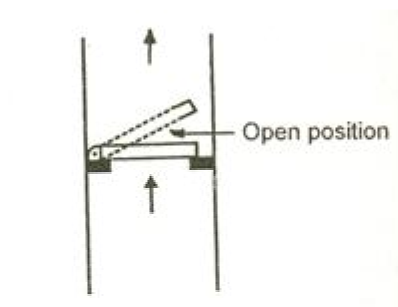
SUMMER-14 EXAMINATION

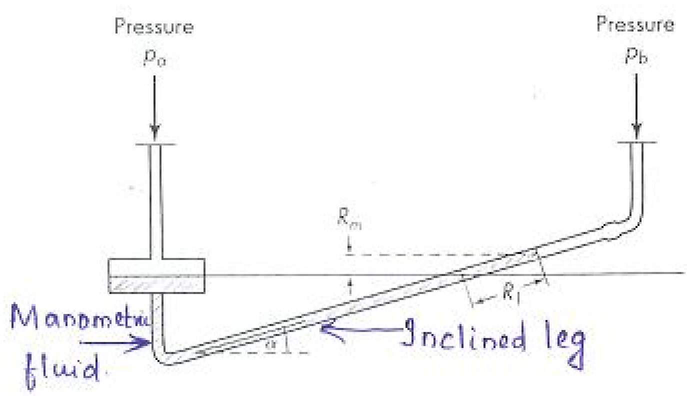
Model Answer

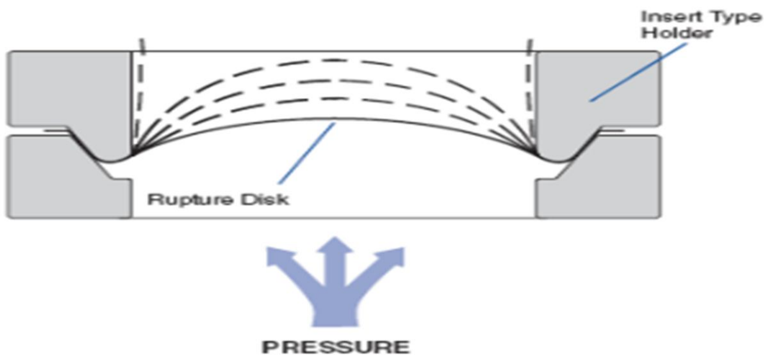
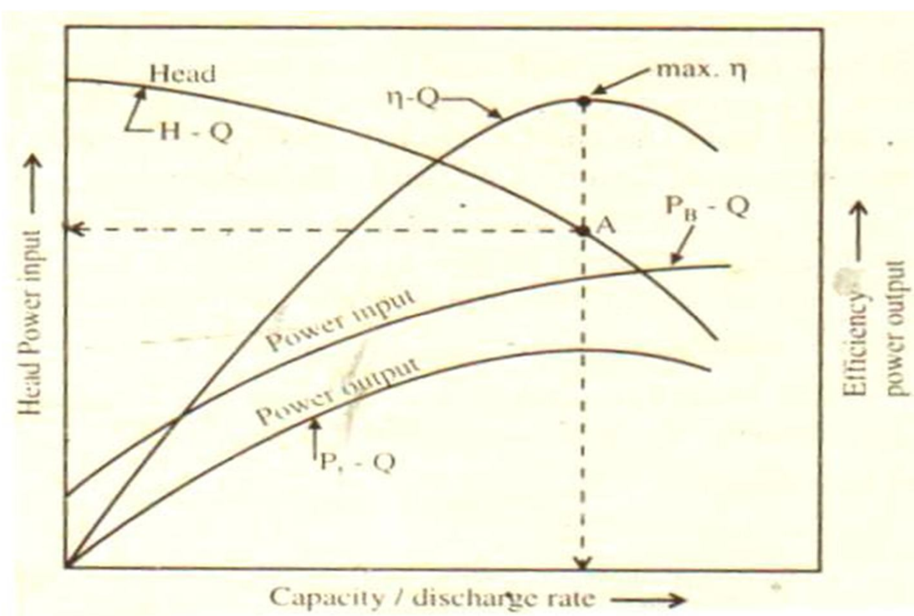
Important Instructions to examiners:

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.

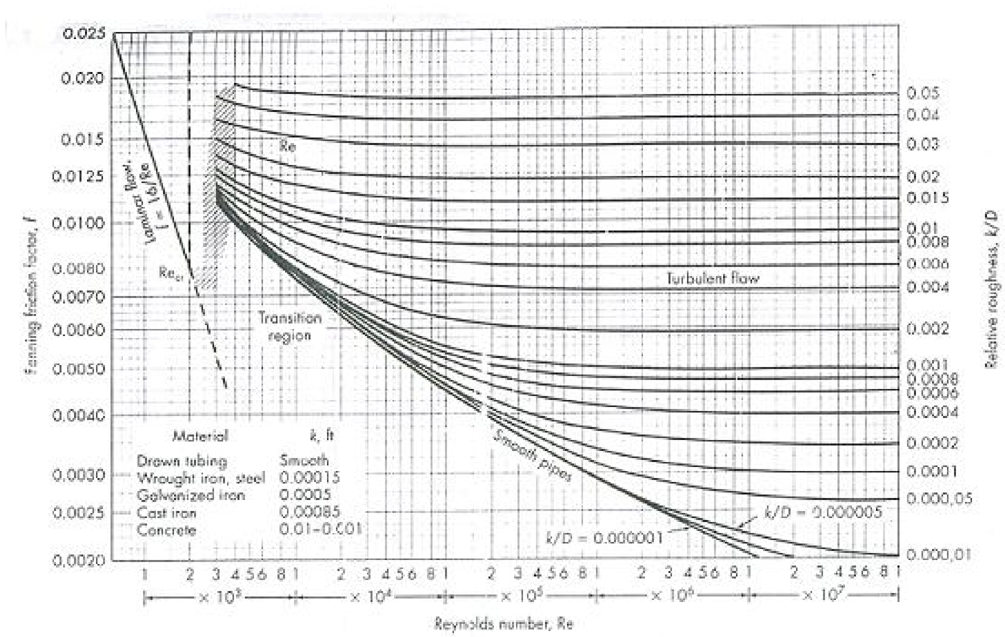
Q No.	Answer	marks	Total marks
1a-i	**Partial Pressure**: The pressure that would be exerted by one of the gases in a mixture if it occupied the same volume on its own. **Unit of pressure in SI:** N / m^2	1 1	2
1a-ii	**Compressible fluid:** If the density of the fluid is appreciably affected by moderate changes in temperature and pressure, the fluid is said to be compressible.	2	2
1a-iii	**Critical velocity:** It is the velocity at which the flow changes from laminar to turbulent.	2	2
1a-iv	**Fanning's friction factor:** Fanning's friction factor is defined as the ratio of shear stress at the wall to the product of velocity energy and density.	2	2
1a-v	**Equivalent length of pipe fittings** : It is defined as that length of straight pipe of the same nominal size as that of fittings, which would cause the same friction loss as that caused by fitting or valve.	2	2
1a-vi	**Application of diaphragm pump:** They are used for pumping hazardous and toxic liquids.	2	2
1a-vii	**Application of steam jet ejector**: 1, used for handling corrosive gases that would damage mechanical vacuum pump. 2. It is used for handling large volume of vapour,	2	2
1b-i	**Difference between velocity calculated using pitot tube and venturimeter:** Velocity found out from a pitot tube is point velocity(velocity at a particular point in a flowing fluid) and velocity obtained from a venturimeter is average	2	4

	velocity. **Formula to calculate velocity:** From pitot tube $V_{P} = C_p\sqrt{2gH}$ From venturimeter $V = C_V \sqrt{\frac{2gH}{1-\beta^4}}$	1 1	
1b-ii	**Diagram of non return valve fitted on a vertical pipe:**  **Application:** For unidirectional flow, non return valve is used.	3 1	4
1b-iii	**Priming:** Removal of air from the suction line and pump casing and filling it with the liquid to be pumped is called priming. It is done by providing a non return valve in the suction line so that suction line and pump casing will be filled with the liquid to be pumped when the pump is in shut down condition. If the non return valve is not functioning, priming has to be done from an external source	2 2	4

2-a	**Diagram of inclined manometer:** 	4	4
2-b	**Hagen Poiseuille's equation** $\Delta P = \frac{32\mu v L}{d^2}$ Where ΔP is the pressure drop. μ – Viscosity of the fluid. v- Average velocity. L- Length of pipe. d- Diameter of the pipe.	2 2	4
2-c	**Construction and working of rupture disc**: A rupture disc is normally made in disc form. The membrane is usually made of metal (carbon steel, stainless steel, graphite), but any material can be used. It is a non- reclosing pressure relief device that protects a pressure vessel, equipment or system from over pressurization or potentially damaging vacuum conditions. A rupture disc is a one-time-use membrane that fails at a predetermined differential pressure.. Rupture discs provide instant response (within milliseconds) to an increase or decrease in system pressure, but once the disc has ruptured it will not reseal. They can be used as single protection devices or as a backup device for a conventional safety valve, if the pressure	3	4

	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. 	1	
2-d	**Characteristics curve of centrifugal pump:** 	4	4

Q. No.	Answer	Marks	Total
2-e	**Friction factor chart:**	2	4

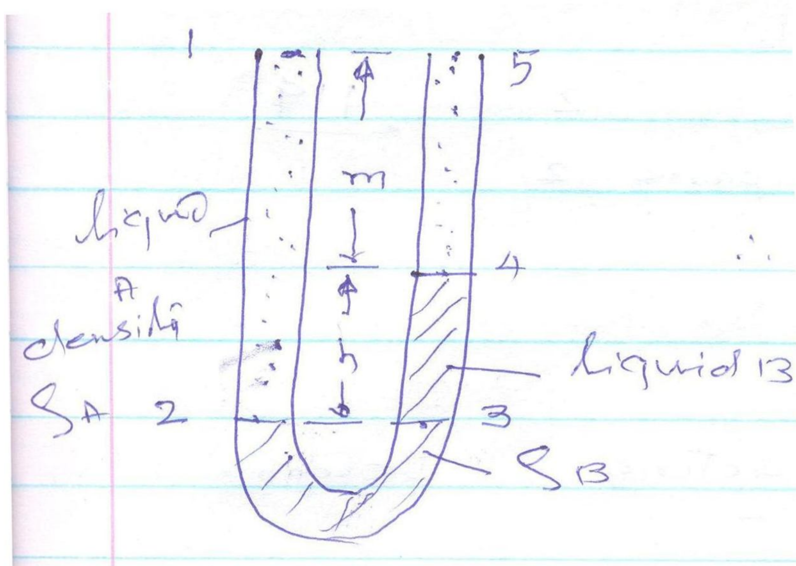


Friction factor chart or friction factor-Reynolds number correlation chart is a logarithmic plot of friction factor as a function of Reynolds number over a wide range of Reynolds number for flow through rough and smooth pipes. This plot is a straight line with a slope of -1 for laminar flow. For turbulent flow, the lowest line represents the friction factor for smooth tubes. The other curved lines in the turbulent flow range represents the friction factors for various types of commercial pipe, each of which is characterized by a different value of roughness parameter(k). — 2

2-f **Comparison between variable head meter and variable area meter** — 1 mark each — 4

	Variable head meter	Variable area meter
i. Area of flow	Constant with flow rate	Varies with flow rate
ii)Pressure drop	Varies with flow rate	Constant with flow rate
iii) Measurement of flow rate	Cannot give volumetric flow rate directly	Can give volumetric flow rate directly
iv) Cost	Cheap	Costly

3-a **Derivation for calculating pressure drop using a U tube manometer.** — 4



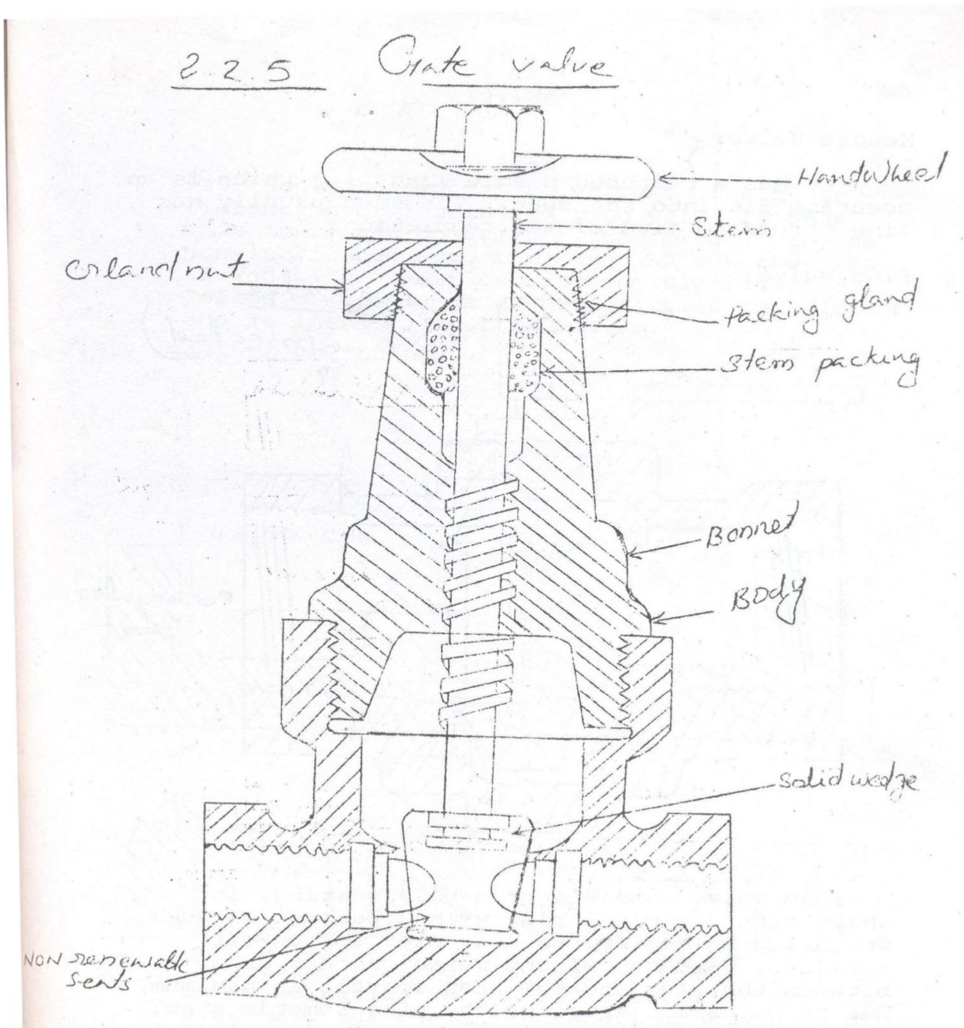
1

Let pressured point

A = P

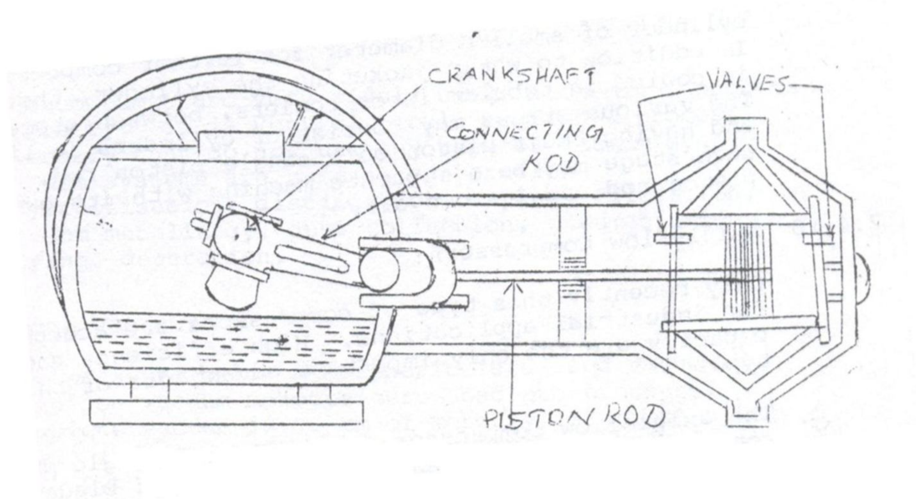
$\therefore P_2 = P_1 + (h + m)\,\rho_A\, {}^{g}/_{gc}$ — 1

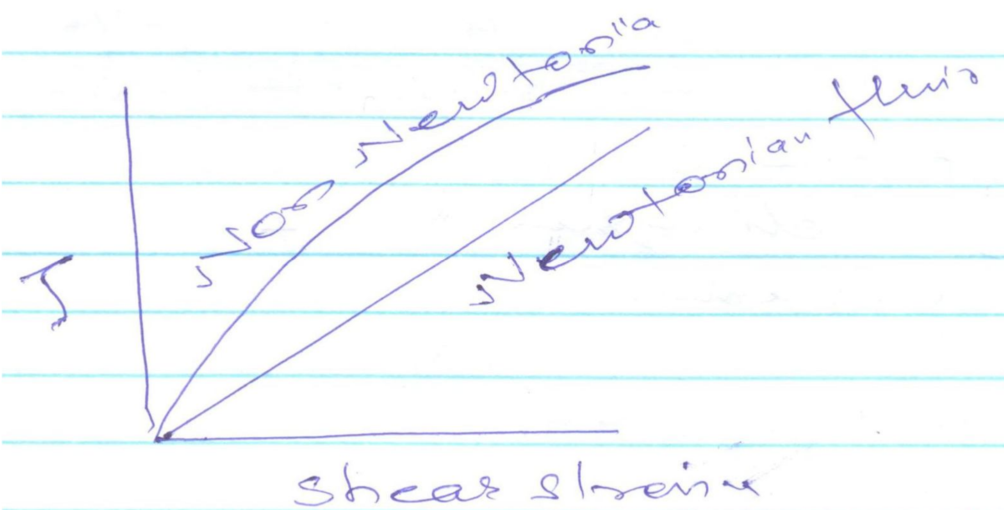
	Point 2 & 3 are on same level $\therefore P_2 = P_3$ $\therefore P_3 = P_1 + (h + m)\ \rho_A \frac{g}{gc}$ $P_4 = P_3 - h\rho_B\ {}^{g}/_{gc}$ $= P_1 + (h + m)\ \rho_A \frac{g}{gc} - h\rho_B \frac{g}{gc}$ $P_5 = P_4 - m\rho_A \frac{g}{gc}$ $= P_1 + (h + m)\ \rho_A \frac{g}{gc} - h\rho_B \frac{g}{gc} - m\rho_A \frac{g}{gc}$ Simplifying $\therefore P_5 = P_1 + h\ [\rho_A - \rho_B] \frac{g}{gc}$ Or $P_1 - P_5 = h\ [\rho_B - \rho_A] \frac{g}{gc}$ Or $\Delta P = \Delta H\ [\rho_B - \rho_A] \frac{g}{gc}$ if $\rho B >> \rho_A$ we can Or $\Delta P = \Delta H \rho_B \frac{g}{gc}$ Or $\frac{\Delta P}{\rho B} = \Delta H \frac{g}{gc}$	1 1	

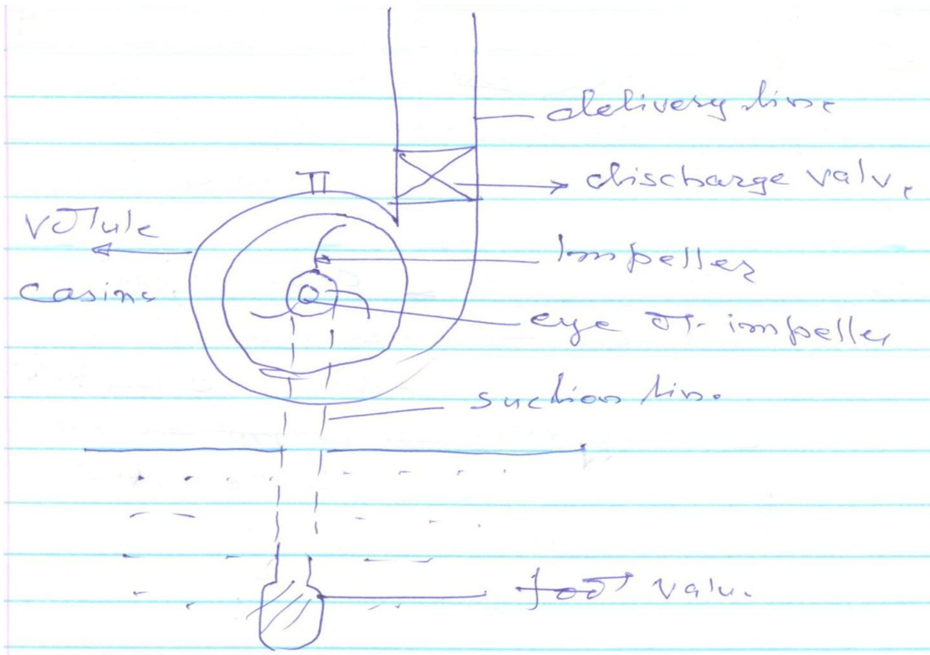
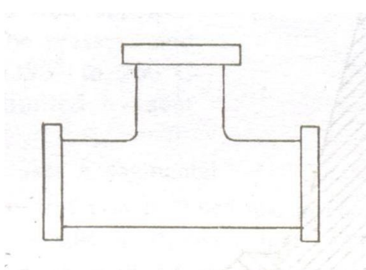
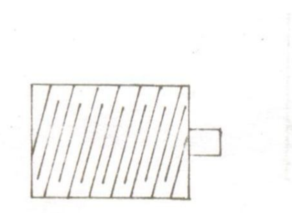
3-b	**Diagram of Gate valve**. 	2 marks for diagram and 2 marks for labeling	4

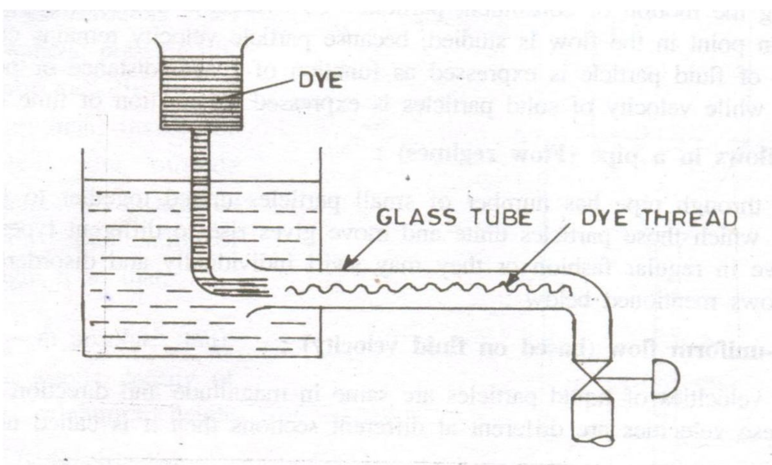
3-c	**Difference between single acting and double acting reciprocating pump.**	2 marks each	4

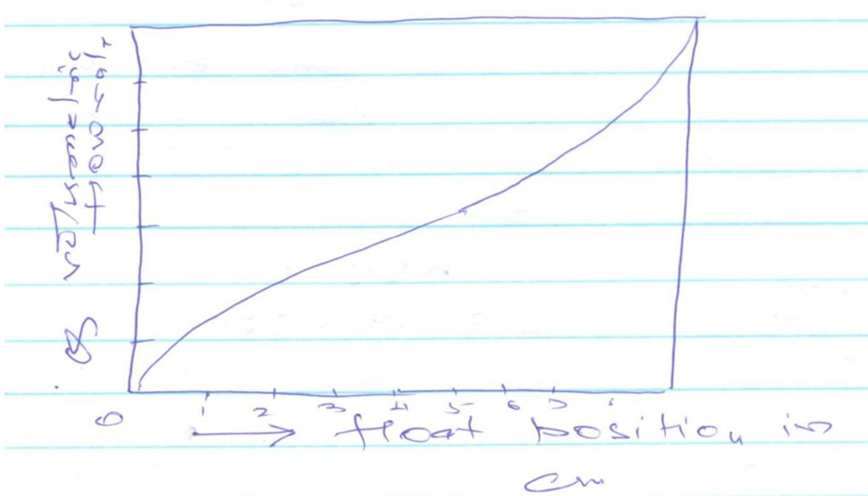
	Single acting	Double acting
1. Number of suction stroke and delivery stroke	Single suction stroke & single delivery stroke	Double suction stroke & double delivery stroke
2. Contact between piston and pumping liquid	One side of the piston is in contact with the pumping liquid	Both sides of the piston are in contact with the pumping liquid

3-d	**Working of reciprocating compressor**.		4
		2	
	Figure shows a single stage double acting compressor with water cooling jackets. The characteristic features of reciprocating compressor are the same as that of reciprocating pumps. A piston, a cylinder with suitable intake and exhaust valves and a crank shaft with drive. Gas being compressed enters and leaves the cylinder through valves which are set to be actuated when the pressure difference between cylinder contents and outside conditions is that desired. The over all efficiency of most reciprocating compressors is 65 to 80 percent.	2	

3-e	**Newtonian fluid and non Newtonian fluid.** Newtonian fluid is these which obey Newton's law of viscosity. e.g H_2O, $CHCl_3$ $\frac{F}{A} = \zeta \frac{dv}{dx}$ Shear stress = coefficient of viscosity × shear rate Non Newtonia fluid is those which do not obey this law e.g complex fluid like latex	2	4
		2	

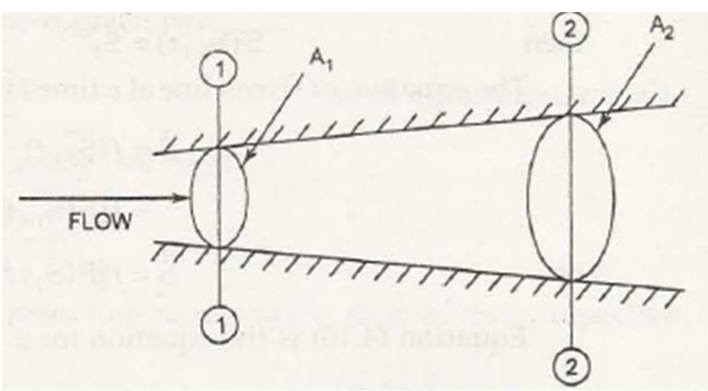
3-f	**Diagram of centrifugal pump** :  	2 marks for diagram and 2 marks for labeling	4
4-a	**i) Tee**  For branching **ii) Plug**  To close the end of pipe	1 1 1 1	4

4-b	**Reynolds experiment**  **Procedure:** Initially regulating valve is kept closed and water in the tank is allowed to stand for several hours. Then regulating valve is slightly opened that allows steady flow of water through tube. Now a jet of dye is allowed to enter in the center of the glass tube in one of the ways shown in diagram depending on the velocity of water through the tube. i. At low velocities the dye thread is in the form of a straight and stable filament as shown in diagram, which hardly seems to be in motion through the glass tube. This indicates that at low flow velocities there is no intermingling of water and dye particles or liquids flow in parallel layers or laminar without any intermixing. Such a flow regime (pattern) is called 'laminar or stream-line flow'. ii. If water flow velocity is slowly increased, a stage comes when dye thread starts becoming irregular as shown in diagram. The flow velocity at which dye thread starts becoming irregular is known as 'lower critical velocity'. If flow velocity is further increased, length of dye thread in the glass tube starts decreasing and ultimately a stage comes when thread is not clearly visible. The flow velocity at which	2 1	4

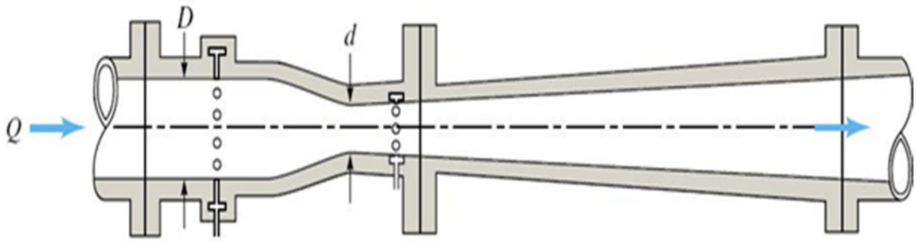
	whole dye thread is diffused is known as 'upper critical velocity'. iii. If water flow velocity is increased beyond the upper critical velocity, the fluctuations in the dye filament increase and ultimately dye diffuses over the entire tube cross-section as shown in diagram. This indicates intermingling or mixing of liquid particles which is called as 'turbulent flow regime.' NRe = $\frac{Du\rho}{gu}$ NRe < 2100 Laminer flow NRe > 4000 turbulent 2100 < Ne < 4000 transient flow	1	
4-c	**Range of pressure developed by fan, blowers and compressor**. Fans - < 0.35 Kg_f/cm^2 Blowers – discharge pressure upto 10 Kg_f/cm^2 Compressor – 2400 Kg_f/cm^2	4	4
4-d	**Rota meter calibration** : 	2	4

	1) For calibration allow the liquid to flow through the Rota meter. 2) Measure the volumetric flow rate. 3) Note the position of float. 4) Plot a graph of Q Vs float position which is known as calibration curve.	2	
4-e	**Friction loss due to sudden contraction:** When pipe diameter and hence the flow area suddenly decreases from A_1 to A_2 with subsequent increase in flow velocity (jetting action) the flow area becomes minimum (less than A_2) at venacontracta. The space between pipe wall and jet is filled with eddies with loss of energy given by: $H_{fc} = 0.4\left(1-\frac{A_2}{A_1}\right)\frac{{V_2}^2}{2g}$ ….. In S.I. units $= 0.4\left(1-\frac{A_2}{A_1}\right)\frac{{V_2}^2}{2g_c}$ …….. In Gravitational units. Where H_{fc} is the head loss due to sudden contraction. A_1 - area of larger pipe . A_2 - area of smaller pipe . V_2 - velocity of fluid in the small diameter pipe.	2 2	4
4-f	1. Water $P = h\rho\frac{g}{gc}$ $= 8 \times 1 \times \frac{980}{980} = 8gm_f/cm^2$ OR $P = h\,\rho\,g$ $= 8 \times 1 \times 980$ $= 7840\ dyne/cm^2 (784.8 N/m^2)$	2	4

	2. Liquid of specific gravity 0.9 $\therefore \rho = 0.9\ gm/cm^3$ $\therefore p = h\rho\frac{g}{gc}$ $= 8 \times 0.9 \times \frac{g}{gc} = 7.2 gmf/cm^2$ OR $P = h\rho g = 8 \times .9 \times 980 = 7056 dyne/cm^2 (705.6 N/m^2)$	2	
5-a	Given: $Q = 0.5\ m^3/s$ D= 0.075 m L = 100 m Density $= \rho = 1100\ kg/m^3$ Viscosity $= \mu = 0.003$ Pa.S = 0.003 kg/ms Area of pipe= $A = \Pi/4 * D^2 = \Pi/4 * (0.075)^2 = 4.418*10^{-3}\ m^2$ As Discharge Q = u A Velocity $u = Q/A = 0.5/4.418*10^{-3} = 113$ m/s $N_{Re} = Du\rho/\mu = 0.075*113*1100/0.003 = 3107500$ As $N_{Re} > 4000$, flow is turbulent Friction factor f is calculated as $f = \frac{0.078}{(NRe^{0.25})} = \frac{0.078}{(3107500^{0.25})} = 0.001857$	1 1 1 1	8

	ΔP = Pressure drop over length L $$\Delta P = \left[\frac{4fL\rho u^2}{2D}\right]$$ $$\Delta P = \left[\frac{4 * 0.001857 * 100 * 113^2 * 1100}{2 * 0.075}\right]$$ $\Delta P = 69555296.8\ N/m^2$ $$\Delta P = 69555.29\ \ kN/m^2$$	2 2	
5-b	**Continuity Equation**: Statement: "For a steady state flow system, the rate of mass entering the flow system is equal to that leaving the system as accumulation is either constant or nil ". Consider a flow system as shown  As flow can not take place across the walls of stream tube, the rate of mass entering the system must be equal to that leaving. Let u_1 ,ρ_1 & A_1 be the avg. velocity, density & area at entrance of tube & u_2 ,ρ_2 & A_2 at the exit of tube.	2	8

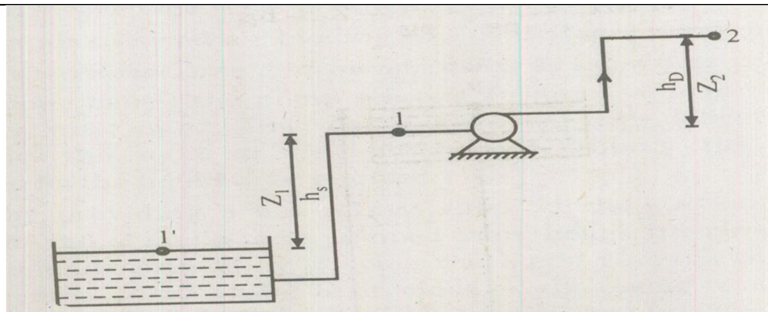
	Let $\dot{m}$ be rate of flow in a unit time (mass flow rate)		
	Rate of mass entering the flow system = $u_1 \rho_1 A_1$	3	
	Rate of mass leaving the flow system = $u_2 \rho_2 A_2$		
	Under steady flow conditions		
	$\dot{m} = \rho_1 u_1 A_1 = \rho_2 u_2 A_2$		
	$\dot{m} = \rho u A$ = constant …….. equation of continuity		
	Equation of continuity is applicable to compressible as well as incompressible fluids.In case of incompressible fluids $\rho_1 = \rho_2 = \rho$		
	Numerical:		
	Given:		
	$D_1 = 0.02$ m		
	$u_1 = 0.08$ m/s		
	ρ of water = 1000 kg/m^3		
	$D_2 = 0.1$ m u_2 = ? m/s		
	$A_1 = \Pi/4\ D_1^2 = 3.14/4*(0.02)^2 = 3.14*10^{-4}$ m^2		
	$A_2 = \Pi/4\ D_2^2 = 3.14/4*(0.1)^2 = 0.00785$ m^2	2	
	According to continuity equation		
	$\dot{m} = \rho_1 u_1 A_1 = \rho_2 u_2 A_2$		
	As $\rho_1 = \rho_2 = \rho$		
	$\dot{m} = u_1 A_1 = u_2 A_2$		
	$u_2 = u_1 A_1 / A_2$		
	$u_2 = 0.08 * 3.14*10^{-4} / 0.00785$		
		1	
	$u_2 = 0.0032$ m/s = 0.32 cm/s		

5-c	Derivation for calculating volumetric flow rate using venturimeter:  Let P_1 ,P_2 & u_1 & u_2 be the pressures &velocities at section 1 & 2 respectively. Let A_1 & A_T be the flow areas at section 1 & 2 respectively. Section 1 is at the upstream side of convergent cone & section 2 is at the throat. Let the fluid be incompressible & no frictional losses between station 1 &2 . Applying the Bernoulli equation between the shown stations (1) and (2) along the center we get: $$\frac{P_1}{\rho}+\frac{\alpha_1 . u_1^2}{2}+gZ_1 = \frac{P_2}{\rho}+\frac{\alpha_2 . u_2^2}{2}+gZ_2$$ The venturimerer is connected in a horizontal pipe ,so $Z_1 = Z_2$ $$\frac{P_1}{\rho}+\frac{\alpha_1 . u_1^2}{2} = \frac{P_2}{\rho}+\frac{\alpha_2 . u_2^2}{2} \quad \ldots\ldots \quad eq1$$	1	8

	From equation of continuity $$\dot{m} = \rho u_1 A_1 = \rho u_2 A_2$$ Where $A_1 = \pi/4 \; D^2$ & $A_T = \pi/4 \; D_T^2$ D & D_T are the diameter of pipe & throat . $$u_{1(\pi/4 \, . D^2)} = u_{2(\pi/4 \, . D_T^2)}$$ Let $\frac{D_T}{D} = \beta$ $u_1 = \beta^2 u_2$ ………… eq2 Putting value of u_1 from eq 2 in eq 1, we get $$\frac{P_1}{\rho} + \frac{\alpha_1 .(\beta^2 u_2)^2}{2} = \frac{P_2}{\rho} + \frac{\alpha_2 .u_2^2}{2}$$ Rearranging we get $$\frac{\alpha_2 u_2^2}{2} - \frac{\alpha_1 \beta^4 u_2^2}{2} = \frac{P_1 - P_2}{\rho}$$ $$\alpha_2 u_2^2 - \alpha_1 \beta^4 u_2^2 = \frac{2(P_1 - P_2)}{2}$$ $$\alpha_1 \left[\frac{\alpha_2}{\alpha_1} u_2^2 - \beta^4 u_2^2\right] = \frac{2(P_1 - P_2)}{\rho}$$	1 1 1	

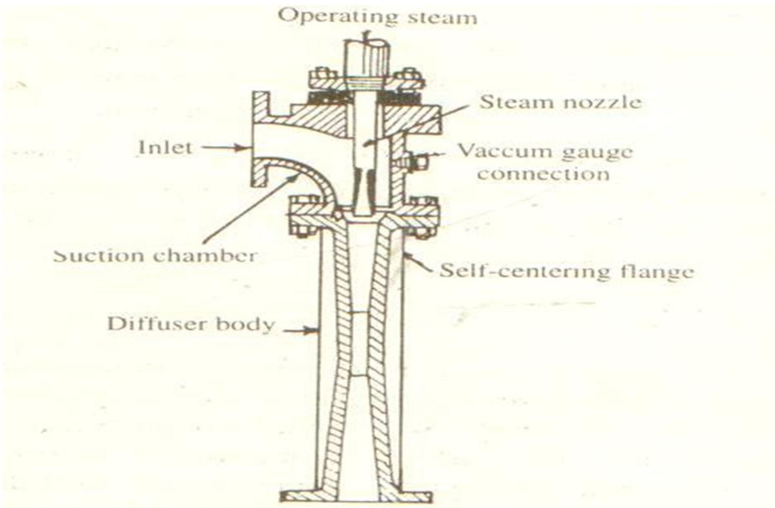
	As $\frac{\alpha_2}{\alpha_1} = 1$	1	
	$$\alpha_{1[u_2^2-\beta^4 u_2^2]} = 2\left(\frac{P_1-P_2}{\rho}\right)$$ $$u_2 = \left[\frac{2(P_1-P_2)}{\rho} * \frac{1}{\alpha(1-\beta^4)}\right]^{1/2}$$	1	
	The above equation is corrected by introducing an empirical factor Cv & writing $$u_2 = Cv\left[\frac{2(P_1-P_2)}{\rho} * \frac{1}{\alpha(1-\beta^4)}\right]^{1/2} \quad \text{eq3}$$ Cv = Coefficient of venturimeter & it takes into account the error introduced by assuming no frictional losses & As $\frac{\alpha_2}{\alpha_1} = 1$ & $\alpha_1 = 1$ Volumetric flow rate Q is given by		
	$$Q = u_2 A_T \quad \text{eq4}$$	1	
	From eq3 & eq4 $$Q = A_T\, Cv\left[\frac{2(P_1-P_2)}{\rho} * \frac{1}{(1-\beta^4)}\right]^{1/2}$$ $$Q = \frac{C_v A_T}{\sqrt{(1-\beta^4)}}\sqrt{\frac{2(P_1-P_2)}{\rho}}$$		
	Q = Actual discharge	1	

	If pressure is measured by U-tube manometer, then discharge is calculated as $Q = \frac{C_v A_T}{\sqrt{(1-\beta^4)}}\sqrt{2g\Delta H}$ Where $\Delta H = \Delta h(\frac{\rho_M-\rho}{\rho})$ ΔH = Difference in head across venture in terms of meters of flowing fluid. Δh= Difference in head across venture in terms of meters of manometric fluid.		
6-a	**Cavitation:** The vapour pressure of the liquid at the pumping temp. sets the lower limit for the pressure. Care must be taken so that the pressure at any point in the suction does not fall below the vapour pressure of the liquid to be pumped. When the pressure in the suction line is less than vapour pressure of liquid ,then some of the liquid get converted into vapours or if the liquid to be pumped contains gases, they may come out of the solution resulting into gas pockets, that will damage the impeller. This phenomenon is called as cavitation	2	8
	Drawbacks of cavitation: 1)Due to cavitation the pump is not capable of developing the required suction head & no liquid can be drawn into pump. 2)Cavitation leads to mechanical damage to the pump as bubble collapse. **Derivation for NPSH:** In order to avoid cavitation, the pressure at the suction point of the pump must exceed the vapour pressure of the liquid by a certain value which is called as net positive suction head.	2	

	 System with suction lift	1	
	If Z_1 is the static suction lift(also denoted by hs),it is the vertical height of the center line of the pump shaft above the liquid surface in the reservoir from which the liquid being raised. Z_2 is the static delivery lift(h_D),it is the vertical height of the liquid surface in the tank to which the liquid is delivered above the center line of pump shaft.	1	
	NPSH = (Absolute pressure head at suction point 1) – (vapour pressure head) $$NPSH = \frac{u_1^2}{2g} + \frac{P_1}{\rho g} - \frac{P_v}{\rho g}$$ Pv = vapour pressure of liquid at pumping temp. The Bernoulli eqn in terms of m of liquid between stations 1' & 1 is $$\frac{P_1'}{\rho g} + \frac{u_1'^2}{2g} + Z_1' = \frac{u_1^2}{2g} + Z_1 + \frac{P_1}{\rho g} + h_{fs}$$ $$h_{fs} = head\ lost\ in\ friction\ in\ suction\ line$$ If $Z_1' = 0$ & $u_1' = 0$		

	$$\frac{P_1'}{\rho g} = \frac{u_1^2}{2g} + Z_1 + \frac{P_1}{\rho g} + h_{fs}$$ Rearranging we get $$\frac{P_1}{\rho g} + \frac{u_1^2}{2g} = \frac{P_1'}{\rho g} - Z_1 - h_{fs}$$ Therefore we can write NPSH = $\frac{P_1'}{\rho g} - \frac{P_v}{\rho g} - Z_1 - h_{fs}$	2	
6-b	Given: $\dot{m}$ = 4 kg/s D= 0.05 m Total length of piping = L= 850+20 = 870 m Density =ρ = 1650 kg/ m^3 Viscosity =μ = 0.0086 Pa.S = 0.0086 kg/ms Area of pipe: Area of pipe= A = Π/4 *D^2 A= Π/4 *(0.05)^2 = 1.963*10^{-3} m^2 As $\dot{m}$ = ρ u A 4 = 1650*u*1.963*10^{-3} u= 1.23 m/s N_{Re} = Du ρ/ μ N_{Re} =0.05*1.23*1650 /0.0086 N_{Re} =11800 As N_{Re} > 4000,flow is turbulent Friction factor f is calculated as	1 1	8

	$f = \frac{0.078}{(NRe^{0.25})} = \frac{0.078}{(11800^{0.25})} = 0.00748$	1	
	h_f = head loss due to friction $= \left[\frac{4fL\rho u^2}{2gD}\right]$		
	$= \left[\frac{4*0.00748*870*1.23^2}{2*9.81*0.05}\right]$ = 40.144m(393.41J/Kg)		
	Writing Bernoulli's equation	1	
	$\frac{P_1}{\rho} + gZ_1 + \frac{\alpha_1 V_1^2}{2} + \eta W_P = \frac{P_2}{\rho} + gZ_2 + \frac{\alpha_2 V_2^2}{2} + h_{fs}$		
	$P_1 = P_2$		
	V_1 is negligible compared to V_2		
	V_2 = 1.23m/s		
	$Z_1 = 0$, Z_2 =870m		
	Bernoulli's equation becomes	2	
	$\eta W_P = gZ_2 + \frac{V_2^2}{2} + h_{fs}$		
	$0.6W_P = 8928.86$		
	$W_P = \frac{14881.4J}{Kg}$	2	
	Power required=$\dot{m}W_P$= 4*14881.4=59525.6W=59.525KW		

6-c	**Steam Jet Ejector**: 	4	8
	Working: An ejector has two inlets: one to admit the motive fluid, usually steam (inlet 1), and the other to admit the gas/vapor 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 vapor 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/vapor 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	4	

	decreasing cross sectional area creates an overall increase in pressure and a 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.		