Applied Mechanics Department, MNNIT Allahabad, India-211004

Mid Semester Examination: Fluid Flow Operations (AMN12101)

B.Tech. (II Semester, Chemical Engineering), Session 2022-2023

Duration-90 Minutes ***M.M.-20 Marks***

Instructions:

1. **All questions are compulsory.**
2. **Give suitable diagram wherever necessary.**
3. **Assume any missing data suitably.**
4. **There are total 3 questions included on both side of the question paper.**

1.

A. Which of the following sets of equations represents possible 3-D incompressible flow cases? **[3 Marks]**

i. $u = 2y^2 + 2xz; v = -2yz + 6x^2yz; w = 3x^2z^2 + x^3y^4$

ii. $u = x^2 + 2y + z^2; \mathrm{v} = \mathrm{x} - 2\mathrm{y} + \mathrm{z};\ \mathrm{w} = -2\mathrm{xz} + y^2 + 2\mathrm{z}$

B. A velocity field is given by $\vec{V} = ax^3\hat{\imath} + bxy^3\hat{\jmath}$, where a=1m^{-2}s^{-1} and b=1 m^{-3}s^{-1}. Find the equation of the streamlines. Plot three streamlines in the first quadrant. **[3 Marks]**

C. Consider the velocity field $\vec{V} = A\,(x^4 - 6x^2y^2 + y^4)\hat{\imath} + A(4xy^3 - 4x^3y)\hat{\jmath}$ in the xy plane, where A=0.25 m^{-3}.s^{-1}, and the coordinates are measured in meters. Calculate the acceleration of fluid particle at point (x, y) = (2, 1). **[3 Marks]**

D. A Velocity field is given as $\vec{V} = -x\hat{\imath} + y\hat{\jmath}$ in the xy plane. Check and comment whether the flow is rotational or irrational. Also find the velocity potential function for the field. **[3 Marks]**

2.

A. Crude oil, with specific gravity SG=0.85 and viscosity μ flows steadily down a surface inclined at θ below the horizontal in a film thickness of h. The velocity profile is given by

$$u = \frac{\rho g}{\mu}(hy - \frac{y^2}{2})\sin\theta$$

Coordinate x is along the surface and y is normal to the surface. Derive an expression for the shear stress that acts on the surface. **[2 Marks]**

B. For the velocity fields given below, determine:

i. Whether the flow field is 1-D, 2-D or 3-D and why.

ii. Whether the flow is steady or unsteady and why

(a and b are constants) **[3 Marks]**

a. $\vec{V} = [ay^2e^{-bt}]\hat{\imath}$

b. $\vec{V} = a(x^2 + y^2)^{1/2}\left(\frac{1}{z^3}\right)\hat{k}$

c. $\vec{V} = (ax + t)\hat{\imath} - by^2\hat{\jmath}$

Contd....

3. A Spherical thrust bearing is as shown in Fig.1 below: The gap between the spherical member and the housing is of consant width h. Obtain an algebraic expression for the non-dimentional torque on the spherical member as a function of angle α. **[3 Marks]**

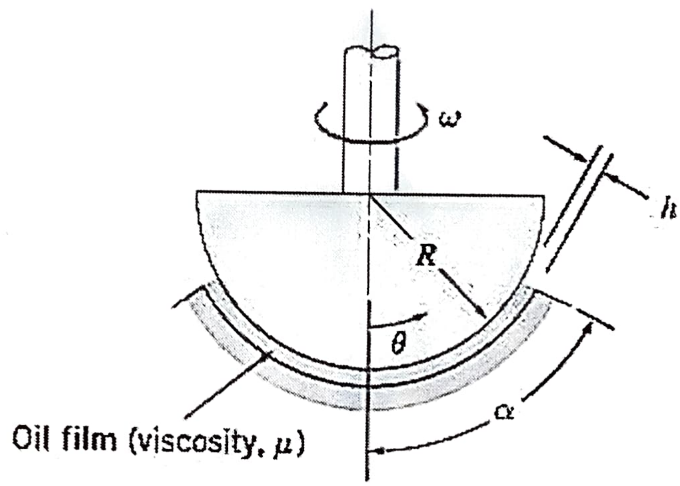

Fig.1

{End of Question paper}

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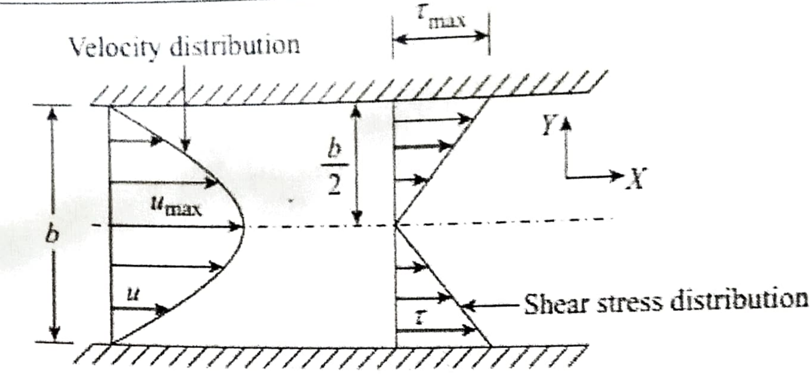
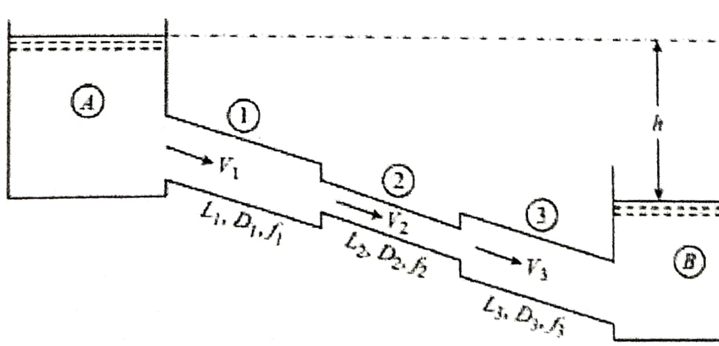
Applied Mechanics Department,
End Semester Examination, Session 2022-23 (Even)

Programme:	*B.Tech.*	**Branch:**	*Chemical Engg.*	**Semester:**	*II^{nd}*
Course Name:	*Fluid Flow Operations*				
Course Code:	*AMN-12101*	**Max. Marks:**	40	25	
Time:	*2 Hrs 30 Min*	**Registration No.:**			

Instructions (related to question paper):
1. Please read the question paper carefully.
2. The question paper has 3 pages and total 5 question.
3. All questions are mandatory.
4. Assume any missing data suitably.
5. Various symbols carries their usual meanings.

			Marks	Corresponding course outcome with weightage (if any)
Q1				CO
	a	How the pressure in Fluids is defined? Explain in light of phenomenon of Continnum.	(2)	CO-i
	b	A flat plate having an area of 0.64 m^2 slides down the inclined plane at an angle of 30° to the horizontal with a speed of 0.35 m/s. A lubricant layer of 1.6 mm thickness is placed between the plane and the plate. Determine the viscosity of the lubricant used if the weight of the plate is 250 N.	(2)	CO-i
	c	The velocity vector in two different flow fields are given by the equations (i) $\vec{V} = 2xi - 2yj$ and (ii) $\vec{V} = 2x^3 i - 6x^2yj$. Determine the equations of streamline in each case when it passes through a point *A* (3, 2)	(2)	CO-i
	d	Find the velocity and acceleration components of a fluid particle at position $\vec{r}(x, y, z) = 2i + j + 3k$ when $t = 1.5$ for the fluid flow described by the velocity vector $\vec{V}(x, y, z, t) = 5xyi + 3x^2j + 2(t^2x + z)k$.	(2)	CO-i
	e	The velocity components of a three-dimensional incompressible fluid flow are $u = (3x + y + z)t$ and v = (x-3y+z) t, w=(x+y) t. State if the flow represented by the given velocity components is a physically possible three-dimensional incompressible flow and also state whether the flow is rotational or irrotational.	(2)	CO-i
	f	For a two-dimensional flow, $\phi = 3xy$ and $\psi = 1.5(y^2 - x^2)$. Find the velocity components at the points *P* (1, 3) and *Q* (2, 3). Also find the discharge between the streamlines passing through the given points.	(2)	CO-i
Q2				
	a	For a laminar flow of a fluid between two fixed parallel plates as shown in Fig.1 prove that the pressure drop between two sections is given as $$\Delta p = \frac{12\mu VL}{b^2}$$ Where , $\mu = viscosity\ of\ fluid$, and V= avergage velocity of flow (u_{av}) L= distance between the sections	(3)	CO-i

		 **Fig.1**		
	b	A Venturimeter with its axis vertical is used to measure the flow rate of petrol (specific gravity = 0.8) in a vertical pipeline. The inlet and throat diameters of Venturimeter are 0.15 m and 0.075 m, respectively. The throat is 0.25 m above the inlet and its coefficient of discharge is 0.97. If the rate of flow through the Venturimeter in the upward direction is 0.03 m^3/s, then determine the pressure difference between the inlet and the throat.	(2)	CO-i
	c	An oil of absolute viscosity 9 poise and specific gravity 0.88 is flowing through a horizontal pipe of diameter 50 mm. If the pressure drop in 80 m length of the pipe is 1620 kPa, then find (i) the rate of flow of oil, (ii) centre line velocity, (iii) total frictional drag over 80 m length, (iv) power required to maintain the flow, (v) velocity gradient at the wall of the pipe and (vi) velocity and shear stress at 6 mm from the wall.	(2)	CO-i
	d	The velocity through a circular orifice depends on the head H causing the flow, diameter of the orifice D, coefficient of viscosity μ , mass density ρ and the acceleration due to gravity g. Using Buckingham-pi theorem, obtain an expression for V.	(2)	CO-i
Q3				
	a	The velocity profile for turbulent flow of water in a pipe of diameter 0.7 m is given by $u = y + (1/5)\ln y$,where velocity u is in metre per second and the distance y from the wall is measured in metres. If shear stress at a point 0.1 m from the wall is measured as 8 N/m^2, then find the turbulence viscosity (η), mixing length (l) according to Prandtl mixing length theory.	(2)	CO-i , CO-ii
	b	A rough pipe of diameter 0.3 m and length 3000 m carrying water has average height of roughness (k) of 0.3 mm. Determine the head loss due to friction for maintaining water flow rate of 0.1 m^3 using Colebrook-white equation.	(2)	CO-i , CO-ii
	c	Three pipes connected in series (Fig.2) have diameters as 0.3 m, 0.2 m and 0.4 m and lengths as 400 m, 200 m and 300 m and coefficients of friction as 0.007, 0.0072 and 0.0074, respectively. If the pipes join two water reservoirs A and B having a difference in water surface levels as 15 m, then determine the discharge of water considering both major and minor energy losses.  **Fig.2**	(2)	CO-i , CO-ii

Q4	a	What do you understand from boundary layer sepration? Explain the phenomeneon for a flow over a cylinder with suitable diagram. Explain various methods of controlling boundary layer sepration with suitable diagrams.	(2)	CO-i, CO-ii
	b	The velocity distribution in the boundary layer is given by $\frac{u}{U} = (\frac{y}{\delta})^{0.22}$. At a section, the freestream velocity (U) is measured to be 20 m/s and the boundary layer thickness (δ) was estimated as 30 mm. Calculate (i) the displacement thickness, (ii) momentum thickness.	(2)	CO-i, CO-ii
	c	Using Momentum Integral equation determine the expressions for boundary layer thickness (δ), shear stress (τ_0), and coefficient of drag (C_D) in terms of Reynolds number for the velocity profile of a laminar boundary layer over a flat plate given by $\frac{u}{U} = \frac{3}{2}\frac{y}{\delta} - \frac{1}{2}(\frac{y}{\delta})^3$.	(3)	CO-i, CO-ii
Q5				
	a	Explain various flow measuring devices along with suitable broad classification. Also explain with suitable diagrams how flow rate can be determined theoretically using Bernoullie's theorem with a Pitot tube.	(2)	CO-i, CO-iii
	b	Determine the specific speed of a centrifugal pump which delivers water at the rate of 2 m^3/s under a head of 20 m while running at 3500 rpm and operating at a maximum efficiency of 85%. Also determine the discharge, head and power input to the pump at the speed of 2500 rpm assuming that the efficiency remains constant at all the speed.	(2)	CO-i, CO-iii
	c	Explain the difference in discharge obtained in case of single acting and double acting reciprocating pump. A double acting reciprocating pump operating at 55 rpm has a piston diameter of 0.2 m and piston rod of diameter 40 mm which is on one side only. The stroke of the piston is 0.3 m. The suction and delivery heads are 5 m and 20 m, respectively. Determine (i) the theoretical discharge and (ii) power required to drive the pump.	(2)	CO-i, CO-iii

Course Outcomes:	CO-i:	To give fundamental knowledge of fluid, its properties, hydrostatic laws and application of mass, momentum and energy equation in fluid flow.
	CO-ii:	Ability to analyze fluid flow problems with the application of the momentum and energy equations.
	CO-iii:	To learn the importance of flow measurements and its applications in Industries and to develop basic knowledge of fluid machinery and its applications.