## B45 Hydraulics and Hydraulic Machinery 3.0

**Preamble:**

This subject aims at an experimental way of studying the fluid flow, which deals with design, measurement and behavior of flow in open channels. Further it is also involves Dimensional analysis, model testing and design of hydraulic machines at an optimum cost.

**Program outcomes addressed**

a. Graduates will demonstrate knowledge of Mathematics, Science, and Engineering.
b. Graduates will demonstrate an ability to identify, formulate and solve complicated engineering problems.
c. Graduates will demonstrate skills to use modern engineering tools, sophisticated equipments to analyse engineering problems.

**Competencies**

At the end of the course the student should be able to

1. Understand the various types of open channel flow
2. Determine cross sections of different types of channels
3. Understand the creation of hydraulic jumps and its advantages
4. Apply the dimensional analysis on hydraulic engineering problems
5. Understand the behavior of turbines and pumps
6. Determine the parameters of turbines and pumps
7. Determine the performance of turbines and pumps under different operating conditions

**Assessment Pattern**

| S.No. | Bloom's Category | Test 1 | Test 2 | Test 3/ End-semester Examination |
|---|---|---|---|---|
| 1 | Remember | 20 | 20 | 20 |
| 2 | Understand | 20 | 20 | 20 |
| 3 | Apply | 60 | 60 | 60 |
| 4 | Analyse | 0 | 0 | 0 |
| 5 | Evaluate | 0 | 0 | 0 |
| 6 | Create | 0 | 0 | 0 |

**Course Level Learning Objectives**

**Remember**

1. What is an open channel flow?
2. Define the following terms
   (i) Hydraulic radius (ii) Wetted Perimeter and (iii) Slope of the bed
3. State Manning's formula.
4. List the advantages of Hydraulic jump.
5. Briefly explain
   (i) Geometric similarity (ii) Kinematic similarity and (iii) Dynamic similarity
6. Enumerate the losses which occur when a centrifugal pump operates.
7. What is negative slip in reciprocating pump? Explain with neat sketches the function of air vessels in a reciprocating pump.
8. Define velocity of approach?
9. What are the advantages of a triangular notch?
10. Draw the velocity triangles for the Pelton wheel.
11. What is a draft tube? Why is it used in reaction turbines?
12. What is the basis of selection of a turbine at a particular place?
13. Define specific speed of a turbine
14. Define hydraulic efficiency of a turbine.

**Understand**

1. Differentiate between steady and unsteady flow in a channel.
2. Why is a bed slope provided for an open channel?
3. Can standing wave serve as a method of dissipating energy?
4. Explain Rayleigh's method of obtaining relation between a given set of variables influencing a phenomenon.
5. Differentiate between fixed and movable bed models
6. Why Centrifugal pumps are connected in series and in parallel?
7. What is the effect of acceleration of the piston on the velocity and acceleration of water in suction and delivery pipes?
8. Obtain an expression for the pressure head due to acceleration in suction and delivery pipes.
9. Differentiate between broad crested weir and narrow-crested weir.
10. What do you understand by cipolletti weir?

11. Differentiate between impulse and reaction turbine and give examples.
12. Differentiate model and prototype.
13. Why the characteristics curves are drawn for pumps and turbines?
14. What are the advantages of air vessels?
15. What are different types of channels?
16. What is the purpose of providing bed slope in channel?
17. What do you mean by most economical section of an open channel?
18. What do you understand by gradually varied flow?
19. What is a hydraulic jump in an open channel?
20. What are the effects of cavitation in turbines?

**Apply**

1. A rectangular channel is 7m wide and 1.8m deep. If the bed of the channel is laid at a slope of 1in 6000, calculate the velocity of flow and discharge. Use Chezy's equation and assume C= 50
2. Determine the dimensions of the most economical trapezoidal earth-lined channel to carry $15m^3/s$ at a slope of 1in 2400. Apply Manning's equation and assume n = 0.020
3. The pressure difference Δp in a pipe of diameter D and length L due to turbulent flow depends on the velocity V, viscosity μ, density ρ and roughness k. Using Buckingham's π-theorem, obtain an expression for Δp.
4. A jet of water 50mm in a diameter, issues with a velocity of 10m/s and impinges on a stationary flat plate which destroys its forward motion. Calculate the force exerted by the jet on the plate and the work done.
5. A Pelton wheel is receiving water from a penstock with a gross head of 600m. One third of gross head is lost in friction in the penstock. The rate of flow through the nozzle fitted at the end of the penstock is $2.5m^3/s$. The angle of deflection of the jet is $162^o$ Calculate the hydraulic efficiency of the Pelton wheel.
6. A Pelton wheel is to be designed for the following specifications
   Shaft power = 9560 kW, Head = 350m, Speed = 750 rpm, Overall efficiency = 85%, Jet diameter = not to exceed $1/6^{th}$ of the wheel diameter. Take $C_v$ = 0.985 and speed ratio = 0.45. Determine (i) The wheel diameter, (ii) Diameter of the jet and (iii) Number of jets required.
7. An inward flow reaction turbine has external and internal diameters as 0.9m and 0.45m respectively. The turbine is running at 200rpm and width of turbine at inlet is 200mm. The velocity of flow through the runner is constant and is equal to 1.8m/s. The guide blade at inlet is $10^0$ and the discharge at the outlet of the turbine is radial. Determine: i)

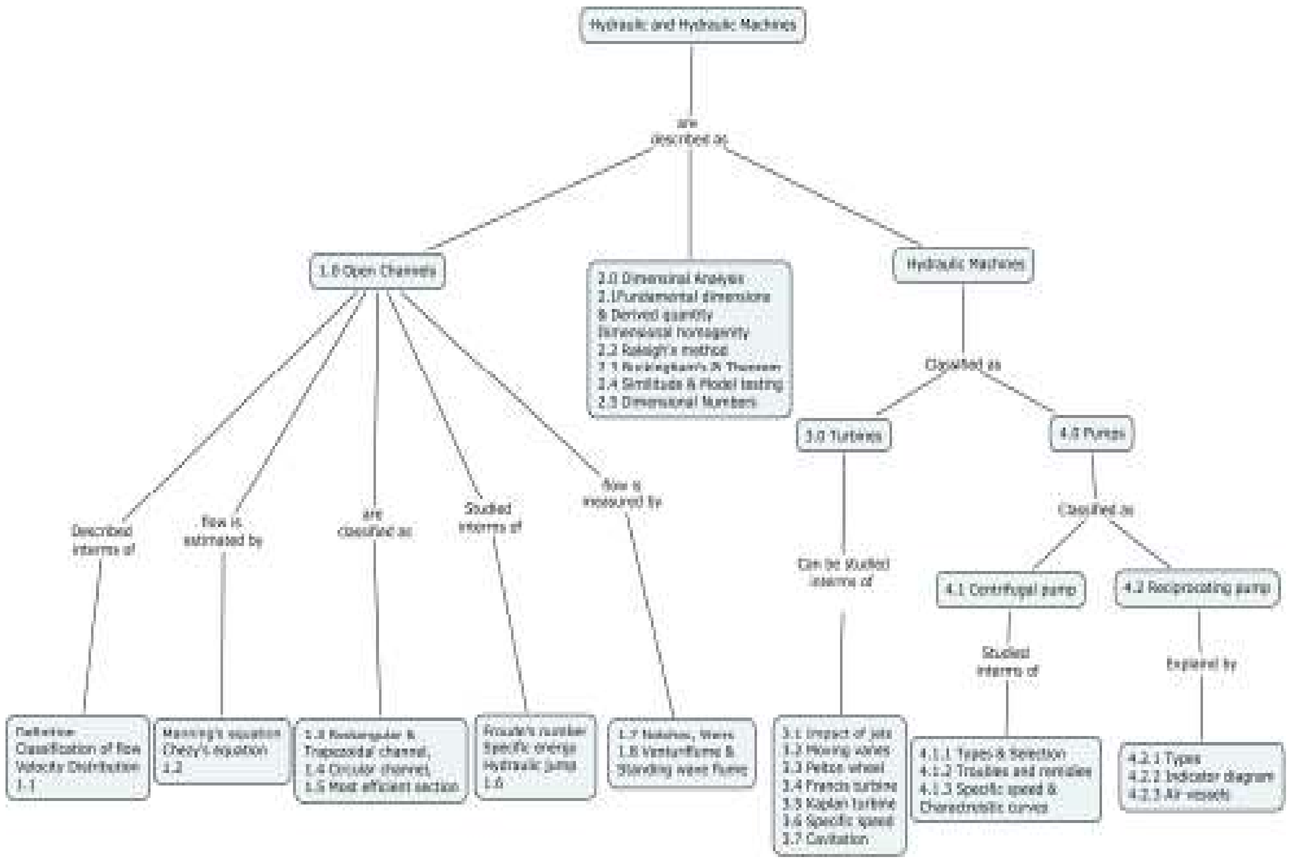
The absolute velocity of water at inlet, ii) The velocity of whirl at inlet, iii) The relative velocity at inlet, iv) The runner blade angles at inlet and at outlet, v) Width of runner at outlet, vi) Rate of flow through the runner vii) Power developed and viii) Hydraulic efficiency of the turbine.

8. A centrifugal pump having outer diameter equal to two times the inner diameter and running at 1000 rpm, works against a total head of 40m. The velocity of flow through the impeller is constant and equal to 2.5 m/s. The vanes are curved back at an angle of $40^{o}$ at outlet. If the outer diameter of the impeller is 500mm and width at outlet is 50mm, determine (i) Vane angle at inlet, (ii) Work done by impeller on water per second and (iii) Manometric efficiency.
9. The cylinder bore diameter of a single acting reciprocating pump is 150mm and its stroke is 300mm. The pump runs at 50 rpm and lifts water through a height of 25m. The delivery pipe is 22m long and 100mm in diameter. Find the theoretical discharge and theoretical power required to run the pump. If the actual discharge is 4.2 litres/s. Find the percentage of slip. Also determine the acceleration head at the beginning and middle of the delivery stroke.
10. A rectangular channel 2.5m wide has a discharge of 300 litres per second, which is measured by a right angled V notch. Find the position of the apex of the notch from the bed of the channel if the maximum depth of water is not to exceed 3.0m. Take Cd = 0.60.
11. The discharge of water through a rectangular channel of width 7m is $16m^3/s$ when the depth of flow of water is 1.2m, Calculate (i) Specific energy of the flowing water, (ii) critical depth and critical velocity and (iii) value of minimum specific energy.
12. Determine the number of jets, diameter of the wheel, diameter of the jet of Pelton wheel turbine for a head of 50m when running at 250 rpm. The Pelton wheel turbine develops 90kW shaft power. The velocity of buckets =0.45 times the velocity of jet, overall efficiency is 85% and co-efficient velocity is 0.98
13. A hydraulic jump forms at the downstream end of spillway carrying 18 $m^3/s$ discharge. If the depth before jump is 0.80m, determine the depth after jump and energy loss.
14. A trapezoidal channel has side slopes of 3 horizontal to 4 vertical and the slope of the bed is 1 in 2000. Determine the optimum dimensions of the channel, if it is to carry water at $0.4m^3/s$. Take Chezy's constant as 80.
15. Using Buckingham's π-theorem, show that the discharge Q consumed by an oil ring is given by $Q = Nd^3\, \Phi\, [\mu / \rho N d^2, \sigma / \rho N^2 d^3, w / \rho N^2 d]$ where, d = internal diameter of

the ring, N = rotational speed, ρ = density, μ = viscosity, σ = surface tension and w = specific weight of oil.

16. The frictional torque T of a disc of diameter D rotating at a speed N in a fluid of viscosity μ and density ρ in a turbulent flow is given by $T = D^5 N^2 \rho \varphi [\mu / D^2 N \rho]$. Prove this by the method of dimension.

**Concept Map**




**Course content and Lecture schedule**

| No | Topic | No. of Lectures |
|---|---|---|
| 1.0 | **Open channel flow** | |
| 1.1 | Definition, classification, and velocity distribution in open channels | 1 |
| 1.2 | Chezy's and Manning's equation | 1 |
| 1.3 | Flow through rectangular and trapezoidal channels | 2 |
| 1.4 | Flow through Circular channels, | 1 |
| 1.5 | Most efficient channel section | 2 |
| 1.6 | Froude's number, Specific energy diagram, Hydraulic jump | 3 |
| 1.7 | Flow measurement by Notches & Weirs, | 2 |

| | | |
|---|---|---|
| 1.8 | Venturiflume and Standing wave flume | 2 |
| 2.0 | **Dimensional Analysis** | |
| 2.1 | Fundamental dimensions, derived quantity, and Dimensional homogeneity | 1 |
| 2.2 | Rayleigh's method | 2 |
| 2.3 | Buckingham's ∏-Theorem | 2 |
| 2.4 | Similitude & Model testing | 2 |
| 2.5 | Dimensionless numbers | 2 |
| 3.0 | **Hydraulic Turbines** | |
| 3.1 | Impact of jets on vanes | 1 |
| 3.2 | Moving vanes | 1 |
| 3.3 | Pelton wheel | 2 |
| 3.4 | Francis turbine | 2 |
| 3.5 | Kaplan turbine | 1 |
| 3.6 | Specific speed of turbines | 1 |
| 3.7 | Cavitation in turbines | 1 |
| 4.0 | **Pumps** | |
| 4.1 | **Centrifugal Pump** | |
| 4.1.1 | Types of centrifugal pumps, Selection of pumps, | 1 |
| 4.1.2 | Troubles and remedies, Multistage pumps | 1 |
| 4.1.3 | Characteristics curves and Specific speed | 1 |
| 4.2 | **Reciprocating Pump** | |
| 4.2.1 | Types of Reciprocating pump | 1 |
| 4.2.2 | Indicator diagram | 1 |
| 4.2.3 | Slip and Air vessels | 1 |
| 4.2.4 | Submersible and jet pumps | 2 |

**Syllabus**

**Open channel flow:** Definition, classification, and velocity distribution in open channels. Chezy's and Manning's equation. Flow through rectangular, Trapezoidal and Circular channels. Hydraulically most efficient channel section. Froude's number, Specific energy diagram, Hydraulic jump, Notches, Weirs, Venturi flume and Standing wave flume. **Dimensional Analysis:** Fundamental dimensions and derived quantity, Dimensional homogeneity, Rayleigh's method and Buckingham's ∏-Theorem, Similitude, Model testing, Dimensionless number. **Impact of jets:** Impact of jets on vanes. **Hydraulic turbines:** Historical development of turbines and classification, Pelton wheel, Francis turbine, Kaplan turbine, specific speed and Cavitation. **Pumps:** Types of centrifugal pumps, Selection of pumps, Troubles and remedies, Multistage pumps, Characteristics curves, Specific speed. Single and double acting reciprocating pump, Multicylinder pump, Indicator diagram, Slip and Air vessels, submersible and jet pumps.

**Text Book**

1. Modi P.N and Seth S.M, "Hydraulics and Fluid Mechanics" Standard Book House, New Delhi, 2005

**References**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2. Rajput. R.K, "A Text book of Fluid Mechanics", S.Chand and Company, New Delhi, 2009
3. Subramanya K, "Flow in open channels", Tata McGraw-Hill Publishing Company, 2004
4. Ramamrutham S and Narayanan R "Hydraulics and Fluid Mechanics and Fluid Machines", Dhanpat rai Publishing Co (P) Ltd, New Delhi 2000
5. Robert W.Fox and Alan T. Mc Donald, "Introduction to Fluid Mechanics" Fourth Edition, John Willey & sons, New York, 1995
6. Kumar.K.L, "Engineering Fluid Mechanics" S.Chand and Company Ltd, New Delhi, 2004


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