WINTER-19 EXAMINATION

Model Answer

Subject title: Fluid Flow Operation

Subject code 22409

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q No.		Answer	Marking scheme
1		**Attempt any FIVE of the following**	**10**
1	a	**Definition of** **Fluid static:** The branch of fluid mechanics which deals with the study of fluids at rest. **Fluid dynamics:** The branch of fluid mechanics which deals with the study of fluids in motion.	1 1
1	b	**Eg for Newtonian fluid (any two)** H_2O, $CHCl_3$, gases, low viscosity liquids **Eg for Newtonian fluid (any two)** Complex fluid like rubber latex, sewage sludge, polymer solutions, starch solutions, toothpaste, tomato ketch up.	½ mark each ½ mark each
1	c	**SI units of** **Volumetric flow rate:** m^3 /s **Mass flow rate:** kg / s **Density:** kg / m^3 **Reynolds number:** no unit (Dimensionless number)	½ mark each
1	d	**Different flow meter (any four):** Orifice meter, venturimeter, rotameter, pitot tube	½ mark each
1	e	**Definition of NPSH:** Net Positive Suction Head is the amount by which the pressure at the suction point of the pump (sum of velocity head and suction head) is in excess of the vapour pressure of the liquid	2

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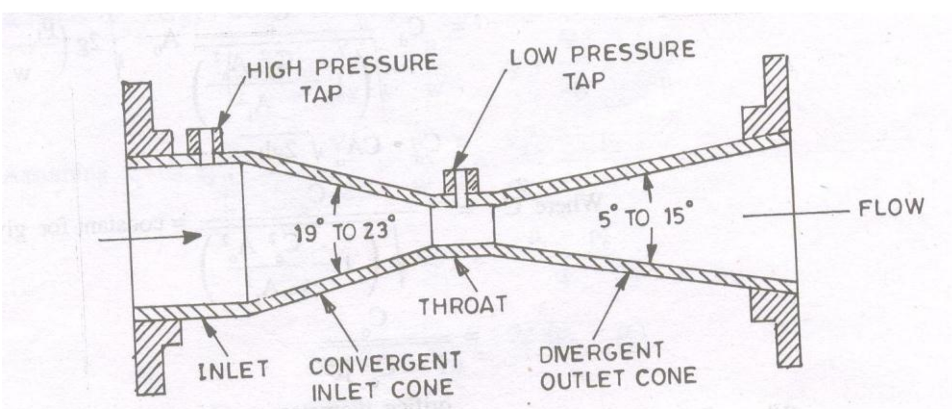
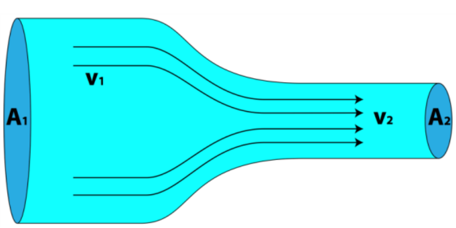
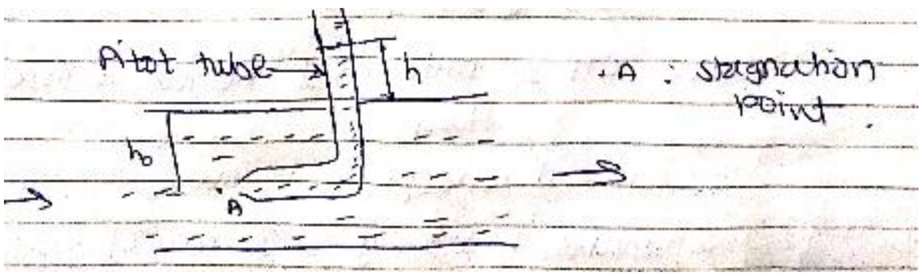
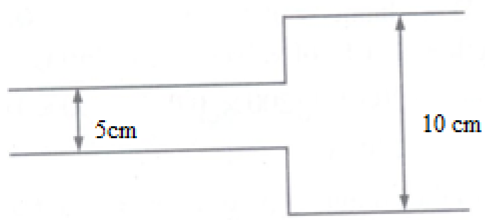
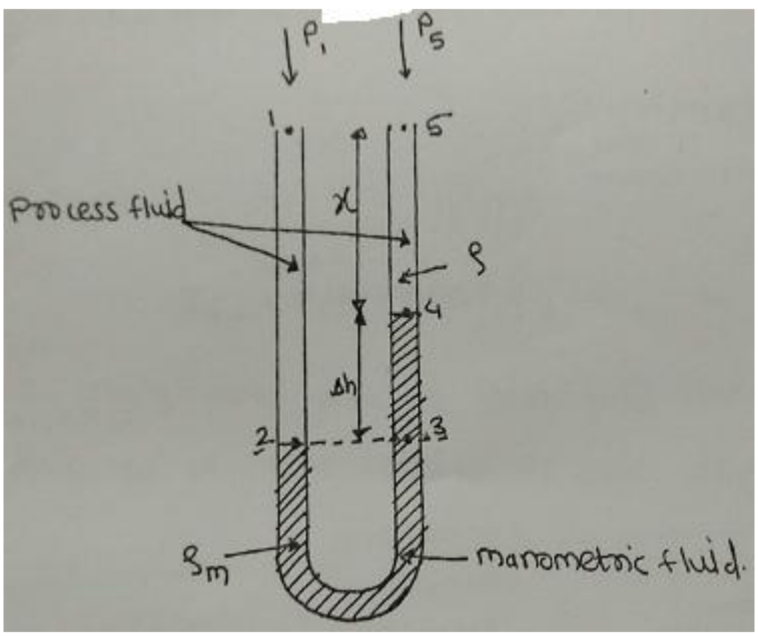
1	f	**Parts of pump (any four):** Suction pipe, delivery pipe, pump casing, impeller or cylinder with a reciprocating element or a rotating element, suction valve, delivery valve	½ mark each
1	g	**Two vacuum generating equipment:** Jet ejectors, vacuum pumps, vacuum blowers	1 mark each
2		**Attempt any THREE of the following**	**12**
2	a	**Newton's law of viscosity:** It states that shear stress τ (F /A) is proportional to shear rate or velocity gradient (du / dy) and the proportionality constant is called viscosity (μ) of the fluid. Shear stress α shear rate $(F/A) \; \alpha \; (du/dy)$ $(F/A) = \mu \, (du/dy)$	2
		Principle of hydrostatic equilibrium: Pressure exerted by a fluid is the force exerted by the fluid on the walls of the container. The principle of hydrostatic equilibrium states that the pressure at any point in a fluid at rest is due to the weight of the overlying fluid.	2
2	b	**Diagram of Venturimeter:** 	2 marks for diagram and 2 marks for labeling.

2	c	**Purpose of fitting:** **(i) Tee:** For branching the pipe in 3 directions. **(ii) Cross:** For branching the pipe in 4 directions. **(iii) Plug:** To close the end of the pipe. **(iv) Bend**: For changing the direction of flow.	1 mark each
2	d	**Classification of pumps:** Pumps can be classified as Positive Displacement Pump and Centrifugal pumps. Positive Displacement Pumps are classified into Reciprocating pumps and Rotary pumps. There are different types of reciprocating pumps like Piston pump, Plunger pump, diaphragm pump etc. There are different types of rotary pumps like gear pump, lobe pump, screw pump etc. Reciprocating pumps can be single acting or double acting pumps. Depending on the number of cylinders, the reciprocating pumps can also be classified as simplex, duplex and triplex pumps.	4
3		**Attempt any THREE of the following**	**12**
3	a	**Derivation of equation of continuity:** Mass balance states that for a steady state flow system, the rate of mass entering the flow system is equal to that leaving the system provided accumulation is either constant or nil.  Let v_1, ρ_1& A_1 be the avg. velocity, density& area at entrance of tube & v_2 , ρ_2& A_2 be the corresponding quantities at the exit of tube.	1

		Let $\dot{m}$ be the mass flow rate Rate of mass entering the flow system = $v_1 \rho_1 A_1$ Rate of mass leaving the flow system = $v_2 \rho_2 A_2$ Under steady flow conditions $\dot{m} = \rho_1 v_1 A_1 = \rho_2 v_2 A_2$ $\dot{m} = \rho v A$ = constant …….. **Equation of continuity**	2 1
3	b	**Pitot tube:** **Diagram:**  **Construction and working:** In simple form, it consists of a single pitot tube with mouth pointing in the direction of flow. In modified pitot tube construction, two concentric tubes are arranged in the directions of flow. The fluid is brought to rest at the entrance of the inner tube. Similarly a hole is made on the outer tube to such size that fluid entering through the hole represents bulk velocity or velocity of fluid in adjacent layer of fluid. These two tubes are in turn connected to two limbs of U tube manometer. The differential pressure created in the manometer represents the velocity at that point. The point velocity or local velocity is calculated as V = $\sqrt{(2g\Delta H)}$ Where ΔH is differential height of manometric fluid. **Application:**	1 2

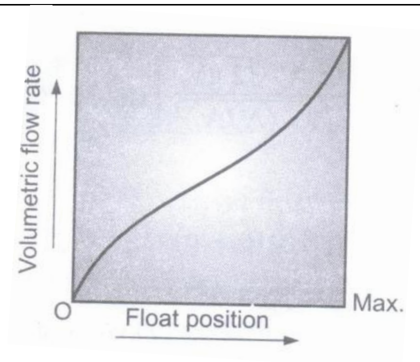
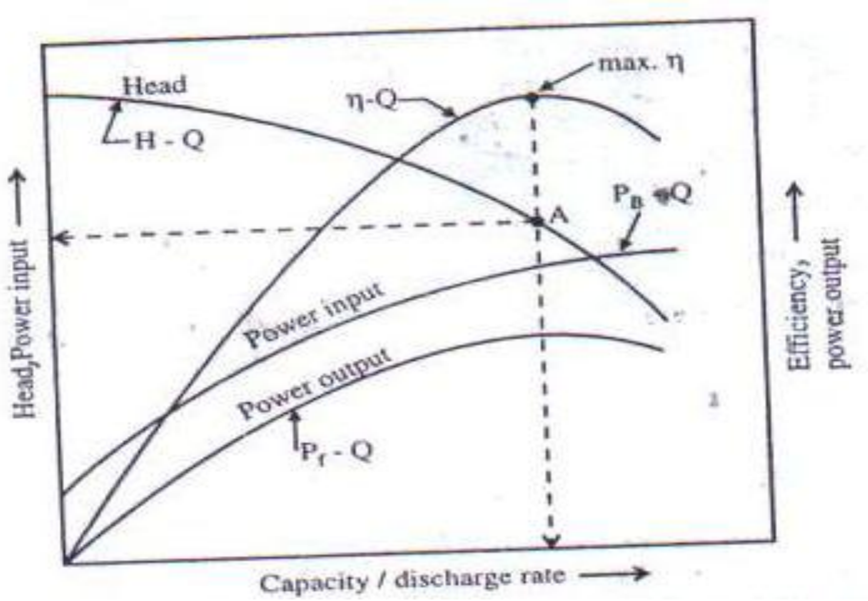
<table>
<tr><td></td><td></td><td>It is a velocity measuring device used to measure local velocity. It is generally used to measure the velocity in open channel.</td><td>1</td></tr>
<tr><td>3</td><td>c</td><td>

Friction loss due to sudden expansion (h_{fe}) is given by the equation
$$(h_{fe}) = Ke\,\frac{u_1^2}{2}$$
Where Ke is expansion loss coefficient
$$Ke = [1 - \frac{A1}{A2}]^2$$
A_1 = area of the smaller pipe = $\frac{\Pi}{4} D_1^2 = \frac{\Pi}{4} (0.05)^2 = 1.9625*10^{-3}\ m^2$
A_2 = area of the larger pipe = $\frac{\Pi}{4} D_2^2 = \frac{\Pi}{4} (0.1)^2 = 7.85*10^{-3} m^2$
$Ke = [1 - \frac{A1}{A2}]^2 = \left(1 - \frac{1.9625*10^{-3}}{7.85*10^{-3}}\right)^2 = 0.5625$
u_1= Velocity of flowing fluid through the smaller pipe = 2 m / s
$h_{fe} = Ke\,\frac{u_1^2}{2} = 0.5625 * \frac{(2)2}{2} =$ **1.125 J /kg**</td><td>1
1
1
1</td></tr>
<tr><td>3</td><td>d</td><td>Comparison between compressor and fan on the basis of following points
<table><tr><th>Criteria</th><th>Fan</th><th>Compressor</th></tr><tr><td>Speed</td><td>High speed machines. Used for air circulation than developing pressure.</td><td>Low speed machines. They are mainly used for discharge at high pressure.</td></tr><tr><td>Pressure developed</td><td>Less.</td><td>High</td></tr></table></td><td>2 marks each</td></tr>
</table>

			Less than 30 kPa.	The pressure developed depends on the type of compressor. Reciprocating compressor develop high pressure than centrifugal compressor.	
4		**Attempt any THREE of the following**			**12**
4	a	**P_1-P_2 = h (ρ_m – ρ)g (Derivation)**  Let P_1= pressure acting due to process at point 1 P_2 = Pressure acting due to process at point 2 (if right leg is open to atmosphere, P_5 is atmospheric pressure) ρ_m- density of manometric fluid ρ - Density of flowing fluid			1

		The differential pressure acting across the manometer can be determined by using principle of hydrostatic equilibrium. As per this principle, pressure exerted by height of liquid column can be expressed as $P = \rho gh$ ……..(1) Where h is the height of liquid column (m) By applying this principle, pressure acting at point 1 can be expressed as $P = P_1$ …….(2) At point 2 in left limb $P_2 = P_1 + (x+\Delta h)\rho g$ ……(3) By using the principle that fluid exert same pressure at same level, we can write $P_2 = P_3$ ……(4) $P_3 = P_2 = P_1 + (x+\Delta h)\rho g$ ……(5) Similarly pressure exerted at point 4 will be less than P_3 by magnitude equal to pressure exerted by mercury column of height Δh $P_4 = P_3 - \Delta h \rho_m g$ …..(6) Using similar procedure, we can write P_5 as $P_5 = P_4 - x\rho g$ …(7) Substituting the value of P_3 and P_4 from equation (5) and (6) , $P_5 = P_3 - \Delta h\rho_m g - x\rho g = P_1 + (x+\Delta h)\rho g - \Delta h\rho_m g - x\rho g$ P_1 is upstream pressure and P_5 is downstream pressure $P_1 > P_5$ Simplifying the above equation, we get $P_1 - P_5 = \Delta h(\rho m - \rho)g$ **$\Delta P = \Delta h(\rho m - \rho)g$**	3
4	b	Kinematic viscosity υ = 30 stokes = 30 $cm^2 / s = 30*10^{-4} m^2 / s$ D = 200 mm = 0.2m	

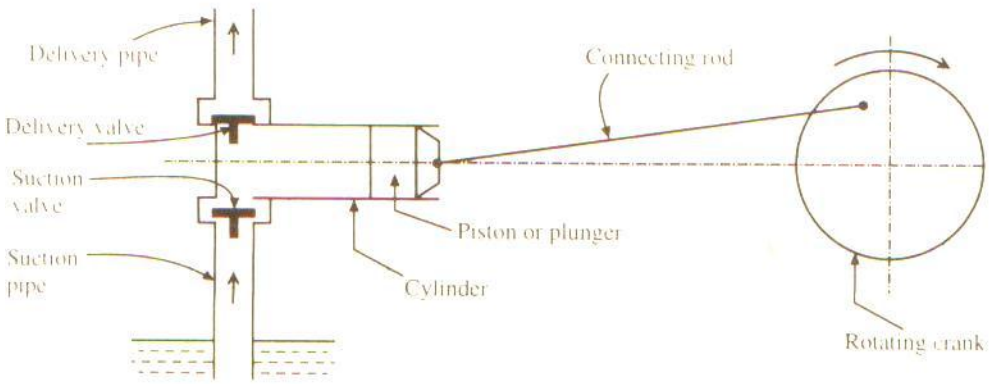
		$Q = 25\ l/s = 25*10^{-3}\ m^3/s$ Area of pipe = $\frac{\Pi}{4} D^2 = (3.14*0.2^2)/4 = 0.0314 m^2$ Velocity $u = Q/A = 0.025/0.0314 = 0.796$ m / s $N_{Re} = \frac{D\,u}{\upsilon} = 0.2 * 0.796 / (30*10^{-4}) =$ **53.06** Since NRe is less than 200, **flow is laminar**	1 1 1 1
4	c	**Calibration of Rotameter with graph** Calibration of Rotameter is establishing a relation between volumetric flow rate and float position. Step wise procedure for calibration of Rotameter is as follows. i. Connect the rotameter in fluid circuit consisting of flow measuring tank, pipe line arrangement and pump. ii. Rotameter should be connected vertically. iii. Start the flow of fluid through the Rotameter. iv. Note down the float position by referring to scale fixed adjacent to Rotameter tube. v. Collect fixed volume of fluid and note down the time required for collection. vi. By varying the flow, note down the float position and corresponding volumetric flow rate by collecting certain volume of fluid and noting down the time for collection each time. vii. Vary the float position over the entire height of Rotameter tube. viii. Plot calibration curve between height of float and corresponding volumetric flow rate	3

			1
4	d	**Characteristic curves of a centrifugal pump :**  Characteristics curve can also be called as performance curve. Generally variation of flow rate, impeller speed varies head developed, power output and efficiency. Even though optimum parameter corresponding to maximum efficiency are specified, actual operating conditions may vary. Characteristics curve consists of ΔH vs Q(Head vs Discharge or volumetric flow rate	2 2

		η vs Q (efficiency vs Discharge or volumetric flow rate) P_B vs Q (power input vs Discharge or volumetric flow rate) P_f Vs Q (power output vs Discharge or volumetric flow rate)	
4	e	**Comparison between reciprocating compressor and centrifugal compressor:**	2 marks each
5		**Attempt any TWO of the following**	**12**
5	a	Data: Density of water = 1000 kg / m^3 Viscosity of water =μ= 0.0008 kg/m.s Fanning Friction factor $f = 0.0001$ Diameter of pipe =d=25 mm =0.025 m Area of pipe: A = π /4 D^2 = π /4*$(0.025)^2$ = 0.0004906 m^2 Length of pipe =L= 100 m Mass flow rate($\dot{m}$) = 1 kg/s $As\ \dot{m} = \rho$ u.A $\dot{m}$ = 1000*u*0.0004906 u = 2.04 m/s	2 1

Criteria	Reciprocating compressor	Centrifugal compressor
Speed	Slow speed machine	High speed machine
Rate of flow	High pressure and low discharge	Low pressure and high discharge Objective is mainly volumetric discharge than pressure.

		The pressure drop through a pipe is given by $$\Delta P = \frac{4\,fL\rho u^2}{2D}$$ $$\Delta P = \frac{4 * 0.0001 * 100 * 1000 * (2.04)^{\,2}}{2 * 0.025}$$ $$\Delta P = \mathbf{3329.28\frac{N}{m^2} = 3.32928 * 10^3 3kN/m^2}$$	1 2
5	b	Data : Diameter of orifice: d_0 = 25 mm = 0.025 m Diameter of pipe: D= 50 mm = 0.05 m Coefficient of orifice = C_o = 0.62 Density of water = 1000 kg/m^3 Density of mercury = 13600 kg/m^3 Area of orifice = A_o= π/4 d_0^2 = π/4 $(0.025)^2$ = 4.906 * $10^{-4}$$m^2$ β= Diameter of throat / Diameter of pipe = 25/50 = 0.5 Pressure drop across the meter = Δh = 11 cm= 0.11 m of mercury Let's find out the value of pressure drop in terms of process fluid(water) ΔH $\Delta H = \Delta h \left[\frac{\rho_{Hg-}\,\rho_{H_2O}}{\rho_{H_2O}}\right]$ $\Delta H = 0.11 \left[\frac{13600-1000}{1000}\right]$ = 1.386 m of water The flow equation of orificemeter is $Q = \frac{C_o A_o}{(1-\beta^4)}.\sqrt{2g\Delta H}$ $$Q = \frac{0.62x4.906x10^{-4}}{\sqrt{(1-0.5^4)}}.\sqrt{2x9.81x1.386} = 1.691\,x\,10^{-3}\ m^3/s$$ Volumetric flow rate $Q = \mathbf{1.691\ x\ 10^{-3}\ m^3/s}$	 1 1 1 2 1
5	c	**Single acting reciprocating pump:** **Diagram**	



Si

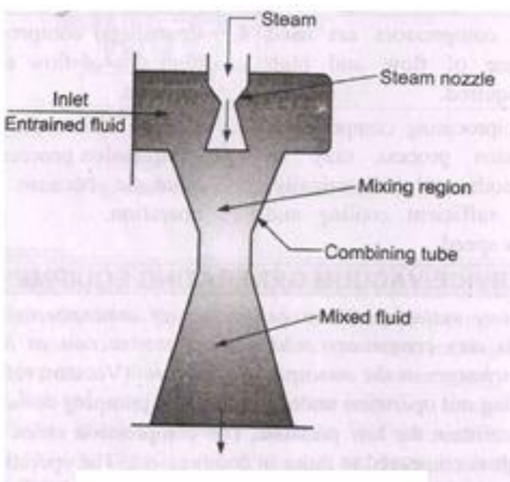
3

Working:

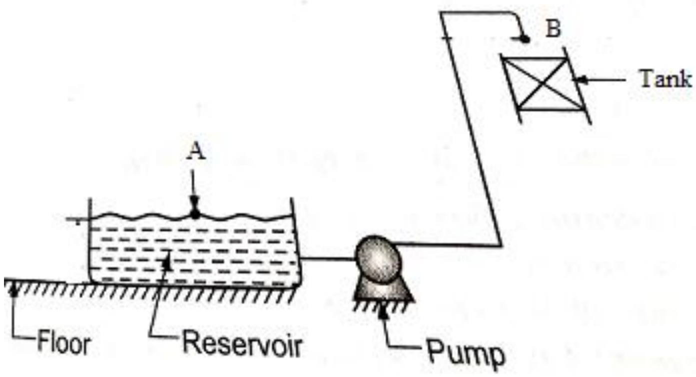
Reciprocating pump consists of a piston or plunger which reciprocates in stationary cylinder. Suppose the piston is initially at extreme left position and when crank rotates thro 180^0 ,piston moves to extreme right position.

Therefore due to outward movement of piston, a partial vacuum is created in cylinder, which enables the atmospheric pressure acting on the liquid surface in the sump below to force the liquid up the suction pipe & fill the cylinder by forcingly opening the suction valve(it is called as a suction stroke).When the crank rotates thro further 180^0 ,piston moves inwardly from its extreme right position towards left. The inward movement of piston causes the pressure of liquid in the cylinder to rise above atmospheric pressure,because of which the suction valve closes & delivery valve opens . The liquid is then forced up the delivery valve & raised to the required height (Delivery stroke).

3

6		**Attempt any TWO of the following**	**12**
6	a	**Steam Jet Ejector** **Diagram**  :	3
		Working: An ejector has two inlets: one to admit the motive fluid, usually steam (inlet 1), and the other to admit the gas/vapour mixture to be evacuated or pumped (inlet 2). Motive steam, at high pressure and low velocity, enters the inlet 1 and exits the steam nozzle at design suction pressure and supersonic velocity, entraining the vapour to be evacuated into the suction chamber through inlet 2. The nozzle throat diameter controls the amount of steam to pass through the nozzle at a given pressure and temperature. The entrained gas/vapour flow and the motive fluid (steam) flow mix while they move through the converging section of the diffuser, increasing pressure and reducing velocity. The velocity of this mixture is supersonic and the decreasing cross sectional area creates an overall increase in pressure and a	3

		decrease in velocity. The steam slows down and the inlet gas stream picks up speed and, at some point in the throat of the diffuser, their combined flow reaches the exact speed of sound. A stationary, sonic-speed shock wave forms there and produces a sharp rise in absolute pressure. Then, in the diverging section of the diffuser, the velocity of the mixture is sub-sonic and the increasing cross sectional area increases the pressure but further decreases the velocity.	
6	b	Pipe length: 30m Pipe ID = 25 mm = 0.025 m Mass flow rate= 1.3 kg/s Height difference between the level of acid in tank and discharge point =12m Viscosity of acid = 0.025N.s/m^2 Density of acid = 1840 kg/m^3 Pump efficiency = 55% Area of pipe A = $\pi/4\ D^2 = \pi/4*(0.025)^2 = 0.0004906\ m^2$ Mass flow rate($\dot{m}$) = 1.3 kg/s $\dot{m} = \rho$ u.A u = 1.3 / (0.0004906 * 1840) = 1.44 m/s To predict the type of flow, value of Reynold's number must be calculated. As $N_{Re} = \frac{D.u\rho}{\mu}$ $N_{Re} = \frac{0.025x1.44*1840}{0.025}$ = 2650 As N_{Re} > 2100 and < 4000,the flow is in a transition region and for practical purpose ,it is treated as turbulent. For turbulent flow, Fanning friction factor	1 1

		$f = \frac{0.078}{N_{Re}^{0.25}} = \frac{0.078}{(2650)^{0.25}} = 0.0109$	1
		The head loss due to friction is given as $h_f = \frac{4\,fLu^2}{2D}$	
		$h_f = \frac{4*0.0109*30*(1.44)^2}{2*0.025} = 54.245$ J / kg	
			
		Writing the Bernoulli's equation between2points A and B	
		$\frac{P_A}{\rho} + gZ_A + \frac{{u_A}^2}{2} + \eta W_P = \frac{P_B}{\rho} + gZ_B + \frac{{u_B}^2}{2} + h_f$	
		$P_A = P_B$(both tanks are open to atmosphere)	
		U_A is negligible compared to V_B	
		$Z_A = 0$ (Datum)	
		$Z_B = 12$m	2
		$U_B = 1.44$ m/s	
		Substituting the values in Bernoulli's equation	
		$\eta W_P = 9.81*12 + 1.44^2/2 + 54.245$	
		$\eta W_P = 173.0018$	1
		$W_P = 173.0018 / \eta = 173.0018 / 0.55 = 314.54$ J / kg	
		Power required = $\dot{m} W_P = 1.3 * 314.54 =$ **408.9 W**	

6	c	Data: Diameter of pipe= D = 250 mm =0.25 m Specific gravity of oil = 0.8 Density of oil = Specific gravity * density of water = = 0.8*1000 =800 kg/m^3 Pressure at station A = 120945 N/m^2 Volumetric flow rate of oil = Q = 120 lit/s = $120*10^{-3}$ m^3/s Area of pipe = A= $\pi/4\ d^2 = \pi/4\ (0.25)^2 = 0.04906\ m^2$ $u = \frac{Q}{A} = \frac{120*10^{-3}}{0.04906} = = 2.44\ m/s$ Total energy at point A (in terms of meters of oil) $= \frac{P}{\rho.g} + Z + \frac{u^2}{2.g}$ $= \frac{120945}{800*9.81} + 3.5 + \frac{(2.44)^2}{2.9.81}$ = **19.21 m of oil** Total energy at point A (in terms of J/kg of oil) = $\frac{P}{\rho} + g.Z + \frac{u^2}{2}$ $= \frac{120945}{800} + 9.81 * 3.5 + \frac{(2.44)^2}{2}$ **=188.5 J/kg**	 1 1 2 2