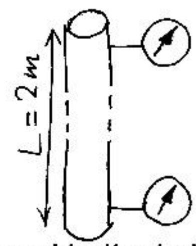
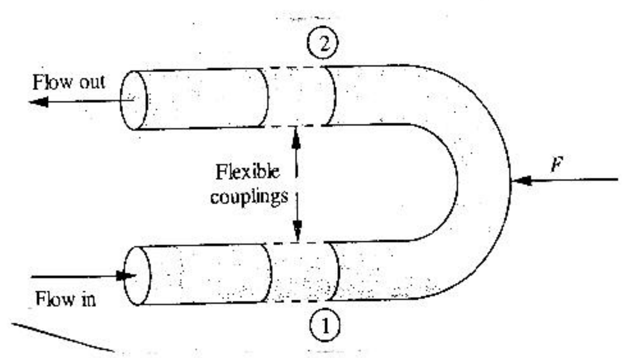
Ref No. Ex/CHE/T/214/2017

B. CHEMICAL ENGINEERING 2nd YEAR 1st SEMESTER EXAMINATION, 2017
SUBJECT: MECHANICS OF FLUIDS

Time: Three hours   Full marks 100

Answer any four questions. State all the assumptions. Assume the missing data (if any).

No. of questions		Marks
1. (a)	Figure 1 shows two pressure gauges that are mounted on a vertical water pipe 2m apart, yet they read exactly the same pressure, 100 psig. Is the water flowing? If yes, in which direction is it flowing? Justify your answer.  FIG.1	(4)
(b)	Figure 2 shows an idealized view of a return elbow or U bend, which is connected to two pipes by flexible hoses that transmit no forces. Water flows at a velocity 10 m/s through the pipe, which has an internal diameter of 0.1 m. The gauge pressure at points 1 and 2 are 3.0 and 2.5 bar respectively. What horizontal force is needed to keep the return elbow in position? FIG 2 	(13)
(c)	$\vec{V} = 2y\hat{i} - 2x\hat{j}$ (i)What are the dimensionality and directionality of flow? (ii)Derive the equation of streamline passing through (1,1) at time t=0 (iii) Is the flow rotational? If yes what is the value of vorticity?	(2+3+3)

[Turn over

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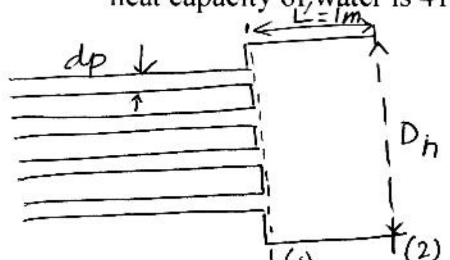
2. (a)	**(i)Consider the expansion of flow through multiple pipes into the header** (refer to Fig. 3). There are 40 number of steel tubes of inside diameter dp= 0.025m of length L=1 m. The diameter of header is D_h=0.25m. The average velocity of a Newtonian incompressible fluid (ρ=1000kg/m^3, μ=0.001 Pa s (kg/m s)) through each steel tube is uo=0.6 m/s. (i) Derive an expression of ΔP across section 1-2. Assume that the pressure at section 1 is uniform across the cross-section. (ii) Derive an expression for frictional loss (dissipation) per kg fluid flowing between section 1 and 2. (iii) The temperature of the fluid entering section 1 (T_1) is 25°C and the temperature of the fluid leaving section 2 (T_2) is 60°C. What is the rate of heat added per unit mass? The heat capacity of water is 4187 J/(kg K).  FIG.3	(5+5+5)
(b)	A pitot tube is inserted at the center of an air duct having 1 inch inside diameter. A pressure gauge attached to the pitot tube reads 7.9 N/m^2. Calculate the mass flow rate of air, at a temperature of 40°C and a pressure of 100 kN/m^2. Assume ideal gas law to be valid.	(10)

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<table>
<tr><th>No. of questions</th><th></th><th>Marks</th></tr>
<tr><td>3. ([redacted])</td><td>

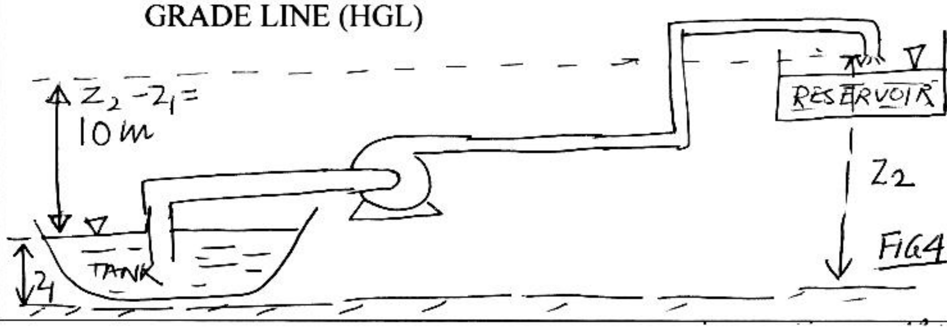
Water is pumped from a tank to a reservoir as shown in Fig.4. The pipes having inside diameter of 0.025 m are made of commercial steel (ε/D=0.0018). The total length (excluding fittings) of suction pipeline (from tank to the pump suction) is 5 m and that of discharge pipe line (from pump discharge to the reservoir) is 10m. The suction pipe line contains one fully open gate valve, two 90° standard elbows and the discharge pipeline contains one fully open globe valve and two 90° standard elbows. The loss coefficient values of the fittings are as follows:

Type of fitting	Loss Coefficient
Gate valve fully open	0.2
90° standard elbow	1.5
Globe valve fully open	8.2

The characteristic head versus capacity curve of the pump is given by: $\Delta H=30-2Q^2$; ΔH is the head developed by the pump (m) and Q is the flow rate (m^3/hr).

(A) Calculate:
(i) The flow rate (m^3/s)
(ii) The pressure increase across the pump (P_d-P_s)(N/m^2)
(iii) The Reynolds number Re in the pipeline
(iv) The Fanning friction factor
(v) The power input to the pump assuming that the efficiency is 72%.

(B) Draw the ENERGY GRADE LINE (EGL) and HTDRAULIC GRADE LINE (HGL)



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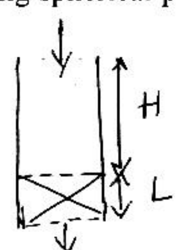
Answer any four questions. State all the assumptions. Assume the missing data (if any).

No. of questions		Marks
4. (a)	As shown in Figure 5 a bed (diameter 5 cm) of ion exchange resin particles (cylindrical in shape, diameter D=1mm and length 2mm, ρ_p=1300 kg/m^3) of depth L= 5 cm is supported by a metal screen that offers negligible resistance to flow at the bottom of a cylindrical container. Water (μ=1 cP and ρ=1000kg/m^3) flows steadily down the bed. The pressures at both the free surface of the water and at the exit from the bed are atmosphere. (i) Calculate the value of the sphericity of the cylindrical particles. (ii) Calculate the superficial velocity and flow rate of water passing through the packed bed for H=60 cm. The void fraction of the packed bed ε=0.36. Ergun equation for flow through packed bed having spherical particles is given below: $\frac{(-\Delta P_f)g_c}{L}\frac{\phi_s D_p}{\rho V_o^2}\frac{\varepsilon^3}{(1-\varepsilon)} = 150\frac{(1-\varepsilon)}{\phi_s N_{\mathrm{Re}\,p}} + 1.75$  FIG 5	(5+10)
4. (b)	A lubricated shaft rotates inside a concentric sleeve bearing at 1200 rpm. The clearance δ is small with respect to the radius R; so a linear velocity distribution in the lubricant may be assumed. The torque required to rotate the shaft is 0.8 Nm. R= 2 cm, L=6 cm and δ= 0.1 mm. What is the value of the viscosity of the lubricant?	(10)
5. (a)	A Newtonian fluid of density ρ= 800 kg/m^3 and viscosity μ=230 cP flows at a rate Q=1560 cm^3/s through a horizontal pipe of diameter 10 cm. Evaluate the (i) average velocity (ii) the Reynolds number, (iii) the pressure drop per unit length (iv) the wall shear stress (v) the fanning friction factor (vi) the frictional loss for 100 cm of pipe. Show the derivation of the necessary equations to be solved.	(12)
(b)	Water at 15°C flows through a 30 cm diameter riveted steel pipe of length 300m, ε= 3 mm, with a head loss of 6m. Determine the flow neglecting the minor losses.	(8)

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5. (c)	Explain the working principle of a rotameter	(5)
6. (a)	A vertically mounted packed bed deionizer (1 m in diameter by 3 m long) of ion exchange resin (spherical particles of average diameter 2 mm, density 1300 kg/m^3)is regenerated by back-flushing with 10 % brine solution (towards the upward direction) of density 1070 kg/m^{3}at a rate such that the bed is expanded 100%. The porosity of the bed packed bed before back flushing was 0.36. (i) What rate of brine flow is required? (ii) Is the bed fluidized? If yes, what kind of fluidization (particulate/aggregative) is it? (iii) What is the void fraction (ε) of the expanded bed?	(15)
(b)	A horizontal 2 inch inside diameter pipe carries kerosene at 35^{o}C with density 900 kg/m^3 and viscosity 4 cP. In order to measure the flow rate, the line is to be fitted with a venturimeter, with pressure tapping those are connected to mercury manometers that reads up to 15 inch. difference in mercury levels. If the maximum flow rate of kerosene is expected to be 5 kg/s, specify the throat diameter of the venturimeter.	(10)

The Moody chart