Institute / School Name	Darbhanga College of Engineering, Darbhanga
Program Name	B.Tech Mechanical Engineering.
Course Code	021510
Course Name	Fluid Mechinery
Course Coordinator Name	Mr. Prabhakar kumar

DEPARTMENT OF MECHANICAL ENGINEERING

INDEX

Department of Mechanical Engineering

Vision

- To strengthen the region through imparting superior quality technical education and research; which enables the fulfillment of industrial challenge and establish itself as a Centre of Excellence in the field of Mechanical Engineering.

Mission

- To build an academic environment of teaching and lifelong learning for students to make them competitive in context with advance technological, economical and ecological changes.
- To enable the students to enhance their technical skills and communications through research, innovation and consultancy projects.
- To share and explore the accomplishments through didactic, enlightenment, R & D programs with technical institution in India and abroad.

Mechanical Engineering Program Educational Objectives

After 4 year of graduation a B.TECH (ME) graduate would be able to

- Graduates will spread and enhance their technical capabilityand proficiency through vital domain of economical, environmental and social concerns affiliated with the mankind and industry.
- Graduates will able to work professionally with modern methods in the area of Thermal, Mechanical System Design, Manufacturing, Measurement, Quality control and other interdisciplinary fields of concerns.
- Graduates will practice Mechanical engineering in sensible, flexible and ethical manner to benefit the society, industry and nation toward the rapidly changing global technical standards.
- Graduates will serve as ambassadors for engineering by their knowledge, creativity, imagination and innovation and set new extremes in their profession through lifelong learning.

Mechanical Engineering Student Outcomes

Students who complete the B.TECH degree in ME will be able to:

1. An ability to apply the knowledge of mathematics, basic sciences and engineering concepts to solve the complex engineering problems.

2. The ability to conduct experiments and to critically analyze and interpret the experimental data to reach at substantial outcomes.
3. An ability to design systems, components, or processes to meet appropriate needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
4. An ability to identify, formulates, and solves the complex engineering problems.
5. An ability to function on multi-disciplinary teams that leads the multi-disciplinary projects.
6. An understanding of professional and ethical responsibility.
7. An ability to communicate effectively with written, oral, and visual means.
8. An ability to understand the impact of engineering solutions in a global, environmental, economical and societal context.
9. An ability to recognize the need to engage in life-long learning.
10. An ability to attain knowledge of contemporary issues.
11. An ability to use the techniques, skills, and modern tools necessary for Mechanical engineering practice.
12. Possess ability to estimate costs, estimate quantities and evaluate materials for design and manufacturing purposes.

Course Description:

Fluid mechanics is the branch of physics that studies fluids (liquids, gases, and plasmas) and the forces on them. Fluid mechanics can be divided into fluid statics, the study of fluids at rest; fluid kinematics, the study of fluids in motion; and fluid dynamics, the study of the effect of forces on fluid motion. It is a branch of continuum mechanics, a subject which models matter without using the information that it is made out of atoms, that is, it models matter from a macroscopic viewpoint rather than from a microscopic viewpoint. Fluid mechanics, especially fluid dynamics, is an active field of research with many unsolved or partly solved problems. Fluid mechanics can be mathematically complex. Sometimes it can best be solved by numerical methods, typically using computers. A modern discipline, called computational fluid dynamics (CFD), is devoted to this approach to solving fluid mechanics problems. Also taking advantage of the highly visual nature of fluid flow is particle image velocimetry, an experimental method for visualizing and analysing fluid flow.

Pre-requisites

1 Basic system of units
2 Statics and dynamics
3 Mathematics of the motion of particles and rigid bodies and the relation of force and motion of particles
4 Fundamental concepts and laws of mechanics including equilibrium and Newton's laws of motion
5 Differential calculus

Course Objectives of the Hydraulic Machines

The objective of the course is to enable the student;

1. Define the nature of a fluid.
2. Show where fluid mechanics concepts are common with those of solid mechanics and indicate some fundamental areas of difference.
3. To introduce the concepts of momentum principles
4. To impart the knowledge on pumps and turbines
5. To impart the knowledge of impact of jets.
6. To introduce the concepts of the working and design aspects of hydraulic machines like turbines and pumps and their applications

Instructional learning out Comes

1. Student will be able to develop to gain basic knowledge on Fluid Statistics, Fluid Dynamics, closed conduit flows, hydro-electric power stations.
2. Student will be able to design various components of pumps and turbines and study their characteristics.

Mapping on to Programme Educational Objectives and Programme Out Comes:

Relationship of the course to Programme out comes:

1	Graduates will demonstrate knowledge of mathematics, science and engineering applications	√
2	Graduates will demonstrate ability to identify, formulate and solve engineering problems	
3	Graduates will demonstrate an ability to analyze, design, develop and execute the programs efficiently and effectively	
4	Graduates will demonstrate an ability to design a system, software products and components as per requirements and specifications	
5	Graduates will demonstrate an ability to visualize and work on laboratories in multi-disciplinary tasks like microprocessors and interfacing, electronic devices and circuits etc.	
6	Graduates will demonstrate working in groups and possess project management skills to develop software projects.	
7	Graduates will demonstrate knowledge of professional and ethical responsibilities	
8	Graduates will be able to communicate effectively in both verbal and written	

9	Graduates will show the understanding of impact of engineering solutions on society and also be aware of contemporary issues like global waste management, global warming technologies etc.	
10	Graduates will develop confidence for self education and ability for life long learning.	
11	Graduates can participate and succeed in all competitive examinations and interviews.	

Relationship of the course to the program educational objectives :

PEO 1	Our graduates will apply their knowledge and skills to succeed in a computer engineering career and/or obtain an advanced degree.	
PEO 2	Our graduates will apply basic principles and practices of computing grounded in mathematics and science to successfully complete hardware and/or software related engineering projects to meet customer business objectives and/or productively engage in research.	√
PEO 3	Our graduates will function ethically and responsibly and will remain informed and involved as fully in their profession and in our society.	√
PEO 4	Our graduates will successfully function in multi-disciplinary teams.	
PEO 5	Our graduates will communicate effectively both orally and in writing.	

Teaching/Learning Methodology

A mixture of lectures, tutorial exercises, and case studies are used to deliver the various topics. Some of these topics are covered in a problem-based format to enhance learning objectives. Others will be covered through directed study in order to enhance the students' ability of "learning to learn." Some case studies are used to integrate these topics and thereby demonstrate to students how the various techniques are inter-related and how they can be applied to real problems in an industry.

02 1x10 FLUID MACHINERY
L-T-P : 3-0-3 **Credit : 5**

Introduction – classification of fluid machinery. **Lecture: 1**

Dynamic action of fluid jet – Impact of fluid jet on fixed and moving flat places, impact of jet on fixed and moving curved vanes, flow over radial vanes, jet propulsions. **Lecture: 4**

Euler's fundamental equation, degree of reaction. **Lecture: 2**

Hydraulic turbines, introduction, classification, impulse turbine, construction details, velocity triangles, power and efficiency calculations, reaction turbines; constructional details, working principle, velocity triangles, power and efficiency calculations, draft tube, cavitation, governing. **Lecture: 10**

Principle of similarity in fluid machinery; unit and specific quantities, testing models and selection of hydraulic turbines Lecture **: 3**

Positive displacement pumps: Reciprocating pump; working principle, classification, slip, indicator diagram, effect of friction and acceleration, theory of air vessel, performance characteristics gas gear oil pump and screw pump. **Lecture: 4**

Rotodynamic pumps: Introduction, classification, centrifugal pump; main components, working principle velocity triangle, effect of shape of blade specific speed, heats, power and efficiency, calculations minimum steering speed, multi stage pumps, performance characteristic, comparison with reprobating pump.

Air compressor: Reciprocating compressor, introduction, P-V diagram, calculation of isothermal and adiabatic work and efficiency, free air delivery, slippage, volumetric efficiency, effect of clearance, multistage compression,inter cooling. **Lecture: 5**

Rotary compressor: Introduction fans, blower and compressor, state and total head, centrifugal compressor, velocity triangles, slip factor, losses and efficiencies, performance characteristic. **Lecture: 6**

Text Books :

- Hydraulics & Hydraulic Machines by Vasandari
- Hydrantic Machine by RD Purohit
- Hydraulics & Hydraulic Machines by R.K Bansal

Course Plan

Lecture Number	Date of Lecture	Topics	Web Links for video lectures	Text Book / Reference Book / Other reading material	Page number of Text Book(s
1		**Introduction**		TB1	
		Introduction – classification of fluid machinery			
4		**Dynamic action of fluid jet**			
		Dynamic action of fluid jet – Impact of fluid jet on fixed and moving flat places, impact of jet on fixed and moving curved vanes, flow over radial vanes, jet propulsions.		Self-prepared notes, PK NAG	
6		**Euler's fundamental equation**		TB1	8-26
		Euler's fundamental equation, degree of reaction		Self-prepared notes	
Mid-Semester Exam (Syllabus covered from 1-10 lectures)					
8		**Hydraulic turbines, introduction**		TB1	28-39
		Hydraulic turbines, introduction, classification, impulse turbine, construction details, velocity triangles, power and efficiency calculations, reaction turbines; constructional details, working principle, velocity triangles, power and efficiency calculations, draft tube, cavitation, governing.		Self-prepared notes	
Assignment 1					
5				TB1	41-74
		Principle of similarity in fluid machinery; unit and specific quantities, testing models and selection of hydraulic turbines		Self-prepared notes	
4				TB1	99-112
		Positive displacement pumps: Reciprocating pump; working principle,			

		classification, slip, indicator diagram, effect of friction and acceleration, theory of air vessel, performance characteristics gas gear oil pump and screw pump			
4		**Rotodynamic pumps**		TB1	140-148
		Rotodynamic pumps: Introduction, classification, centrifugal pump; main components, working principle velocity triangle, effect of shape of blade specific speed, heats, power and efficiency, calculations minimum steering speed, multi stage pumps, performance characteristic, comparison with reprobating pump.			
4		**Air compressor**		TB1	149-159
		Air compressor: Reciprocating compressor, introduction, P-V diagram, calculation of isothermal and adiabatic work and efficiency, free air delivery, slippage, volumetric efficiency, effect of clearance, multistage compression,inter cooling			
6		**Rotary compressor**			
		Rotary compressor: Introduction fans, blower and compressor, state and total head, centrifugal compressor, velocity triangles, slip factor, losses and efficiencies, performance characteristic.			

SESSION PLAN

d No.	Date	Topic to be covered in One Lecture	Remarks
UNIT-I: FLUID STATICS			
1		Introduction to fluid mechanics and hydraulic machines	
2		Types of fluids and description, Dimensions and units	
3		Fluids and their properties: Continuum, density, and specific properties, viscosity: Newton's law of viscosity, factors affecting viscosity, units involved and Calculation of viscosity	
4		surface tension- bubble, droplet and jet, calculations, compressibility and bulk modulus concepts, formula derivation and related problems	
5		Vapour pressure atmospheric pressure, gage pressure and vacuum pressure	
6		Tutorial - Problems on Density & Viscosity	
7		Tutorial- Problems on surface tension	
8		Concept of pressure- Pressure measurement-piezometer, U-tube manometer	
9		Manometry: Types of manometers, Single-tube manometer, problem	
10		Tutorial - Problems on single tube Manometers	
11		U-tube manometers, concept involved and problems	
12		Differential manometer concept involved and problems, Inclined manometer and problem Discussion of assignment problem	
13		Tutorial- Problems on differential manometer	
14		Tutorial- Problems on differential manometer	
15		Tutorial - Problems on Inverted U-tube Manometer	
UNIT-II: FLUID KINEMATICS			
16		System and Control Volume, Definition, Differences	
17		Types of flow: Lagrangian and Eulerian types of flow, difference existing between them	
18		Steadiness and uniformity of flow. Acceleration of flow	

19		Stream, streak and path lines, Rotational flow and ir-rotational flow, practical examples for the concepts Stream line, streak line & path line	
20		Continuity equation derivation in differential form and problem	
21		Tutorial- Problems on Continuity equation	
22		One dimensional flow derivation	
23		Three dimensional flow derivation	
24		Tutorial - Problems on one dimensional flow equation	
25		Tutorial - Problems on three dimensional flow equation	
	UNIT-II: FLUID DYNAMICS		
26		Euler's - linear momentum equation derivation	
27		Tutorial - Problems on momentum equation	
28		Concept of angular momentum, equation derivation. Bernoulli's equation from Euler's equation, problem	
29		Application on force on pipe bend, problems	
30		Tutorial - Problems on force on pipe bend, problems	
	UNIT-III: BOUNDARY LAYER CONC EPTS		
31		Boundary layer theory- boundary development on a flat plate, laminar' transition, turbulent curves, displacement	
32		Momentum thickness formula derivation	
33		Boundary layer Transition	
34		Separation of flow over bodies: stream linec and bluff bodies, Flow over cylinders in stationery, rotation, ae:ofoil	
35		Problems to calculate lift and drags forces and their co-efficient	
	UNIT-III: CLOSED CONDUIT FL(W		
36		Reynolds's experiment	
37		Development of flow in pipes, Losses encountered in pipe flow-Pipe friction-Darcy- Weisbach equation on derivation	
38		Minor Loss, Types of minor losses, formulas in olved in each minor loss	
39		Problems with combined major and minor loss. Discussion of assignment	
40		Pipes in series and pipes in parallel	

41		Total energy line- hydraulic gradient line.	
42		Venturi-meter, Actual and theoretical discharge, derivation of co-efficient of discharge, problems to calculate Cd. Discussion Assignment problem	
43		Orifice meter, Actual and theoretical discharge, derivation of co-efficient of discharge, problems to calculate Cd.	
44		Tutorial - Problems on Venturi-meter and Orifice meter	
45		Pitot tube and flow nozzle	
UNIT-IV: BASICS OF TURBO MACHINERY			
46		Force acting on stationary flat and inclined plate	
47		Force acting on moving flat and inclined plate	
48		Jet striking tangentially, velocity diagrams	
49		Velocity triangles	
50		Hinged plate and radial curved vanes	
51		Flow over radial vanes, problems	
UNIT-IV: HYDRAULIC TURBINES			
52		Turbines- classification, working principle involved. Impulse turbine, velocity triangle, formula involved	
53		Working principles Pelton wheel	
54		Problems in impulse turbine with velocity triangle	
55		Working principles Francis turbine	
56		Reaction turbine- velocity triangle, formula involve	
57		Problems in reaction turbine using velocity triangle	
58		Working principles Kaplan turbine	
59		Problems in reaction turbine using velocity triangle	
60		Performance comparison of hydraulic machines- relating efficiency, work done, head	
61		Draft tube theory functions	
UNIT-IV: PERFORMANCE OF HYDRAULIC TURBINES			
62		Geometric similarity, Unit and specific quantities	
63		Performance Characteristic curves of Hydraulic Turbines, cavitation	
64		Governing of turbines	
65		Selection of turbine, surge tank, water hammer, problems	

66		Discussion of assignment problems, over view of all the above units	
UNIT-V:CENTRIFUGAL PUMP			
61		Centrifugal pump: Classification, Concept involved, Work done and efficiency formula, Working principles	
62		Barometric Head, Losses and efficiencies	
63		Specific Speed and unit quantities, NPSH, problems	
64		Pumps in series and parallel, performance characteristic curves	
65		Problems in centrifugal pump	
66		Problems in centrifugal pump	
67		Working of principles Reciprocating pump	
68		Discharge and slip, Indicator diagrams	
69		Discussion of previous question papers	
70		Problems in centrifugal pump	

QUESTION BANK

1. (a) Differentiate between: (i) Liquids and Gases (ii) Cohesion and Adhesion (iii) Real fluid and Ideal fluid (iv) Compressible and Incompressible fluids. (v) Specific weight and specific volume of a fluid.

   (b) In a stream of glycerin in motion, the velocity gradient at a certain point is 0.30 meters per sec per meter. Calculate the shear stress at the point If the mass density of the liquid is 1275 kg/m and the kinematic viscosity is 6.30 x $10^{-4}m^2$/sec.

2. Two large plane surfaces are 2.4 cm apart. The space between the surfaces is filled with glycerine. What force is required to drag a very thin plate of surface area 0.5 square metre between the two large plane surfaces at a speed of 0.6 m/s, if (i) The thin plate is in the middle of the two plane surfaces, and (ii) The thin plate is at a distance of 0.8 cm from one of the plane surfaces. Dynamic viscosity of glycerine = 8.10 x 10^{-1} Ns/m^2.

3. (a) The pressure of water increases with depth in the ocean. At the surface, the density was measured as 1024.5 kg/m^3. The atmospheric pressure is 1.01 bar. At a certain depth where the pressure was 900 bar the density was measure as 1065.43 kg/m^3. Determine the average value of bulk modulus.

   (b) Differentiate between the three states of mater.

   (c) Distinguish between compressible and incompressible fluids and vapour and gas.

4. (a) Explain the concepts of (i) vapour pressure (ii) partial pressure (iii) surface tension

   (b) A shaft of 150 mm diameter rotates in bearings with a uniform oil of thickness 0.8 mm. Two bearing of 150 cm width are used. The viscosity of the oil is 22 Centi Poise. Determine the torque if the speed is 210 rpm.

5. (a) determine the pressure difference between A and B shown in figure 1

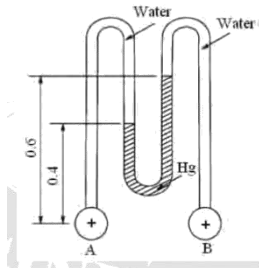


Figure 1:

(b) Determine the pressures at locations 1 and 2 in figure 2.

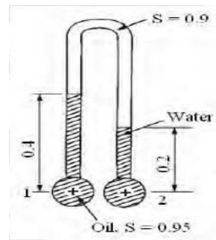


Figure 2:

6. A U-tube manometer has both its limbs enlarged to 25 times the tube area. Initially the tube is filled to some level with oil of specific weight. Then both limps are filled with fluid of specific weight to the same level, both limbs being exposed to the same pressure. When a pressure is applied to one of the limbs the manometric fluid rises by 'h' m. derive an expression for the pressure difference in the limbs. In both cases assume that the liquid level remains in the enlarged section.
7. A circular disc rotates over a large stationary plate with a 2 mm thick fluid film between them, the viscosity of the fluid being 40 Centi Poise. The torque required to rotate the disc at 200 rpm was 0.069 Nm. Determine the diameter of the disc.
8. (a) Define density, specific volume, weight density and specific gravity.

   (b) A liquid with kinematic viscosity of 2.7 centistokes fills the space between a large stationary plate and a parallel plate of 500 mm square, the film thickness being 1 mm. if the force required to pull the smaller plate with a uniform velocity of 3 m/s was 1.734 N, determine specific weight of the liquid. Assume that the liquid film is maintained all over.
9. (a) Define kinematic viscosity and explain the significance of the same.

   (b) Derive an expression for the torque and power required to overcome the viscous drag for a shaft running at a particular rpm.

(c) A hydraulic lift shaft of 500 mm diameter moves in a cylindrical sleeve the length of engagement being 2 m. The interface is filled with oil of kinematic viscosity of 2.4 x 10^{-4} m^2/sec. and density of 888 kg/m^3. The drag resistance when the shaft moves at 0.2 m/s is 267.81 N. Determine the inner diameter of the cylinder.

10. Oil of specific gravity 0.8 flows through a pipe of 0.25 m diameter. An orifice of 0.1 m diameter is fitted to the pipe to measure the flow rate. A mercury manometer fitted across the orifice records a reading of 0.8 m. Calculate the coefficient of discharge of the orifice meter if the flow rate measured by it is 0.082 m^3/s.

11. (a) Explain how a U tube differential manometer works with the help of sketch.

(b) Calculate the pressure due to a column of 0.2 m of (i). Water (ii). Gasoline of specific gravity 0.75 (iii). Mercury of specific gravity 13.6. Take mass density of water as 1000Kg/m3

UNIT-II

1. (a) What is Stream tube? What are its characteristics?

   (b) A pipe AB branches into two pipes from B. One pipe C has a diameter of 150 mm and the other D has a diameter of 200 mm. The diameter at A is 450 mm and at B is 300 mm. The velocity of water at A is 2 m/s. If the velocity in pipe D be 4 m/s, determine the discharge through pipe AB, the velocity at B and velocity at C.

2. (a) Define steady, non-steady, uniform and non-uniform flows

   1. A 0.4 m x 0.3 m, 90^0 vertical reducing bend carries 0.5 m^3/s of oil specific gravity 0.85 with a pressure of 118 kN/m^2 at inlet to the bend. The volume of the bend is 0.1 m^3. Find the magnitude and direction of the force on the bend. Neglect friction and assume both inlet and outlet sections to be at same horizontal level. Also assume that water enters the bend at 45^0 to the horizontal.

3. Differentiate between: (a) Stream function and velocity potential function (b) Stream line and streak line (c) Rotational and irrotational flows (d) Uniform flow and non-uniform flow.

4. (a) Name different forces present in a fluid flow. For Euler's equation of motion, which forces are taken into consideration?

   (b) The diameters of a pipe at the sections 1 and 2 are 15 cm and 25 cm respectively. Find the discharge through the pipe if velocity of water at section 1 is 10 m/s. determine also the velocity at section 2.

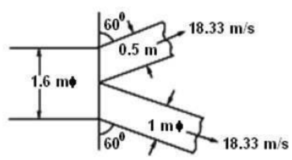
5. (a) Differentiate between: (i) Stream-lines body and bluff body (ii) Friction drag and pressure drag.

   (b) What do you mean by 'Terminal velocity of a body'? What is the relation between the weight of the body, drag force on the body and buoyant force when the body has acquired terminal velocity?

6. (a) Define the following: (i) Steady flow (ii) Non-uniform flow (iii) Laminar flow and (iv) Two-dimensional flow (v) Turbulent flow

   (b) The velocity vector in a fluid flow is given by $V = 2x^3i - 5x^2yj + 4tk$. Find the velocity and acceleration of a fluid particles at (1, 2, 3) at time, t = 1.

7. A horizontal Y is show in figure below. Determine the x and y components of the force exerted in the pipe



8. State Bernoulli's theorem for steady flow of an incompressible fluid. Derive an expression for Bernoulli's theorem from first principle and state the assumptions made for such a derivation.

9.

UNIT-III

1. (a) Explain the terms: hydraulic gradient and equivalent pipe with the help of a neat sketch.

   (b) A 10 cm by 6 cm orifice meter is used to measure the discharge of bromine. If the pressure difference across the orifice plate is 18250 N/m^2, determine the discharge in 1it/m. Assume C_d = 0.64. Specific gravity of bromine = 3.1.

2. (a) Explain the laminar and turbulent boundary layers

3. (b) Find the frictional drag on one side of the plate 200 mm wide and 500 mm long placed longitudinally in a stream of crude oil (G=0.925 and kinematic viscosity = 0.9 stoke) flowing with undisturbed velocity of 5m/sec. Also, find the thickness of boundary layer and the shear stress at the trailing edge of the plate.
4. (a) Define steady, non-steady, uniform and non-uniform flows.

   (b) A 0.4 m x 0.3 m, 90^0 vertical reducing bend carries 0.5 m^3/s of oil specific gravity 0.85 with a pressure of 118 kN/m^2 at inlet to the bend. The volume of the bend is 0.1 m^3. Find the magnitude and direction of the force on the bend. Neglect friction and assume both inlet and outlet sections to be at same horizontal level. Also assume that water enters the bend at 45^0 to the horizontal.
5. (a) What is a pitot-tube? How will you determine the velocity at any point with the help of pitot-tube?

   (b) A 20 x 10 cm venturimeter is provided in a vertical pipe line carrying oil of specific gravity 0.8, the flow being upwards. The difference in elevation of the throat section and entrance section of the venturimeter is 50 cm. The differential U-tube mercury manometer shows a gauge deflection of 40 cm. Calculate (i) The discharge of oil, and (ii) The pressure difference between the entrance section and the throat section. Take C_d = 0.98 and specific gravity of mercury is 13.6.
6. The velocity distribution in the boundary layer is given by $\frac{u}{U} = 2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2$, δ being boundary layer thickness. Calculate the following (i) Displacement thickness (ii) Momentum thickness, and (iii) Energy thickness
7. (a) An oil Kinematic Viscosity 0.5 stoke is flowing through a pipe of diameter 300 mm at the rate of 320 litres per sec. Find the head lost due to friction for a length of 60 m of the pipe.

   (b) Calculate the rate of flow of water through a pipe of diameter 300 mm, when the difference of pressure head between the two ends of a pipe 400 mm apart is 5 m of water. Take the value of f = 0.009 in the formula $h_f = \frac{4fLV^2}{2gd}$
8. (a) How are drag and lift forces caused on a body immersed in a moving fluid.

   (b) What is the drag force on a sphere in the stoke range?

   (c) Explain the terms: (i) Friction drag (ii) Pressure drag and profile drag.
9. (a) What do you mean by boundary layer separation? What is the effect of pressure gradient an boundary layer separation?

(b) Air is flowing over a smooth plate with a velocity of 8 m/s. The length of the plate is 1.5 m and width 1 m. If the laminar boundary exists upto a value of Reynolds number = 5 x 10^5, find the maximum distance from the leading edge upto laminar boundary layer exists. Find the maximum thickness of $\frac{u}{U} = 2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2$. Take v for air = 0.15 stokes.

10. (a) Define and explain the terms: (i) Hydraulic gradient and (ii) Total energy line.

    (b) Air velocity in a duct is measured as 38.2 m/s by a pitot tube. Density of flowing air 1.3 kg/m^3. If the pressure difference recorded by the pitot static tube is 0.1 m of water, calculate the coefficient of velocity of the pitot static tube.

11. The suction pipe of a pump slopes at 1 m vertical for 5 m length. If the flow velocity in the pipe is 1.8 m/s and if the pressure in the pipe should not fall by more than 7 m water, determine the maximum length.

12. (a) What do you mean by equivalent pipe? Obtain an expression for equivalent pipe.

    (b) An Orifice meter of 0.15 m diameter is fitted in a 0.3 m diameter pipe to measure the flow rate of water through it. If the pressure difference across the orifice is 10 m of water head, calculate the discharge in the pipe. Assume the coefficient of discharge of the orifice meter as 0.59.

13. (a) A straight pipe 600 m length and 1 m in diameter, with a constant friction factor f =0.025 and a sharp inlet, leads from a reservoir where a constant level is maintained at 25 m above the pipe outlet which is initially closed by a globe valve (K=10). If the valve is suddenly opened, find the time required to attain 90% of steady state discharge.

    (b) A valve at the outlet end of a pipe 1 m in diameter and 700 m long is rapidly opened. The pipe discharges to atmosphere and the piezometric head at the inlet end of the pipe is 23 m (relative to outlet level). The head loss through open valve is 10 times the velocity head in the pipe, other minor losses of amount to twice the velocity head and friction factor f = 0.02. What is the velocity after 12 seconds?

14. (a) What is a compound pipe? What will be loss of head when pipes are connected in series?

    (b) A Venturimeter with 0.08 m throat diameter is used to measure the flow in a pipe line of 0.16 m diameter. A mercury manometer attached to it shows deflection of 0.29 m. Assuming coefficient of discharge as 1, calculate the flow rate in the pipe.

15. A venturimeter having a throat diameter of 5 cm is introduced in a horizontal pipe line of diameter 7.5 cm conveying water. The venturimeter is connected to an inverted U-tube manometer having a liquid of specific gravity 0.9 as the manometric liquid. If the

difference in level of the separating surfaces is 5 cm, find the discharge. Assume C_d = 0.98.

16. The inlet and throat diameters of a horizontal venturimeter conveying water are 30 cm and 10 cm respectively. The pressure intensity at the inlet is 140 kN/m^2. While the vacuum, pressure at the throat is 37 cm of mercury, assume that 4% of differential head is lost between the inlet and the throat. Find C_d for the venturimeter.
17. (a) For the two cases of flow in a sudden contraction in a pipeline and flow in a sudden expansion in a pipeline, draw the flow pattern, piezometric grade line and total energy line.

    (b) An orifice meter with 5 cm diameter is used to measure the flow rate of liquid. Under a head of 4 m, the velocity of liquid at vena contracta is 7.5 m/s. If the actual discharge through the pipe is 8 liters per second, calculate the coefficients of velocity, discharge and contraction.
18. (a) Show that the loss of head due to sudden expansion in pipe line is a function of velocity head.

    (b) Oil of specific gravity 0.8 flows through a pipe of 0.25 m diameter. An orifice of 0.1 m diameter is fitted to the pipe to measure the flow rate. A mercury manometer fitted across the orifice records a reading of 0.8 m. Calculate the coefficient of discharge of the orifice meter if the flow rate measured by it is 0.082 m3/s.
19. 19.

UNIT-IV

1. (a) Define the term 'Governing of a turbine'. Describe with a neat sketch, the working of an oil pressure governor for a pelton wheel.

    (b) Give the range of specific speed values of the Kaplan, Francis turbine and Pelton wheels. What factors decide whether Kaplan, Francis, or a Pelton type turbine would be used in a hydroelectric project?
2. (a) Describe the theory of a draft tube with the help of a neat sketch.

    (b) Design a single jet Pelton wheel to develop a power of 600 KW under a head of 180 m while running at 320 rpm. Assume Ku = 0.45, C_v = 0.985 and overall efficiency = 85%. Calculate the jet diameter, wheel diameter and number of buckets. Give a fully dimensional sketch of the bucket.
3. A jet of water having a velocity of 60m/sec is deflected by a vane moving at 25m/sec in a direction at 300 to the direction of jet. The water leaves the vane normally to the motion

of the vane. Draw the inlet and outlet velocity triangles and find out the vane angles for no shock at entry and exit. Take the relative velocity at the exit as 0.8 times the relative velocity at the entrance.

4. A jet of water having a velocity of 30 m/s strikes a series of radial curved vanes mounted on a wheel which is rotating at 200 rpm. The jet makes an angle of 20^0 with the tangent to the wheel at inlet and leaves the wheel with a velocity of 5 m/s at an angle of 130^0 to the tangent to the wheel at outlet. Water is flowing from outward in a radial direction. The outer and inner radii of the wheel are 0.5 m and 0.25 m respectively. Determine; (i) Vane angles at inlet and outlet (ii) Work done per unit weight of water, and (iii) Efficiency of the wheel.

5. (a) Draw a schematic diagram of a Francis turbine and explain its construction and working.

   (b) The jet of water coming out of nozzle strikes the buckets of a Pelton wheel which when stationary would deflect the jet through 165^0. The velocity of water at exit is 0.9 times at the inlet and the bucket speed is 0.45 times the jet speed. If the speed of the Pelton wheel is 300 rpm and the effective head is 150m, determine: (i) Hydraulic efficiency, and (ii) Diameter of the Pelton wheel. Take co-efficient of velocity c_V = 0.98.

6. (a) Define specific speed of a turbine and derive an expression for the same. Show that Pelton turbine is a low specific speed turbine.

   (b) What is specific speed? State its significance in the study of hydraulic machines.

7. (a) What is governing and how it is accomplished for different types of water turbines?

   (b) A Kaplan turbine develops 1480 kW under a head of 7 m. The turbine is set 2.5 m above the tailrace level. A vacuum gauge inserted at the turbine outlet records a suction head of 3.1 m. If the hydraulic efficiency is 85%, what would be the efficiency of draft tube having inlet diameter of 3 m? What would be the reading of suction gauge if power developed in reduced to half (740 kW), the head and speed remaining constant.

8. (a) Determine the error in calculating the excess pressure of water hammer in a steel pipe carrying water with an inner diameter 'd' is 15 mm and a wall thickness 't' is 2 mm if the elasticity of the material of the pipe wall is disregarded. Take E = 2.07 x 10^3 MN/m^2 water.

   (b) A steel penstock 1200 mm diameter and 1500 mm long conveys water at the rate of 1.5 m^3/sec. A valve at the end is closed in 2.5 seconds. Assume E for steel as 2.07 x 10^8

kM/m^2, K=6.30 x 106/m^2 and the thickness of the pipe wall is 20 mm. Find the water hammer pressure developed.

9. (a) A jet of water is moving at 60 m/s and is deflected by a vane moving 25 m/s in a direction at 300 to the direction of the jet. The water leaves the blades with no velocity component in the direction of motion of vane. Determine the inlet and outlet angles of the vanes for no shock at entry or exit. Assume outlet velocity of water relative to the blades to be 0.85 of the relative velocity at entry.

   (b) A 100 mm diameter jet discharging at 0.40 m^3/sec impinges in a series of curved vanes moving at 18 m/s. the direction of the jet and the direction of motion of the vane are the same at inlet. Each vane is so shaped that if stationary it would deflect the jet at 170^0. Calculate (i) The force exerted in the direction of motion of the vanes (ii) The power developed and (iii) The Hydraulic Efficiency.

10. (a) A jet of water having a velocity of 35 m/s impinges on a series of vanes moving with a velocity of 22 m/s. The jet makes an angle of 30^0 to the direction of motion of vanes when entering and leaving at and angle of 120^0. Draw the velocity triangles at inlet and outlet and find: (i) the angles of vanes tip so that water enters and leaves without shock (ii) The work done per N of water entering the vanes and (iii) The efficiency

    (b) Prove that the force exerted by a jet of water on a fixed semi0circular plate in the direction of the jet when jet strikes at the center of the semi circular plate is two times the force exerted by the jet on a fixed vertical plate.

11. (a) An inward flow reaction turbine is required to produce a power of 280 kW at 220 rpm. The effective head on the turbine is 20 m. The inlet diameter is twice as the outlet diameter. Assume hydraulic efficiency as 83% and overall efficiency as 80%. The radial velocity is 3.75 m/s and is constant. The ratio of wheel diameter to breadth is 0.1 and 6% of the flow area is blocked by vane thickness. Determine the inlet and outlet diameters, inlet and exit vane angle and guide blade angle at the inlet. Assume radial discharge.

    (b) In a Francis turbine, the blade angle is 15^0 and the flow enters in a radial direction. The flow velocity is constant and is equal to 8.25 m/s. The outlet diameter is 0.6 times the inlet diameter and the runner rotates at 400 rpm. The width of the wheel is 0.1 times the inlet diameter and 7% of the flow area is blocked by blade thickness. Assume radial flow at outlet. Calculate: (i) Diameters at outlet and inlet (ii) Blade angle at outlet (iii) The head and power developed.

12. (a) The following are the data of a Pelton wheel turbine; Head at nozzle is 600 m; shaft power is 70 MW; speed is 550 rpm; Discharge is 13 m^3/sec; number of jects are 4; runner

diameter is 2 m; Diameter of jets is 0.20 ml outlet vane angle is 16^0; mechanical efficiency is 98%. Determine the head lost in the nozzle, head lost in the buckets. Find also the power lost in the nozzle and the buckets.

(b) The runner of pelton wheel turbine has tangential velocity of 18 m/s and works under a head of 62 m. The jet is turned through 17^0. The discharge through the nozzle is 110 liters per second. Determine the power developed by the runner and the efficiency of. Assume C_V=0.98.

13. (a) A free jet of water of velocity V strikes against a series of curved semi-circular vanes tangentially. The vanes are moving in the direction of the jet with velocity equal to 0.6V. Assuming the relative velocity of water is reduced by 10% by moving over the vanes, show that the vanes have an efficiency of 91.33%.

(b) A jet of water of diameter 40 mm and 22 m/s impinges on: (i) A normal flat vane moving in the direction of jet at 8 m/s and (ii) A series of normal flat vanes mounted on a wheel which has a tangential velocity of 7.5 m/s. Calculate force exerted, work done by water and efficiency of the system in both cases.

14. (a) What are the different types of efficiencies of turbine?

(b) Hydraulic tests were conducted on Francis turbine of 0.75 m diameter under a head of 10 m. The turbine developed 120 kW running at 240 rpm and consuming 1.25 m^3/sec. If the same turbine is operated under a head of 15 m predict its new speed, discharge and power.

15. 9a) A 1250 m long pipeline, with frictional coefficient 0.005, supplies three single jet Pelton wheels the top water level of the reservoir being 350 m above the nozzles. The C_V for each nozzle is 0.98. The efficiency of each turbine based on the head at the nozzle is 85%. The head lost in the friction is 12.50 m. The specific speed of each wheel is 15, and the working speed is 550 rpm. Find the; (i) Total power developed (ii) Discharge (iii) Diameter of each nozzle (iv) Diameter of the pipe line.

(b) For maximum conversion of hydraulic power into mechanical power, what should be the shape of velocity diagram at the outlet in case of a reaction turbine.

16. (a) A jet of diameter 40 mm strikes horizontally on a plate held vertically. What force is required to hold plate for a flow of oil of specific gravity 0.8 with a velocity of 30 m/s.

(b) A 75 mm diameter jet having a velocity of 37 m/s strikes normally a flat plate, the normal at 45^0 to the axis of the jet. Find the normal pressure on the plate; (i) When the plate is stationary (ii) When the plate is moving with a velocity of 17 m/s in the direction of the away from the jet. Also determine the power and the efficiency of the jet when the plate is moving.

17.

UNIT-V

1. (a) What is NPSH. Discuss the significance of NPSH in pump settings.

   (b) A centrifugal pump delivers water against a net head of 14.5m and design speed of 1000 rpm. The vanes are curved back to an angle of 300 with periphery. The impeller diameter is 300 mm and outlet width 50 mm. Determine the discharge of the pump if the manometric efficiency is 95%.

2. A three stage centrifugal pump has impeller 400 mm in diameter and 20 mm wide. The vane angle at outlet is 45^0 and the area occupied by the thickness of the vanes may be assumed 8 percent of the total area. If the pump delivers 3.6 m^3 of water per minute when running at 920 rpm. Determine: (i) power of the pump (ii) manometric head, and (iii) specific speed.

3. (a) A multi-stage pump is required to feed preheated water to a boiler. The quantity of water to be handled is 40 liter per second against a pressure difference of 3200 kN/m^2. The speed of rotation of impeller being 3000 rpm. The specific weight of the preheated water is 960 kg/m^3. All impellers are identical and the specific speed per stage is not to exceed 5400. Determine: (i) The minimum number of stages and the head per stage. (ii) The diameter of the impeller assuming a peripheral velocity 0.95 $\sqrt{2gH_m}$ (iii) the shaft power required to drive the pump, if the overall efficiency is 80%.

   (b) Derive an expression for the work done by a reciprocating pump with air vessels.

4. (a) A centrifugal pump with impeller of 150 mm diameter discharges 0.038 m^3/sec water when running at 1500 rpm against a head of 10 m. Determine the corresponding speed and the head of a geometrically similar pump with impeller of 375 mm diameter delivering 0.75 m^3/sec.

   (b) Starting from first principles show that in a rotodynamic fluid machine, the head transferred by the fluid to the machine is given by $(V_{w1}u_1 - V_{w2}u_2)/g$, where V_{w1}, V_{w2} are the whirl velocity components of the inlet and outlet respectively while u_1 and u_2 are the velocity of vane of inlet and outlet respectively.

5. (a) What are the functions of air vessels in reciprocating pumps? Explain with neat sketches.

   (b) Draw a neat sketch of an indicator diagram, considering the effect of acceleration and friction in suction and delivery pipe. Derive an expression for work done per second for a single acting reciprocating pump.

6. During a laboratory test a pump, appreciable cavitation began when the pressure plus the velocity head at inlet was reduced to 3.26 m while the change in total head across the pump was 36.5 m and the discharge was 48 liters per second. Barometric pressure was 750 mm of Hg and the vapour pressure of water is 1.8 kPa. What is the value of α_c? If the pump is to give the same total head and discharge in a location where the normal atmospheric pressure 622 mm of Hg and the vapour pressure of water of 830 Pa, by how much must the height of the pump above the supply level be reduced?

7. (a) What is meant by priming of a centrifugal pump? What are the arrangements employed for priming of centrifugal pump?

   (b) A centrifugal pump of 250 mm diameter runs at 1450 rpm and delivers 0.35 m^3/sec against a head of 14 m. Calculate the specific speed of the pump. A similar pump with half the size is to run at a head of 11 m. Find the working speed, discharge and power required assuming efficiency of the pumps to be 78%.

8. The impeller of a centrifugal pump is 300 mm diameter and runs at 1450 rpm. The pressure gauges on suction and delivery sides show the difference of 25 m. The blades are curved back to an angle of 33^0. The velocity of flow through impeller, being constant, equal to 2.5 m/s, find the manometric efficiency of the pump. If the frictional losses in impeller amounts to 2 m, find the fraction of total energy which is converted into pressure energy by impeller. Also find the pressure rise in pump casing.

9. A single stage centrifugal pump has an impeller of 320 mm diameter rotates at 2200 rpm and lifts water of 3.2 m^3/sec to a height of 35 m with an efficiency of 81%. Find the number of stages and diameter of each impeller of a similar multistage pump to lift 5 m^3/sec of water to a height of 200 m when rotating at 1600 rpm.

10. (a) The plunger diameter of a single acting reciprocating pump is 160 mm and its stroke 300 mm. The pump runs at 55 rpm, and lifts water through a height of 28 m. Find the theoretical discharge and the theoretical power required to run the pump. If the actual discharge is 4.5 liters per second, find the percentage of slip. The delivery pipe 25 m long has a diameter of 100 mm, determine the acceleration head at the beginning of the delivery stroke. If a large air vessel is fitted very close to the cylinder on the delivery side,

determine the head in the cylinder necessary to overcome friction in the delivery pipe. The friction factor in the Darcy-Weisbach equation has a value of 0.285.

(b) prove that area of indicator diagram is proportional to the work done by the reciprocating pump.