SUMMER-19 EXAMINATION

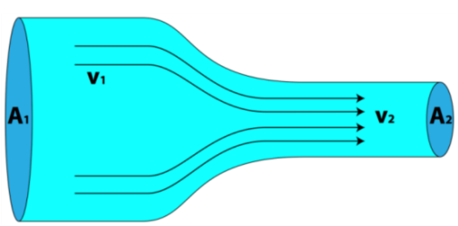
Model Answer

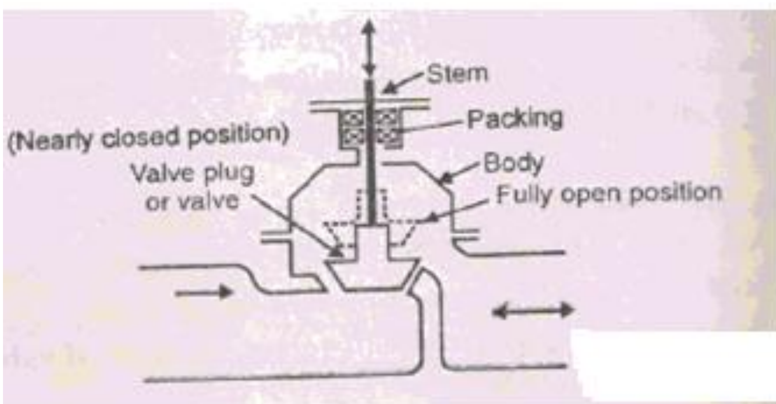
Subject title: Fluid Flow Operation Subject code 17426

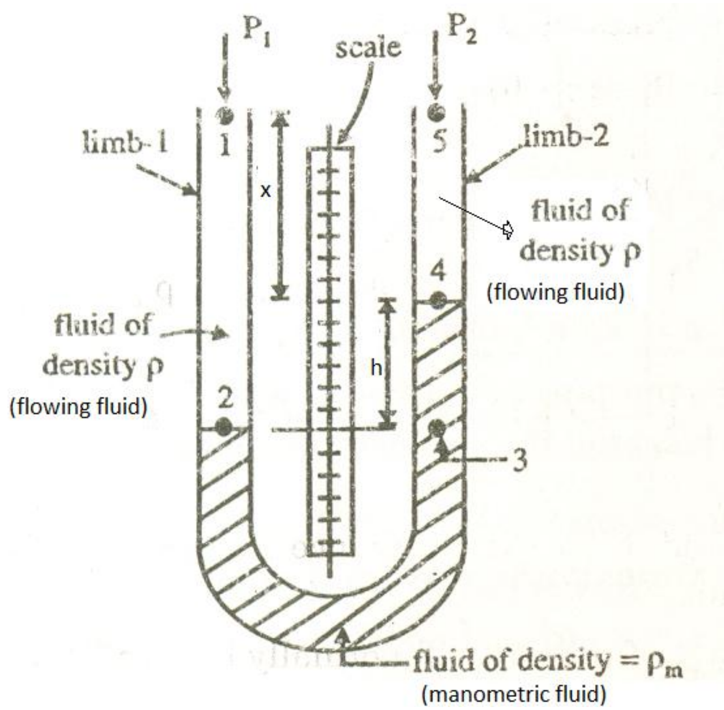
Important Instructions to examiners:

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 A		**Attempt any SIX of the following**	**12**
1A	a	**Viscosity:** It is the property of the fluid by virtue of which it offers resistance to the movement of one layer of fluid over an adjacent layer. **SI Unit** is Pa.S	1 1
1A	b	**Eg of incompressible fluid (any one)** Water, sodium chloride solution , sugar solution **Eg of compressible fluid (any one)** Oxygen, nitrogen, carbon dioxide (any gas)	1 1
1A	c	**Significance of Reynold's Number** It is a dimension less number which indicates the nature of flow. If $N_{Re} < 2100$ flow is laminar $N_{Re} > 4000$ flow is turbulent $2100 < N_{Re} < 4000$ – flow is transition It is the ratio of inertial force to viscous force.	2
1A	d	**Suitable pipe fitting** **(i) Termination of pipe:** Plug **(ii) Frequent removal of section pipe in a pipe line:** Union	 1 1
1A	e	**Hydraulically smooth pipe**: When a rough pipe is smoothed, the friction factor reduces and a stage will be reached when further smoothening of the pipe will not reduce the friction factor for a given Reynolds's number. The pipe is then said to be hydraulically smooth. In other words when roughness is zero or negligible, the pipe is known as hydraulically smooth pipe.	2

1A	f	**Air binding:** The pressure developed by the pump impeller is proportional to the density of fluid in the impeller. If air enters the impeller, the pressure developed is reduced by a factor equal to the ratio of the density of air to the density of liquid. Hence, for all practical purposes the pump is not capable to force the liquid through the delivery pipe. This is called Air binding **To avoid air binding,** the centrifugal pump needs priming.	1 1
1A	g	**Pressure developed by** **(i) Fan:** <30KPa **(ii) Centrifugal blower :** Centrifugal blower with multistage construction 275 to 700 Kpa	1 1
1b		**Attempt any TWO of the following**	**08**
1B	i	**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. 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 = $v_2\ \rho_2\ A_2$	2

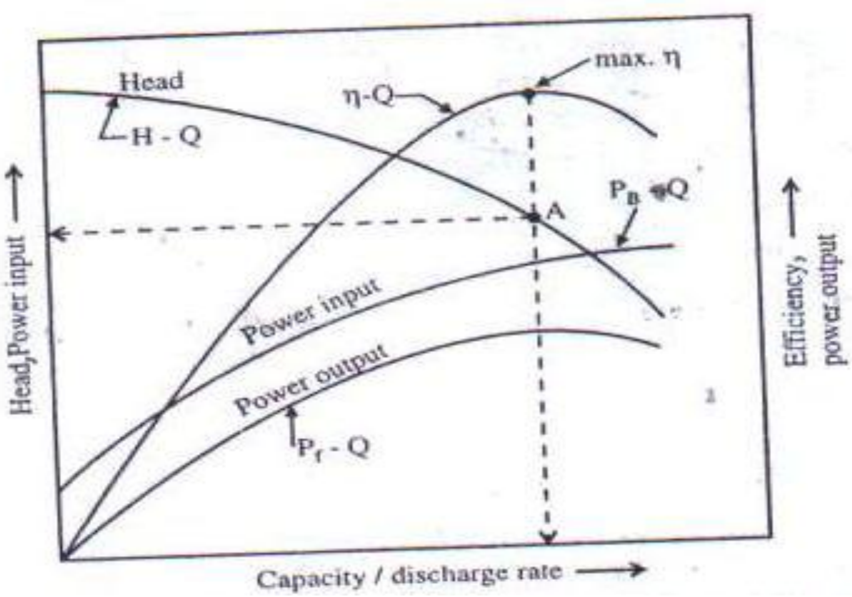
		Under steady flow conditions $\dot{m} = \rho_1 v_1 A_1 = \rho_2 v_2 A_2$ $\dot{m} = \rho v A = \text{constant}$ …….. **Equation of continuity**	2
1B	ii	**Globe valve** **Diagram**  	2 marks for diagram and 2 marks for labeling.
1B	iii	**Cavitation:** The vapour pressure of the liquid at the pumping temperature sets the lower limit for the suction pressure. If the pressure in the suction line is less than the vapour pressure of the liquid at the pumping temperature, some of the liquid flashes into vapour or if the liquid contain gases, they may come out of the solution resulting into gas pockets. This phenomenon is known as cavitation. **To avoid cavitation,** the pressure at the pump inlet must exceed the vapour pressure of the liquid by a certain value called the Net Positive Suction Head. NPSH is the amount by which the pressure at the suction point of the pump (sum of velocity and pressure heads) is in excess of vapour pressure of the liquid.	2 2

<table>
<tr><td>2</td><td></td><td>Attempt any FOUR of the following</td><td>16</td></tr>
<tr><td>2</td><td>a</td><td>Derivation for calculation of pressure drop using a U tube manometer


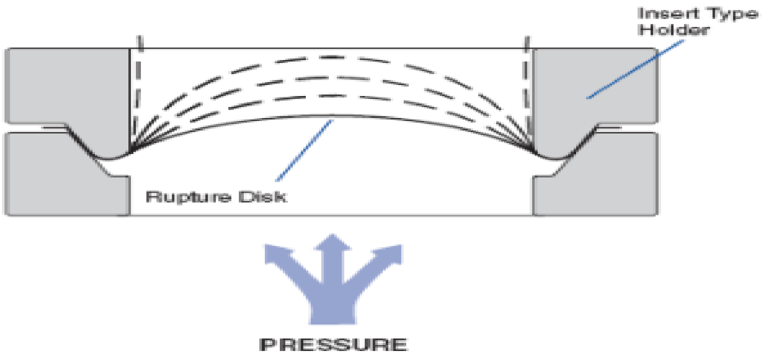
Pressure at the point 1 = P_1
Pressure at the point 2 = $P_1 + (x+h)\rho g$
Pressure at the point 3 = Pressure at the point 2 (2,3 on same plane)
Pressure at the point 4= Pressure at the point 3 – $h\,\rho_m g$
= $P_1 + (x+h)\rho g - h\,\rho_m g$
Pressure at the point 5 P_2 = Pressure at the point 4 – $x\rho g$
$P_2 = P_1 + (x+h)\rho g - h\,\rho_m g - x\rho g$
$= P_1 + hg(\rho - \rho_m)$
$(P_1 - P_2) = \Delta P = h(\rho_m - \rho)g$
$\Delta P = h(\rho_m - \rho)g$</td><td>1

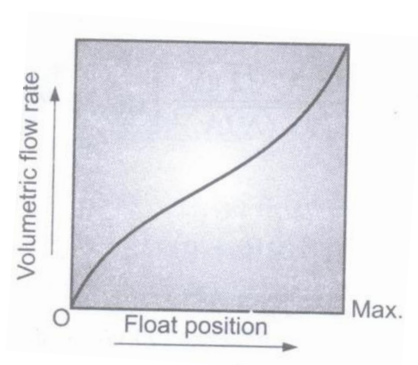
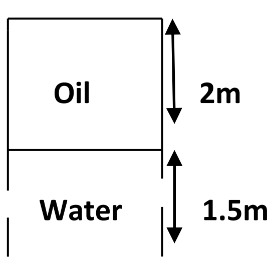
2

1</td></tr>
</table>

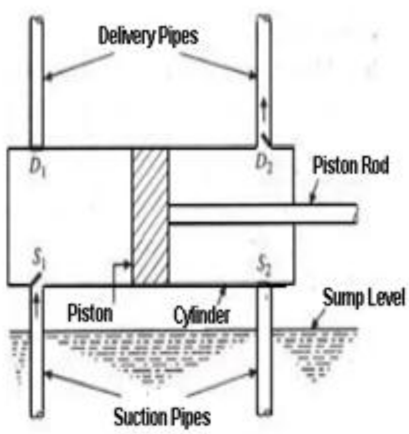
2	b	Data: D = 4cm r_w = 2cm Umax = 4 cm / s r = 1cm U = Umax$\left(1-\left(\left(\frac{r}{r_w}\right)^2\right)\right)$ = 4 $\left(1-\left(\left(\frac{1}{2}\right)^2\right)\right)$ = **3 cm / s**	2 2
2	c	**Characteristic curves of a centrifugal pump :**  **Duty point:** A is the duty point. The duty point is the point where the H-Q curve cuts the ordinate through the point of maximum efficiency, shows the optimum operating conditions. **Importance of characteristics curve:** Characteristics curve shows the relationship between discharge and the	1.5 1

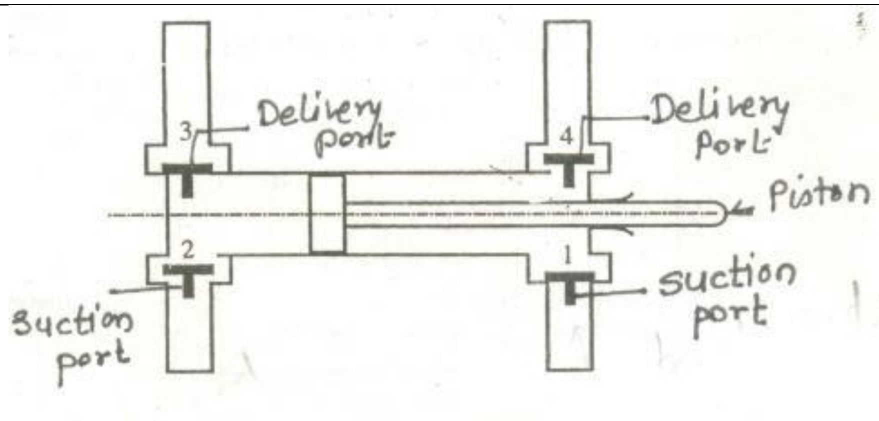
		various parameters like head, power and efficiency. From the H-Q curve, it is clear that head increases continuously as the capacity is decreased. The head corresponding to zero or no discharge is known as the shut off head of the pump. From H-Q curve, it is possible to determine whether the pump will handle the necessary quantity of liquid against a desired head or not and the effect of increase or decrease of head. The η-Q curve shows the relationship between pump efficiency and capacity. It is clear from η-Q curve that efficiency rises rapidly with discharge at low discharge rate, reaches a maximum in the region of the rated capacity and then falls. The P_B- Q curve gives us an idea regarding the size of motor required to operate the pump at the required conditions and whether or not motor will be overloaded under any other operating conditions.	1.5
2	d	**Difference between safety valve and rupture disc:** A safety valve is designed to open and release excess pressure. It closes again when overpressure ceases. The ultimate safety device used in pressure vessel to avoid accident is rupture disc. Rupture disc, is a non-reclosing pressure-relief device. A rupture disc is a one-time-use membrane. They can be used as single protection devices or as a backup device for a conventional safety valve, if the pressure increases and the safety valve fails to operate (or can't relieve enough pressure fast enough) the rupture disc will burst. Rupture discs are very often used in combination with safety relief valves, isolating the valves from the process, thereby saving on valve maintenance and creating a leak-tight pressure relief solution.	2

		Diagram of Rupture disc: 	2
2	e	**For laminar flow, f = $\frac{16}{NRe}$ (Proof)** Fanning's friction f is defined as the ratio of shear stress at the wall (τw)to the product of velocity energy and density(ρ) ie f = $\frac{\tau_w}{\frac{\rho V^2}{2}}$ ....(i) But average velocity v = $\frac{\tau_w r_w}{4\mu}$ where r_w is the radius at the wall and μ is the viscosity of the fluid So $\tau_w = \frac{4\mu V}{r_w}$ ....(ii) Substituting the value of τ_w from equation 2 in equation 1 $f = \frac{8\mu V}{\rho r_w V^2}$ $= \frac{16\mu}{\rho DV}$ where D is the diameter $= \frac{16}{\frac{\rho DV}{\mu}} = \frac{16}{NRe}$. Hence the proof.	2 2
2	f	**Calibration of Rota meter:** 1) For calibration, allow the liquid to flow through the Rota meter.	4

		2) Adjust the float to the lowest position by slightly opening the valve and note down the position of float. 3) Note down the time taken for collecting a known volume of water and calculate the volumetric flow rate. Volumetric flow rate = $\frac{\text{volume of liquid collected}}{\text{time}}$ 4) Repeat the steps 2 and 3 by increasing the flow rate. 5) Plot a graph of Q Vs float position which is known as calibration curve. Calibration chart for rotameter  	
3		**Attempt any FOUR of the following**	**16**
3	a	Data:  Specific gravity of oil =0.8	1 mark for data and appropriate conversion 1 mark for formula , 2 marks for calculation and final

		Level of water in tank $=h_w=1.5m$ Level of oil in tank $=h_o= 0.8m$ By definition, $\rho_w= 1000\ kg/m^3$ Specific gravity$=\frac{density\ of\ oil}{density\ of\ water}$ $0.8=\frac{\rho o}{\rho w}$ $\rho_o = 0.8 * \rho_w$ $\rho_w=0.8 * 1000 = 800\ kg/m^3$ by definition of hydrostatic equilibrium, pressure exerted by liquid column of height h can be calculated as : $P=h\rho g$ For given situation $\begin{pmatrix}\text{Pressure exerted} \\ \text{at} \\ \text{bottom of tank}\end{pmatrix} = \begin{pmatrix}\text{Pressure exerted} \\ \text{by} \\ \text{oil column}\end{pmatrix} + \begin{pmatrix}\text{Pressure exerted by} \\ \text{water column}\end{pmatrix}$ $P = h_w\rho g + h_o\rho g$ $P=(1.5 * 1000 * 9.81)+(2 * 800 * 9.81)$ $P=30411\frac{N}{m^2}$ Gauge pressure exerted at the bottom of tank **= 30411**$\mathbf{\frac{N}{m2}}$	answer
3	b	**Classification of valve** The valves are classified on different basis and criteria as follows. a. On-Off valve e.g. Ball valve, Gate valve, Plug valve b. Unidirectional valve e.g. Non return valve c. Flow regulating valve e.g. Globe valve, Diaphram valve,Needle valve, control valve etc.	2

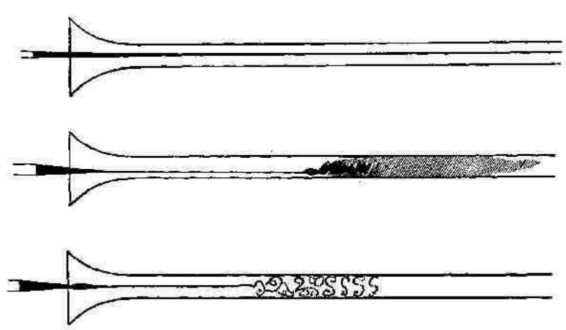
		d. Special purpose valve e.g. Safety valve, Pressure regulating valve, etc. **Valve used for** **(i) Accurate control of extremely smaller flow rate** Needle valve **(ii) Flow regulation of corrosive fluids:** Diaphragm valve	 1 1
3	c	**Diagram of Double acting reciprocating pump:**  **OR**	Diagram 3 marks and labeling 1 mark

		 	
3	d	**Reason for providing interstage cooling in multistage reciprocating compressor** As per the ideal gas equation ,the relation between pressure,volume,number of moles and absolute temperature can be written as, PV=nRT For compression process we can write $$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right).\left(\frac{V_2}{V_1}\right)$$ During compression, $P_2 > P_1$ Also $V_2 < V_1$ However the net change is so that $\frac{T2}{T1}$>1 We know that when temperature increases expanding tendency also increases as a result power required for compression also increases which increase cost of compression. When interstage cooling is applied an attempt is made so as to approach nearly isothermal conditions.Due to this power required for compression decreases and as the temperature is reduced o-rings and other accessories do not get damaged .Due to this interstage cooling is provided to	4

		multistage compressor.	
3	e	**Newton's law of viscosity** Newton law of viscosity states that shear stress is proportional to shear rate or velocity gradient. **Mathematical expression:** $\tau \propto \frac{du}{dy}$ $\tau = \mu \frac{du}{dy}$ T=shear stress acting on fluid (N/m^2) du/dy=shear rate (m^{-1}) μ=constant of proportionality mentioned as coefficient of viscosity.	Statement : 1 mark Mathematical expression : 2 mark Units and meaning : 1 mark
3	f	Data : Vapour pressure of the liquid (P_v) = 40kN / m^2 = 40*10^3 N / m^2. Atmospheric pressure (P_A) = 101325 N / m^2. Distance between suction line and level of liquid in the reservoir = 1.5m Density of the liquid (ρ) = 840 kg / m^3 h_{fs} = 3.5 J / kg h^1_{fs} = 3.5 J / kg =3.5 / 9.8 = = 0.3567 m NPSH = $\frac{P_a - P_V}{\rho g}$ - Z_a – h^1_{fs} = $\frac{101325-40000}{840*9.81}$ - 1.5 – 0.3567 = 20.46 J /Kg = **5.5852m**	1 2 1
4 a		**Attempt any FOUR of the following**	**16**
4	a	**Difference between Pipes and Tubes**	1 mark each

Criteria	Tube	Pipe
(i) Length	Tubes are flexible and available up to several hundread meters length.	Pipes are usually rigid, straight and generally available up to length 6m.
(ii) Method of expressing thickness	Tube thickness is generally expressed in Birmigham Wire Guage(BWG). BWG 7 represents heavy walled tube and 24 represents thin pipe.	Pipe thickness is function of internal pressure and allowable stress of material. It is generally expressed in scheduled number.
(iii) MOC	Tubes are generally made up of metal and alloys like copper, stainless steel, monel, etc.	Pipes are made of metal as well as non metal like cast iron, steel, PVC, etc.
(iv) Method of Fitting	Fitted by flaring and brazing	Fitted by weding, flanged joints and pipe fittings.

4	b	**Reynolds experiment** Scientist Osborne Reynold"s observed the flow of fluid . He did did some fundamental experiments to understand the influence of various paramters on	Description-3 marks, Diagram :

		the nature of fluid flow. The schematic sketch is as shown below. A square tank is divided partially in two halves. At the bottom of tank a bell mouth outlet is provided. A staight transperent glass tube is fitted and at the end of pipe section, flow regulating valve is fixed. The overflow arrangement is made to the tank so as maintain constant head of liquid. To observe the nature of flow, a dye was introduced through syringe fixed at the centre of bell mouth outlet and concentric with glass tube connected to tank outlet. It was observed that the flow of fluid is function of diameter of pipe, density of flowing fluid, velocity and viscosity of fluid. During the experimentation, flow rate is gradually varied and parameters such as flow rate, nature of dye filament are noted. The data obtained is used to calculate Reynolds number. Based on his classical experiment, the concept of Reynold number was proposed which was used to decide the type of flow. The flow was designated as laminar when $N_{Re} < 2100$, transition for $2100 < N_{Re} < 4000$ and turbent when $N_{Re} > 4000$. Fig. (a), (b) and (c) represents laminar, turbuleant and transition flow schematically.  (a) (b) (c) Draw	1mark

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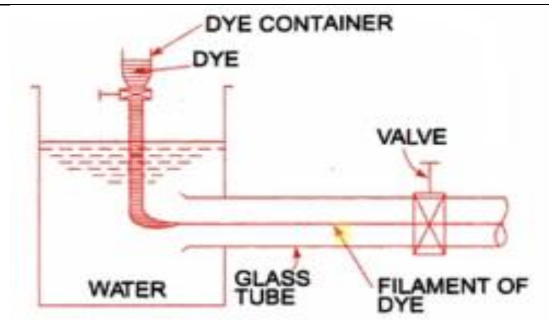
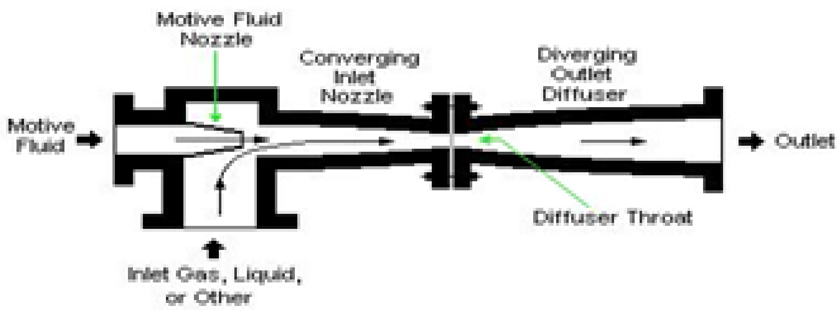
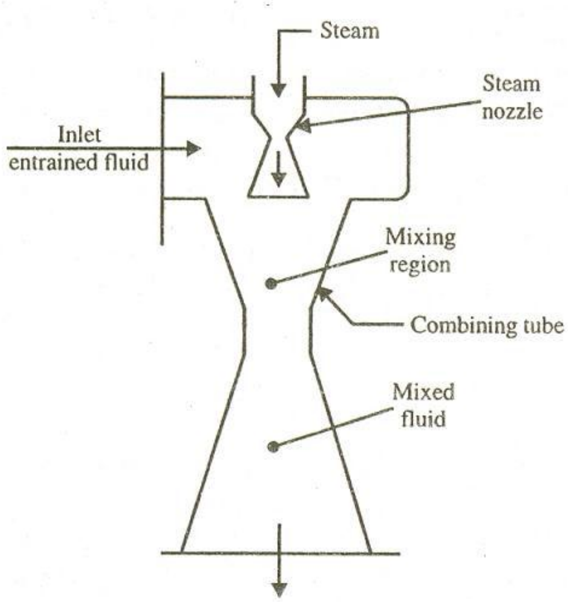
<tr><td></td><td></td><td>
</td><td></td></tr>
<tr><td>4</td><td>c</td><td>Steam jet ejector:


OR

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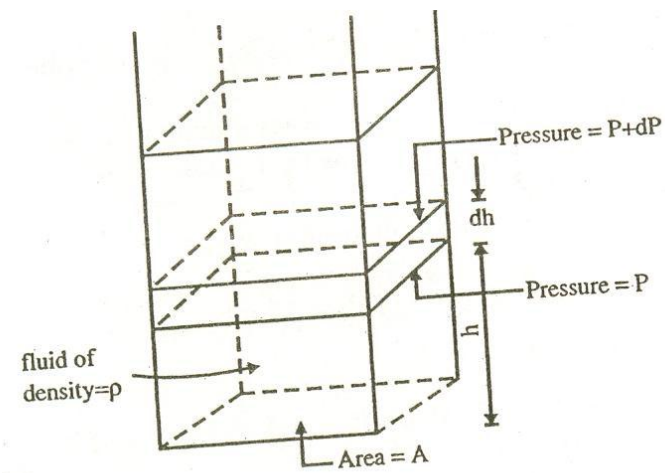
		Application of jet ejectors Steam jet ejectors are used as vaccum generating device. Depending upon the magnitude of vaccum generation the single stage or multistage ejectorsare used. Reaction under vacuum,vacuum distillation and pneumatic conveying under vacuum uses steam jet ejector as a vacuum generating device.	1 mark each for any two application
4	d	**Difference between variable head meter and variable area meter:**	1 mark each

Criteria	Variable head flowmeter	Variable area flowmeter
(i)Working principle	Flowrate is directly proportional to differential head across the restriction.	Flowrate is directly proportional to area available for flow.
(ii) Method of mounting	Flowmeters can be installed horizontal or vertically.	Due to effect of gravity force on measurement and float position, horizontal mounting not possible.
(iii) Method of estimating flow rate	Differential head across restriction is measured using manometer and using flow equation, flow rate is calculated.	It gives direct value of flow. The reading on the scale corresponding to top edge of the float directly gives value of flow rate.

		(iii)Examples | Venturimeter, orificemeter, pitot tube. | Rotameter	
4	e	Data: $Q = 1\ m^3 / hr = 1 / 3600 = 2.77 * 10^{-4}\ m^3 / s$ $D_1 = 8cm = 0.08m$ $D_2 = 5cm = 0.05m$ A_1 = area of larger pipe = $\pi /4 * D_1^2 = 3.14 * 0.08^2 / 4 = 5.024 * 10^{-3}\ m^2$ A_2 = area of smaller pipe = $\pi /4 * D_2^2 = 3.14 * 0.05^2 / 4 = 1.9625 * 10^{-3}\ m^2$ V_2 = velocity of fluid in the small diameter pipe = Q / A_2 $= 2.77 * 10^{-4} / 1.9625 * 10^{-3} = 0.14\ m/s$ $K_c = 0.4 \left(1 - \frac{A_2}{A_1}\right)$ $= 0.4 (1- (1.9625 * 10^{-3} / 5.024 * 10^{-3}))$ $= 0.244$ $h_{fc} = K_c \frac{V_2{}^2}{2g}$ $= 0.244 * 0.14^2 / (2*9.81) =$ **$2.435 * 10^{-4} m$**	Data and conversion : 1mark Formula : 1 mark Estimation of Kc : 1 mark Final answer : 1 mark
4	f	Data: Q = 12 l/minute D= 1.5 cm =0.015m $\rho = 0.9\ g/cm^3 = 0.9*1000\ kg/m^3$ i) Q in m^3/s Q = 12 l/minute= $12 * 10^{-3} / 60$ **$= 2 * 10^{-4}\ m^3/s$** ii) $\dot{m}$ in g/s $\dot{m} = Q * \rho = 2 * 10^{-4} * 900 = 0.18$ Kg / S = **180 g / s**	2 2

5		**Attempt any TWO of the following**	**16**
5	a	Data: D =75mm = 0.075m Density ρ =1.1 g / cm^3 = 1.1 *1000 kg/m^3 Viscosity μ = 1.5poise = 0.15 N-S/m^2 Volumetric flow rate Q =3 l/ minute= 3 *10^{-3} / 60 = 5 *$10^{-5}$$m^3$ / S Area A= $\frac{\pi D^2}{4}$ = $\frac{3.14*0.075^2}{4}$ = **4.41 *$10^{-3}$$m^2$** L = 50m Velocity V = $\frac{Q}{A}$ = = 5 *10^{-5}/ 4.41 *10^{-3}= **0.01134 m / s** NRe = $\frac{DV\rho}{\mu}$ = 0.075 *0.01134*1.1*1000 / 0.15 = **6.237** Since NRe < 2100, flow is laminar f = 16 / NRe = 16 / 6.237 = **2.565** h_{fs} = 4flV^2 / 2D = 4*2.565 *50* 0.01134^2 / (2*0.075) **= 0.439 J/kg** ΔP = hfs *ρ = 0.439 * 1.1*1000 = **483.78 Pa**	1 1 1 1 3 1
5	b	**Hydrostatic equilibrium:** A fluid is said to be in hydrostatic equilibrium or hydrostatic balance when it is at rest, or when the flow velocity at each point is constant over time. This occurs when external forces such as gravity are balanced by a pressure gradient force. **Expression to calculate pressure** Consider a vertical column of liquid of height h1cm. Let us consider a small element of fluid of height dh cm , which is at a height hcmfrom the bottom of the column. A is the cross sectional area of the column in m^2.ρis the density of the liquid in g/cm^3.	2

Let P and P+dP be the pressure at a height h cm and h+ dh cmfrom the base of the column respectively.



Force acting on the small element of fluid are

(1) Force (P+dP)A acting downward

(2) Force PA acting upward

(3) Force due to gravity Adhρ1g acting downward.

At equilibrium, sum of all these forces is zero.

3

$PA-(P+dP)A- Adh\rho g = 0$

$dP + dh\rho g = 0$……(1)

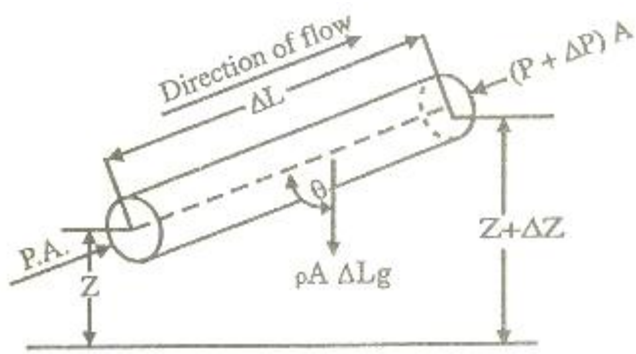
For incompressible fluids, density is constant

Let P_2 and P_1 be the pressure at a height h cm and at the base of the column respectively.

Integrating equation (1)

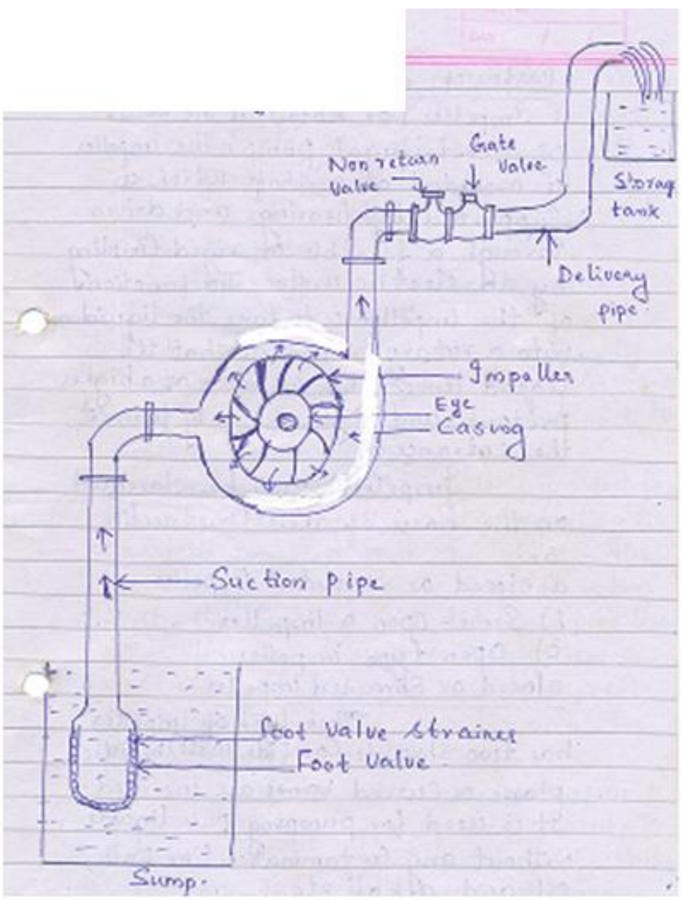
$$\int_{P_1}^{P_2} dP + g\rho\int dh = 0$$

		P_1 is the pressure at the base of the column where h = 0 $P_2 - P_1 + \rho gh = 0$ $P_1 - P_2 = \rho g h$ **$\Delta P = \rho g h$**	3
5	c	Data: Mass flow rate ($\dot{m}$) = 90 kg / minute = 90/ 60 = 1.5 kg / s Diameter of pipe= D = 50mm = 0.05 m Diameter of throat = D_o =25 mm = 0.025 m Density of water = ρ_{H2O}= 1000 kg /m^3 Density of mercury = ρ_{Hg}= 13600 kg /m^3 Coefficient of venturimeter = C_o= 0. 62 $Q = \dot{m} / \rho = 1.5 / 1000 = 1.5*10^{-3}\ m^3 / s$ The flow equation of orifice meter is $$Q = \frac{C_o A_o \sqrt{2 * g * \Delta H}}{\sqrt{1-\beta^4}}$$ Area of orifice= $A_o = \pi/4 * D_o^2 = \pi/4 * (0.025)^2 =$ **$0.00049\ m^2$** $\beta = \frac{DT}{D}$ = 0.025 /0.05 = **0.5** $$1.5 * 10 - 3 = \frac{0.62 * 0.00049\sqrt{2 * 9.81 * \Delta H}}{\sqrt{1 - 0.5^4}}$$ ΔH= Difference in levels in terms of water = **1.16m of water** $\Delta H = \Delta h \frac{(\rho_{Hg} - \rho_{H2O})}{\rho_{H2O}}$ where Δh = Difference in levels in mercury manometer $1.16 = \Delta h \frac{(13600-1000)}{1000}$	2 2 2

		$1.16 \quad = 1.26\,\Delta h$ $\Delta h =$ 0.092m of Hg = **92 mm of Hg**.	2
6		**Attempt any TWO of the following**	**16**
6	a	**Bernoulli's theorem:** **Assumptions made:** 1. Velocity is constant over the entire cross sectional area. 2. No pump work. 3. Frictional losses are negligible.  For steady, irrotational flow of an incompressible fluid, the sum of pressure energy, kinetic energy & potential energy at any point is constant. Let us consider an element of length ΔL of a stream tube of constant cross sectional area as shown above. Let us assume that cross-sectional area of element be A & the density of the fluid be ρ. Let u & P be the velocity & pressure at the entrance & (u + Δu), (P +Δ P) are the corresponding quantities at the exit. The forces acting on the element are 1) The force from upstream pressure = P.A (acting in the direction of flow)	2 1

		2) The force from downstream pressure normal to the cross-section of the tube = (P +Δ P).A(in opposite direction of flow) 3) The force from the weight of fluid (gravitational force acting downward) = ρ.A.ΔL.g The component of this force acting opposite to direction of flow = ρ.A.ΔL.gcosθ The rate of change of momentum of the fluid along the fluid element = $\dot{m}$ [u + Δu – u] = $\dot{m}$Δu As mass flow rate= $\dot{m}$ = ρ. uA . Δu According to Newton's Second law of motion {sum of forces acting in the direction of flow} = {rate of change of momentum of a fluid} P.A - (P +Δ P).A - ρ.A.ΔL.gcosθ = ρ. uA . Δu -Δ P.A - ρ.A.ΔL.gcosθ = ρ. uA . Δu Δ P.A + ρ.A.ΔL.gcosθ + ρ. uA . Δu = 0 Eq.I Dividing each term of eq.I by A.ΔL. ρ we get $$\frac{\Delta P}{\rho \Delta L} + g.cos\theta + \frac{u.\Delta u}{\Delta L} = 0$$ As cosθ = $\frac{\Delta Z}{\Delta L}$,we can write $$\frac{1}{\rho}\frac{\Delta P}{\Delta L} + g\frac{\Delta Z}{\Delta L} + u\,\frac{\Delta u}{\Delta L} = 0 \qquad Eq.II$$ If we express the changes in the pressure, velocity , height etc. in the differential form ,eq .II becomes	3

		$\frac{1}{\rho}\frac{dP}{dL} + g\ \frac{dZ}{dL} + \frac{d\left(\frac{u^2}{2}\right)}{dL}$ Which can be written as $\frac{dP}{\rho} + g\,.dZ + d\left(\frac{u^2}{2}\right) = 0 \qquad Eq.III$ Eq.III is called as Bernoulli Equation. It is differential form of the Bernoulli Equation. For incompressible fluid, density is independent of pressure & hence ,the integrated form of eq.III is $\frac{P}{\rho} + gZ + \frac{u^2}{2} = constant$ Hence proved that low of conservation of energy is applicable for flowing fluid. The Bernoulli Equation relates the pressure at a point in the fluid to its position & velocity.	2
6	b	**Centrifugal pump:** **Principle:** By centrifugal action, the liquid is lifted from a lower level to higher level. The impeller blades in revolving produce a reduction in pressure at eye of impeller, therefore liquid flows into the impeller from the suction pipe. The liquid is thrown outward by centrifugal action along the blades. As a result of high speed of rotation, the liquid acquires a high kinetic energy. The acquired kinetic energy is converted into pressure energy when it leaves the blade tips and the liquid passes into the volute chamber and finally is discharged through the outlet at high pressure. **Construction:** The parts of a centrifugal pump are (i) Impeller: It is the heart of a centrifugal pump. It is mounted on a shaft. The function of impeller is to force the liquid in to a rotary motion so that the	2

		liquid leaves the impeller at a higher velocity than at the entrance. (ii) Casing: It is provided for housing the impeller and it has provision for connecting with the delivery and suction pipe lines. (iii) Suction pipe: It is a pipe whose upper end is connected with the pump on suction side and lower end is submerged in the liquid in the sump. The lower end is fitted with a foot valve and strainer. (iv) Delivery pipe: it connects the discharge end of the pump and supply end of the reservoir.	2
			2

		Working: First priming of pump is done. Then delivery valve is kept closed and power from electric motor is applied to shaft. The delivery valve is kept closed in order to reduce the starting torque for the motor. Impeller rotating in the casing produces a forced vortex which imparts a centrifugal head to the liquid and pressure is increased throughout the liquid. As long as delivery valve is closed and impeller is rotated, there will be just churning of the liquid within the casing. When delivery valve is opened, liquid is flown in outward radial direction, leaving the vanes of impeller at outer circumference with high velocity and pressure. Vacuum is created at the eye of impeller, therefore liquid from sump flows through suction pipe to eye of impeller thereby replacing the liquid which is being discharged from the entire circumference of the impeller. The high pressure is utilized in lifting of the liquid to required height through delivery pipe.	2
6	c	**Application of** **(i) Centrifugal compressor** 1) Oil refineries 2) To provide oil free compressed air in food processing 3) Refrigeration and air conditioning 4) Gas turbines **(ii) Centrifugal blower** 1)Sewage aeration 2) Furnaces like Blast, Cupola etc. 3)Municipal gas plant 4) Hot air blowers **(iii) Reciprocating compressor**	1.5 marks for any two application 1.5 marks for any two application

		1)Refrigeration plants 2) Gas pipelines 3)Compressed air for automobiles 4)Manufacturing of LDPE(Low Density Polyethelene)	1.5 marks for any two application
		(iv) Fan 1)To remove flue gases from boiler to the atmosphere 2)To draw air through the cooling tower	1.5 marks
		Justification for size of impeller required in the case of centrifugal blower is large: Centrifugal Blowers require large diameter impellers and high speed of operations since very high heads in terms of low density fluid (eg. gas or vapour)are needed for generating moderate pressure ratios.	2