shown in Fig.4.1
 A centrifugal pump having performance characteristics given below. What are the operating conditions for this pump if $f = 0.02$?

Q (l/s)	0	10	20	30	40	50	
H (m)		25	23	21	17	12	
η (%)		-	45	65	71	65	45

4. A pump is to deliver water from a tank against a static head of 40 m. The suction pipe is 50 m long of 25 cm diameter of 0.02 and the delivery pipe is of 20 cm diameter, 1600 m long has an $f = 0.022$. The pump characteristics can be defined as $H_p = 100 - 6000 \cdot Q^2$, where H in m and Q in m^3/s . Calculate the operating head and discharge of the pump. (Ans: $H = 76.21 \text{ m}$, $Q = 0.0628 \text{ m}^3/\text{s}$)

5. Performance characteristics of a pump are as follows:

Q (gpm)	0	500	800	1000	1300	1600
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H (ft)	124	117	112	104	90	70			
η (%)		-		54		64	68	70	67

Two pumps of above characteristics are to be used to supply water between two tanks with static lift 40 ft. The pipe line is 6 inch diameter and 1200 ft long, with minor loss 20 times the velocity head. Determine the

- operating conditions and input powers, when a) pumps are connected in series
- pumps are connected in parallel

6. The suction side of a pipe system is shown in Fig.4.2. The pump discharges 495 gpm of water under a total head of 100 ft at 40° F. Atmospheric pressure is 32.7 ft of water. Determine the available NPSH and cavitation parameter. If the required NPSH is 9, will there be a cavitation problem? (Ans: NPSH=21 ft, No)

7. A pump can deliver a discharge of 0.1 m³/s to a head of 30 m. The critical cavitation number for the pump is found to be 0.12. The pump is to be installed at a location where the barometric pressure is 96 Kpa (abs) and the vapour pressure is 3 Kpa (abs). Assuming an intake pipe friction of 0.3 m, determine the minimum value of NPSH. What would be the maximum allowable elevation above the sump water surface at which the pump can be located ? (Ans: NPSH_{min.}=3.6 m, Z_{max}=5.6 m)

TUTORIAL -5

Problems on Open Channel Flow

1. A concrete-lined trapezoidal channel has a bed width of 3.5 m, side slopes at 45° to the horizontal, a bed slope 1 in 1000 and Manning roughness coefficient of 0.015. Calculate the depth of uniform flow when the discharge is $20 \text{ m}^3/\text{s}$. (**Ans. $y_n=1.73 \text{ m}$**).
2. A sewer pipe is proposed to be laid on a slope of 1 in 2500 and is required to carry $1.5 \text{ m}^3/\text{s}$. What size of a circular pipe should be used if the pipe has to flow half full ($n=0.015$)?. (**Ans. $D=2.1 \text{ m}$**).
3. A 3 m wide rectangular channel carries $2.4 \text{ m}^3/\text{s}$ discharge at a depth 0.7 m. Determine the i) specific energy at 0.7 m ii) the critical depth iii) the alternate depth to 0.7 m and iv) the critical slope if $n=0.015$. (Ans: $H=0.766 \text{ m}$, $y_c=0.403 \text{ m}$, $y_2=0.252 \text{ m}$, $S_c = 0.00538$)
4. A triangular concrete channel ($n= 0.012$) with side slope 2 (horizontal) : 1 (vertical) is to carry water 10 l/s at a slope of 0.0015. Find i) normal depth, ii) critical depth, iii) critical slope iv) whether the flow is supercritical or subcritical.
5. A rectangular channel ($n=0.012$) is laid on slope of 0.0036 and carries $580 \text{ ft}^3/\text{s}$ flow. What width is required to maintain critical flow. (Ans: $b= 8.33 \text{ ft}$)
6. A trapezoidal channel with side slope of 0.5 H:1V is to be designed as the most efficient channel to carry $30 \text{ m}^3/\text{s}$ discharge at a slope of 0.000556. Using Chezy's $C =60$, determine the bottom width and the depth of flow. (Ans: $b= 3.84\text{m}$, $y= 3.125 \text{ m}$)
7. A 3.5 m wide rectangular channel carries a discharge of $10 \text{ m}^3/\text{s}$ at a depth of 1.75 m. If the width of channel is required to 2.25 m and the bed level is lowered by 0.97 m, determine the difference in water level elevations between the upstream and contracted sections. Assume energy loss. (Ans: $\Delta Z= 2.72 \text{ m}$)

TUTORIAL -6

Problems on Open Channel flow, Dimensional Analysis and Similitudes theory:

1. Analyse the water surface profile in a long rectangular channel ($n=0.013$). The channel is 10 ft wide, the flow rate is $150 \text{ ft}^3/\text{s}$, and there is an abrupt change in slope from 0.0016 to 0.0150. Make a sketch showing normal depth, critical depths, and water-surface profile types. If slope changes from 0.0016 to 0.0006, compute the distance upstream from the break to the point where normal depth occurs, using one reach. (Ans: $y_c=1.92 \text{ ft}$, $y_{n1}=2.38 \text{ ft}$, $y_{n2}=1.13 \text{ ft}$, $y_{n2}=3.36 \text{ ft}$, $\Delta x=1139.0 \text{ ft}$)
2. A discharge of $160 \text{ ft}^3/\text{s}$ occurs in rectangular open channel 6 ft width with $S=0.002$ and $n=0.012$. If the channel ends in a free outfall, calculate the depth at the brink, y_n and y_c . Determine the shape of the water surface profile for a distance of 100 ft upstream from the brink. (Ans: $y_n=3.5 \text{ ft}$, $y_c=2.81 \text{ ft}$, $y_b=2.0 \text{ ft}$)
3. A hydraulic jump occurring in rectangular channel, the discharge per unit width is $2.5 \text{ m}^3/\text{s}/\text{m}$ and the depth before the jump is 0.25 m. Estimate the sequent depth and energy loss due to jump. (Ans: $y_2=2.136 \text{ m}$ and $E_{\text{loss}}=3.14 \text{ m}$)
4. The discharge over a geometrically similar model (scale=1:100) is 1.5 lit./sec, What should be the corresponding discharge in the prototype? (Ans: $150 \text{ m}^3/\text{s}$)
5. A model of an open channel is built to a scale of 1/100. If the model Manning's $n=0.013$, to what value of prototype roughness coefficient would be corresponds? (Ans: $n_p=0.028$)
6. Oil of density $917 \text{ kg}/\text{m}^3$ and dynamic viscosity $0.29 \text{ Pa}\cdot\text{s}$ flows in a 15 cm dia pipe at a velocity of 2 m/s. What would be the velocity of flow of water in 1 cm diameter pipe, to make two flows dynamically similar? The density and viscosity of water is taken as $998 \text{ kg}/\text{m}^3$ and $1.31 \times 10^{-3} \text{ Pa}\cdot\text{s}$ respectively. (Ans: $0.1246 \text{ m}/\text{s}$)
7. If the capillary rise (h) depends upon the specific weight γ , surface tension σ of the fluid and tube radius (r), using Raleigh's method show that

$$h = r\phi \left[\frac{\sigma}{\gamma r^2} \right]$$

8. Show that the discharge per unit length (q) over a rectangular weir can be expressed as following non-dimensional arrangement

$$q = g^{1/2} H^{3/2} \phi \left[\frac{\rho g^{1/2} H^{3/2}}{\mu}, \frac{\rho g^{1/2} H^2}{\sigma}, \frac{P}{H} \right]$$

where ρ is the fluid density, μ is the dynamic viscosity, σ is the surface tension, H is the head over the crest of weir, P is the weir height. Use Buckingham Pi-theorem.