SUMMER-22 EXAMINATION

Model Answer

Subject title: Fluid Flow Operation

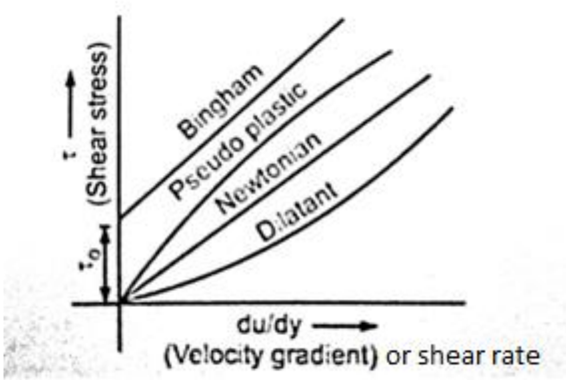
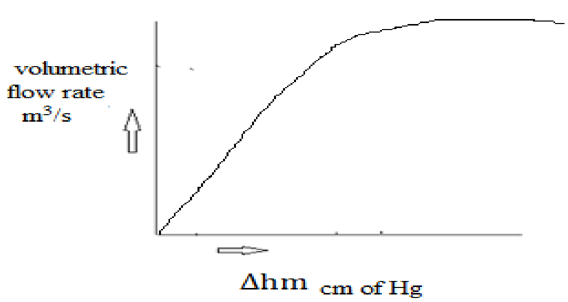
Subject code: 22409

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.
8) As per the policy decision of Maharashtra State Government, teaching in English/Marathi and Bilingual (English + Marathi) medium is introduced at first year of AICTE diploma Programme from academic year 2021-2022. Hence if the students in first year (first and second semesters) write answers in Marathi or bilingual language (English +Marathi), the Examiner shall consider the same and assess the answer based on matching of concepts with model answer.

Q No.		Answer	Marking scheme
1		**Attempt any five**	**10**
1	a	**Ideal fluid:** Fluid which do not offer resistance to flow/ deformation. ie it has no viscosity, it is frictionless and incompressible **Real fluid:** Fluid which offer resistance to flow	1 1
1	b	**Critical velocity** It is the velocity at which the flow changes from laminar to turbulent **Formula to calculate critical velocity:** $N_{Re} = \frac{D\,u\,\rho}{\mu}$ Critical Reynolds number = 2100 $u = \frac{N_{Re}\mu}{D\rho} = \frac{2100*\mu}{D\rho}$	1 1
1	c	**Flow meters used in chemical industry(any four):** Orifice meter, venturimeter, rotameter, pitot tube, electromagnetic flow meter, ultrasonic flow meter, turbine flow meter, rotating vane meter, cylinder and piston type flow meter, mass flow meter etc	½ mark each
1	d	**Pipe fitting used for** i) Branching of pipe – Tee ,cross(any one) ii) Connecting pipes of different diameters– Reducer, expander(any one) iii) Changing direction of flow – Elbow / bend(any one) iv) Termination of pipeline – Plug	½ mark each
1	e	**Net Positive Suction Head (NPSH)**	2

		Net Positive Suction Head is the amount by which the pressure at the suction point of the pump (sum of velocity head and pressure head) is in excess of the vapour pressure of the liquid.	
1	f	**Equipment used for transportation of gases in the industry (any two):** Fan, blower,compressor	1 mark each
1	g	**Eg of incompressible fluid with its density (any one):** Water Density -1 g/cm^3 or 1000kg/m^3 Generally liquids are considered to be incompressible	 1 1
2		**Attempt any three**	**12**
2	a	**Define** **Newtonian fluid:** A fluid, which obeys Newton's law of viscosity, is known as Newtonian Fluid. Generally low viscosity fluids exhibit Newtonion flow behavior **Non-Newtonian fluid** A fluid, which does not obey Newton's law of viscosity, is known as Non-Newtonian Fluid. **Graph showing the relation between shear stress and shear rate for Newtonian and Non Newtonian fluid**	 1 1

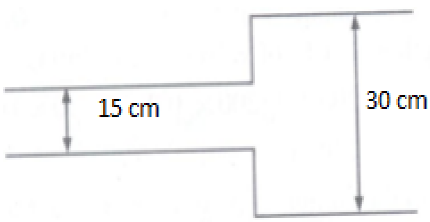
			2
2	b	**Calibration of Orificemeter** It is establishing a relation between pressure drop (Δhm) and volumetric flow rate Start the pump. Remove air from the manometer and experimental set up by opening the air vent valve. Allow water to flow through the orifice meter. Adjust the valve for a small flow rate. Wait till steady state is reached. Note down h_1 and h_2 from the U – tube manometer. Note the time taken for collecting a known volume of water. Repeat the procedure by changing the flow rate. Plot calibration curve  Calibration curve	4

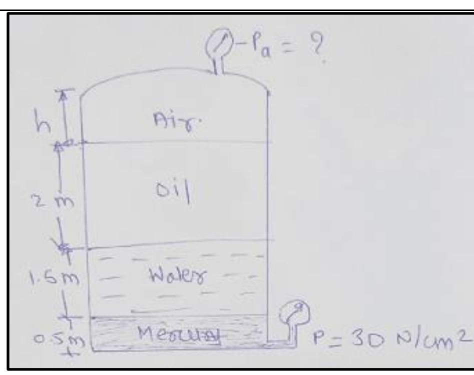
2	c	**Application of** i) **Needle valve:** For accurate controlling of the flow. ii) **Check valve:** Used when unidirectional flow is required. iii) **Gate valve:** For on-off service iv) **Diaphragm valve:** To control the flow ie for regulating the flow	1 mark each
2	d	NPSH = $\frac{P_{B-P_V}}{\rho}$ - gZ_A - h_{fs} P_V = 200 mm of Hg = $\frac{200*101325}{760}$ = 26664.47N/m^2 P_B = 101325N/m^2 Z_A = 1.2m h_{fs} = 3.43J / kg NPSH = $\frac{P_{B-P_V}}{\rho}$ - gZ_A - h_{fs} = $\frac{101325-26664.47}{865}$ – (9.81*1.2)-3.43 = 71.04J/kg = $\frac{71.04}{9.8}$ = **7.25m**	1 3
3		**Attempt any three**	**12**
3	a	**Hagen-Poiseuille equation.** Hagen Poiseuille equation is used for estimation of pressure drop during laminar flow of fluids through a pipe. It is the relation between pressure drop during flow through pipe (ΔP), internal diameter of pipe(D), wall shear stress (τ_w), average velocity of flowing fluid(u) and viscosity of flowing(μ) and length of pipe(L) for laminar flow. Average velocity of flowing fluid can be represented as, $u = \frac{\tau_w r_w}{4\mu}$ (i) Similarly, the dependence of pressure drops on shear stress, length of pipe,	

		diameter and wall shear is expressed as, $\frac{dP}{dL}+\frac{2\tau_w}{r_w}=0$ (ii) As we are considering viscous flow, the energy loss due to skin friction is pressure energy only which can be represented as, $h_{fs}=\frac{\Delta P}{\rho}$ (iii) Now integrating equation (ii) for pipe of finite length 'L', we get, $\Delta P=\frac{2\tau_w L}{r_w}$ (iv) Above equation can be rearranged to eliminate τ_w. $\therefore\ \tau_w=\frac{\Delta P r_w}{2L}$ (v) Combining equation (i) and (v), we can write, $u=\frac{\Delta P r_w}{2L}\ x\ \frac{r_w}{4\mu}=\frac{\Delta P r_w^2}{8\mu L}$ (vi) We can substitute D/2 in place of r_w. Thus equation (vi) can be rewritten as, $u=\frac{\Delta P((D/2)^2)}{8\mu L}=\frac{\Delta P D^2}{32\mu L}$ (vii) Rearranging above equation, we can write equation (vii) as, $\Delta P=\frac{32\mu u L}{D^2}$ (viii) Above equation is Hagen-Poiseuille equation.	2 2
3	b	**Derivation for discharge through a venturi meter by applying Bernoulli's equation** In schematic representation of venturi meter, consider variables representing area, velocity and diameter at upstream section 1 and throat represented by 2. Let the notation used for representing area, velocity and diameter are as follows.	

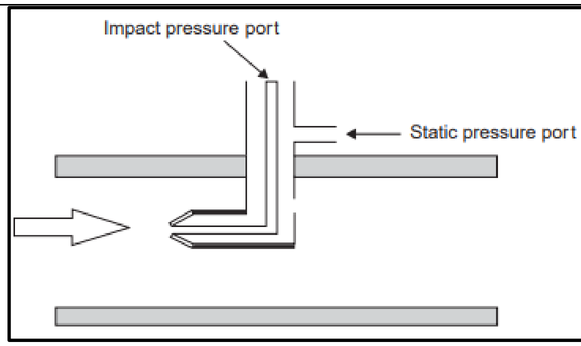
		A_1 = cross sectional area of upstream section (m^2) D = Upstream diameter (m). d = Diameter of the throat. A_2 = Area Throat area in m^2. P_1 = Pressure measured at upstream tap (N/m^2) P_2 = Pressure at the throat (N/m^2) u_1 = Upstream velocity(m/s) u_2 = Velocity at throat (m/s) Δh = differential manometer reading (m) C_v = Coefficient of discharge. Q_a = Actual discharge in m^3/s. Q_{th} = Theoretical discharge in m^3/s. Considering above variables, we can write, $A_1 = \frac{\pi}{4}D^2$ (i) $A_2 = \frac{\pi}{4}d^2$ (ii) $\frac{A_1}{A_2} = \frac{d^2}{D^2} = (\frac{d}{D})^2 = \beta^2$ (iii) Whereas $\frac{d}{D} = \beta$= Coefficient of contraction (iv) Applying Bernoulli's equations at sections 1 and 2, we can write: $\frac{P_1}{\rho} + \frac{u_1^2}{2} + gz_1 = \frac{P_2}{\rho} + \frac{u_2^2}{2} + gz_2$ (v) Considering ideal flow and applying continuity equation across venturi meter, we can write, $u_1A_1 = u_2A_2$ (vi) Therefore, we can replace u_2 as,	1

		$u_2 = u_1 \frac{A_2}{A_1} = \frac{u_1}{\beta^2}$ (vii) Similarly, as the venturi meter is horizontal, $z_1 = z_2$ $\frac{P_1}{\rho} + \frac{u_1^2}{2} = \frac{P_2}{\rho} + \frac{(u_1\beta^2)^2}{2}$ $\frac{P_1 - P_2}{\rho} = \frac{(u_2)^2}{2} - \frac{(u_2\beta^2)^2}{2}$ $\frac{2(P_1 - P_2)}{\rho} = (u_2)^2 - u_2^2\beta^4$ $\frac{2(P_1 - P_2)}{\rho} = u_2^2(1 - \beta^4)$ After simplifying, we can rewrite equation as $u_2 = \frac{1}{\sqrt{1-\beta^4}}\sqrt{\frac{2(P_1 - P_2)}{\rho}}$ (viii) From above expression, volumetric flow rate can be written as, $Q_{th} = A_2 . u_2$ After substituting expression for u_2, Q_{th} can be rewritten as, $Q_{th} = \frac{A_2}{\sqrt{1-\beta^4}}\sqrt{\frac{2(P_1 - P_2)}{\rho}}$ (ix) However, We can further simplify above equation using expression for differential pressure and differential height in manometer, $(P_1 - P_2) = \Delta h(\rho_m - \rho)g$ (x) Substituting expression for differential pressure, the equation can be rewritten as $Q_{th} = \frac{A_T}{\sqrt{1-\beta^4}}\sqrt{\frac{2\Delta h(\rho_m - \rho)g}{\rho}}$ (xi) However actual flowrate (Q_a) is always less than theoretical flowrate (Q_{th}). The ratio of actual flowrate to theoretical flowrate is coefficient of discharge.	2

		$C_v = \frac{Q_a}{Q_{th}}$ (xii) Rearranging above equation, we can write expression for actual flow rate as, $Q_a = \frac{C_v A_T}{\sqrt{1-\beta^4}}\sqrt{\frac{2\Delta h(\rho_m-\rho)g}{\rho}}$ (xiii)	1
3	c	Schematic sketch for piping arrangement resembling to sudden enlargement can be represented as below.  D_1 = 15 cm D_2 = 30 cm u_1 =8.5 m/s The formula to calculate the energy loss due to sudden enlargement is: $h_{fe} = K_{fe}\frac{u_1^2}{2}$ Where h_{fe} : Energy loss due to friction (J/kg) K_{fe} : Expansion or enlargement loss coefficient $K_{fe} = (1-\frac{A_1}{A_2})^2$ $A_1 = \frac{\pi}{4}D_1^2 = \frac{\pi}{4}(0.15)^2 = 1.767 * 10^{-2}$ m² $A_2 = \frac{\pi}{4}(0.3)^2 = 7.08 * 10^{-2}\ m^2$ The energy loss or frictional loss due to sudden enlargement can be calculated as: $h_{fe} = \left(1-\frac{A_1}{A_2}\right)^2 * \frac{u_1^2}{2}$ $h_{fe} = \left(1-\frac{1.767 * 10^{-2}}{7.08 * 10^{-2}}\right)^2 * \frac{8.5^2}{2}$ h_{fe} = **20.3432 J/kg**	1 1 2

3	d	**Industrial Applications of** **Blower:** i. Blowers can achieve much higher pressures than fans, as high as 1.20 kg/cm^2. They are also used to produce negative pressures for industrial vacuum systems. ii. Blowers are used for supplying combustion air. iii. These are also used for sewage aeration. iv. For loading of dust in dust handling systems such as bag house. v. For circulation of air in ventilation system. **Compressor:** i. Compressors are used for compressing gas to facilitate its storage in bullets. ii. To operate pneumatic devices. iii. Compressing reactant gas as per process pressure requirements. iv. To facilitate spray painting v. In sand blasting operation.	1 mark each for any two 1 mark each for any two
4		**Attempt any three**	**12**
4	a	 By referring the sketch, we can write: $P_b = P_{Hg} + P_{water} + P_{oil} + P_{air}$	1

		P_b = Pressure exerted at bottom of tank (N/m^2) P_{Hg} = Pressure by mercury column (N/m^2) P_{water} = Pressure by water column (N/m^2) P_{oil} = Pressure by oil column (N/m^2) P_{air}= Pressure by air column (N/m^2) $300000 = h_m \rho_m g + h_{water.} \rho_{water.} g + h_{oil.} \rho_{oil.} g + P_{air}$ $300000 = 0.5 * 13600 * 9.81 + 1.5 * 1000 * 9.81 + 2 * 800 * 9.81 + P_{air}$ $300000 = 66708 + 14175 + 15696 + P_{air}$ P_{air} = **203421 N/m²**	2 1
4	b	Data given: D_1: 30 cm =0.3 m, D_2: 10 cm=0.1 m u_1: 4 m/s, ρ_1: 0.01 g/cm.s=0.001 kg/m.s, ρ_2: 0.025 g/cm.s=0.0025 kg/m.s, u_2? As per the problem statement, It is mentioned that dynamic similarity is maintained. This in turn means Reynold number might be maintained same. $\therefore\ N_{ReWater} = N_{ReOil}$ $\frac{D_w u_w \rho_w}{\mu_w} = \frac{D_{oil} u_{oil} \rho_{oil}}{\mu_{oil}}$ Substituting the values in above equation, we can find the velocity of oil in another pipe. $\frac{0.3\ X\ 4\ X\ 1000}{0.001} = \frac{0.1\ X\ u_{oil}\ X\ 800}{0.0025}$ Solving above, u_{oil}: 37.5 m/s **Assuming condition of dynamic similarity, velocity of oil: 37.5 m/s**	1 1 2
4	c	**Pitot tube**	

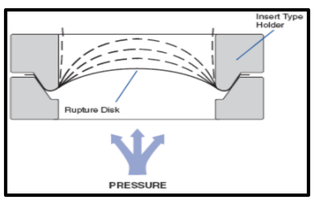
			2
		Construction: Pitot tube is variable head flow measuring device. In simple form, it consists of a single pitot tube with mouth pointing in the direction of flow. In modified pitot tube construction, two concentric tubes are arranged in the directions of flow. It is installed in flow stream of which velocity is to be measured. In case of simple single tube construction, rise in level of liquid above pipe cross section is used for calculation of velocity of flowing fluid. In case of modified pitot tube, differential a manometer is connected between static pressure port and impact pressure port. 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.	2
4	d	**Rupture disc:** A rupture disk is a device designed to function by the bursting of a pressure-retaining disk. **Construction:** This assembly consists of a thin, circular membrane usually made of metal, plastic, or graphite that is firmly clamped in a disk holder. The thickness and material of construction of rupture disc depends upon operating conditions and process fluid in contact. Rupture disks can be installed alone or in	

combination with other types of devices.

Rupture disks are commonly used in series (upstream) with a Relief valve to prevent corrosive fluids from contacting the metal parts of the valve. In addition, this combination is a reclosing system. Rupture disks may be used either in primary relief, in secondary relief, in series with a Relief valve, or for other functions like "quick opening" valves.

2

The burst tolerances of rupture disks are typically about ±5% for set pressures > 40 psig. Rupture disks are widely accepted and used in industry and are normally available from 3 mm to 1200 mm sizes.



Working:

When the process reaches the bursting pressure of the disk, the disk ruptures and releases the pressure. Once blown, rupture disks do not reseat; thus, the entire contents of the upstream process equipment will be vented. To prepare vessel for further operation the new disc is placed between disc holder.

2

4 e **Difference between reciprocating pump and centrifugal pump**

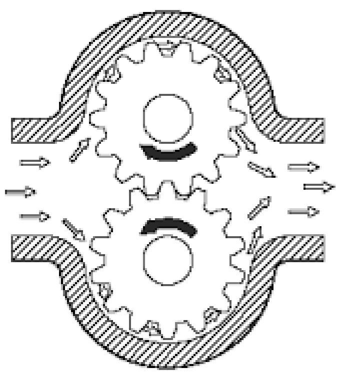
1 mark for each point

Criteria	Reciprocating Pump	Centrifugal pump

			Pressure developed	It develops high pressure compared to a centrifugal pump. The extent of pressure developed depends upon constructional features and number of stages.	The pressure developed by centrifugal is much less than reciprocating pump. However, in case of high discharge requirement, a multistage centrifugal pump can be used. In this case also the pressure developed by the centrifugal pump is much less than reciprocating pump.		
			Discharge type	The discharge is pulsating in nature. However, if we use double acting and multi-stage pump pulsation can be reduced.	The discharge is continuous and uniform.		
			Efficiency	Efficiency of reciprocating pump is less than centrifugal pump (typically 90 % and above).	Efficiency of centrifugal pump relatively greater than reciprocation pump (typically between 55 to 65 %).		

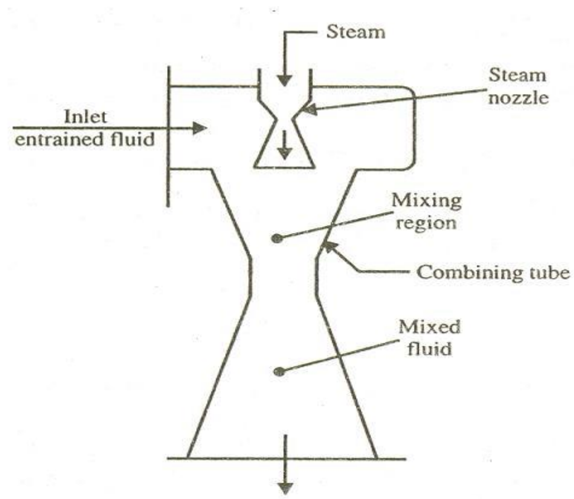
		<table><tr><td>Priming</td><td>It does not require priming.</td><td>It requires priming.</td></tr></table>	
5		**Attempt any two**	**12**
5	a	**Data**: Diameter of pipe : d =300 mm = 0.3 m Discharge: Q= 300 lit/sec. = 300*0.001=0.3m^3/s Kinematic Viscosity = ν =0.4 stoke = 0.4 *0.0001 = 0.00004 m^2/s Area of pipe = π /4 x d^2 = π /4 x $(0.3)^2$ = 0.07 m^2 $u = \frac{Q}{A} = 0.3/0.07 = 4.28\ m/s$ Reynolds no.= $N_{Re} = \frac{diameter*velocity}{kinematic\ viscosity} = \frac{du}{\nu} = \frac{0.3*4.28}{0.00004} = 32100$ As N_{Re}> 4000, flow is turbulent For turbulent flow , $f = \frac{0.078}{NRe^{0.25}} = \frac{0.078}{(32100)^{0.25}} = \frac{0.078}{13.38} = 0.0058$ $Frictional\ losses: hf = \frac{4fLu^2}{2D}f = \frac{4*0.0058*50*(4.28)^2}{2*0.3}$ $\boldsymbol{hf = 35.59\ J/kg}$ **= 3.63m**	 1 1 1 1 1 1
5	b	Data: Specific gravity of oil = 0.87 Density of oil = 0.87*1000 = 870 kg /m^3 D_1 = 200 mm =0.2 m D_2 =500mm = 0.5 m P_1 = 9.81 N /cm^2 = 98100 N /m^2 P_2 = ? Z_1= 0 m (assume as datum level)	

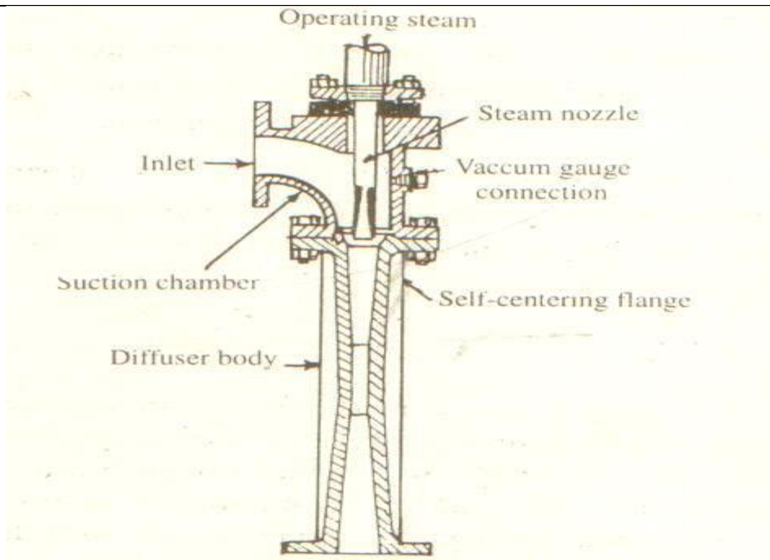
		Z_2= 4 m	
		Q = 200 lit/s =0.2 m^3/s	1
		Let us calculate velocities at point 1 and point 2	
		Area at point 1 , $=A_1 = \pi/4\,(D_1)^2 = \pi/4\,(0.2)^2$ = 0.0314m^2	1
		Area at point 2, $A_2 = \pi/4\,(D_2)^2$ $= \pi/4\,(0.5)^2$ =0.19625 m^2	
		Let's find out the velocity of water at point A and B	
		As Q = uA	
		$u_1 = Q/A_1 = \frac{0.2}{0.0314}$= 6.37m/s	2
		Similarly $u_2 = Q/A_2 = \frac{0.2}{0.19625}$= 1.019m/s	
		As per Bernoulli's equation ,	
		Total energy at point 1 = Total energy at point 2 (neglecting frictional losses)	
		$\frac{P_1}{\rho g} + \frac{u_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{u_2^2}{2g} + Z_2$	
		$\frac{98100}{870*9.81} + \frac{6.37^2}{2*9.81} + 0 = \frac{P_2}{870*9.81} + \frac{1.019^2}{2*9.81} + 4$	
		$11.49 + 2.068 = \frac{P_2}{8534.7} + 0.0529 + 4$	
		$9.5051 = \frac{P_2}{8534.7}$	2
		P_2 = **81123.17 N/m^2 = 8.1123 N/cm^2**	
5	c	**Gear Pump**: **Construction:** It consists of two toothed gear wheels (spur gears) enclosed in a casing which is provided with inlet and outlet connections for the liquid to be pumped. Of the two gear wheels, one is driven by an electric drive and other rotates in mesh with it.	2

		Diagram:  	2
		Working: The liquid to be pumped enters in pump through the inlet connection. As one of the gear wheel is driven by the electric motor, the other gear wheel also rotates inside the casing. Due to rotation of both the gear wheels, there is reduction in pressure at the inlet. Therefore the liquid entered in casing is carried round in the space between the gear teeth & the casing during the rotation of the gear wheels & after further rotation the liquid is pumped out of the discharge side as the teeth come into mesh.	2
6		**Attempt any TWO of the following**	12
6	a	**Data:** Diameter of pipe= D = 20 cm = 0.2 m Diameter of throat = D_T =10 cm = 0.1 m Specific gravity of oil = 0.8 Density of oil = ρ_{oil} = 0.8 *1000 = 800 kg /m^3 Specific gravity of mercury =13.6 Density of mercury = ρ_{Hg}= 13.6*1000 = 13600 kg /m^3 Coefficient of venturimeter = C_v = 0. 98	

		Δh = Difference in levels in mercury manometer = 30 cm = 0. 3 m The flow equation of venturimeter is $Q = \frac{C_v A_T\sqrt{2*g*\Delta H}}{\sqrt{1-\beta^4}}$ Area of throat = $A_T = \pi/4 * D_T^2 = \pi/4 *(0.1)^2 = 0.00785\ m^2$ $\beta = \frac{DT}{D} = \frac{0.1}{0.2} = 0.5$ ΔH= Difference in levels in terms of oil $\Delta H = \Delta h \frac{(\rho_{Hg} - \rho_{oil})}{\rho_{oil}} = 0.3\ \frac{(13600-800)}{800} = 4.8\ m\ of\ oil$ $Q = \frac{0.98*0.00785\sqrt{2*9.81*4.8}}{\sqrt{1-0.334^4}} = \frac{0.07462}{0.9682}$ Q = **0.077 m^3/s = 77.07 lit/s**	1 1 1 1 2
6	b	**Data**: Pipe length:800 m Pipe ID = 70 mm = 0.07m Density of fluid = 1900 kg/m^3 Viscosity = 0.07 Poise = 0.007 kg/ms Height = 25 m Pump efficiency = 60% Mass flow rate = $\dot{m}$= 2.5 kg/sec Area of pipe: A = π /4 D^2 = π /4*(0.07)^2 = 0.0038 m^2 Bernoulli's equation for pump work is $$\frac{P_1}{\rho} + \frac{\alpha_1 . u_1^2}{2} + gZ_1 + \eta W_p = \frac{P_2}{\rho} + \frac{\alpha_2 . u_2^2}{2} + gZ_2 + h_f \quad eq\ I$$ $P_1 = P_2 = 101.325\ N/m2$ as both open to atmosphere $\alpha_{1.} = \alpha_{2.}$	1

		u_1 is negligible as compared to velocity at station 2 Z_1= 0 (Assuming datum level as surface of liquid in tank) Z_1 = 25m $\eta = 0.6$ W_p = Pump work in J/kg $U_2 = v = \frac{\dot{m}}{\rho A} = \frac{2.5}{1900*0.0038}$ = 0.34m/s Eq.I becomes $\boldsymbol{\eta W_p = \frac{u_2^2}{2} + gZ_2 + h_f}$ eq II Head loss due to friction $h_f = \frac{4fLu^2}{2D}$ Where $f = friction\ factor$ $$N_{Re} = \frac{D.u_2\rho}{\mu} = \frac{0.07*0.34*1900}{0.007} = 6460$$ $N_{Re} > 4000$, Flow is turbulent flow Therefore $f = \frac{0.078}{(N_{Re})^{0.25}} = \frac{0.078}{(6460)^{0.25}} = 0.0087$ $$h_f = \frac{4*0.0087*825*(0.34)^2}{2*0.07} = 23.7J/kg$$ Putting all the values in eq.II $$0.6W_p = \frac{(0.34)^2}{2} + 9.81*25 + 23.7$$ $$0.6W_p = 269$$ W_p =448.35 J/kg Power required = $\dot{m}.W_p$ = 2.5 *448.35 = **1120.9 J/s =1120.9 W**	1 1 1 1 1
6	c	Steam Jet Ejector **Construction:** Basic ejector components are the steam chest, nozzle, suction	

		for entrained fluid, diffuser and the discharge. Diffuser consists of three parts- converging section, throat and diverging section	2
		Working: Steam at about 7 atm is admitted to a converging-diverging nozzle, from which it issues at supersonic velocity into a diffuser cone. The air or other gas to be moved is mixed with the steam in the first part of the diffuser, lowering the velocity to acoustic velocity or below. In the diverging section of the diffuser, the kinetic energy of the mixed gas is converted to pressure energy so that the mixture can be discharged directly to atmosphere.	2
		Diagram:  OR	2

		Operating steam Steam nozzle Inlet Vaccum gauge connection Suction chamber Self-centering flange Diffuser body :	