MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION

SUMMER-13 EXAMINATION

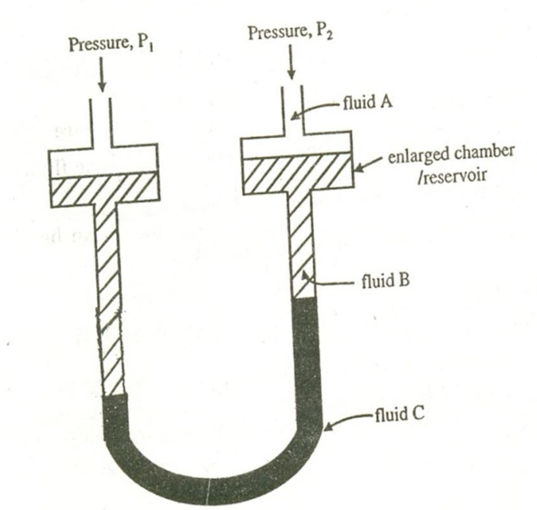
Model Answer

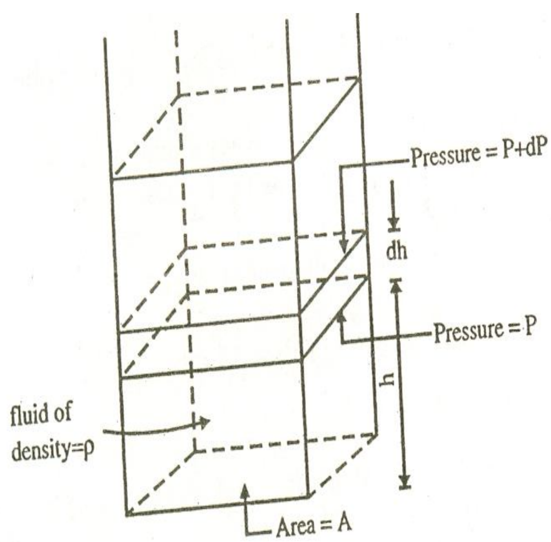
Subject & code : FFO(12128)

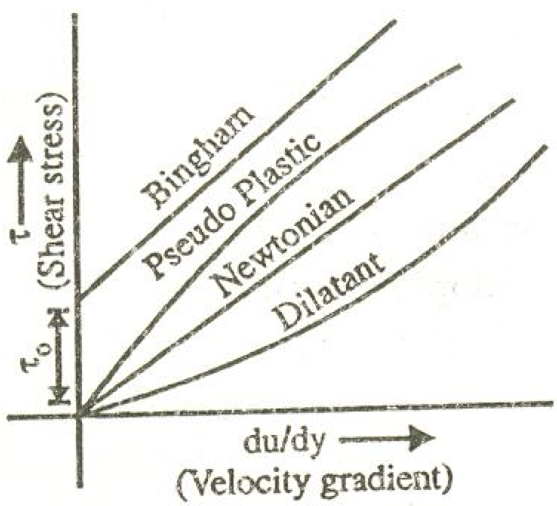
Important instructions to examiners :

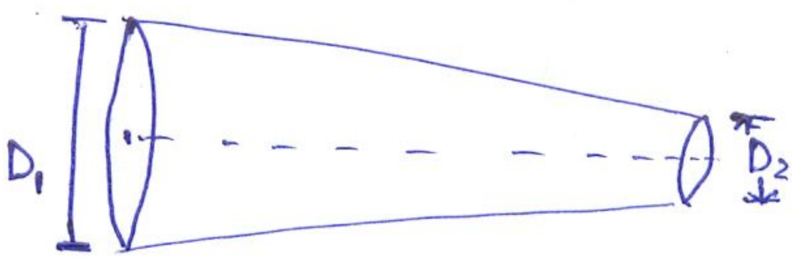
1. The answers should be examined by keywords and not as word to word as given in the model answer scheme.
2. The model answer and the answer written by candidate may vary, but the examiner may try to assess the understanding level of the candidate.
3. The language errors such as grammatical, spelling errors should not given more importance.
4. While assessing figures, examiner may give credit for principal components indicated in a 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 answer and model answer.
6. In case of some questions credit may be given by judgment of relevant answer based on candidates understanding.

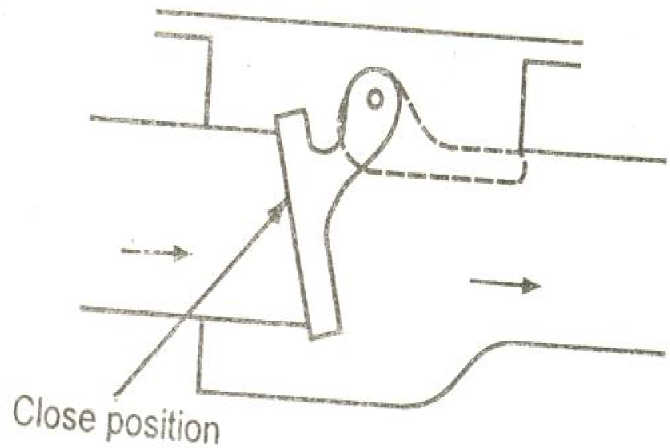
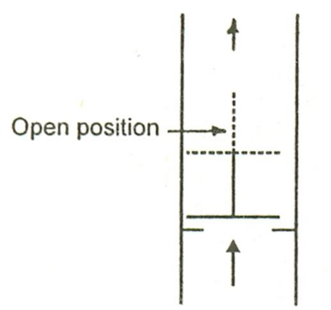
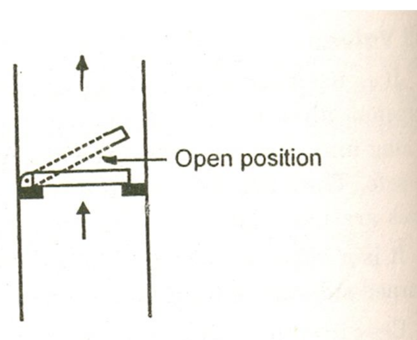
Q No:	**Answer**	**Mark**	**Total marks**
1.a.i	Water vapour is compressible. Its density is sensitive to changes in temperature and pressure.	1 1	2
1.a.ii	Flow is turbulent.	2	2
1.a.iii	**Fanning's friction factor for turbulent flow:** $f = 0.078/(N_{Re})^{0.25}$ or $1/\sqrt{f} = 4 \log(N_{Re}\sqrt{f}) - 0.4$	2 marks for any one formula	2
1.a.iv	**Application of reducer and elbow** i. Reducer: For connecting pipes of different diameter or for connecting a large diameter pipe with a small diameter pipe(any	1	2

	one) ii. Elbow: For changing the direction of flow through 90^o	1	
1.a.v	**M.S pipe**: M.S. is mild steel pipe. It is a carbon alloy containing 0.3-0.6% carbon, iron and other elements like manganese, copper, silicon, cobalt, chromium, nickel etc. It is a cheaper alternative to steel, is corrosion resistant than iron and have high durability and strength	2	2
1.a.vi	**Equipment for transporting slurry from a lower point to a higher point** Centrifugal pump, diaphragm pump	2 marks for any one	2
1.a.vii	**Pump for handling of viscous fluid:** Gear pump	2	2
1.a.viii	Pressure inside the vessel = 600mm of Hg. Vacuum = atmospheric pressure- absolute pressure = 760 – 600 = 160 mm of Hg	2	2
1.b.i	**Diagram of differential manometer**  	4	4
1.b.ii	**Expression to relate shear stress and shear rate:** F / A α du/dy ie τ α du/dy **Unit of proportionality constant in MKS system:** Kg/m.s	2 2	4

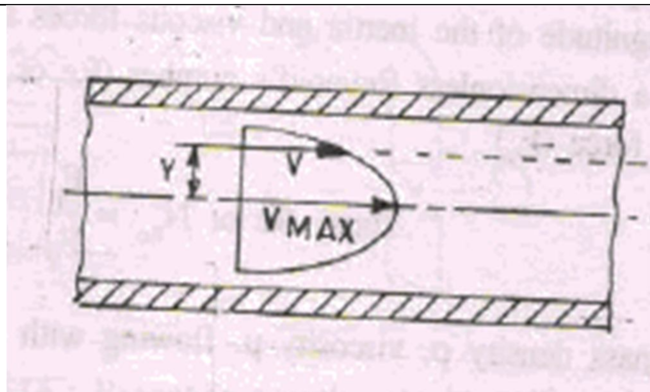
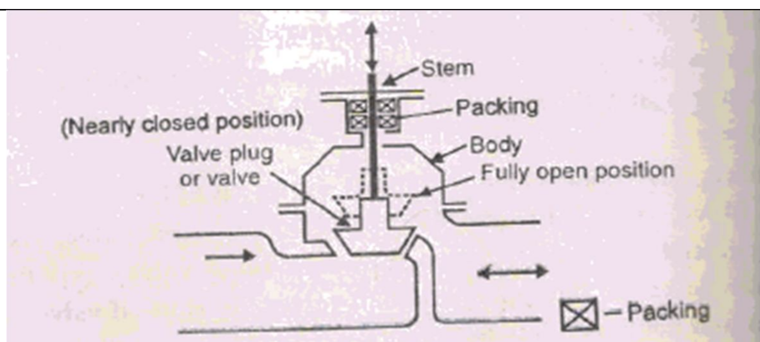
1.b.iii	**Application of fan, blower and compressor:** Fans are used in industry for ventilation works, supplying air to dryers,supplying draft to boilers , removal of fumes etc Blowers are used for supplying air to furnaces, cooling and drying purposes, for ventilation purpose etc. Compressors are used in petroleum refinery, chemical plants (in the production of ammonia, nitric acid, urea etc.).	4	4
2.a	 Consider a vertical column of liquid of height $h_1$cm. Let us consider a small element of fluid of height dh cm , which is at a height hcm from the bottom of the column. A is the cross sectional area of the column in m^2. $\rho_1$is the density of the liquid in g/cm^3. Let P and P+dP be the pressure at a height h cm and h+ dh cm from 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 Adh ρ_1g acting downward. At equilibrium, sum of all these forces is zero.	1 1 1	4

	$PA-(P+dP)A- Adh\,\rho_1 g = 0$ $dP + dh\,\rho_1 g = 0$……(1) **For incompressible fluids**, density is constant Integrating equation (1) $\int_{P_1}^{P_2} dP + g\rho_1 \int_0^{h_1} dh = 0$ P_1 is the pressure at the base of the column where h = 0 $P_2 - P_1 + \rho_1 g h_1 = 0$ $P_1 - P_2 = \rho_1 g\, h_1$	1	
2.b	 Or shear rate	4	4
2.c	Mass flow rate = 1000kg/ hr Diameter of the pipe = 5cm = 0.05m Density of liquid = $1000kg/m^3$ Area of the pipe = $\pi d^2 / 4 = 1.9625 . 10^{-3} m^2$ i)Average velocity = <u>Mass flow rate</u>	2	4

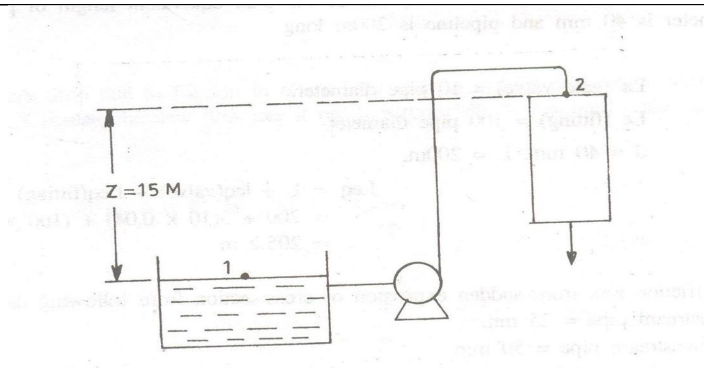
	area of pipe * density of liquid 1000 = ---------------------------- $1000 * 1.9625.10^{-3}$ = 509.5 m/hr ii)Mass velocity = Mass flow rate 1000 ----------------- = ------------------------ area of pipe $1.9625.10^{-3}$ = 509554 kg/ m^2hr	2	
2.d	**Relation between velocity and diameter of pipe in tapering form.**  $A_1 = \pi D_1^2 / 4$ $A_2 = \pi D_2^2 / 4$ From equation of continuity , $\rho_1 u_1 A_1 = \rho_2 u_2 A_2$ Same fluid is flowing through the pipe, $\rho_1 = \rho_2$ $u_1 A_1 = u_2 A_2$ $u_1 * \pi D_1^2 / 4 = u_2 * \pi D_2^2 / 4$ $u_1 * D_1^2 = u_2 * D_2^2$	2 2	4
2.e		Any one	4

	 Swing check valve.  Lift check valve.  Foot valve.	diagram 4 marks	
2.f	$N_{Re} = DV\rho / \mu$ Where D is the diameter of the pipe in cm or m v is the velocity of fluid in cm/s or m/s	1 2	4

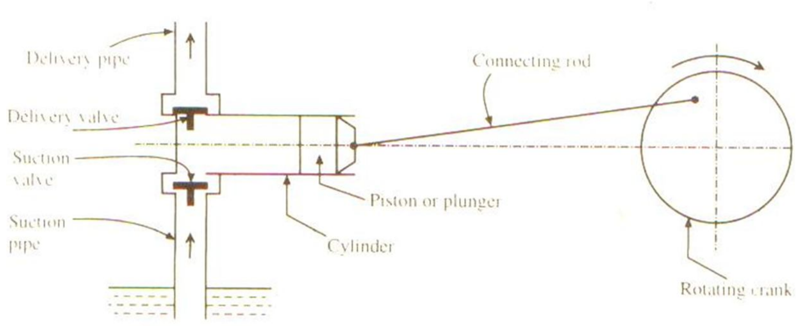
	ρ is the density of fluid in g/cm^3 or kg/m^3 μ is the viscosity of the fluid in g/cm.s or kg/m.s unit of N_{Re} = unit of D. unit of v. unit of ρ /unit of μ $= \dfrac{cm.\ cm/s.\ g/cm^3}{g/cm.s}$ = dimensionless or $= \dfrac{m.\ m/s\ .\ kg/m^3}{kg/m.s}$ = dimensionless	1	
3.a	$X_A\, g/gc+uA^2/2gc+PA/\rho A-f+\hbar W_p=XB\, g/gc+UB^2/2g+PB/\rho B$ Potential energy= mgh/gc =(kg*m/sec^2*m)/(kg*m/kgf*sec^2) =kgf.m	2 2	4
3.b	positive displacement pump is more dangerous. Because in this pump liquid sucked in the pump is discharged with a positive pressure.if by chance, N.R.V provided does not open,then the fluid will break open the cylinder and come out.	1 3	4
3.c	Average velocity is the velocity which is calculated as follows Vavg=Q(cm^3/sec)/area(cm^2) =Q/A(cm/sec) =volumetric flowrate/area of cross section Point velocity is the velocity at any particular point in the pipeline. $U/Umax=[1-(r/R)^2]$ U=point velocity Umax=maximum velocity r=distance of point from centre line of pipe R=radius of pipe Average velocity is determined by measuring volumetric flowrate. This divided by area of cross section gives average velocity. Point velocity is determined by pitot tube.	1 1 2	4

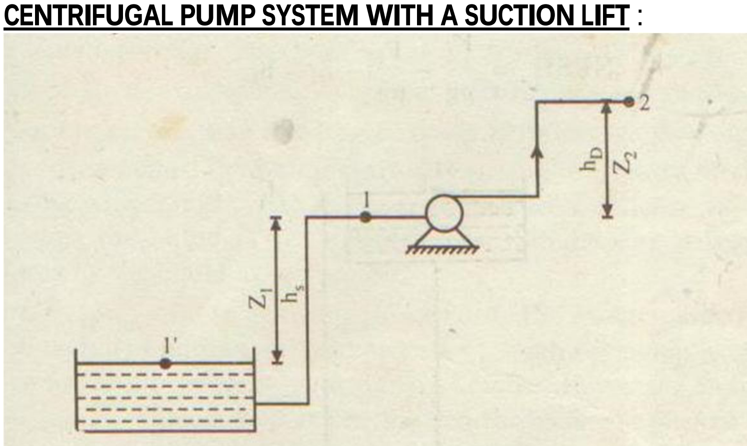
3.d	 When liquid is flowing through a pipeline, velocity at center is maximumand it is zero at the surface of pipe. There is very small region near surface where velocity is very small and hence flow is laminar. This layer is called viscous sub layer.	1 3	4
3.e	Equivalent length of pipe fitting is straight length of pipe of same diameter which will give the same pressure drop as is given by the fitting. Le/D= Number Therefore Le=equivalent length of straight pipe. = D* Number For a fitting Le can be determined by using the pressure drop across the fittingand should be same as pressure drop across straight length found experimentally. Equivalent length is necessary to find out pressure drop in a pipe line without actual experiment.	1 1 1 1	4
3.f	 Fig. 3.10 : Globe valve	2	4

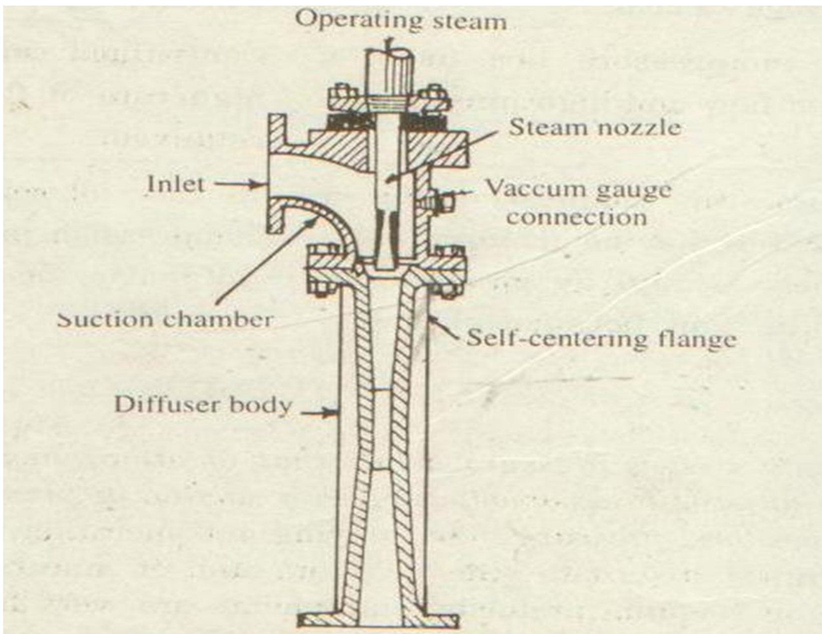
	Globe valve is used to regulate flow of liquid. It is used for efficient regulation of critical service. It is used extensively for automatic process control and for high temperature applications. A globe valve is a valve generally having a spherical body in which the axis of the stem is at right angles to that of the body ends. Pressure drop through globe valve is much greater than for gate valves due to change in the direction of fluid flow.	2	
4.a	a) Solution Pipe A=5.515cm^2=5.515*10-$^4m^2$ PipeB=21.64cm^2=2.164*10-$^3m^2$ PipeC=47.78cm2=4.778*10-$^3m^2$ Density of fluid=0.9*1000=900kg/m^3 (Since density of water is 1000 kg/m^3) Mass flow rate, m=10*900=9000kg/hr In section A: $V_A=10/5.515*10^{-4}$ $=1.8132*10^4$m/hr =5.037 m/sec $G_A=9000/5.515*10^{-4}$ $=1.632*10^7$ kg/hm^2 In section B: $V_B=10/2.164*10^{-3}=4.261*10^3$ m/hr=1.284 m/sec $G_B=9000/2.164*10^{-3}$ $=4.159*10^6$ kg/hm^2 In section C: $V_C=10/4.778*10^{-3}=2.09*10^3$ m/hr=0.581m/sec $G_C=9000/4.778*10^{-3}$ $=1.884*10^6$$kg/hrm^2$ Section D Since there are 2 pipes and equal quantity flows through each of them, volumetric flow rate and mass flow rate are 5m^3/hr and 4500 kg/hr respectively. $V_D=5/1.314*10^{-3}$ $=3.805*10^3$ m/hr $G_D=4500/1.314*10^{-3}=3.425*10^6$ kg/hm^2	2 2 2 2	8
4.b	b) Solution Volumetricflow rate,Qis 5m^3/hr		8

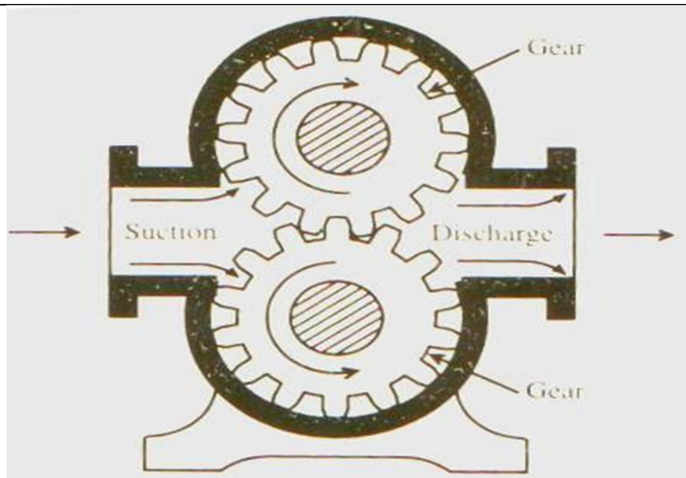
	$Q=5*10^6/3600=1389cm^3/sec$	1	
	Cross sectional area of pipe$=\pi/4*(7.8)^2=47.784$	1	
	Linear average velocity $V=1389/47.784= 29.068cm/sec$	1	
	$NRe= 7.8*29.068*1/0.1*10^{-2}=226730.4$	1	
	Flow is turbulent.	1	
	$f =0.078/(NRe)^{0.25}=0.078/(226730.4)^{0.25}=3.57*10^{-3}$	1	
	$hf=\Delta P/\rho= 4fLV^2/2gc*d=4*3.57*10^{-3}*50*100*(29.068)^2/2*981*7.8=3.93gmf\ cm/gm$	1	
	$\Delta P=6.637gmf/cm^2$	1	
4.c		2	8
	Given:		
	$z_1 = 0$, $z_2 = 15m$, $d=40mm$, $V_2=3m/s$, Leq(valve) = 200*d		
	Leq (fitting) = 15*d, L=30m , η = 60%, f = 0.004, μ = 0.008 kg/m-sec		
	Consider points 1 and 2 as shown in the figure,		
	Equivalent length L' = L + Leq(valve) + Leq(fitting)	1	
	= 30 + (200*0.04) + (150*0.04)		
	= 44m		
	.'. Heat loss due to friction,		
	$hf = 4fL' V^2/ 2gd$		
	$= 4*0.004*44*3^2/(2*9.81*0.04)$	1	
	= 8.07kgf-m/kg		
	Applying Bernoulli's equation between points 1 and 2,		

	$P_1/\rho + V_1^2/2g + z_1 + \eta Wp = P_2/\rho + V_2^2/2g + z_2 + hf$		
	Assuming $z_1=0$, $V_1= 0$, $p_1=p_2=1atm$.	1	
	$\eta Wp = z_2 + V_2^2/2g + hf$		
	$= 15 + (3^2/(2*9.81)) + 8.07$		
	$= 23.52$		
	Pump work $Wp = 23.76/\eta = 23.52/0.6 = 39.21$ N-m/kg	1	
	(mass flow rate)= $m = \rho* Q = \rho*A_2*V_2 = \rho * ((\Pi/4)*d^2)*V_2$		
	$= 1000*(\Pi/4)*0.004^2 *3$		
	$= 3.76$ kg/sec		
	.’. Pump work P= m Wp / 75		
	=(3.76*39.21)/75	1	
	= 1.965hp		
	= 2hp	1	
5.a	**<u>Types of Valves</u>**: A **valve** is a device that regulates, directs or controls the flow of a fluid (gases, liquids, fluidized solids, or <u>slurries</u>) by opening, closing, or partially obstructing various passageways. Valves are technically valves <u>fittings</u>, separate category. In an open valve, fluid flows in a direction from higher pressure to lower pressure. VALVE is not only a flow controlling device, It also regulates the flow, regulates and controls the pressure. Types of valves:(based on controlling action) 1) **On-Off Valves**: used for on- off purpose (to start or stop the flow of fluids thro pipes) Ex: Plug valve 2) **Regulating valves**: used to regulate /control the flow of fluids Ex: Gate valve, Globe valve, .Needle valve 3) **Non-Return Valve**: required for Unidirectional flow Ex:Ball valve	2 2	4
5.b	**Given data**:		4

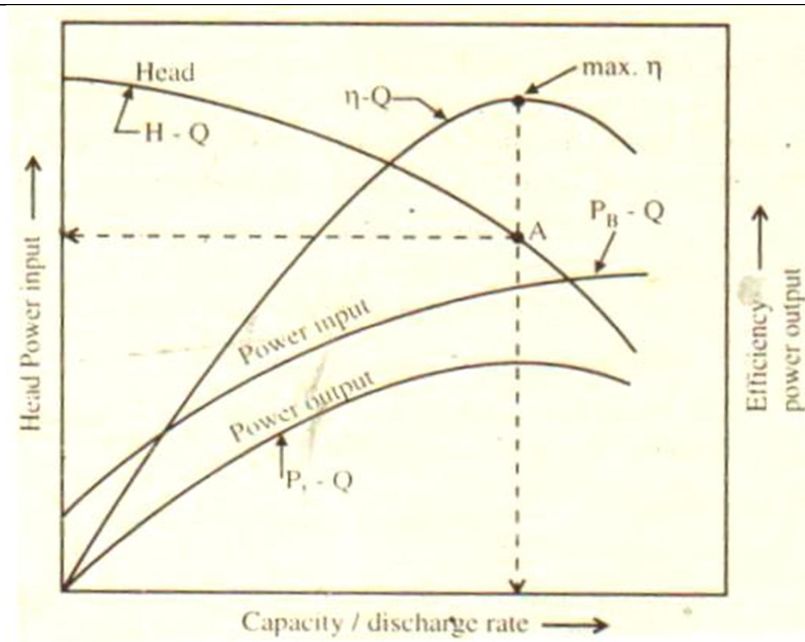
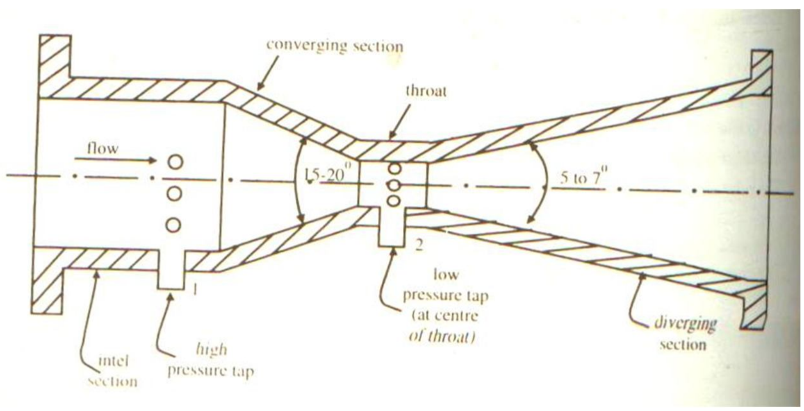
	Diameter of pipe : d = 0.055 m Discharge :Q= 4 lit/min = 4000/60 cm^3/s Q= 66.67 cm^3/s = 66.67 x $10^{-6}m^3/s$ Viscosity = 1.5 poise = 0.15 kg/m.s Density = =1.04 gm/cm^3 = 1040 kg/m^3 Area of pipe = π /4 x d^2 Area of pipe = π /4 x $(0.055)^2$ Area of pipe = 2.376 x 10^{-3}m2 As discharge Q = area * velocity u = Q/A u = 66.67 x 10 -6 / 2.376 x 10-3 u = **0.028 m**/s Reynolds no.= NRe= d u ρ /μ NRe = 0.055x 0.028 x1040 /0.15 NRe = **10.67** As NRe<2100,the flow is laminar. Friction factor: f = 16 /NRe f = 16/10.67=**1.5** Frictional losses:hf = 4 $fLu^2/2d$ hf= 4 x 0.15 x 10 x $(0.028)^2$ /2x 0.55 hf= **0.043** N.m/kg= **0.043** J/kg	1 1 1 1	
5.c	**WORKING OF RECIPROCATING PUMP:** 	1	4

	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 it's 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	
5.d	**CENTRIFUGAL PUMP SYSTEM WITH A SUCTION LIFT** :  Total head developed by pump: $\eta\ Wp/g = (Z_2 + u_2^2/2g + P_2/\rho g + hf/g) - (Z_1 + u_1^2/2g + P_1/\rho g)$ $\eta\ Wp/g = H2 - H1 = \Delta H$ $\eta\ Wp/g = \Delta H$ where	2 2	4

	η= efficiency of pump Wp = pump work per unit mass of fluid. Z_1&Z_2 = elevations of stations 1 & 2 repectively above the ground level. u_1&u_2 = velocities P_1&P_2 = pressures at stations 1 & 2 rept.		
5.e	**Steam Jet Ejector:**  In steam jet ejector ,low pressure gas is entrained in high pressure steam. The vapour from the process equipment is sucked & entrained by steam,& then carried into a venturi shaped diffuser which converts the kinetic energy of the steam into pressure energy. The vapours along with steam are finally discharged thro the ejector.it handles large volumes of vapour at low pressures. It is suitable for corrosive fumes or vapours.	1 3	4
6.a	**GEAR PUMP** :	4	4

			
6.b	**<u>PRESSURE DEVELOPMENT IN CENTRIFUGAL PUMP</u>**: Once the trapped air in pump is removed (priming),the delivery valve is kept closed & power from electric motor is appied to the shaft. The delivery valve is kept closed to reduce the starting torque for motor. The impeller rotates within the casing , which produces the forced vortex & it imparts a centrifugal head to the liquid .The pressure throughout the liquid is increased. When delivery valve is opened, the liquid is made to flow in an outward radial direction thereby leaving the vanes of the impeller at the outer circumference of the impeller with high velocity & pressure. Due to centrifugal action, a partial vacuum is created at the eye of impeller. This causes the liquid from sump to rush through the suction pipe to the eye of impeller thereby replacing the liquid which is being discharged from the entire circumference of the impeller. The high pressure of the liquid leaving the impeller is utilized in lifting the liquid to the required height through the delivery pipe.	1 1 1 1	4
6.c	**1)<u>NET POSITIVE SUCTION HEAD(NPSH</u>)** Def : "It is the amount by which the pressure at the suction point of pump expressed as a head of the liquid to be pumped(sum of	2	4

	velocity &pressure heads)is in excess of vapour pressure of the liquid." For any installation of pump, NPSH must be calculated by taking into consideration the absolute pressure of the liquid, the level of pump, the velocity head in suction line & friction head in suction line. If the required value of NPSH is not obtained ,then partial vaporisation takes place & both the suction & delivery heads get reduced. NPSH = (absolute pressure head at suction point) - (vapour pressure head) NPSH= $P_1/\rho g$ - $P_v/\rho g$- h_{fs} +Z_1 **2)CAVITATION**: Def: "The vapour pressure of the liquid at pumping temperature sets the lower limit for the suction pressure. Hence pressure at any point in suction should not fall below the vapour pressure of the liquid to be pumped. If pressure in suction line is less than vapour pressure of the liquid ,then some of the liquid flashes into vapour or if liquid contains gases, they may come out of the solution resulting into gas pockets that damage impeller. This phenomenon is called as cavitation." Cavitation results in no pumping of liquid. It leads to mechanical damage to pump as bubbles collapse. Cavitation can be reduced by reducing the pumping rate or by slight modification in impeller design to give better streamlining & avoiding use of sharp beds in suction line to reduce loss of head.	2	
6.d	**CHARACTERISTICS CURVES IN CENTRIFUGAL PUMP**: Def: " The graphical relationship between head & discharge rate, efficiency & discharge rate& power input & discharge rate and discharge rate at a particular speed."	4	4

			
6.e	**Venturi meter:**  **<u>Advantages of venturimeter over orifice plate</u>**: 1) Pressure recovery in venture meter is high than in orifice meter. 2) Venturi meter can be used where only a small head is available. ,orifice meter can not be used 3) Venturi meter consumes smaller power consumption than orifice meter. 4) There is no flow separation in venturimeter	3 1 mark for any one point	4
6.f	GIVEN DATA: Diameter of orifice = d_o = 20 mm = 0.02 m		4

	Diameter of pipe =Dp= 80 mm = 0.08 m ΔH = 21.4 cm of water = 0.214 m of water. Coefficient of discharge(Co) = 0.64 The Flow Equation of orificemeter: $$Q = \frac{C_o A_o \sqrt{2g\Delta H}}{\sqrt{(1-\beta^4)}}$$	2	
	$A_o = \pi/4 * d_o^2$ $A_o = 3.14/4 * (0.02)^2$ $A_o = 3.14 \times 10^{-4} m^2$ $\beta = 0.08/0.02 = 0.25$ $$Q = \frac{0.64 * 3.14 * 10^{-4}(\sqrt{2 * 9.81 * 0.214}}{\sqrt{(1-0.25^4)}}$$	1	
	$$Q = \frac{2.009 * 10^{-4} * 2.04}{0.9979}$$ $Q = 4.1 * 10^{-4} m^3/s$ Q = 0.41 lit/s = 24.6 lit/min	1	