

**4<sup>TH</sup> SEMESTER**  
**CIVIL ENGINEERING**  
**HYDRAULICS**  
**&**  
**IRRIGATION**  
**ENGINEERING**  
**(TH-1)**

## UNIT - 1 (Pressure measurement and Hydrostatic pressure)

### 2 Marks Questions:

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#### Q1. Define a fluid. Give two examples.

**Sol:** A fluid is a substance which cannot resist shear stress and deforms continuously under even a small shear force. Examples: Water and Air.

#### Q2. Define Fluid Mechanics and Hydraulics.

**Sol:** Fluid Mechanics is the study of fluids at rest and in motion. Hydraulics deals with engineering applications of liquids, mainly water.

#### Q3. Define density, specific weight and specific gravity with units.

**Sol:** Density ( $\rho$ ) =  $\frac{m}{V}$  Unit: kg/m<sup>3</sup>

Specific weight ( $\gamma$ ) =  $\rho g$  Unit: N/m<sup>3</sup>

Specific gravity (SG) =  $\frac{\rho}{\rho_w}$  Unit: dimensionless

#### Q4. State Newton's law of viscosity.

**Sol:** Shear stress is directly proportional to the velocity gradient.

$$\tau = \mu (du/dy)$$

#### Q5. Define surface tension and capillarity.

**Sol:** Surface tension is the tensile force acting on the free surface of liquid per unit length. Capillarity is the rise or fall of liquid in a small tube due to surface tension.

#### Q6. Differentiate between ideal fluid and real fluid.

**Sol:** Ideal fluid: No viscosity and imaginary.

Real fluid: Has viscosity and exists in nature.

#### Q7. Define atmospheric, gauge and absolute pressure.

**Sol:** Atmospheric pressure: Pressure exerted by atmosphere.

Gauge pressure: Pressure above atmospheric pressure.

Absolute pressure:  $P_{abs} = P_{gauge} + P_{atm}$ .

#### Q8. State Pascal's law with two applications.

**Sol:** Pressure applied to a confined fluid is transmitted equally in all directions.  
Applications: Hydraulic press and hydraulic jack.

**Q9. What is pressure head? Write its formula and unit.**

**Sol:** Pressure head is the height of liquid column equivalent to a given pressure.

$$h = \frac{p}{\rho g}$$

Unit: metre (m).

**Q10. Define center of pressure. Why is it below centroid?**

**Sol:** Centre of pressure is the point at which the total hydrostatic force acts on an immersed surface. It lies below the centroid because pressure increases with depth.

**5 Marks Questions:**

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**Q1. A liquid has a mass of 850 kg occupying a volume of 1 m<sup>3</sup>. Find:**

**(a) Density ( $\rho$ )**

**(b) Specific weight ( $\gamma$ )**

**(c) Specific gravity (SG)**

**Sol:** Density,  $\rho = \frac{m}{V} = \frac{850}{1} = 850 \text{ kg/m}^3$

Specific weight,  $\gamma = \rho g = 850 \times 9.81 = 8338.5 \text{ N/m}^3 = 8.34 \text{ kN/m}^3$

Specific gravity,  $S = \frac{\rho}{\rho_w} = \frac{850}{1000} = 0.85$

**Q2. Two parallel plates are 12 mm apart. The space is filled with oil of viscosity  $\mu = 0.9 \text{ N}\cdot\text{s/m}^2$ . If the top plate moves with velocity 2 m/s, find shear stress and force required on an area of 0.5 m<sup>2</sup>.**

**Sol:** Velocity gradient,  $\frac{du}{dy} = \frac{2}{0.012} = 166.67 \text{ s}^{-1}$

Shear stress,  $\tau = \mu (du/dy) = 0.9 \times 166.67 = 150 \text{ N/m}^2$

Force,  $F = \tau A = 150 \times 0.5 = 75 \text{ N}$

**Q3. Water is subjected to a gauge pressure of 120 kPa. Find:**

**(a) Absolute pressure**

**(b) Pressure head**

**Given: Atmospheric pressure = 101.3 kPa**

**Sol:** Absolute pressure = Gauge pressure + Atmospheric pressure  
 $= 120 + 101.3 = 221.3 \text{ kPa}$

$$\begin{aligned} \text{Pressure head, } h &= \frac{P}{\rho g} \\ &= \frac{12000}{(1000 \times 9.81)} \\ &= 12.23 \text{ m of water} \end{aligned}$$

**Q4. A vertical rectangular tank wall is 2 m wide and 3 m deep, filled with water.**

**Find total hydrostatic force on the wall and center of pressure.**

**Sol:** Area,  $A = b h = 2 \times 3 = 6 \text{ m}^2$   
 Depth of centroid,  $\bar{y} = h/2 = 1.5 \text{ m}$

$$\begin{aligned} \text{Total pressure, } P &= \rho g A \bar{y} \\ &= 1000 \times 9.81 \times 6 \times 1.5 \\ &= 88,290 \text{ N} = 88.29 \text{ kN} \end{aligned}$$

$$\begin{aligned} \text{Moment of inertia, } I &= \frac{bh^3}{12} \\ &= \frac{(2 \times 3^3)}{12} = 4.5 \text{ m}^4 \end{aligned}$$

Center of pressure depth,

$$\begin{aligned} y_{cp} &= \bar{y} + \frac{I}{A\bar{y}} \\ &= 1.5 + \frac{4.5}{6 \times 1.5} \\ &= 2.0 \text{ m} \end{aligned}$$

**Q5. A U-tube manometer contains mercury ( $S_g = 13.6$ ). The difference in mercury level is 0.25 m. Find pressure difference between the two points.**

**Sol:** Density of mercury =  $13.6 \times 1000 = 13600 \text{ kg/m}^3$   
 Pressure difference,  
 $\Delta P = \rho g h$   
 $= 13600 \times 9.81 \times 0.25$   
 $= 33,354 \text{ N/m}^2$   
 $= 33.35 \text{ kPa}$

**10 Marks Questions:**

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- Q1. (a)** A vertical rectangular tank wall is 2.5 m wide and contains water up to a depth of 3 m. Determine the total hydrostatic force on the wall and the position of centre of pressure. Take  $\rho = 1000 \text{ kg/m}^3$  and  $g = 9.81 \text{ m/s}^2$ .  
**(b)** State Pascal's law of fluid pressure. Derive the relation for hydraulic press and list its applications.

**Sol:**

$$\text{Area, } A = b h = 2.5 \times 3 = 7.5 \text{ m}^2$$

$$\text{Depth of centroid, } \bar{y} = h/2 = 1.5 \text{ m}$$

$$\text{Total force, } P = \rho g A \bar{y} = 1000 \times 9.81 \times 7.5 \times 1.5 = 110.36 \text{ kN}$$

$$\text{Moment of inertia, } I = \frac{bh^3}{12} = 5.625 \text{ m}^4$$

$$\text{Centre of pressure, } y_{cp} = \bar{y} + \frac{I}{A\bar{y}} = 2.0 \text{ m}$$

Pascal's law: Pressure applied to a confined fluid is transmitted equally in all directions.

$$\text{Hydraulic press relation: } \frac{F_1}{A_1} = \frac{F_2}{A_2} \Rightarrow F_2 = F_1 \frac{A_2}{A_1}$$

Applications: hydraulic jack, lift, press, brakes.

**Q2. (a) Oil of viscosity  $0.8 \text{ N}\cdot\text{s}/\text{m}^2$  fills the space between two parallel plates 10 mm apart. If the top plate moves at 1.5 m/s, find the shear stress and the force required to move a plate of area  $0.6 \text{ m}^2$ .**

**(b) Define atmospheric pressure, gauge pressure, absolute pressure and pressure head. Write their relations.**

**Sol:**

$$\text{Velocity gradient, } du/dy = 1.5/0.01 = 150 \text{ s}^{-1}$$

$$\text{Shear stress, } \tau = \mu (du/dy) = 0.8 \times 150 = 120 \text{ N}/\text{m}^2$$

$$\text{Force, } F = \tau A = 120 \times 0.6 = 72 \text{ N}$$

Atmospheric pressure: pressure exerted by atmosphere.

Gauge pressure: pressure above atmospheric.

$$\text{Absolute pressure: } P_{abs} = P_{atm} + P_{gauge}$$

$$\text{Pressure head: } h = P/(\rho g), \text{ unit} = \text{metre.}$$

## UNIT - 2 (Fluid Flow Parameters)

### 2 Marks Questions:

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**Q1. Define gravity flow and pressure flow.**

**Sol:** Gravity flow is the flow of liquid due to difference in elevation only (e.g., open channels). Pressure flow is the flow caused by pressure difference in a closed conduit (e.g., pipes).

**Q2. Define laminar flow and turbulent flow.**

**Sol:** Laminar flow is smooth flow in which fluid particles move in layers without mixing. Turbulent flow is irregular flow with eddies and mixing of particles.

**Q3. What are steady and unsteady flows?**

**Sol:** In steady flow, velocity and pressure at a point do not change with time. In unsteady flow, these properties change with time.

**Q4. Define uniform and non-uniform flow.**

**Sol:** Uniform flow is one in which velocity remains constant along the flow direction. Non-uniform flow is one in which velocity changes from section to section.

**Q5. What is Reynolds number? Write its expression and significance.**

**Sol:** Reynolds number is the ratio of inertial forces to viscous forces.

$$Re = \frac{\rho V D}{\mu}$$

It indicates type of flow: laminar, transition or turbulent.

**Q6. Define discharge. Write its unit and formula.**

**Sol:** Discharge is the volume of liquid flowing per unit time.

$$Q = A V$$

Unit: m<sup>3</sup>/s.

**Q7. State the continuity equation for incompressible flow.**

**Sol:** For incompressible flow, discharge remains constant at all sections.

$$A_1 V_1 = A_2 V_2 = \text{constant.}$$

**Q8. Write the different forms of energy possessed by a flowing liquid.**

**Sol:** A flowing liquid possesses:

- Potential energy (z)

- Pressure energy  $\frac{P}{\rho g}$
- Kinetic energy  $\frac{V^2}{2g}$

**Q9. State Bernoulli's theorem.**

**Sol:** Bernoulli's theorem states that for steady, incompressible and frictionless flow, the total energy of fluid remains constant along a streamline.

**Q10. Write Bernoulli's equation with assumptions.**

**Sol:** Equation:  $\frac{P}{\rho g} + \frac{V^2}{2g} + z = \text{constant}$

Assumptions: steady flow, incompressible fluid, no friction loss, flow along a streamline.

**5 Marks Questions:**

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**Q1. Water flows through a pipe of diameter 50 mm with an average velocity of 1.2 m/s. Determine (i) Reynolds number and (ii) type of flow. Take  $\rho = 1000 \text{ kg/m}^3$  and  $\mu = 0.001 \text{ N}\cdot\text{s/m}^2$ .**

**Sol:** Given:

$$D = 50 \text{ mm} = 0.05 \text{ m}$$

$$V = 1.2 \text{ m/s}$$

$$\rho = 1000 \text{ kg/m}^3$$

$$\mu = 0.001 \text{ N}\cdot\text{s/m}^2$$

Formula:

$$\text{Re} = (\rho V D) / \mu$$

Substituting:

$$\text{Re} = (1000 \times 1.2 \times 0.05) / 0.001$$

$$\text{Re} = 60 / 0.001 = 60,000$$

Since  $\text{Re} > 4000$ , the flow is Turbulent.

**Q2. A pipe of diameter 200 mm carries water with velocity 3 m/s. Find (i) discharge and (ii) velocity when the diameter reduces to 100 mm.**

**Sol:** Given:

$$D_1 = 0.2 \text{ m}, V_1 = 3 \text{ m/s}$$

$$D_2 = 0.1 \text{ m}$$

Area of section 1:

$$A_1 = (\pi/4) D_1^2 = (\pi/4)(0.2)^2 = 0.0314 \text{ m}^2$$

Discharge:

$$Q = A_1 V_1 = 0.0314 \times 3 = 0.0942 \text{ m}^3/\text{s}$$

Area of section 2:

$$A_2 = (\pi/4)(0.1)^2 = 0.00785 \text{ m}^2$$

Using continuity:

$$Q = A_2 V_2$$

$$V_2 = Q / A_2 = 0.0942 / 0.00785 = 12 \text{ m/s}$$

Discharge =  $0.0942 \text{ m}^3/\text{s}$ , Velocity at smaller section =  $12 \text{ m/s}$ .

**Q3. At a point in a pipe, pressure is 300 kPa and velocity is 4 m/s. Determine pressure head, velocity head and total head of water. Take  $g = 9.81 \text{ m/s}^2$ .**

**Sol:** Given:

$$P = 300 \text{ kPa} = 300000 \text{ N/m}^2$$

$$V = 4 \text{ m/s}$$

$$\rho = 1000 \text{ kg/m}^3$$

Pressure head:

$$h_p = \frac{P}{\rho g} = \frac{300000}{1000 \times 9.81} = 30.6 \text{ m}$$

Velocity head:

$$h_v = \frac{V^2}{2g} = \frac{4^2}{2 \times 9.81} = 16 / 19.62 = 0.82 \text{ m}$$

Total head:

$$H = h_p + h_v = 30.6 + 0.82 = 31.42 \text{ m}$$

**Q4. Water flows horizontally in a pipe. At section 1, pressure = 200 kPa and velocity = 2 m/s. At section 2, velocity = 5 m/s. Find pressure at section 2 using Bernoulli's theorem. Assume no losses.**

**Sol:** Given:

$$P_1 = 200000 \text{ N/m}^2$$

$$V_1 = 2 \text{ m/s}$$

$$V_2 = 5 \text{ m/s}$$

$$z_1 = z_2$$

Bernoulli equation:

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} = \frac{P_2}{\rho g} + \frac{V_2^2}{2g}$$

$$\frac{P_1}{\rho g} = 200000 / (1000 \times 9.81) = 20.39 \text{ m}$$

$$\frac{V_1^2}{2g} = 0.20 \text{ m}$$

$$\frac{V_2^2}{2g} = 1.27 \text{ m}$$

$$\frac{P_2}{\rho g} = 20.39 + 0.20 - 1.27 = 19.32 \text{ m}$$

$$P_2 = 19.32 \times 1000 \times 9.81 = 1.895 \times 10^5 \text{ N/m}^2 = 189.5 \text{ kPa}$$

**Q5. Water flows through a pipe at a height of 5 m above datum with pressure 150 kPa and velocity 3 m/s. Find potential head, pressure head, velocity head and total energy head.**

**Sol:** Given:

$$z = 5 \text{ m}$$

$$P = 150000 \text{ N/m}^2$$

$$V = 3 \text{ m/s}$$

Potential head =  $z = 5 \text{ m}$

Pressure head:

$$h_p = \frac{P}{\rho g} = 150000 / (1000 \times 9.81) = 15.29 \text{ m}$$

Velocity head:

$$h_v = \frac{v^2}{2g} = 9/19.62 = 0.46 \text{ m}$$

Total head:

$$H = 5 + 15.29 + 0.46 = 20.75 \text{ m}$$

### 10 Marks Questions:

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**Q1. (a) Water flows through a pipe of diameter 150 mm with velocity 2.5 m/s. The pipe contracts to 75 mm diameter. Determine (i) discharge and (ii) velocity in the smaller pipe using continuity equation. (5 Marks)**

**(b) Define laminar flow, turbulent flow and Reynolds number. Write the expression of Reynolds number and state the critical values. (5 Marks)**

**Sol:**

(a) Given:

$$D_1 = 0.15 \text{ m}, V_1 = 2.5 \text{ m/s}, D_2 = 0.075 \text{ m}$$

Area at section 1:

$$A_1 = (\pi/4)D_1^2 = (\pi/4)(0.15)^2 = 0.01767 \text{ m}^2$$

Discharge:

$$Q = A_1V_1 = 0.01767 \times 2.5 = 0.0442 \text{ m}^3/\text{s}$$

Area at section 2:

$$A_2 = (\pi/4)(0.075)^2 = 0.00442 \text{ m}^2$$

Velocity at section 2:

$$V_2 = Q/A_2 = 0.0442/0.00442 = 10 \text{ m/s}$$

$$Q = 0.0442 \text{ m}^3/\text{s}, V_2 = 10 \text{ m/s}$$

b) Laminar flow: fluid moves in smooth layers without mixing.

Turbulent flow: irregular motion with eddies and mixing.

$$\text{Reynolds number: } R_e = \frac{\rho V D}{\mu}$$

If  $Re < 2000 \rightarrow$  Laminar

2000–4000  $\rightarrow$  Transition

Re > 4000 → Turbulent.

**Q2. (a) Water flows horizontally from section 1 to section 2. At section 1, pressure = 250 kPa and velocity = 3 m/s. At section 2, velocity = 6 m/s. Using Bernoulli's theorem, find the pressure at section 2. Assume no losses. (5 Marks)**

**(b) State Bernoulli's theorem with assumptions. Also write the forms of energy possessed by flowing liquid. (5 Marks)**

**Sol:**

(a) Given:

$$P_1 = 250 \text{ kPa} = 250000 \text{ N/m}^2$$

$$V_1 = 3 \text{ m/s}$$

$$V_2 = 6 \text{ m/s}$$

$$\rho = 1000 \text{ kg/m}^3, g = 9.81 \text{ m/s}^2$$

Bernoulli equation:

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} = \frac{P_2}{\rho g} + \frac{V_2^2}{2g}$$

$$\frac{P_1}{\rho g} = 250000 / (1000 \times 9.81) = 25.48 \text{ m}$$

$$\frac{V_1^2}{2g} = 9 / 19.62 = 0.46 \text{ m}$$

$$\frac{V_2^2}{2g} = 36 / 19.62 = 1.84 \text{ m}$$

$$\frac{P_2}{\rho g} = 25.48 + 0.46 - 1.84 = 24.10 \text{ m}$$

$$P_2 = 24.10 \times 1000 \times 9.81 = 236.5 \text{ kPa}$$

Pressure at section 2 = 236.5 kPa

(b) Bernoulli's theorem: In steady, incompressible and frictionless flow, total energy remains constant along a streamline.

Assumptions: steady flow, incompressible fluid, no friction loss, along a streamline.

Energy forms: pressure energy ( $P/\rho g$ ), kinetic energy ( $V^2/2g$ ), potential energy ( $z$ ).

## UNIT - 3 (Flow through Pipes)

### 2 Marks Questions:

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**Q1. What is major head loss in a pipe? Write Darcy-Weisbach equation.**

**Sol:** Major head loss is the loss of energy of flowing liquid due to friction between the pipe wall and fluid particles while flowing through the length of the pipe. It depends on length, diameter, velocity and roughness of pipe.

$$h_f = \frac{fLV^2}{2gD} \text{ where } f = \text{friction factor.}$$

**Q2. Define minor losses in pipes. Give examples.**

**Sol:** Minor losses are the additional losses of head occurring due to sudden changes in velocity or direction of flow. These losses are caused by pipe fittings and disturbances.

Examples: entrance loss, exit loss, bends, valves, sudden contraction and sudden enlargement.

**Q3. Write expressions for head loss at pipe entrance and exit.**

**Sol:** At entrance, fluid experiences resistance while entering the pipe causing loss:

$$h_e = K V^2 / (2g)$$

At exit, all velocity head is lost, hence:

$$h_{\text{exit}} = V^2 / (2g).$$

**Q4. What is head loss due to sudden enlargement? Write its formula.**

**Sol:** When a pipe suddenly enlarges, flow separates and eddies are formed, resulting in loss of energy.

The head loss is given by:

$$h_{se} = (V_1 - V_2)^2 / (2g).$$

**Q5. State the conditions for pipes connected in series.**

**Sol:** In pipes connected in series, the same discharge flows through all pipes. The total head loss is equal to the sum of individual losses of each pipe.

$$h_{\text{total}} = h_1 + h_2 + h_3.$$

**Q6. State the conditions for pipes connected in parallel.**

**Sol:** In parallel connection, the head loss between common junctions is same for all branches. The total discharge is the sum of discharges in individual pipes.

$$Q = Q_1 + Q_2 + Q_3.$$

**Q7. What is an equivalent pipe? State Dupuit's equation.**

**Sol:** An equivalent pipe is a single pipe which can replace a compound pipe system and gives the same discharge and head loss. Dupuit's equation for pipes in series is:

$$\frac{L_e}{D_e^5} = \frac{L_1}{D_1^5} + \frac{L_2}{D_2^5} + \dots$$

**Q8. Define Hydraulic Gradient Line (HGL) and Total Energy Line (TEL).**

**Sol:** HGL is a line joining the pressure heads at different points in a pipeline and represents pressure head plus datum head. TEL represents the total energy of fluid and includes pressure head, velocity head and datum head. TEL always lies above HGL by an amount equal to  $V^2/(2g)$ .

**Q9. Explain the construction and working principle of a Venturimeter.**

**Sol:** A Venturimeter consists of a converging section, throat and diverging section fitted in a pipe. It works on Bernoulli's theorem. The pressure difference between inlet and throat is measured and used to calculate discharge.

$$Q = C_d A_2 \sqrt{\frac{2gh}{1 - \left(\frac{A_2}{A_1}\right)^2}}$$

**Q10. Define coefficient of discharge, coefficient of velocity and coefficient of contraction for an orifice.**

**Sol:** Coefficient of discharge ( $C_d$ ) is the ratio of actual discharge to theoretical discharge. Coefficient of velocity ( $C_v$ ) is the ratio of actual velocity to theoretical velocity. Coefficient of contraction ( $C_c$ ) is the ratio of area of jet at vena contracta to area of orifice.

$$C_d = C_c \times C_v.$$

### 5 Marks Questions:

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**Q1. Water flows through a pipe of length 60 m and diameter 150 mm with velocity 2 m/s. The friction factor  $f = 0.02$ . Using Darcy-Weisbach equation, calculate head loss due to friction. Take  $g = 9.81 \text{ m/s}^2$ .**

**Sol:** Given:

$$L = 60 \text{ m}$$

$$D = 150 \text{ mm} = 0.15 \text{ m}$$

$$V = 2 \text{ m/s}$$

$$f = 0.02$$

$$g = 9.81 \text{ m/s}^2$$

Formula (Darcy-Weisbach):

$$h_f = \frac{fLV^2}{2gD}$$

Substitution:

$$h_f = (0.02 \times 60 \times 2^2) / (2 \times 9.81 \times 0.15)$$

$$h_f = (0.02 \times 60 \times 4) / (2.943)$$

$$h_f = 4.8 / 2.943 = 1.63 \text{ m}$$

Head loss due to friction = 1.63 m of water.

**Q2. Two pipes are connected in series: Pipe 1 - 40 m long, 100 mm diameter; Pipe 2 - 60 m long, 150 mm diameter. If discharge is  $0.02 \text{ m}^3/\text{s}$  and  $f = 0.02$  for both pipes, determine total head loss due to friction.**

**Sol:**

Given:

$$Q = 0.02 \text{ m}^3/\text{s}$$

$$\text{Pipe 1: } L_1 = 40 \text{ m, } D_1 = 0.10 \text{ m}$$

$$\text{Pipe 2: } L_2 = 60 \text{ m, } D_2 = 0.15 \text{ m}$$

$$f = 0.02, g = 9.81 \text{ m/s}^2$$

Step 1: Velocity in each pipe

$$A_1 = (\pi/4)D_1^2 = (\pi/4)(0.10)^2 = 0.00785 \text{ m}^2$$

$$V_1 = Q/A_1 = 0.02/0.00785 = 2.55 \text{ m/s}$$

$$A_2 = (\pi/4)D_2^2 = (\pi/4)(0.15)^2 = 0.01767 \text{ m}^2$$

$$V_2 = Q/A_2 = 0.02/0.01767 = 1.13 \text{ m/s}$$

Step 2: Head loss in each pipe (Darcy-Weisbach)

$$h_{f1} = (f L_1 V_1^2)/(2 g D_1)$$

$$h_{f1} = (0.02 \times 40 \times 2.55^2)/(2 \times 9.81 \times 0.10) = 2.64 \text{ m}$$

$$h_{f2} = (f L_2 V_2^2)/(2 g D_2)$$

$$h_{f2} = (0.02 \times 60 \times 1.13^2)/(2 \times 9.81 \times 0.15) = 0.52 \text{ m}$$

Step 3: Total head loss in series

$$h_{\text{total}} = h_{f1} + h_{f2}$$

$$h_{\text{total}} = 2.64 + 0.52 = 3.17 \text{ m}$$

Total head loss = 3.17 m of water.

**Q3. Two pipes are connected in parallel between two reservoirs. Pipe A carries  $0.04 \text{ m}^3/\text{s}$  and Pipe B carries  $0.06 \text{ m}^3/\text{s}$ . If the head loss in each branch is 3 m, find (i) total discharge and (ii) percentage discharge through each pipe.**

**Sol:**

Given:

$$Q_A = 0.04 \text{ m}^3/\text{s}$$

$$Q_B = 0.06 \text{ m}^3/\text{s}$$

(For parallel pipes, head loss is same in each branch; given as 3 m.)

Step 1: Total discharge

$$Q_{\text{total}} = Q_A + Q_B$$

$$Q_{\text{total}} = 0.04 + 0.06 = 0.10 \text{ m}^3/\text{s}$$

Step 2: Percentage share

$$\% \text{ through A} = (Q_A/Q_{\text{total}}) \times 100 = (0.04/0.10) \times 100 = 40\%$$

$$\% \text{ through B} = (Q_B/Q_{\text{total}}) \times 100 = (0.06/0.10) \times 100 = 60\%$$

Total discharge =  $0.10 \text{ m}^3/\text{s}$ ; A carries 40%, B carries 60%.

**Q4. A Venturimeter is fitted to a pipe of diameter 200 mm and throat diameter 100 mm. The difference in pressure head between inlet and throat is 0.5 m of water. If  $C_d = 0.98$ , determine the discharge through the meter. Take  $g = 9.81 \text{ m/s}^2$ .**

**Sol:**

Given:

$$D_1 = 0.20 \text{ m}, D_2 = 0.10 \text{ m}$$

$$h = 0.5 \text{ m of water}$$

$$C_d = 0.98, g = 9.81 \text{ m/s}^2$$

Step 1: Areas

$$A_1 = (\pi/4)D_1^2 = (\pi/4)(0.20)^2 = 0.0314 \text{ m}^2$$

$$A_2 = (\pi/4)D_2^2 = (\pi/4)(0.10)^2 = 0.00785 \text{ m}^2$$

Step 2: Discharge formula (Venturimeter)

$$Q = C_d A_2 \sqrt{\frac{2gh}{1 - \left(\frac{A_2}{A_1}\right)^2}}$$

$$(A_2/A_1) = 0.00785/0.0314 = 0.25$$

$$1 - (A_2/A_1)^2 = 1 - (0.25)^2 = 0.94$$

$$Q_{th} = 0.00785 \times \sqrt{(2 \times 9.81 \times 0.5 / 0.94)} = 0.0254 \text{ m}^3/\text{s}$$

$$Q_{act} = C_d \times Q_{th} = 0.98 \times 0.0254 = 0.0249 \text{ m}^3/\text{s}$$

$$\text{Discharge through Venturimeter} = 0.0249 \text{ m}^3/\text{s}.$$

**Q5. Water flows through an orifice of diameter 40 mm under a constant head of 3 m. If coefficient of discharge  $C_d = 0.62$ , calculate the actual discharge. Take  $g = 9.81 \text{ m/s}^2$ .**

**Sol:**

Given:

$$d = 40 \text{ mm} = 0.04 \text{ m}$$

$$h = 3 \text{ m}$$

$$C_d = 0.62$$

$$g = 9.81 \text{ m/s}^2$$

Step 1: Area of orifice

$$a = (\pi/4)d^2 = (\pi/4)(0.04)^2 = 0.001257 \text{ m}^2$$

Step 2: Theoretical discharge

$$Q_{th} = a \sqrt{2gh}$$

$$Q_{th} = 0.001257 \times \sqrt{(2 \times 9.81 \times 3)} = 0.00964 \text{ m}^3/\text{s}$$

Step 3: Actual discharge

$$Q_{\text{act}} = C_d \times Q_{\text{th}}$$

$$Q_{\text{act}} = 0.62 \times 0.00964 = 0.00598 \text{ m}^3/\text{s}$$

Actual discharge through orifice =  $0.00598 \text{ m}^3/\text{s}$ .

### 10 Marks Questions

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**Q.1 (a) Water flows through a pipe 80 m long and 200 mm diameter with velocity 2.5 m/s. If friction factor  $f = 0.02$ , calculate head loss using Darcy-Weisbach equation.**

**(b) Explain major and minor losses in pipes. Write formulas for entrance loss, exit loss and sudden enlargement loss.**

**Sol:**

(a) Given:

$$L = 80 \text{ m}$$

$$D = 0.20 \text{ m}$$

$$V = 2.5 \text{ m/s}$$

$$f = 0.02$$

$$g = 9.81 \text{ m/s}^2$$

Formula:

$$h_f = (f L V^2) / (2 g D)$$

Substitution:

$$h_f = (0.02 \times 80 \times 2.5^2) / (2 \times 9.81 \times 0.20)$$

$$h_f = 2.55 \text{ m}$$

Head loss = 2.55 m of water.

(b) Major loss: energy loss due to friction along pipe length.

Minor losses: losses due to fittings and sudden changes in flow.

$$\text{Entrance loss: } h_e = K V^2 / (2g)$$

$$\text{Exit loss: } h_{\text{exit}} = V^2 / (2g)$$

$$\text{Sudden enlargement: } h_{\text{se}} = (V_1 - V_2)^2 / (2g)$$

**Q.2 (a) A Venturimeter is installed in a pipe of diameter 250 mm and throat diameter 125 mm. Pressure head difference is 0.6 m of water. If  $C_d = 0.97$ , determine the discharge.**

**(b) Define Hydraulic Gradient Line (HGL) and Total Energy Line (TEL). Explain their relation.**

**Sol:** (a)

Given:

$$D_1 = 0.25 \text{ m}, D_2 = 0.125 \text{ m}$$

$$h = 0.6 \text{ m}$$

$$C_d = 0.97$$

Areas:

$$A_1 = 0.0491 \text{ m}^2$$

$$A_2 = 0.0123 \text{ m}^2$$

Formula:

$$Q = C_d A_2 \sqrt{\frac{2gh}{1 - \left(\frac{A_2}{A_1}\right)^2}}$$

$$\text{Theoretical discharge} = 0.0435 \text{ m}^3/\text{s}$$

$$\text{Actual discharge} = 0.0422 \text{ m}^3/\text{s}$$

$$\text{Discharge} = 0.0422 \text{ m}^3/\text{s}$$

(b) HGL represents pressure head plus datum head ( $P/\rho g + z$ ).

TEL represents total head ( $P/\rho g + V^2/2g + z$ ).

TEL always lies above HGL by velocity head  $V^2/2g$  and shows total energy of flowing liquid.

#### UNIT - 4 (Flow through Open Channel)

#### 2 Marks Questions:

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**Q1. Define wetted area, wetted perimeter and hydraulic radius.**

**Sol:** Wetted area (A) is the cross-sectional area of flow normal to the direction of flow.

Wetted perimeter (P) is the length of boundary in contact with water. Hydraulic radius (R)

is the ratio of wetted area to wetted perimeter,  $R = A/P$ .

**Q2. Write expressions for wetted area, wetted perimeter and hydraulic radius for a rectangular channel.**

**Sol:** For a rectangular channel of width  $b$  and depth  $y$ :

$$A = b y$$

$$P = b + 2y$$

$$R = A/P = \frac{by}{b+2y}$$

**Q3. Write expressions for wetted area and wetted perimeter for a trapezoidal channel section.**

**Sol:** For a trapezoidal channel with bottom width  $b$ , depth  $y$  and side slope  $m:1$ :

$$A = y(b + m y)$$

$$P = b + 2y\sqrt{1 + m^2}$$

**Q4. State Chezy's equation for discharge and define the terms.**

**Sol:** Chezy's equation is used to determine velocity of flow in open channels:

$$V = C \sqrt{RS}$$

Discharge,  $Q = A V = A C \sqrt{RS}$ , where  $C$  = Chezy's constant,  $R$  = hydraulic radius and  $S$  = bed slope.

**Q5. State Manning's equation for discharge.**

**Sol:** Manning's equation gives velocity as:

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

Discharge,  $Q = A V = \frac{A^2 R^{2/3} S^{1/2}}{n}$ , where  $n$  is Manning's roughness coefficient.

**Q6. State the condition for most economical rectangular channel.**

**Sol:** For most economical rectangular channel, hydraulic radius is maximum.

Condition:  $b = 2y$  or depth = half of width. Also,  $R = y/2$ .

**Q7. State the condition for most economical trapezoidal channel.**

**Sol:** In the most economical trapezoidal channel, half of the top width equals one sloping side. The hydraulic radius becomes maximum and wetted perimeter minimum for given area.

**Q8. Write discharge formula for rectangular and triangular notches.**

**Sol:** For rectangular notch:

$$Q = \frac{2}{3} C_d b \sqrt{2gH^3}$$

For triangular notch:

$$Q = \frac{8}{15} C_d \tan\left(\frac{\theta}{2}\right) \sqrt{2gH^5}$$

**Q9. Name different devices used for measurement of velocity in open channels and briefly state their principle.**

**Sol:** Velocity measuring devices include current meter, floats and Pitot tube. Current meter measures velocity by rotation of cups, floats measure surface velocity, and Pitot tube measures velocity using pressure difference.

**Q10. Define specific energy and Froude number.**

**Sol:** Specific energy is the total energy per unit weight of water relative to channel bed:

$$E = y + V^2 / (2g).$$

Froude number is the ratio of inertial force to gravitational force:

$Fr = \frac{V}{\sqrt{gy}}$ . It indicates subcritical, critical or supercritical flow.

**5 Marks Questions:**

---

**Q1. A rectangular channel has width 4 m and water depth 1.5 m. Determine (i) wetted area, (ii) wetted perimeter and (iii) hydraulic radius.**

**Sol:**

Given:

$$b = 4 \text{ m}$$

$$y = 1.5 \text{ m}$$

Step 1: Wetted area

$$A = b \times y = 4 \times 1.5 = 6.00 \text{ m}^2$$

Step 2: Wetted perimeter

$$P = b + 2y = 4 + 2(1.5) = 7.00 \text{ m}$$

Step 3: Hydraulic radius

$$R = A / P = 6.00 / 7.00 = 0.86 \text{ m}$$

$$A = 6.00 \text{ m}^2, P = 7.00 \text{ m}, R = 0.86 \text{ m}$$

**Q2. Water flows in an open channel having area  $6 \text{ m}^2$  and hydraulic radius  $0.75 \text{ m}$ . If Chezy's constant  $C = 55$  and bed slope  $S = 0.001$ , determine the discharge using Chezy's equation.**

**Sol:**

Given:

$$A = 6 \text{ m}^2$$

$$R = 0.75 \text{ m}$$

$$C = 55$$

$$S = 0.001$$

Formula:

$$V = C \sqrt{RS}$$

Substitution:

$$V = 55 \sqrt{(0.75 \times 0.001)} = 1.51 \text{ m/s}$$

Discharge:

$$Q = AV = 6 \times 1.51 = 9.04 \text{ m}^3/\text{s}$$

$$\text{Discharge} = 9.04 \text{ m}^3/\text{s}$$

**Q3. An open channel has area  $8 \text{ m}^2$  and hydraulic radius  $1 \text{ m}$ . If Manning's  $n = 0.015$  and slope  $S = 0.0004$ , calculate discharge using Manning's equation.**

**Sol:**

Given:

$$A = 8 \text{ m}^2$$

$$R = 1 \text{ m}$$

$$n = 0.015$$

$$S = 0.0004$$

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

Substitution:

$$V = \frac{1}{0.015} 1^{2/3} 0.0004^{1/2} = 1.33 \text{ m/s}$$

Discharge:

$$Q = AV = 8 \times 1.33 = 10.67 \text{ m}^3/\text{s}$$

$$\text{Discharge} = 10.67 \text{ m}^3/\text{s}$$

**Q4. A rectangular notch of width  $0.5 \text{ m}$  measures water under a head of  $0.3 \text{ m}$ . If coefficient of discharge  $C_d = 0.62$ , calculate the discharge. Take  $g = 9.81 \text{ m/s}^2$ .**

**Sol:**

Given:

$$b = 0.5 \text{ m}$$

$$H = 0.3 \text{ m}$$

$$C_d = 0.62$$

$$g = 9.81 \text{ m/s}^2$$

Formula:

$$Q = \frac{2}{3} C_d b \sqrt{2gH^3}$$

Substitution:

$$Q = \frac{2}{3} \times 0.62 \times 0.5 \sqrt{2 \times 9.81 \times 0.3^3}$$

$$Q = 0.1504 \text{ m}^3/\text{s}$$

$$\text{Discharge} = 0.1504 \text{ m}^3/\text{s}$$

**Q5. Water flows in a channel with velocity 3 m/s and depth 1.2 m. Determine the Froude number and state the type of flow.**

**Sol:**

Given:

$$V = 3 \text{ m/s}$$

$$y = 1.2 \text{ m}$$

$$g = 9.81 \text{ m/s}^2$$

Formula:

$$Fr = V / \sqrt{(g y)}$$

Substitution:

$$Fr = 3 / \sqrt{(9.81 \times 1.2)} = 0.87$$

Since  $Fr < 1$ , the flow is Subcritical (tranquil flow).

Froude number = 0.87, Flow is subcritical.

**10 Marks Questions:**

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**Q1. (a) A rectangular channel of width 5 m carries water at a depth of 1.2 m. If Manning's  $n = 0.015$  and bed slope  $S = 0.001$ , calculate the discharge.**

**(b) Define wetted area, wetted perimeter and hydraulic radius. Also derive the condition for most economical rectangular channel.**

**Sol:**(a) Given:

$$b = 5 \text{ m}, y = 1.2 \text{ m}$$

$$n = 0.015, S = 0.001$$

Step 1: Wetted area

$$A = b \times y = 5 \times 1.2 = 6.00 \text{ m}^2$$

Step 2: Wetted perimeter

$$P = b + 2y = 5 + 2(1.2) = 7.40 \text{ m}$$

Step 3: Hydraulic radius

$$R = A/P = 6.00/7.40 = 0.81 \text{ m}$$

Step 4: Velocity by Manning's equation

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

$$V = 1.83 \text{ m/s}$$

Step 5: Discharge

$$Q = A V = 6.00 \times 1.83 = 11.00 \text{ m}^3/\text{s}$$

$$\text{Discharge} = 11.00 \text{ m}^3/\text{s}$$

(b) Wetted area (A): Area of flow section.

Wetted perimeter (P): Length of boundary in contact with water.

Hydraulic radius (R):  $A/P$ .

For most economical rectangular channel:

Hydraulic radius is maximum and wetted perimeter minimum.

Condition:

$$b = 2y \text{ (width = twice the depth).}$$

**Q2. (a) Water flows over a 90° triangular notch under a head of 0.4 m. If coefficient of discharge  $C_d = 0.62$ , determine the discharge. Take  $g = 9.81 \text{ m/s}^2$ .**

**(b) Define specific energy and Froude number. Calculate the Froude number for velocity 4 m/s and depth 1.5 m. State the type of flow.**

**Sol:** (a) Given:

$$\theta = 90^\circ, H = 0.4 \text{ m}, C_d = 0.62, g = 9.81 \text{ m/s}^2$$

Formula for triangular notch:

$$Q = \frac{8}{15} C_d \tan\left(\frac{\theta}{2}\right) \sqrt{2gH^3}$$

$$Q = \frac{8}{15} \times 0.62 \times \tan(45^\circ) \sqrt{2 \times 9.81 \times 0.4^3}$$

$$Q = 0.1482 \text{ m}^3/\text{s}$$

$$\text{Discharge} = 0.1482 \text{ m}^3/\text{s}$$

(b) Specific energy (E) is total energy per unit weight of water with respect to channel bed.

$$E = y + V^2/(2g).$$

Froude number:

$$Fr = V/\sqrt{gy}$$

$$Fr = 4/\sqrt{(9.81 \times 1.5)} = 1.04$$

Since  $Fr > 1$ , flow is supercritical (rapid flow).

## UNIT - 5 (Hydraulics Pumps)

### 2 Marks Questions:

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**Q1. Define a pump and state its basic function in hydraulic systems.**

**Sol:** A pump is a hydraulic machine that converts mechanical energy into hydraulic energy to lift or transport liquids from a lower level to a higher level.

**Q2. List any four components of a centrifugal pump.**

**Sol:** Impeller, casing (volute/diffuser), suction pipe with foot valve and strainer, and delivery pipe.

**Q3. Explain the working principle of a centrifugal pump in two points.**

**Sol:** Rotation of the impeller produces centrifugal force which throws water outward. This creates low pressure at the eye, causing continuous suction and discharge of water.

**Q4. Distinguish between centrifugal and reciprocating pumps based on principle of operation.**

**Sol:** Centrifugal pump works on centrifugal force (rotodynamic action), whereas reciprocating pump works on positive displacement by piston or plunger motion.

**Q5. A pump lifts water from a well 4 m below the pump and delivers it 12 m above the pump. Determine suction head and delivery head.**

**Sol:** Suction head = 4 m, Delivery head = 12 m.

**Q6. Using the data of Q5, calculate the static head of the pump.**

**Sol:** Static head = Suction head + Delivery head = 4 + 12 = 16 m.

**Q7. Define manometric head of a centrifugal pump.**

**Sol:** Manometric head is the actual head against which the pump works and equals the total head developed including losses between suction and delivery sides.

**Q8. Differentiate between single acting and double acting reciprocating pumps with respect to discharge.**

**Sol:** Single acting delivers water during one stroke only, giving less discharge. Double acting delivers during both strokes, giving nearly double discharge.

**Q9. Write the formula for power required by a centrifugal pump and state the meaning of each term.**

**Sol:** Power =  $\rho g Q H_m / \eta$ , where  $\rho$  = density,  $g$  = gravity,  $Q$  = discharge,  $H_m$  = manometric head,  $\eta$  = efficiency.

**Q10. Suggest one suitable type of pump for deep bore wells and justify your choice.**

**Sol:** Submersible pump, because it operates underwater, avoids suction problems, and provides higher efficiency for deep lifting.

#### **5 Marks Questions:**

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**Q1. Explain the construction and working of a centrifugal pump with neat, labelled description.**

**Sol:** A centrifugal pump consists of an impeller, casing, suction pipe with foot valve and strainer, and delivery pipe.

The impeller is mounted on a shaft and enclosed inside a volute casing.

**Working:** When the impeller rotates, water at the eye of the impeller is subjected to centrifugal force and is thrown outward. This creates a vacuum at the centre, causing water to enter through the suction pipe. The water gains velocity and pressure energy and is discharged through the delivery pipe continuously.

Thus, mechanical energy is converted into hydraulic energy.

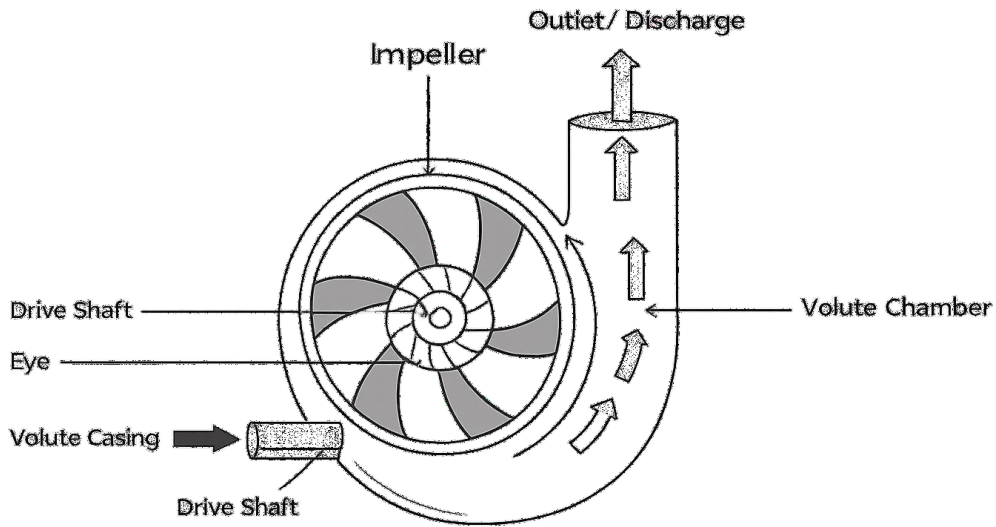


Fig. Centrifugal Pump

**Q2. Describe the working of a double acting reciprocating pump and state its advantages over a single acting pump.**

**Sol:** A double acting reciprocating pump consists of a cylinder, piston, suction valves and delivery valves on both sides of the piston.

**Working:** During the forward stroke, suction occurs on one side and delivery occurs on the other side. During the return stroke, the actions are reversed. Hence discharge takes place during both strokes.

**Advantages:**

1. Higher discharge for the same speed.
2. Uniform flow of water.
3. Better efficiency.
4. Suitable for high pressure applications.

**Q3. A centrifugal pump delivers  $0.05 \text{ m}^3/\text{s}$  of water against a manometric head of 20 m. If overall efficiency is 70%, calculate the power required to drive the pump. (Take  $\rho = 1000 \text{ kg/m}^3$ ,  $g = 9.81 \text{ m/s}^2$ ).**

**Sol:**

Given:

$$Q = 0.05 \text{ m}^3/\text{s}$$

$$H_m = 20 \text{ m}$$

$$\eta = 0.70$$

$$\text{Power required} = \frac{\rho \times g \times Q \times H_m}{\eta}$$

$$= (1000 \times 9.81 \times 0.05 \times 20) / 0.70$$

$$= 9810 / 0.70$$

$$= 14014 \text{ W}$$

$$= 14.01 \text{ kW}$$

Required power = 14.01 kW.

**Q4. A pump lifts water from a sump 5 m below the pump centre and delivers it to a tank 18 m above the pump centre. Determine (i) suction head, (ii) delivery head, and (iii) static head.**

**Sol:**

Suction head = 5 m

Delivery head = 18 m

Static head = Suction head + Delivery head

$$= 5 + 18$$

$$= 23 \text{ m}$$

Hence:

Suction head = 5 m

Delivery head = 18 m

Static head = 23 m.

**Q5. A single acting reciprocating pump has a piston diameter of 200 mm and stroke length of 300 mm. If it runs at 40 rpm, find the theoretical discharge in m<sup>3</sup>/s.**

**Sol:**

Given:

D = 0.2 m  
L = 0.3 m  
N = 40 rpm

Area of piston,  
 $A = (\pi/4) D^2$   
 $= (\pi/4) \times (0.2)^2$   
 $= 0.0314 \text{ m}^2$

Theoretical discharge,

$$Q = \frac{A \times L \times N}{60}$$
$$= \frac{0.0314 \times 0.3 \times 40}{60}$$
$$= 0.00628 \text{ m}^3/\text{s}$$

Theoretical discharge = 0.00628 m<sup>3</sup>/s.

### 10 Marks Questions:

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**(a) Explain with a neat, labelled diagram the construction and working of a centrifugal pump. State the function of impeller, casing, suction pipe, delivery pipe and foot valve.**

**(b) A centrifugal pump delivers 0.08 m<sup>3</sup>/s of water against a manometric head of 25 m. If the overall efficiency is 75%, calculate the power required to drive the pump.**

**(Take  $\rho = 1000 \text{ kg/m}^3$ ,  $g = 9.81 \text{ m/s}^2$ ).**

**Sol:** (a) A centrifugal pump consists of an impeller mounted on a rotating shaft enclosed inside a volute casing.

When the impeller rotates, water is thrown outward by centrifugal force creating a vacuum at the eye.

This causes continuous suction of water and discharge at higher pressure.

Functions:

- Impeller – imparts kinetic energy to water
- Casing – converts velocity energy into pressure energy
- Suction pipe – draws water from source

- Delivery pipe – carries water to outlet
- Foot valve – prevents backflow and maintains priming

(b) Given:

$$Q = 0.08 \text{ m}^3/\text{s}$$

$$H_m = 25 \text{ m}$$

$$\eta = 0.75$$

Power required,

$$\begin{aligned} P &= (\rho g Q H_m) / \eta \\ &= (1000 \times 9.81 \times 0.08 \times 25) / 0.75 \\ &= 26160 \text{ W} \\ &= 26.16 \text{ kW} \end{aligned}$$

Required power = 26.16 kW

**Q2. (a) Describe the construction and working of a double acting reciprocating pump. Compare it with a single acting reciprocating pump.**

**(b) A single acting reciprocating pump has piston diameter 250 mm, stroke length 400 mm and speed 50 rpm. Determine the theoretical discharge of the pump in m<sup>3</sup>/s.**

**Sol:** (a) A double acting reciprocating pump consists of a cylinder, piston, suction and delivery valves on both sides.

During the forward stroke, suction occurs on one side and delivery on the other.

During the return stroke, the process reverses.

Hence discharge occurs during both strokes.

Comparison:

- Discharge – higher than single acting
- Efficiency – higher
- Flow – more uniform
- Application – suitable for high pressure supply

(b) Given:

$$D = 0.25 \text{ m}$$

$$L = 0.4 \text{ m}$$

$$N = 50 \text{ rpm}$$

Area of piston,

$$\begin{aligned} A &= (\pi/4) D^2 \\ &= (3.14/4) \times (0.25)^2 \\ &= 0.0491 \text{ m}^2 \end{aligned}$$

Theoretical discharge,

$$\begin{aligned} Q &= A \times L \times N / 60 \\ &= 0.0491 \times 0.4 \times 50 / 60 \\ &= 0.0164 \text{ m}^3/\text{s} \end{aligned}$$

Theoretical discharge = 0.0164 m<sup>3</sup>/s

## UNIT - 6 (Introduction to Hydrology)

### 2 Marks Questions:

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#### Q1. Define Hydrology.

**Sol:** Hydrology is the science that deals with the occurrence, distribution, movement and properties of water on, above and below the earth's surface.

#### Q2. Explain the hydrological cycle in brief.

**Sol:** The hydrological cycle is the continuous circulation of water through evaporation, condensation, precipitation, infiltration and runoff between earth and atmosphere.

#### Q3. What is a rain gauge? State its purpose.

**Sol:** A rain gauge is an instrument used to measure the depth of rainfall at a particular place and time. It is used to record precipitation data.

#### Q4. List any two differences between Symons rain gauge and automatic rain gauge.

**Sol:** Symons gauge gives manual readings and is simple in construction, whereas an automatic rain gauge records rainfall continuously and automatically on a chart.

#### Q5. State the formula for arithmetic mean method of average rainfall.

**Sol:** Average rainfall,  $P = (P_1 + P_2 + \dots + P_n) / n$ , where  $P_1, P_2, \dots$  are station rainfalls and  $n$  is number of stations.

#### Q6. Define Thiessen polygon method.

**Sol:** It is a weighted average method in which the catchment is divided into polygons and rainfall is calculated based on the area weight of each rain gauge.

**Q7. Define runoff and mention any two factors affecting runoff.**

**Sol:** Runoff is the portion of precipitation that flows over the ground surface to streams. Factors include rainfall intensity and soil infiltration capacity.

**Q8. A catchment receives rainfalls of 8 cm, 10 cm and 12 cm at three stations. Compute average rainfall by arithmetic mean method.**

**Sol:**  $P = (8 + 10 + 12)/3 = 30/3 = 10$  cm. Average rainfall = 10 cm.

**Q9. State the rational formula for maximum flood discharge.**

**Sol:**  $Q = C I A$ , where  $Q$  = peak discharge,  $C$  = runoff coefficient,  $I$  = rainfall intensity and  $A$  = catchment area.

**Q10. Define yield and dependable yield of a catchment.**

**Sol:** Yield is the total quantity of water available from a catchment during a period. Dependable yield is the quantity that can be supplied with a specified reliability (usually 75–90% of time).

**5 Marks Questions:**

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**Q1. Explain the hydrological cycle with the help of a neat sketch and describe the different processes involved.**

**Sol:** The hydrological cycle is the continuous movement of water between the earth's surface and the atmosphere.

Water from oceans, rivers and lakes evaporates due to solar energy and forms water vapor. The vapor rises, cools and condenses to form clouds.

When condensation becomes heavy, precipitation occurs in the form of rain or snow. A part of the rainfall infiltrates into the soil to recharge groundwater, some is stored as surface water and the remaining flows as runoff into streams and rivers.

Thus evaporation, condensation, precipitation, infiltration and runoff complete the cycle. This process maintains the water balance of the earth.

**Q2. Describe the construction and working of a Symons rain gauge. State its advantages and limitations.**

**Sol:** A Symons rain gauge is a non-recording type rain gauge widely used in India for measuring rainfall.

It consists of a circular collector funnel of 127 mm diameter fixed at the top of a cylindrical container. The rainwater collected through the funnel is stored in a bottle kept inside the outer casing.

After a fixed time interval, the collected water is poured into a graduated measuring jar and the rainfall depth is noted in millimeters.

Advantages:

- Simple construction
- Cheap and easy to maintain
- Reliable measurements

Limitations:

- Manual observation required
- Does not give continuous record
- Chances of human error during measurement.

**Q3. Explain runoff and discuss the factors affecting runoff from a catchment area.**

**Sol:** Runoff is the portion of precipitation that flows over the ground surface and ultimately reaches streams, rivers or reservoirs. It occurs when the rainfall intensity exceeds the infiltration capacity of the soil.

Factors affecting runoff:

- Rainfall intensity and duration – heavy rainfall produces more runoff
- Nature of soil – impervious soil increases runoff
- Slope of catchment – steep slopes increase flow velocity
- Vegetation cover – reduces runoff by increasing infiltration
- Catchment area and shape – larger areas produce more runoff
- Evaporation and temperature – high evaporation reduces runoff

Hence, runoff depends on both meteorological and physical characteristics of the basin.

**Q4. The rainfall recorded at four stations in a catchment are 12 cm, 10 cm, 15 cm and 13 cm. Calculate the average rainfall using the arithmetic mean method.**

**Sol:** Given rainfall values:

$$P_1 = 12 \text{ cm}, P_2 = 10 \text{ cm}, P_3 = 15 \text{ cm}, P_4 = 13 \text{ cm}$$

Number of stations,  $n = 4$

Average rainfall,

$$\begin{aligned} P &= (P_1 + P_2 + P_3 + P_4) / n \\ &= (12 + 10 + 15 + 13) / 4 \\ &= 50 / 4 \\ &= 12.5 \text{ cm} \end{aligned}$$

Therefore, the average rainfall over the catchment = 12.5 cm.

**Q5. Estimate the maximum flood discharge for a catchment of 60 hectares using the rational method. Assume runoff coefficient  $C = 0.7$  and rainfall intensity  $I = 50 \text{ mm/hr}$ .**

**Sol:** Given:

$$\text{Area, } A = 60 \text{ hectares} = 60 \times 10^4 \text{ m}^2 = 600000 \text{ m}^2$$

$$\text{Runoff coefficient, } C = 0.7$$

$$\text{Rainfall intensity, } I = 50 \text{ mm/hr} = 0.05 \text{ m/hr}$$

Using rational formula,

$$Q = C I A$$

$$Q = 0.7 \times 0.05 \times 600000$$

$$Q = 21000 \text{ m}^3/\text{hr}$$

Convert into  $\text{m}^3/\text{s}$ ,

$$Q = 21000 / 3600$$

$$Q = 5.83 \text{ m}^3/\text{s}$$

Therefore, maximum flood discharge =  $5.83 \text{ m}^3/\text{s}$ .

### 10 Marks Questions:

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**Q1. (a) Explain the construction and working of an automatic rain gauge (tipping bucket type). State its advantages over a non-recording rain gauge. (b) The runoff from a catchment of area  $2 \text{ km}^2$  during a storm produced a total runoff volume of  $180,000 \text{ m}^3$ . If the total rainfall during the storm was  $12 \text{ cm}$ , determine (i) runoff depth and (ii) runoff coefficient of the catchment.**

**Sol:**(a) An automatic rain gauge is a recording type instrument used to measure rainfall continuously with respect to time.

In a tipping bucket rain gauge, rainwater is collected through a funnel and directed into a small bucket divided into two compartments. When one compartment fills to a fixed volume, it tips automatically and empties, while the other compartment starts filling. Each tip is recorded electrically on a chart or data logger.

Advantages:

- Provides continuous rainfall record
- Gives rainfall intensity and duration
- No manual observation required
- More accurate for storm analysis

(b) Given:

Area,  $A = 2 \text{ km}^2 = 2 \times 10^6 \text{ m}^2$

Runoff volume =  $180000 \text{ m}^3$

Rainfall depth =  $12 \text{ cm} = 0.12 \text{ m}$

(i) Runoff depth,

$$\begin{aligned}\text{Runoff depth} &= \text{Runoff volume} / \text{Area} \\ &= 180000 / (2 \times 10^6) \\ &= 0.09 \text{ m} = 9 \text{ cm}\end{aligned}$$

(ii) Runoff coefficient,

$$\begin{aligned}C &= \text{Runoff depth} / \text{Rainfall depth} \\ &= 0.09 / 0.12 \\ &= 0.75\end{aligned}$$

Runoff depth =  $9 \text{ cm}$

Runoff coefficient =  $0.75$

**Q2. (a) Explain the factors affecting maximum flood discharge in a catchment and discuss the importance of estimating peak flood discharge in engineering works.**

**(b) Using Dicken's empirical formula, estimate the flood discharge for a catchment area of 150 km<sup>2</sup>.**

**Assume the constant C = 14.**

**Sol:**(a) Maximum flood discharge is the highest rate of flow occurring during a storm. It is important for the design of dams, spillways, bridges and drainage structures.

Factors affecting flood discharge:

- Intensity and duration of rainfall
- Catchment area and shape
- Slope of the basin
- Soil type and infiltration capacity
- Vegetation cover
- Storage and drainage characteristics

Importance:

Proper estimation prevents structural failure and ensures safety and economy of hydraulic structures.

(b) Dicken's formula:

$$Q = C A^{\frac{3}{4}}$$

Given:

$$A = 150 \text{ km}^2$$

$$C = 14$$

$$Q = C A^{\frac{3}{4}} \approx 600.6 \text{ m}^3/\text{s}$$

Therefore, Peak flood discharge  $\approx 601 \text{ m}^3/\text{s}$

## UNIT – 7 (Crop water requirement and Reservoir Planning)

### 2 Marks Questions:

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#### **Q1. What do you mean by Gross Command Area (GCA)?**

**Sol:** Gross Command Area is the total area which can be commanded (served) by an irrigation project/canal system. It includes both cultivable and non-cultivable areas like roads, villages, forests, water bodies, etc. within the command boundary.

#### **Q2. Write two benefits of irrigation.**

**Sol:** Any two benefits are:

- 1) Assures water supply to crops during dry periods and increases crop yield.
- 2) Enables multiple cropping and cultivation of cash crops, improving farm income.

#### **Q3. Define duty of irrigation water.**

**Sol:** Duty is the area of land that can be irrigated by a unit discharge of water flowing continuously during the base period. It is usually expressed as hectares per cumec (ha/cumec).

#### **Q4. Define duty, delta and base period.**

**Sol:** • Duty (D): Area irrigated by 1 cumec flowing continuously during base period (ha/cumec).

• Delta ( $\Delta$ ): Total depth of water required by a crop during its base period (in cm or m).

• Base period (B): Time (in days) between first watering and the last watering of a crop.

#### **Q5. What is crop season?**

**Sol:** Crop season is the part of the year in which a crop is grown under prevailing climatic conditions. Examples: Kharif (monsoon), Rabi (winter) and Zaid (summer).

#### **Q6. Differentiate between GCA and CCA.**

**Sol:** GCA: Total commanded area including cultivable + non-cultivable land.

CCA: Cultivable Command Area—only the cultivable portion of command area that is fit for cultivation and can be irrigated. Hence,  $CCA < GCA$ .

#### **Q7. What do you mean by surface and sub-surface irrigation?**

**Sol:** Surface irrigation: Water is applied and allowed to flow/spread over the soil surface (e.g., flooding, border, furrow).

Sub-surface irrigation: Water is supplied below the ground surface (through porous pipes/channels or by raising water table) so that moisture reaches roots by capillary action.

**Q8. What is crop period?**

**Sol:** Crop period is the total time from sowing/planting of a crop to its harvesting (maturity). It includes the entire growing duration of the crop.

**Q9. What is base period?**

**Sol:** Base period is the time interval between the first watering (first irrigation) and the last watering (last irrigation) before harvesting. It is expressed in days.

**Q10. Differentiate between crop period and base period.**

**Sol:** Crop period: Time from sowing to harvesting.

Base period: Time from first irrigation to last irrigation.

Generally, base period is slightly less than crop period because irrigation may not be applied exactly at sowing and may stop a little before harvesting.

**5 Marks Questions:**

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**Q1. Define duty and derive the relationship between duty, delta and base period.**

**Sol:** Duty (D): It is the area of land irrigated by a unit discharge of water flowing continuously during the base period. It is expressed in hectares per cumec (ha/cumec).

Delta ( $\Delta$ ): It is the total depth of water required by a crop during its base period. It is expressed in metres or centimetres.

Base Period (B): It is the time interval between the first irrigation and the last irrigation of a crop, expressed in days.

Derivation of relationship:

Let 1 cumec discharge flow for B days.

Volume of water supplied,  
 $= 1 \times 86400 \times B \text{ m}^3$

If D hectares are irrigated,  
Area =  $D \times 10,000 \text{ m}^2$

If  $\Delta$  is depth of water,  
Volume required =  $D \times 10,000 \times \Delta$

Equating volumes,  
 $D \times 10,000 \times \Delta = 86400 B$

$\Delta = 8.64 B / D$  (in metres)

Thus,  $\Delta \propto B$  and  $\Delta \propto 1/D$ .  
Higher duty means smaller delta and efficient use of water.

**Q2. List out factors affecting duty in irrigation.**

**Sol:** The duty of irrigation water is affected by the following factors:

1. Type of crop – Water intensive crops like paddy have low duty, while wheat has higher duty.
2. Climate – High temperature and wind increase evaporation losses and reduce duty.
3. Soil type – Sandy soils need more water (low duty); clay soils retain water (high duty).
4. Method of irrigation – Efficient methods like sprinkler/drip increase duty.
5. Canal condition – Lined canals reduce seepage losses and improve duty.
6. Topography – Uneven land causes runoff and wastage of water.
7. Cultivation practices – Proper levelling, timely irrigation and field management improve duty.
8. Rainfall contribution – Effective rainfall reduces irrigation requirement and increases duty.

Hence, better management practices lead to higher duty and water saving.

**Q3. Write down factors affecting silting in canals.**

**Sol:** Silting in canals means deposition of silt particles carried by flowing water, which reduces carrying capacity.

Factors affecting silting are:

1. Velocity of flow – Low velocity causes deposition; high velocity causes erosion.
2. Silt concentration – Higher sediment load increases silting.
3. Size of particles – Coarser particles settle faster than fine particles.
4. Canal slope – Flatter slopes reduce velocity and promote deposition.
5. Shape and alignment – Bends and sudden widening cause eddies and deposition.
6. Roughness of bed – Rough beds reduce velocity and increase silt settlement.
7. Discharge variation – Sudden reduction in discharge leads to silt deposition.

**Q4. A crop requires a delta ( $\Delta$ ) of 1.0 m during a base period of 100 days.**

**Find:**

**(a) Duty of irrigation water, and**

**(b) Capacity of canal required to irrigate 1800 hectares.**

**Sol:** Given,

$$\Delta = 1.0 \text{ m}$$

$$B = 100 \text{ days}$$

$$\text{Relation: } \Delta = 8.64 B / D$$

(a) Duty,

$$D = 8.64 B / \Delta$$

$$D = (8.64 \times 100) / 1.0$$

$$D = 864 \text{ ha/cumec}$$

(b) Canal capacity,

$$\text{Area (A)} = 1800 \text{ ha}$$

$$Q = A / D$$

$$Q = 1800 / 864$$

$$Q = 2.08 \text{ cumec}$$

$$\text{Duty} = 864 \text{ ha/cumec}$$

$$\text{Required canal discharge} \approx 2.08 \text{ m}^3/\text{s}$$

**Q5. The Gross Command Area (GCA) of a canal system is 6000 hectares.  
Intensity of irrigation for Kharif season is 60%.  
The duty of water for the crop is 900 ha/cumec.**

**Calculate the discharge required in the canal.**

**Sol:** Given,

GCA = 6000 ha

Intensity = 60%

Area to be irrigated,

CCA irrigated =  $60/100 \times 6000$   
= 3600 ha

Duty (D) = 900 ha/cumec

Discharge,

$Q = \text{Area} / \text{Duty}$

$Q = 3600 / 900$

$Q = 4$  cumec

Required canal discharge =  $4 \text{ m}^3/\text{s}$

### **10 Marks Questions:**

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**Q1. Define irrigation and explain its need. Classify irrigation systems based on source and method of application.**

**Sol:** Irrigation:

Irrigation is the artificial supply of water to crops at required time and quantity to meet crop water requirement when rainfall is insufficient.

Necessity/Advantages:

- Ensures assured crop growth
- Increases yield and multiple cropping
- Protects crops from drought

- Improves food production and farm income

Classification of Irrigation:

1. Based on source:

- Canal irrigation
- Well/Tube well irrigation
- Tank irrigation
- Lift irrigation

2. Based on method of application:

- Surface irrigation – flooding, basin, border, furrow
- Sub-surface irrigation – water supplied below ground
- Sprinkler irrigation – water sprayed like rainfall
- Drip irrigation – water applied drop by drop near roots

3. Based on availability:

- Perennial irrigation
- Non-perennial (inundation) irrigation

Thus, irrigation method is selected based on soil, crop, topography and water availability.

**Q2. Define duty and delta of irrigation water. Describe different methods of application of irrigation water and explain how irrigation water is assessed/measured in the field.**

**Sol:** Duty (D):

Area irrigated by 1 cumec of water flowing continuously during base period. Unit: ha/cumec.

Delta ( $\Delta$ ):

Total depth of water required by a crop during base period. Unit: m or cm.

Relation:

$$\Delta = 8.64 B / D$$

Methods of application:

1. Surface irrigation:

Water flows over field by gravity.

Examples: basin, border, furrow.

Simple and economical but more losses.

2. Sub-surface irrigation:

Water supplied below soil surface.

Less evaporation but costly.

3. Sprinkler irrigation:

Water sprayed under pressure.

Uniform distribution and suitable for uneven land.

4. Drip irrigation:

Water supplied drop by drop near roots.

Very high efficiency and saves water.

Assessment of irrigation water:

- Discharge measured using weirs/notches or current meter
- Volume =  $Q \times \text{time}$
- Depth applied = Volume / Area
- Efficiency checked by conveyance and application efficiency

Proper assessment improves water use efficiency and increases duty.

## UNIT – 8: (Dams & Spillways)

### 2 Marks Questions:

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**Q1. Define a dam.**

**Sol:** A dam is a hydraulic structure constructed across a river or stream to obstruct and store water for irrigation, water supply, flood control, and power generation.

**Q2. Define free board.**

**Sol:** Free board is the vertical distance between the maximum water level in a reservoir and the top of the dam.

**Q3. Define spillway.**

**Sol:** A spillway is a structure provided in a dam to safely discharge excess flood water from the reservoir downstream.

**Q4. Write two components and their function of an earth dam.**

**Sol:** Components include the impervious core, which prevents seepage, and the shell, which provides stability to the dam.

**Q5. Differentiate between high dam and low dam.**

**Sol:** A high dam has a height greater than 30 m, while a low dam has a height less than 30 m.

**Q6. Write the function of spillway.**

**Sol:** The primary function of a spillway is to safely pass excess flood water without damaging the dam.

**Q7. What is an earthen dam?**

**Sol:** An earthen dam is a dam constructed mainly using soil materials such as clay, sand, and gravel.

**Q8. What is seepage?**

**Sol:** Seepage is the slow movement of water through the body or foundation of a dam.

**Q9. Write two failures of earthen dam.**

**Sol:** Failure due to seepage and failure due to slope instability.

**Q10. Write the components of spillway.**

**Sol:** Components include the control structure, discharge channel, energy dissipator, and downstream apron.

**5 Marks Questions:**

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**Q1. Explain the causes of failure of a gravity dam.**

**Sol:** The failure of a gravity dam may occur due to several reasons related to forces acting on it and foundation conditions.

**Overturning Failure:**

When the horizontal water pressure is very high, the dam may rotate about its toe and overturn.

**Sliding Failure:**

If the frictional resistance at the base is less than the horizontal water force, the dam may slide.

**Uplift Pressure Failure:**

Water pressure acting upward at the base reduces the effective weight of the dam, leading to instability.

**Crushing Failure:**

Excessive compressive stresses at the toe may cause crushing of concrete or masonry.

**Seepage and Earthquake Effects:**

Seepage through foundation and earthquake forces may further weaken the dam structure.

**Q2. Explain the forces acting on a dam.**

**Sol:** A dam is subjected to various forces during its operation.

**Water Pressure:**

Horizontal pressure exerted by stored water on the upstream face.

**Self-weight of the Dam:**

Acts vertically downward and provides stability against overturning and sliding.

**Uplift Pressure:**

Upward pressure at the base due to seepage flow under the dam.

Silt Pressure:

Pressure exerted by deposited silt on the upstream side.

Earthquake and Wave Forces:

Additional forces acting during earthquakes and wave action.

**Q3. Differentiate between earthen dam and gravity dam.**

**Sol:**

<b>Earthen Dam</b>	<b>Gravity Dam</b>
Constructed using soil materials	Constructed using concrete or masonry
Economical and easy to build	Costly and requires skilled construction
Suitable for wide valleys	Suitable for narrow valleys
Flexible in nature	Rigid structure
Suitable for weak foundations	Requires strong rock foundation

**Q4. Explain the methods of construction of an earthen dam.**

**Sol:** Earthen dams are constructed by the following methods:

Rolled Fill Method:

Soil is placed in layers and compacted using rollers. This method provides maximum strength and stability.

Hydraulic Fill Method:

Soil is carried by water and deposited at the dam site. It is less commonly used.

Semi-hydraulic Method:

Combination of rolled fill and hydraulic methods.

**Q5. Explain the function, location, and components of a spillway.**

**Sol:** Function:

A spillway safely disposes excess flood water from the reservoir to prevent overtopping of the dam.

Location:

It is usually located near the dam abutment or at a natural low point of the reservoir.

Components:

Control structure

Discharge channel

Energy dissipator

Downstream apron

### **10 Marks Questions:**

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**Q1. What is an earthen dam? Under what conditions is it preferred? Explain the different types of earthen dams.**

**Sol:** An earthen dam is a dam constructed mainly from compacted soil such as clay, sand, and gravel. These dams are widely used due to their low cost and simple construction. Earthen dams are suitable for wide valleys where construction of concrete dams is not economical.

Earthen dams are preferred when suitable soil materials are available near the site, foundation conditions are weak, and construction cost needs to be reduced. They are also preferred in earthquake-prone regions because of their flexible nature.

Based on construction, earthen dams are classified into the following types:

**Homogeneous Earthen Dam:**

Constructed using one type of soil throughout the dam section.

**Zoned Earthen Dam:**

Consists of an impervious core surrounded by pervious shells to control seepage.

**Diaphragm Dam:**

Contains a thin impervious membrane at the center to reduce seepage.

**Q2. Explain the causes of failure of a gravity dam. Draw the profile of a gravity dam.**

**Sol:** Failure of a gravity dam occurs when the resisting forces are less than the applied forces.

**Overturning:**

Occurs when water pressure creates excessive moment about the toe.

**Sliding:**

Happens when frictional force at the base is insufficient.

Uplift Pressure:

Reduces effective weight and leads to instability.

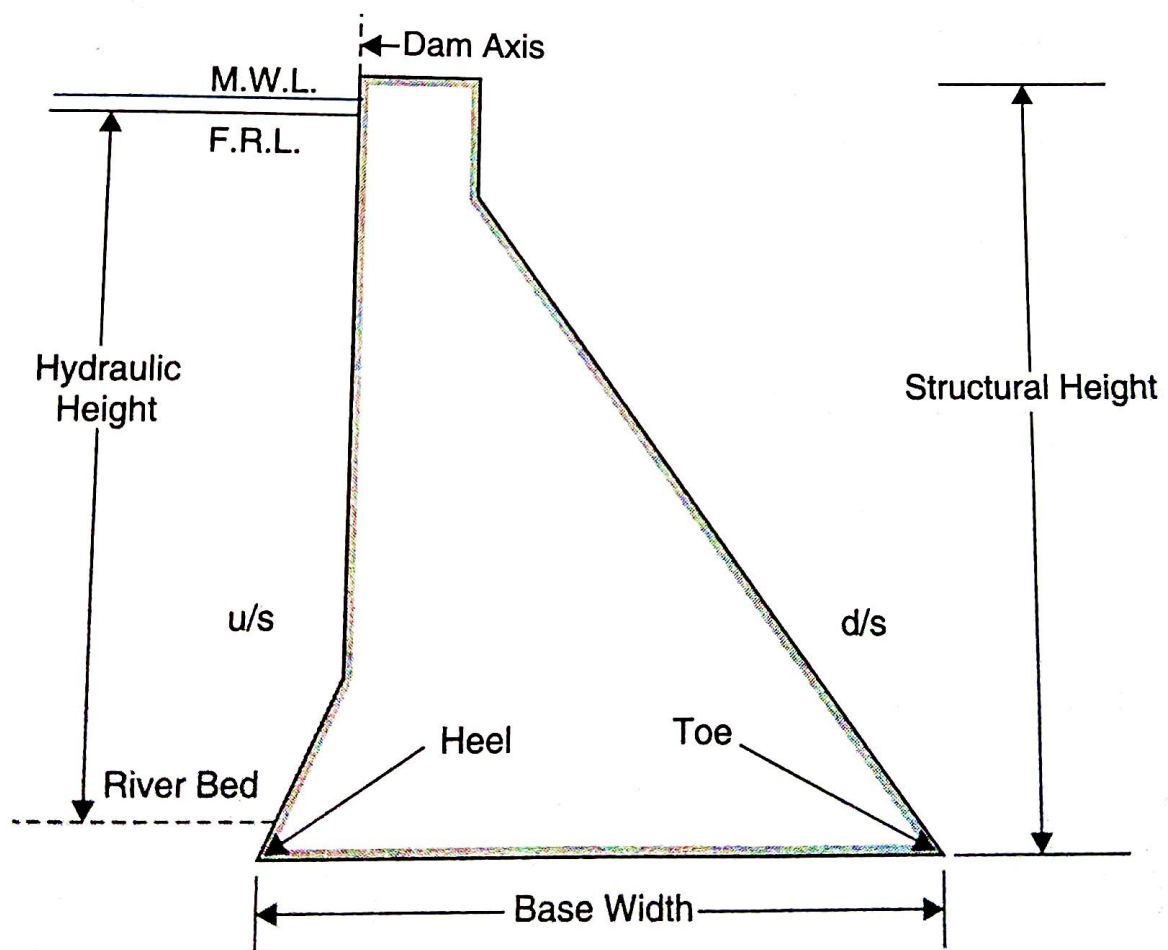
Crushing:

High compressive stress at the toe may crush concrete.

Foundation Failure:

Weak foundation strata and seepage may cause failure.

A gravity dam profile generally has a vertical upstream face and a sloping downstream face. Its stability depends mainly on its own weight.



## UNIT – 9 (Diversion Head Works & Canals)

### 2 Marks Questions:

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**Q1. What is a weir? Write its types.**

**Sol:** A weir is a low overflow structure constructed across a river to raise the water level and regulate discharge.

Types of weirs:

Sharp crested weir

Broad crested weir

Ogee weir

Vertical drop weir

Trapezoidal (Cipoletti) weir

**Q2. What are the components of a weir?**

**Sol:** Crest

Upstream glacis

Downstream glacis

Abutments

Apron

Cut-off walls

**Q3. What is cutting?**

**Sol:** Cutting is an earthwork operation in which soil is removed from natural ground to reach the required canal bed level.

**Q4. What is balancing depth?**

**Sol:** Balancing depth is the depth at which cutting equals filling, so no extra soil is required to be transported.

**Q5. What is an aqueduct?**

**Sol:** An aqueduct is a cross-drainage structure in which a canal passes over a drainage such as a river or stream.

**Q6. What is siphon?**

**Sol:** A siphon is a closed conduit used to convey water under pressure from a higher to a lower level.

**Q7. What is drainage?**

**Sol:** Drainage is the process of removing excess surface and sub-surface water from agricultural land.

**Q8. What is level crossing?**

**Sol:** A level crossing is a cross-drainage work in which the canal bed and drainage bed are at the same elevation.

**Q9. What is canal lining?**

**Sol:** Canal lining is the process of providing an impervious layer on the bed and sides of a canal to prevent seepage losses.

**Q10. Write components of barrage.**

**Sol:** Crest gates

Piers

Abutments

Upstream and downstream floors

Stilling basin

Divide wall

**5 Marks Questions:**

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**Q1. Describe the different types of losses in canals.**

**Sol:** Canal losses refer to the water that is lost during its conveyance from the source to the fields. The different types of canal losses are:

Seepage Loss:

Water seeps through the bed and sides of the canal due to the permeability of soil. It is the major loss in unlined canals.

Evaporation Loss:

Loss of water from the canal surface into the atmosphere due to heat, wind, and low humidity.

Transpiration Loss:

Water absorbed and released by vegetation growing along the canal banks.

Percolation Loss:

Downward movement of water into deeper soil layers, contributing to waterlogging.

Operational Losses:

Losses due to leakage at regulators, breaches, overtopping, and improper canal operation.

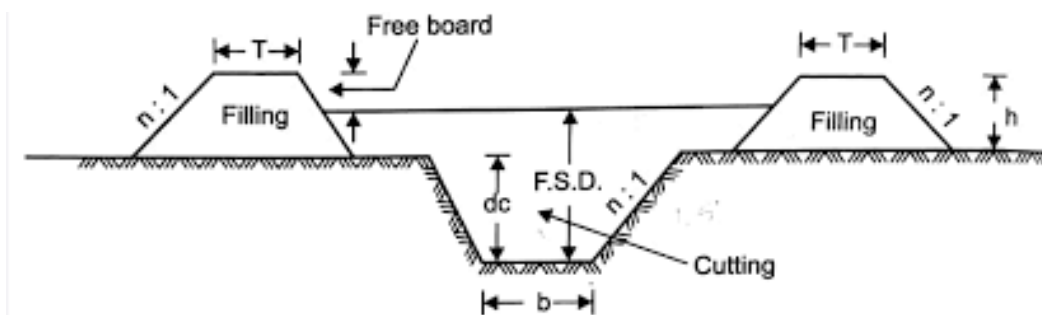
**Q2. Draw the cross-section of a canal in partially cutting and partially filling.**

**Sol:** A canal in partially cutting and partially filling is constructed when the natural ground level lies between the canal bed level and the top of the banks.

The lower portion of the canal is excavated (cut).

The upper portion is constructed using a bank embankment (fill) of excavated soil.

This type of canal section is economical as it balances earthwork and reduces transportation cost.



**Q3. Write the necessity and objectives of diversion head works.**

**Sol:** Necessity:

Diversion head works are required to divert river water into canals for irrigation, especially when the river water level is lower than the canal command area.

Objectives:

Raise the river water level

Divert required discharge into the canal

Regulate and control water supply

Exclude silt and debris from entering canals

Protect canal system from floods

**Q4. What is meant by cross-drainage work? Explain its necessity.**

**Sol:** Cross-drainage works are hydraulic structures constructed where a canal crosses a natural drainage, such as a river, stream, or nallah.

Necessity:

Ensure safe crossing of canal and drainage

Prevent damage to canal during floods

Maintain uninterrupted irrigation supply

Avoid excessive erosion and silting

Improve hydraulic efficiency of the system

**Q5. Write the different types of canal lining. Explain the advantages and disadvantages of canal lining.**

**Sol:** Types of Canal Lining:

Cement concrete lining

Brick lining

Stone pitching

Asphalt lining

Soil-cement lining

Advantages:

Reduces seepage losses

Prevents waterlogging

Increases discharge capacity

Reduces maintenance cost

Disadvantages:

High initial construction cost

Cracking due to temperature variation

Requires skilled labor

Difficult repairs

## 10 Marks Questions:

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### **Q1. Define diversion head works. Explain their necessity, objectives, and functions in an irrigation system.**

**Sol:** Diversion head works are permanent hydraulic structures constructed across rivers with the primary purpose of raising the upstream water level and diverting the required quantity of water into irrigation canals. They form the most important component of an irrigation system, particularly in alluvial rivers where water levels fluctuate significantly between seasons.

The necessity of diversion head works arises because, during dry seasons, the river water level often falls below the canal offtake level, making gravity flow into canals impossible. By creating a ponded water level upstream, diversion head works ensure a continuous and assured supply of irrigation water. They also help in regulating river flow during floods, thereby protecting the canal headworks and downstream structures from damage.

The objectives of diversion head works are multifold. They aim to raise the river water level to provide sufficient head for canal diversion and to control the quantity of water entering the canal system. These structures are designed to regulate and distribute water equitably according to irrigation demand. They also minimize silt entry into canals through the provision of under-sluices and sediment control arrangements, which improves canal efficiency and reduces maintenance. Furthermore, diversion head works protect the canal system against flood damage, reduce erosion near the canal head, and contribute to the overall stability and effectiveness of the irrigation network. Thus, diversion head works are indispensable for efficient water management and sustainable agricultural development.

### **Q2. Define waterlogging. Explain its causes, effects on agriculture, and methods of controlling waterlogging.**

**Sol:** Waterlogging is an adverse soil condition in which the groundwater table rises close to or above the root zone of crops, resulting in excessive soil saturation and poor aeration. This condition restricts oxygen availability to plant roots, adversely affecting crop growth, reducing soil fertility, and ultimately lowering agricultural productivity. Waterlogging is a major problem in irrigated command areas and poses a serious threat to sustainable agriculture.

The causes of waterlogging are primarily associated with faulty irrigation and drainage practices. Excessive and unscientific irrigation leads to an accumulation of

water in the soil profile. Seepage from unlined canals, distributaries, and reservoirs further contributes to the rise of the groundwater table. Poor surface drainage, flat terrain, heavy rainfall, and the presence of impervious sub-soil layers prevent natural percolation and outflow of water, thereby aggravating waterlogging conditions over time.

Controlling waterlogging requires an integrated approach that combines preventive and remedial measures. Canal lining is an effective method for reducing seepage losses and limiting groundwater recharge. Proper surface drainage systems are essential for quickly removing excess rainwater and irrigation runoff, while subsurface drainage helps lower the groundwater table. Regulated irrigation practices, such as optimum water application and improved scheduling, prevent over-irrigation. Agronomic measures, such as crop rotation and deep-rooted crop cultivation, improve soil aeration and water uptake. In severely affected areas, pumping and lowering of the water table provide effective relief. With proper planning and management, waterlogging can be effectively controlled, ensuring improved agricultural productivity and long-term sustainability.

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