CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
MET203	MECHANICS OF FLUIDS	PCC	3	1	-	4

Preamble :

This course provides an introduction to the properties and behaviour of fluids. It enables to apply the concepts in engineering, pipe networks. It introduces the concepts of boundary layers, dimensional analysis and model testing

Prerequisite : NIL

Course Outcomes :

After completion of the course the student will be able to

CO1	Define Properties of Fluids and Solve hydrostatic problems
CO2	Explain fluid kinematics and Classify fluid flows
CO3	Interpret Euler and Navier-Stokes equations and Solve problems using Bernoulli's equation
CO4	Evaluate energy loses in pipes and sketch energy gradient lines
CO5	Explain the concept of boundary layer and its applications
CO6	Use dimensional Analysis for model studies

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2										
CO2	3	2	1									
CO3	3	2	1									
CO4	3	3	2									
CO5	3	2	1									
CO6	3	2	1									

Assessment Pattern

Blooms Category	CA			ESA
	Assignment	Test - 1	Test - 2	
Remember	25	20	20	10
Understand	25	40	40	20
Apply	25	40	40	70
Analyse	25			
Evaluate				
Create				

Continuous Internal Evaluation Pattern:

Attendance : 10 marks

Continuous Assessment Test (2 numbers) : 25 marks

Assignment/Quiz/Course project : 15 marks

Mark distribution & Duration of Examination :

Total Marks	CA	ESE	ESE Duration
150	50	100	3 Hours

End semester pattern:

There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

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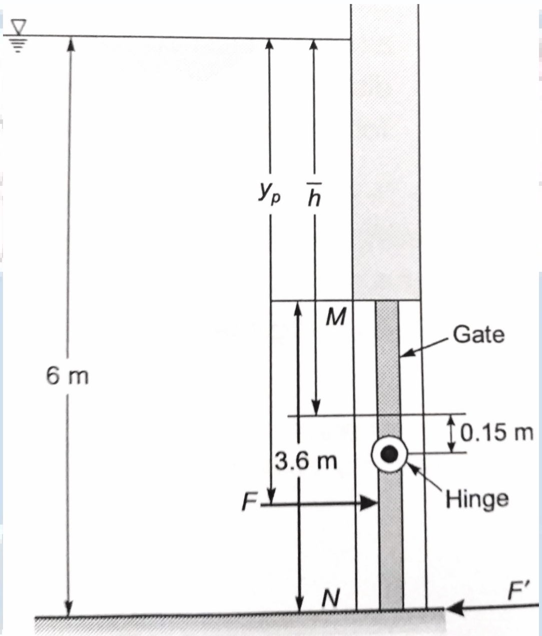
COURSE LEVEL ASSESSMENT QUESTIONS

MECHANICAL ENGINEERING

Course Outcome 1

1. A 3.6×1.5 m wide rectangular gate MN is vertical and is hinged at point 0.15 m below the center of gravity of the gate. The total depth of water is 6 m. What horizontal force must be applied at the bottom of the gate to keep the gate closed.



2. A stationary liquid is stratified so that its density is $\rho_0(1+h)$ at a depth h below the free surface. At a depth h in this liquid, what is the pressure in excess of $\rho_0 g h$?

3. If the velocity profile of a fluid is parabolic with free stream velocity 120 cm/s occurring at 20 cm from the plate, calculate the velocity gradients and shear stress at a distance of 0, 10, 20 cm from the plate. Take the viscosity of fluid as 8.5 poise.

Course Outcome 2

1. Differentiate between the Eulerian and Lagrangian method of representing fluid motion.

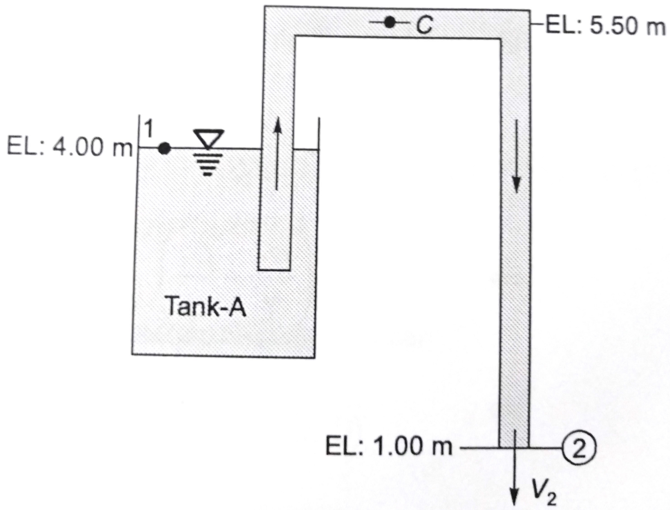
2. A velocity field is given by $u = 3y^2$, $v = 2x$ and $w = 0$ in arbitrary units. Is this flow steady or unsteady? Is it two or three dimensional? At (x,y,z)=(2,1,0), compute
   (a) velocity
   (b) local acceleration
   (c) convective acceleration

3. A stream function in two dimensional flow is $\psi = 2xy$. Show that the flow is irrotational and determine the corresponding velocity potential ϕ.

Course Outcome 3

MECHANICAL ENGINEERING

1. A siphon consisting of a pipe of 15 cm diameter is used to empty kerosene oil (relative density=0.8) from tank A. The siphon discharges to the atmosphere at an elevation of 1.00 m. The oil surface in the tank is at an elevation of 4.00 m. The center line of the siphon pipe at its highest point C is at an elevation of 5.50 m. Estimate,



   (a) Discharge in the pipe
   (b) Pressure at point C.

   The losses in the pipe can be assumed to be 0.5 m up to the summit and 1.2 m from summit to the outlet.

2. Derive the Euler's equation of motion along a streamline and from that derive the Bernouli's equation.

3. What is water hammer? Explain different cases of water hammer. Derive the expression for pressure rise in any one of the case.

Course Outcome 4

1. Two reservoir with a difference in water surface elevation of 10 m are connected by a pipeline AB and BC joined in series. Pipe AB is 10 cm in diameter, 20 m long and has a value of friction factor $f = 0.02$. Pipe BC is 16 cm diameter, 25 m long and has a friction factor f=0.018. The junctions with reservoirs and between pipes are abrupt.

   (a) Sketch Total energy line and Hydraulic gradient line
   (b) Calculate the discharge.

2. Oil of viscosity 0.1 Pas and specific gravity 0.9 flows through a horizontal pipe of 25 mm diameter. If the pressure drop per meter length of the pipe is 12 KPa, determine

   (a) Discharge through the pipe
   (b) Shear stress at the pipe wall
   (c) Reynolds number of the flow

(d) Power required in Watts if the length of the pipe is 50m

3. In a hydraulic power plant, a reinforced concrete pipe of diameter D is used to transmit water from the reservoir to the turbine. If H is the total head supply at the entrance of the pipe and h_f is the loss of head in the pipe, then derive the condition for maximum power supply through the pipe.

Course Outcome 5

1. Write a short note on boundary layer separation and discuss any two methods to control the same.

2. Find the displacement thickness, momentum thickness and energy thickness for velocity distribution in boundary layer given by

$$\frac{u}{U_\infty} = 2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2$$

3. A thin plate is moving in still atmospheric air at a velocity of 4m/s. The length of the plate is 0.5 m and width 0.4 m. Calculate the

   (a) thickness of the boundary layer at the end of the plate and

   (b) drag force on one side of the plate.

   Take density of air as 1.25 kg/m^3 and kinematic viscosity 0.15 stokes.

Course Outcome 6

1. State and explain Buckingham's pi theorem.

2. An underwater device is 1.5m long and is to move at 3.5 m/s speed. A geometrically similar model 30 cm long is tested in a variable pressure wind tunnel at a speed of 35 m/s. Calculate the pressure of air in the model if the model experience a drag force of 40 N, calculate the prototype drag force. [Assume density of water = 998 kg/m^3, density of air at standard atmospheric pressure = 1.17 kg/m^3, dynamic viscosity of air at local atmospheric pressure = $1.95 * 10^{-5}$ Pas and dynamic viscosity of water = $1 * 10^{-3}$ Pas]

3. Explain the importance of dimensionless numbers and discuss any two similarity laws. Where are these model laws used?

SYLLABUS

Module 1: Introduction: Fluids and continuum, Physical properties of fluids, density, specific weight, vapour pressure, Newton's law of viscosity. Ideal and real fluids, Newtonian and non-Newtonian fluids. Fluid Statics- Pressure-density-height relationship, manometers, pressure on plane and curved surfaces, center of pressure, buoyancy, stability of immersed and floating bodies, fluid masses subjected to uniform accelerations, measurement of pressure.

Module 2: Kinematics of fluid flow: Eulerian and Lagrangian approaches, classification of fluid flow, 1-D, 2-D and 3-D flow, steady, unsteady, uniform, non-uniform, laminar, turbulent, rotational, irrotational flows, stream lines, path lines, streak lines, stream tubes, velocity and acceleration in fluid, circulation and vorticity, stream function and potential function, Laplace equation, equipotential lines, flow nets, uses and limitations.

Module 3: Control volume analysis of mass, momentum and energy, Equations of fluid dynamics: Differential equations of mass, energy and momentum (Euler's equation), Navier-Stokes equations (without proof) in cartesian co-ordinates. Dynamics of Fluid flow: Bernoulli's equation, Energies in flowing fluid, head, pressure, dynamic, static and total head, Venturi and Orifice meters, Notches and Weirs (description only for notches and weirs). Hydraulic coefficients, Velocity measurements: Pitot tube and Pitot-static tube.

Module 4: Pipe Flow: Viscous flow: Reynolds experiment to classify laminar and turbulent flows, significance of Reynolds number, critical Reynolds number, shear stress and velocity distribution in a pipe, law of fluid friction, head loss due to friction, Hagen Poiseuille equation. Turbulent flow: Darcy-Weisbach equation, Chezy's equation Moody's chart, Major and minor energy losses, hydraulic gradient and total energy line, flow through long pipes, pipes in series, pipes in parallel, equivalent pipe, siphon, transmission of power through pipes, efficiency of transmission, Water hammer, Cavitation.

Module 5: Boundary Layer : Growth of boundary layer over a flat plate and definition of boundary layer thickness, displacement thickness, momentum thickness and energy thickness, laminar and turbulent boundary layers, laminar sub layer, velocity profile, Von- Karman momentum integral equations for the boundary layers, calculation of drag, separation of boundary and methods of control. Dimensional Analysis: Dimensional analysis, Buckingham's theorem, important non dimensional numbers and their significance, geometric, Kinematic and dynamic similarity, model studies. Froude, Reynolds, Weber, Cauchy and Mach laws- Applications and limitations of model testing, simple problems only

Text Books

John. M. Cimbala and Yunus A. Cengel, Fluid Mechanics: Fundamentals and Applications (4th edition, SIE), 2019

Robert W. Fox, Alan T. McDonald, Philip J. Pritchard and John W. Mitchell, Fluid Mechanics, Wiley India, 2018

Reference Books

White, F. M., Fluid Mechanics, McGraw Hill Education India Private Limited, 8th Edition, 2017

Rathakrishnan, E. Fluid Mechanics: An Introduction, Prentice Hall India, 3rd Edition 2012

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COURSE PLAN

Module	Topics	Hours Allotted
I	Introduction: Fluids and continuum, Physical properties of fluids, density, specific weight, vapour pressure, Newton's law of viscosity. Ideal and real fluids, Newtonian and non-Newtonian fluids. Fluid Statics- Pressure-density-height relationship, manometers, pressure on plane and curved surfaces, center of pressure, buoyancy, stability of immersed and floating bodies, fluid masses subjected to uniform accelerations, measurement of pressure.	7-2-0
II	Kinematics of fluid flow: Eulerian and Lagrangian approaches, classification of fluid flow, 1-D, 2-D and 3-D flow, steady, unsteady, uniform, non-uniform, laminar, turbulent, rotational, irrotational flows, stream lines, path lines, streak lines, stream tubes, velocity and acceleration in fluid, circulation and vorticity, stream function and potential function, Laplace equation, equipotential lines, flow nets, uses and limitations.	6-2-0
III	Control volume analysis of mass, momentum and energy, Equations of fluid dynamics: Differential equations of mass, energy and momentum (Euler's equation), Navier-Stokes equations (without proof) in cartesian co-ordinates Dynamics of Fluid flow: Bernoulli's equation, Energies in flowing fluid, head, pressure, dynamic, static and total head, Venturi and Orifice meters, Notches and Weirs (description only for notches and weirs). Hydraulic coefficients, Velocity measurements: Pitot tube and Pitot-static tube.	6-2-0
IV	Pipe Flow: Viscous flow: Reynolds experiment to classify laminar and turbulent flows, significance of Reynolds number, critical Reynolds number, shear stress and velocity distribution in a pipe, law of fluid friction, head	9-3-0

	loss due to friction, Hagen Poiseuille equation. Turbulent flow: Darcy-Weisbach equation, Chezy's equation Moody's chart, Major and minor energy losses, hydraulic gradient and total energy line, flow through long pipes, pipes in series, pipes in parallel, equivalent pipe, siphon, transmission of power through pipes, efficiency of transmission, Water hammer, Cavitation.	
V	Boundary Layer : Growth of boundary layer over a flat plate and definition of boundary layer thickness, displacement thickness, momentum thickness and energy thickness, laminar and turbulent boundary layers, laminar sub layer, velocity profile, Von- Karman momentum integral equations for the boundary layers, calculation of drag, separation of boundary and methods of control. Dimensional Analysis: Dimensional analysis, Buckingham's theorem, important non dimensional numbers and their significance, geometric, Kinematic and dynamic similarity, model studies. Froude, Reynolds, Weber, Cauchy and Mach laws- Applications and limitations of model testing, simple problems only	8-2-0

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MODEL QUESTION PAPER

MECHANICAL ENGINEERING

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

IV SEMESTER B.TECH DEGREE EXAMINATION

MET203: MECHANICS OF FLUIDS

Mechanical Engineering

Maximum: 100 Marks Duration: 3 hours

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

PART A

Answer all questions, each question carries 3 marks

1. The specific gravity of a liquid is 3.0. What are its specific weight, specific mass and specific volume.
2. State Pascal's law and give some examples where this principle is used.
3. Explain Streamlines, Streaklines and Pathlines.
4. What do you understand by the terms: (*i*) Total acceleration, (*ii*) Convective acceleration, and (*iii*) Local acceleration.
5. Name the different forces present in a fluid flow. For the Euler's equation of motion, which forces are taken into consideration.
6. Differentiate between pitot tube and pitot static tube.
7. Define and explain the terms (*i*) Hydraulic gradiant line and (*ii*) Total energy line.
8. Show that the coefficient of friction for viscous flow through a circular pipe is given by

$$f = \frac{16}{Re}$$

   where Re is the Reynolds number.
9. What do you mean by repeating variables? How repeating variables are selected for dimensional analysis.
10. How will you determine whether a boundary layer flow is attached flow, detached flow or on the verge of separation.

(10×3=30 Marks)

PART B

Answer one full question from each module MECHANICAL ENGINEERING

MODULE-I

11. (a) Through a very narrow gap of height h, a thin plate of large extend is pulled at a velocity V. On one side of the plate is oil of viscosity μ_1 and on the other side oil of viscosity μ_2. Calculate the position of the plate so that

    i. the shear force on the two sides of the plate is equal.

    ii. the pull required to drag the plate is minimum.

    Assume linear velocity distribution in transverse direction. (7 Marks)

    (b) A metallic cube of 30 cm side and weight 500 N is lowered into a tank containing two fluid layers of water and mercury. Top edge of the cube is at water surface. Determine the position of the block at water mercury interface when it has reached equilibrium. (7 Marks)

12. (a) A rectangular tank 1.5 m wide, 3 m long and 1.8 m deep contains water to a depth of 1.2 m. Find the horizontal acceleration which may be imparted to the tank in the direction of length so that

    i. there is just no spilling from the tank

    ii. front bottom corner of the tank is just exposed.

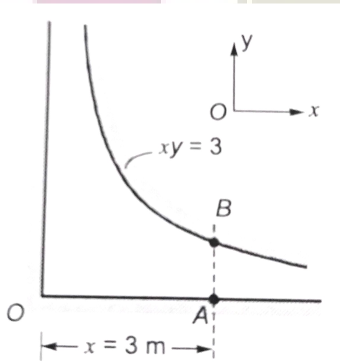
    (7 Marks)

    (b) A spherical water drop of 1 mm diameter splits up in air into 64 smaller drops of equal size. Find the work required in splitting up the drop. The surface tension coefficient of water in air = 0.073 N/m (7 Marks)

MODULE-II

13. (a) In a fluid flow field, velocity vector is given by $v = (0.5 + 8x)i + (0.5 - 0.8y)j$. Find the equation of streamline for the given velocity field. (7 Marks)

    (b) The stream function $\psi = 4xy$ in which ψ is in cm^2/s and x and y are in meters describe the incompressible flow between the boundary shown below:



    Calculate

    i. Velocity at B

    ii. Convective acceleration at B

iii. Flow per unit width across AB

MECHANICAL ENGINEERING

(7 Marks)

14. (a) Consider the velocity field given by $u = x^2$ and $v = -2xy$. Find the circulation around the area bounded by $A(1,1), B(2,1), C(2,2), D(1,2)$. (7 Marks)

(b) Verify whether the following are valid potential functions.

i. $\phi = 2x + 5y$

ii. $\phi = 4x^2 - 5y^2$

(7 Marks)

MODULE-III

15. (a) A submarine moves horizontally in sea and has its axis 15 m below the surface of the water. A pitot tube properly placed just in front of the submarine and along its axis is connected to two limbs of a U tube containing mercury. The difference of level is found to be 170 mm. Find the speed of the submarine knowing that the specific gravity of mercury is 13.6 and that of sea water is 1.026 with respect to water. (7 Marks)

(b) A pitot tube is inserted in a pipe of 30 cm diameter. The static pressure of the tube is 10 cm of mercury vacuum. The stagnation pressure at the centre of the pipe recorded by the pitot tube is 1.0 N/cm^2. Calculate the rate of flow of water through the pipe, if the mean velocity of flow is 0.85 times central velocity. Assume coefficient of tube as 0.98. (7 Marks)

16. (a) A smooth pipe of uniform diameter 25 cm, a pressure of 50 KPa was observed at section 1 which has an elevation of 10 m. At another section 2, at an elevation of 12 m, the pressure was 20 KPa and the velocity was 1.25 m/s. Determine the direction of flow and the head loss between the two sections. The fluid in the pipe is water. (8 Marks)

(b) Petrol of specific gravity 0.8 is following through a pipe of 30 cm diameter. The pipe is inclined at 30° to horizontal. The venturi has a throat diameter of 10 cm. U tube manometer reads 6.25 cm Hg. Calculate the discharge through the pipe. Assume $C_d = 0.98$. (6 Marks)

MODULE-IV

17. (a) Assuming viscous flow through a circular pipe derive the expression for,

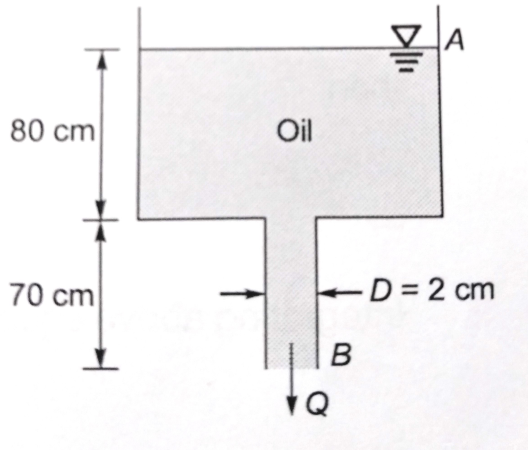
i. Velocity distribution

ii. Shear stress distribution

Also plot the velocity and shear stress distribution. (7 Marks)

(b) A large tank shown in the figure has a vertical pipe 70 cm long and 2 cm in diameter. The tank contain oil of density 920 Kg/m^3 and viscosity 1.5 poise. Find the discharge through the tube when the height of oil level of the tank is 0.80 m above the pipe inlet.

CHANICAL ENGINEERING



(7 Marks)

18. (a) A compound piping system consist of 1800 m of 50 cm, 1200 m of 40 cm and 600 m of 30 com diameter pipes off same material connected in series.

    i. What is the equivalent length of a 40 cm pipe of same material?
    ii. What is the equivalent diameter of a pipe 3600 m long?
    iii. If three pipes are in parallel what is equivalent length of 50 cm pipe?

    (10 Marks)

    (b) A pipe line of 2100 m is used for transmitting 103 KW. The pressure at the inlet of the pipe is 392.4 N/cm^2. If the efficiency of transmission is 80%, find the diameter of the pipe. Take $f = 0.005$. (4 Marks)

MODULE-V

19. (a) The velocity profile u of a boundary layer flow over a flat plate is given by

$$\frac{u}{U_\infty} = \frac{3}{2}\left(\frac{y}{\delta}\right) - \frac{1}{2}\left(\frac{y}{\delta}\right)^3$$

If the boundary thickness is given as

$$\delta = \sqrt{\frac{280\nu x}{13U_\infty}}$$

develop the expression for local drag coefficient C_{fx} over the distance $x = L$ from the leading edge of the plate. (7 Marks)

    (b) A model test is to be conducted in a water tunnel using a 1:20 model of a submarine which is used to travel at a speed of 12 km/h deep under the sea. The water temperature in the tunnel is so maintained that its kinematic viscosity is half as that of the sea water. At what speed the model test is to be conducted. (7 Marks)

20. (a) With a neat sketch explain the different regions of the boundary layer along a long thin flat plate. (7 Marks)

    (b) Using Buckingham's pi theorem show that the velocity through a circular orifice is given by

$$\sqrt{2gH}\phi\left[\frac{D}{H}, \frac{\mu}{\rho V H}\right]$$

where H is the head causing flow, D is the diameter of the orifice, μ is the coefficient of viscosity, ρ is the mass density and g is the acceleration due to gravity. (7 Marks)