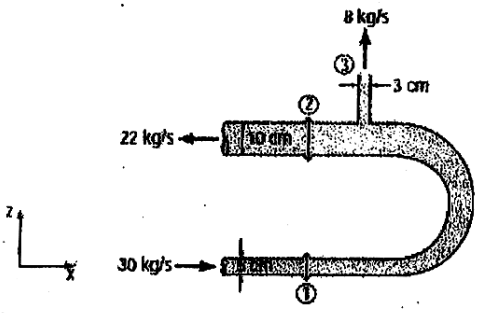
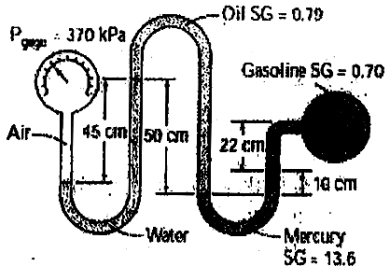
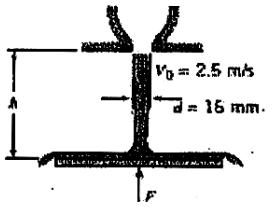
B. E. CHEMICAL ENGINEERING 2nd YEAR 1ST SEMESTER EXAMINATION 2023

SUBJECT: MECHANICS OF FLUID Time: Three hours Full Marks 100

Part I

Use separate answer script for Part1 and Part II. Assume missing data if any. Write all the assumption

No. of Q No./CO	Answer questions 1 and either 2 or 3 and either 4(a) or 4(b)	Marks
1(i) CO1	A velocity field is given by $V=3y\,i - 9x\,j$ What is the directionality and dimensionality of the flow field? Derive the equation of streamline passing through point (1,1). Is the flow irrotational? Justify	(2+5+5)
1(ii) CO1	A wet paint film of uniform thickness, δ, is painted on a vertical wall. The wet paint can be approximated as a Bingham fluid with a yield stress, τ_o, and density, ρ. Derive an expression for the maximum value of δ that can be sustained without having the paint flow down the wall. Calculate the maximum thickness for lithographic ink whose yield stress τ_o= 540 Pa and density is approximately 1000 kg/m^3.	(6)
2. (i) CO2	Water is flowing into and discharging from a pipe U-section as shown in Fig. 1. At flange (1), the total absolute pressure is 200 kPa and 30 kg/s flows into the pipe. At flange (2), the total pressure is 150 kPa. At location (3) 8 kg/s of water discharges to the atmosphere, which is at 100 kPa. Determine the total x and z forces at the two flanges connecting the pipe.	(12)
	 FIG.1	
	 FIG.2	
2(ii) CO4	A gasoline line is connected to a pressure gage through a double-U manometer, as shown in Fig. 2. If the reading of the pressure gage is 370 kPa, determine the gage pressure of the gasoline line.	(6)
	 FIG 3	
3(i) CO2	A uniform jet of water leaves a 15 mm diameter nozzle and flows directly downward (fig3). The jet speed at the nozzle exit plane is 2.5 m/s. The jet impinges on a horizontal disk and flows radially outward in a flat sheet. Develop an expression for the force required to hold the disk stationary, neglecting the mass of the disk and water sheet.	(14)
3(ii) CO4	Orifice meter is used for measuring the flow of a fluid. The discharge coefficient of orifice meter Co=0.61. The orificemeter is replaced by a venturimeter having discharge coefficient Cv =0.98 (the throat diameter being the same as the orifice diameter; i e β remains same). For the same flow, by what factor the reading of manometer will be changed?	(4)

Ref. No. Ex/Che/PC/B/T/213/2023

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Part I

Use separate answer script for Part I and Part II. Assume missing data if any. Write all the assumption

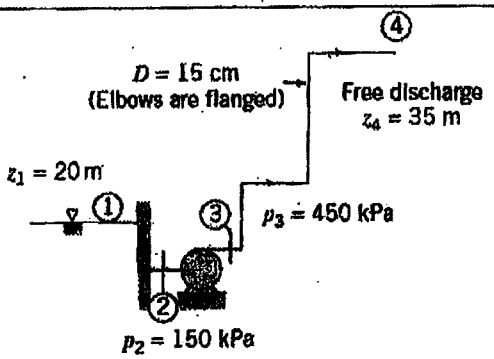
No. of Questions/CO	Answer questions 1 and either 2 or 3 and either 4(a) or 4(b)	Marks
4(a). CO3	 FIG.4 Water is pumped from a reservoir 20 m above a pump to a free discharge 35 m above the pump (Fig 4). The pressure on the intake side of the pump is 150 kPa and the pressure on the discharge side is 450 kPa. All pipes are commercial steel (ε =0.046 mm) of 15 cm diameter. In the pipeline 4 no. 90° flanged Elbows are used to change the direction of flow and 1 no. globe valve is used to control the flow. Determine (i) the head supplied by the pump, (ii) The flow rate of water through the pipe.	(14)
or		
4 (b) (CO3)	A liquid reactant is pumped through a catalytic reactor which consists of a horizontal cylinder packed with catalyst sphere of diameter D_p=2.0mm. Tests summarized in Table 1 show the pressure drops ($-\Delta p_f$) across the reactor at two different volumetric flow rates Q. If the maximum pressure drop is limited by the pump to 350 kPa, what is the upper limit on the flow rate?	(14)

Table 1

Q (m^3/hr)	$-\Delta p_f$, kPa
0.34	66.2
0.68	166.2

Ergun equation for flow through packed bed is as follows

$$\frac{(-\Delta P_f)}{L}\frac{D_p}{\rho V_o^2}\frac{\varepsilon^3}{(1-\varepsilon)} = 150\frac{(1-\varepsilon)\mu}{\rho V_o D_p} + 1.75$$

Representative Dimensionless Equivalent Lengths (L_e/D) for Valves and Fittings

Fitting Type	Equivalent Length,[a] L_e/D
Valves (fully open)	
Gate valve	8
Globe valve	340
Angle valve	150
Ball valve	3
Lift check valve: globe lift	600
angle lift	55
Foot valve with strainer: poppet disk	420
hinged disk	75
Standard elbow: 90°	30
45°	16
Return bend, close pattern	50
Standard tee: flow through run	20
flow through branch	60

[a] Based on $h_L = f(L_e/D)(\overline{V}^2/2)$.

Source: Data from Reference [11].

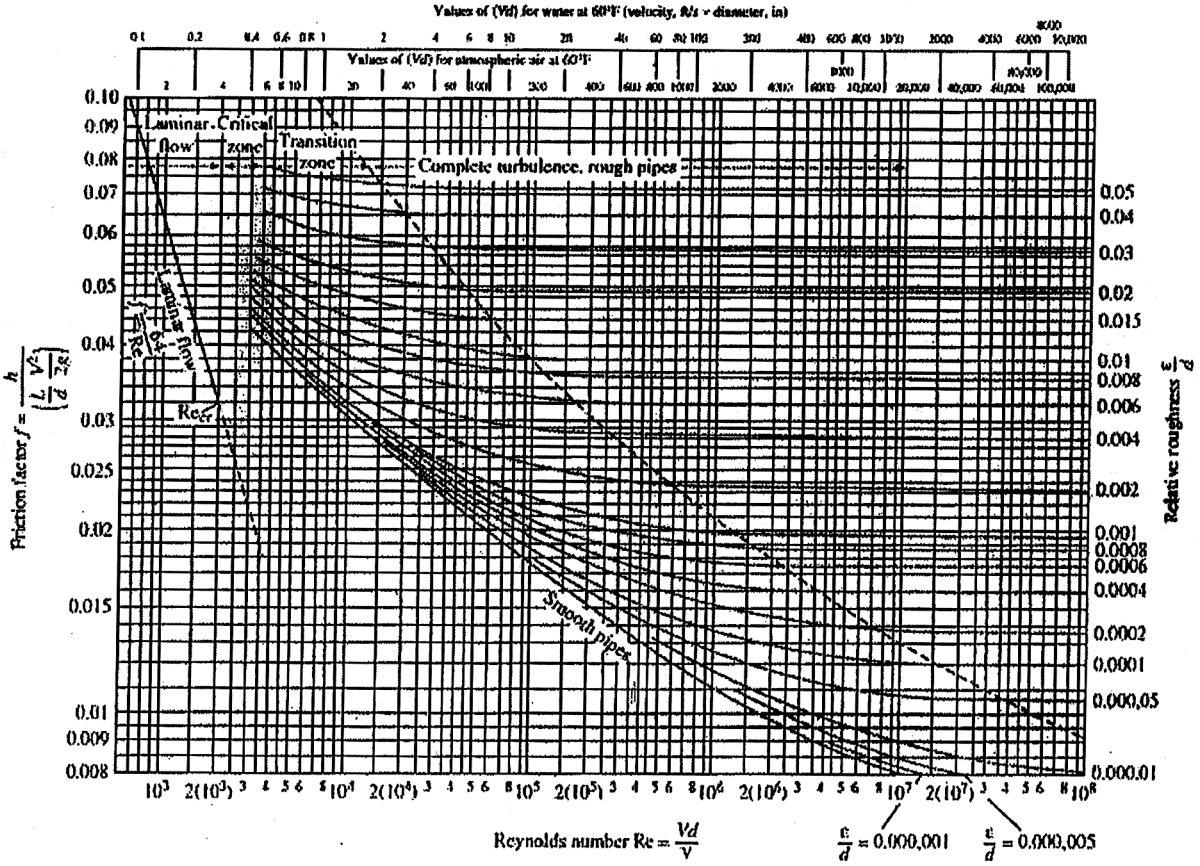


Fig. 6.13 The Moody chart for pipe friction with smooth and rough walls. This chart is identical to Eq. (6.48) for turbulent flow. *(From Ref. 8, by permission of the ASME.)*

Ref. No. Ex/ChE/PC/B/T/213/2023

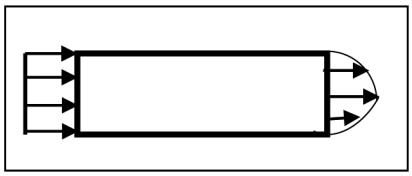
B.E. Chemical Engineering 2nd year 1st Semester Examination, 2023
Mechanics of Fluid

Part II

Answer any four questions.
All questions carry equal marks. (Neatness – 02)
Assume any missing data

1. (a) A flow is described by the velocity field $\vec{V} = ax\hat{\imath} - by\hat{\jmath}$. Find the equation of the flow streamlines.

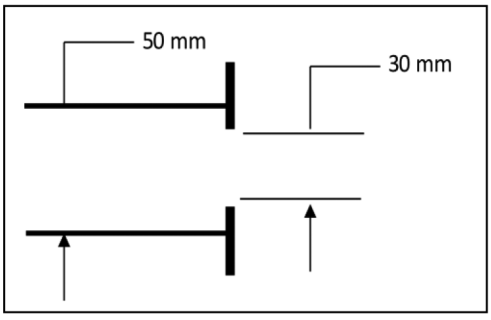
   (b) For the velocity field given in part (a), determine whether the flow one-, two- or three-dimensional and why (9 +3) [CO-1]



2. Water flows steadily through a pipe of radius R. The velocity at the inlet (U) is uniform, while the velocity distribution at the outlet of the pipe is

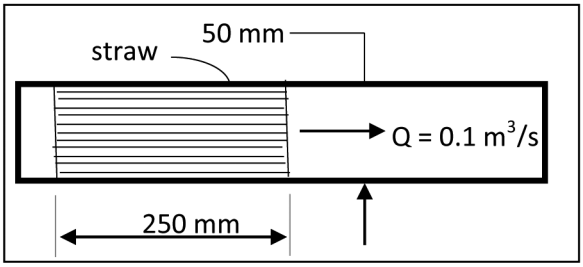
$$u = u_{max}\left(1 - \frac{r^2}{R^2}\right)$$

Obtain the expression of U in terms of R and u_{max}. (12) [CO-2]



3. A flat orifice is located at the end of a 50 mm diameter pipe. Water flows through the pipe and orifice at 0.05 m3/s. The diameter of the water jet downstream from the orifice is 30 mm. Calculate the external force required to hold the orifice in place. Neglect friction on the pipe wall. (12)

4. Water flows through 75 straws (each of diameter 5 mm and length 250 mm) inserted within a pipeline of diameter 50 mm as shown in the figure. Calculate the pressure drop across the straw. The friction factor (*f*) if the flow is turbulent can be obtained from the following equation $f = \frac{0.08}{Re^{0.25}}$ where Re is the Reynold's number. The viscosity of



water may be assumed to be 1 cP. (12)
[CO-3]

5. Water (flow rate = 0.01 m^3/s) is flowing through a smooth pipe of diameter 10 cm. Calculate the velocity at a distance of 1 cm from the wall of the pipe. The friction factor (*f*) if the flow is turbulent can be obtained from the following equation $f = \frac{0.08}{Re^{0.25}}$ where Re is the Reynold's number. The viscosity of water may be assumed to be 1 cP. (12) [CO-4]