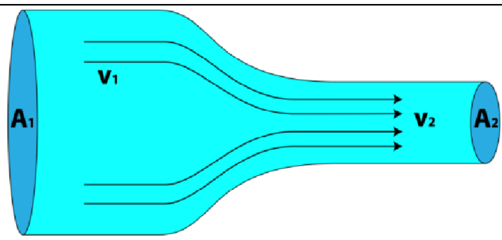
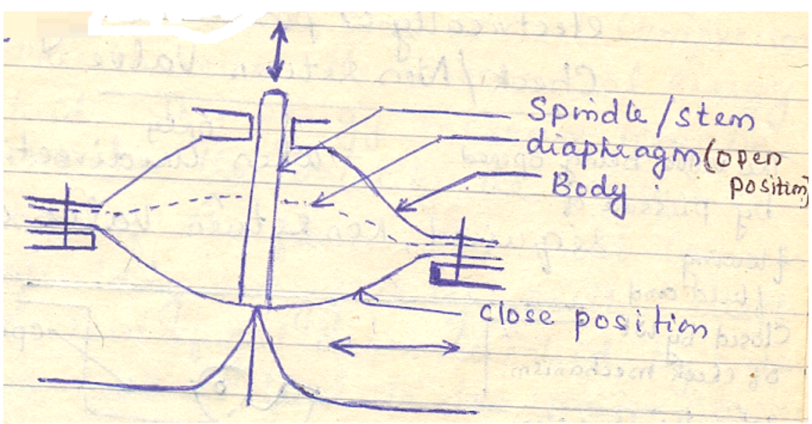
WINTER-15 EXAMINATION

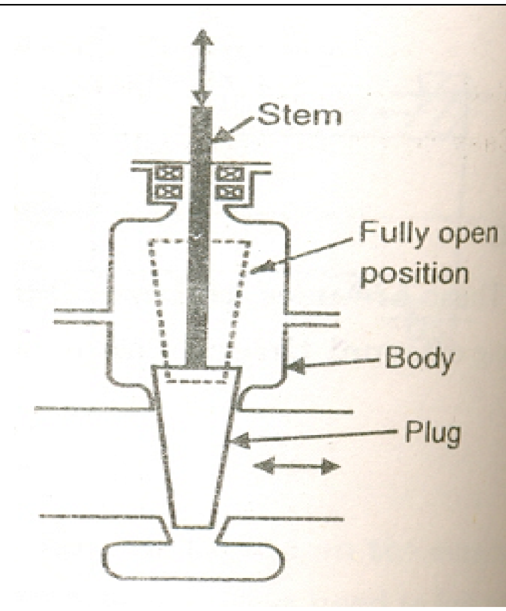
Model Answer

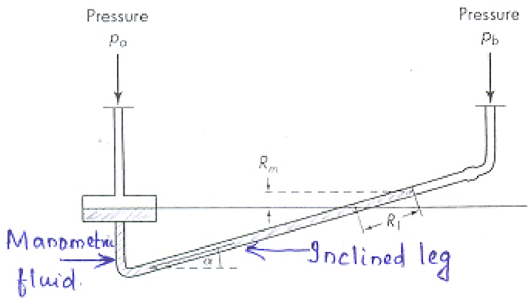
Important Instructions to examiners:

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.

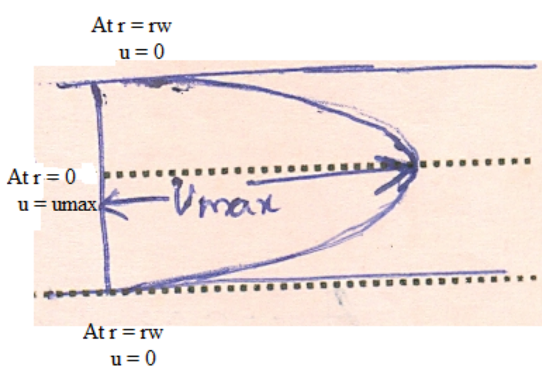
Q No.	Answer	marks	Total marks
1a-i	**Kinematic viscosity with its unit:** Kinematic viscosity: It is the ratio of viscosity of the fluid to its density Unit in SI is m^2/s	1 1	2
1a-ii	**Compressible fluid** If the density of the fluid is appreciably affected by moderate changes in temperature and pressure, the fluid is said to be compressible. **Incompressible fluid** If the density of the fluid is not appreciably affected by moderate changes in temperature and pressure , the fluid is said to be compressible.	1 1	2
1a-iii	**Reynold's Number** is a dimension less number which indicates the nature of flow. It is the ratio of inertial force to viscous force.	2	2
1a-iv	**Relation between friction factor and Reynold's number** **For laminar flow :** $f = \frac{16}{NRe}$ **for turbulent flow:** $f = 0.078/(N_{Re})^{0.25}$ or $1/\sqrt{f} = 4 \log(N_{Re}\sqrt{f}) - 0.4$	 1 1	2
1a-v	**Different types of pipe fittings:(any four)** Union, coupler, plug, reducer, expander, bend, elbow, tee, cross	½ mark each	2
1a-vi	**Pump used for viscous fluids:**Gear pump	2	2
1a-vii	**Two vacuum generating equipments**: vacuum pump, jet ejectors	1 mark each	2
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.	 1	4

	 Let v_1 ,ρ_1& A_1 be the avg. velocity, density& area at entrance of tube &v_2 ρ_2& A_2be the corresponding quantities at the exit of tube. Let be the mass flow rate Rate of mass entering the flow system = $v_1\ \rho_1\ A_1$ Rate of mass leaving the flow system = $v_2\ \rho_2\ A_2$ Under steady flow conditions $= \rho_1 v_1 A_1 = \rho_2 v_2 A_2$ $\rho v A$ = constant …….. **Equation of continuity**	2 1	
1B-ii	**DiaphragmValve:**  **Diagram of gate valve**	2	4

		2	
1B-iii	**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 **Reason for priming is required in centrifugal pump:** The pressure generated by a centrifugal pump is directly proportional to the density of the fluid that is in contact with it. Therefore if the impeller is made to rotate in the presence of air, only negligible pressure will be produced and no liquid will be lifted by the pump.Hence it is necessary to fill the suction pipe, pump casing and portion of the delivery pipe with the liquid to be pumped before starting the pump by priming.	2 2	4
2-a	**Diagram of inclined tube manometer:**		4

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

It is used for the measurement of small pressure difference. One arm of the manometer is inclined at an angle so as to obtain a larger reading. In the vertical leg of this type of manometer an enlargement is provided.
Equation to calculate pressure drop is
$P_a - P_b = \Delta P = R_1 \sin \alpha\, (\rho_m - \rho) g$ where ρ_m is the density of manometric fluid and ρ is the density of flowing fluid.</td><td>2

2</td><td></td></tr>
<tr><td>2-b</td><td>**Expression to calculate velocity distribution for flow of viscous fluid:**
$U = U_{max} [1 - (r / r_w)^2]$
Where r_w is the radius of the pipe where velocity is zero
U_{max} is the maximum velocity at the center of the pipe where radius is zero.
U is the velocity when the distance from the center of the pipe is r.
Diagram:

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2</td><td>4</td></tr>
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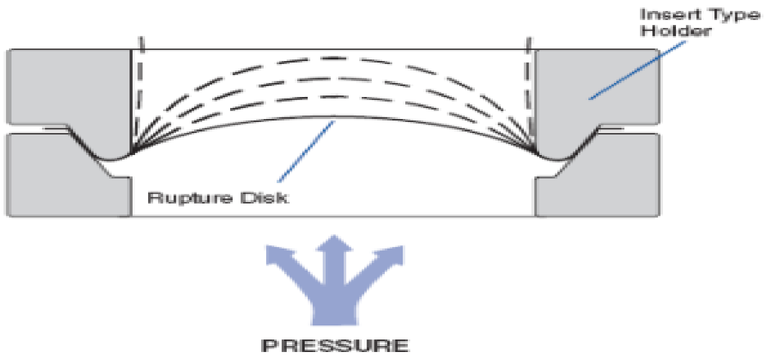
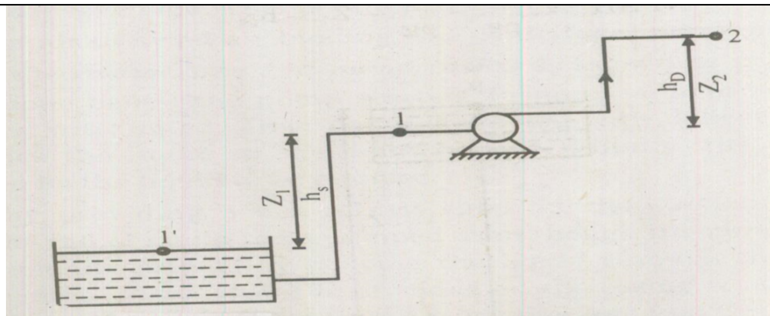
2-c	**Rupture disc:**  Rupture disc, is a non-reclosing pressure relief device that, protects a pressure vessel, equipment or system from over -pressurization or potentially damaging vacuum conditions. A rupture disc is a one-time-use membrane. They can be used as single protection devices or as a backup 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. The membrane is generally made up of metal.	4	4
2-d	**NPSH for a system with suction lift**. NPSH stands for Net positive Suction Head. It is the amount by which the pressure (sum of velocity and pressure head) at the suction point of the pump is in excess of vapour pressure of the liquid.	1	4



System with suction lift

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.

3

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.

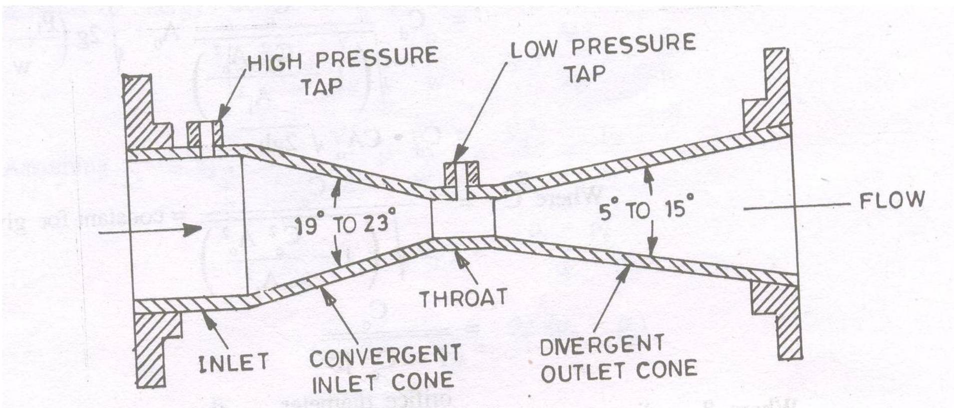
NPSH = (Absolute pressure head at suction point 1) – (vapour pressure head)

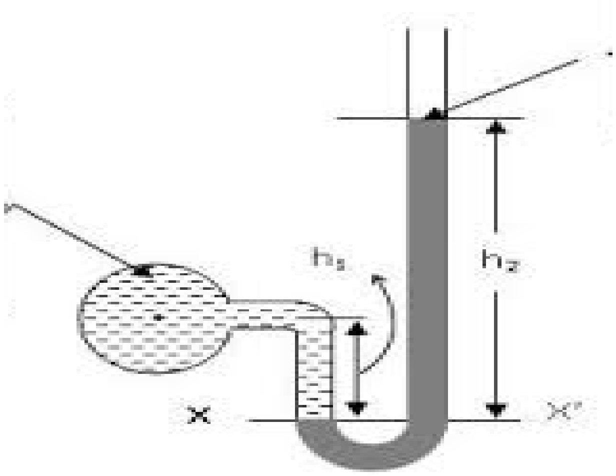
Pv = vapour pressure of liquid at pumping temp.

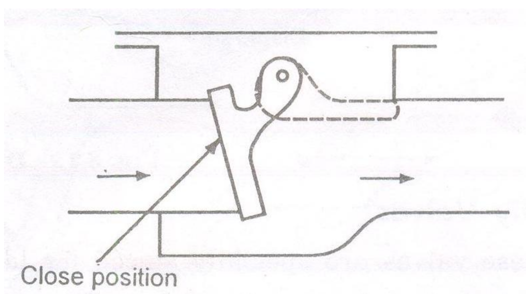
The Bernoulli eqn in terms of m of liquid between stations 1' & 1 is

If = 0 & u_1' = 0

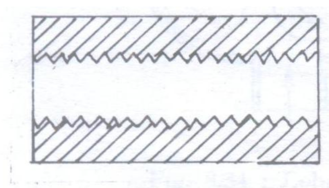
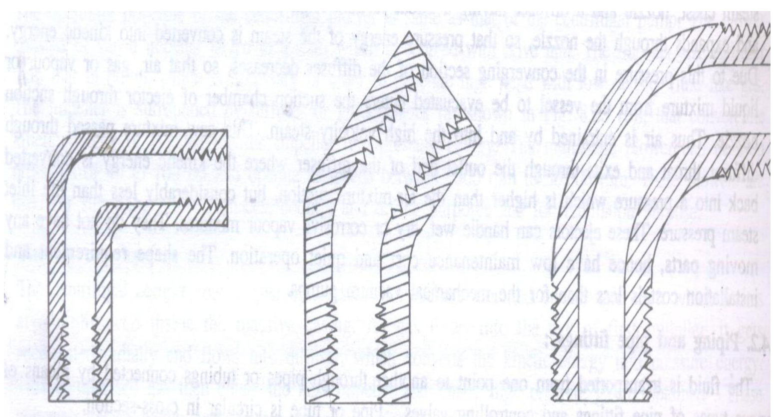
	Rearranging we get $$\frac{P_1}{\rho g}+\frac{u_1^2}{2g}=\frac{P_1'}{\rho g}-Z_1-h_{fs}$$ Therefore we can write NPSH = $\frac{P_1'}{\rho g}-\frac{P_v}{\rho g}-Z_1-h_{fs}$ Where, Z_1= height of pump from the level of liquid in the tank P_1'= Pressure at the eye of impeller P_v= Vapour pressure of liquid h_{fs}=Head lost due to friction on suction side.		
2-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. The frictional loss due to sudden contraction is proportional to velocity head in of the fluid in the small diameter pipe. $h_{fc} = K_c\frac{V_2^2}{2g}$ $K_c = 0.4\left(1-\frac{A_2}{A_1}\right)$ 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
2-f	**Venturimeter:**		4

	Diagram  	2	
	Construction. The venturimeter consists of 1. A convergent section section with converging cone angle of 15-20^o, where the fluid is accelerated. 2. A throat where the area is constant with its length equal to diameter. 3. A long diverging section with cone angle of about 5-7^o where the fluid is accelerated. The high pressure tap is located on inlet section while low pressure tap is located at the middle of throat, the manometer is connected between thesetaps.The venturi tube is made up of cast iron or steel	2	
3-a	**U tube manometer:**		4

	 The U-tube manometer shows a reading of h_2 of heavy liquid. The interface between the heavy liquid and the light liquid of which the pressure is to be measured is $h_1$meters below the point of attachment A. For a U-tube manometer h_1 = Heihgt of light liquid above the datum line h_2 = Heihgt of heavy liquid above the datum line ρ_1 = Density of light liquid ρ_2 = Density of heavy liquid Let, x-x' = The datum line h_1 = Heihgt of light liquid above the datum line h_2 = Heihgt of heavy liquid above the datum line Pressure in left arm above the datum line = $P + \rho_1 h_1 g$, N/m^2. Pressure in right arm above the datum line = $\rho_2 h_2 g$, N/m^2. Since the pressure in both the arms above z-z datum is equal, we can write	1 3	

	$P + \rho_1 h_1 g = \rho_2 h_2 g$ $\mathbf{P = (\rho_2 h_2 g - \rho_1 h_1 g)}$		
3-b	**Non return valve:**  **Uses of non-return valve :** 1)It is used in horizontal pipe lines so that at the start of closing the valve the gravity force is maximum and it becomes minimum at the time of closing. 2)It is used when unidirectional flow is desired.	2 2	4
3-c	**Factors which influences the choice of pumps :** 1) The quantity of liquid to be handled. 2) The head against which the liquid to be pumped. 3) The nature of power supply 4)The flow rate required.	1 mark each	4
3-d	**Non-Newtonian Fluid** A fluid, which does not obey Newton's law of viscosity is known as Non-Newtonian Fluid. **Common types of Non-Newtonian Fluid :** 1.Bingham Fluids or Bingham Plastics : These fluids resist a small shear stress indefinitely but flow linealy under the action of larger shear stress, i.e., these fluids do not deform i.e., floe unless of	1 1	4

	threshold shear stress value (τ_0) is not exceeded. Eg : Toothpaste,. Jellies, paints, sewage sludge. **2.Pseudoplastic fluids :** The viscosity of these fluids decreases with increase in velocity gradient, i.e., shear rate. Eg : Blood, solution of high molecular weight polymers, paper pulp, muds. **3.Dilatent Fluid :** The viscosity of these fluids increases with increase in velocity gradient. Eg : Suspension of starch in water, pulp in water	1 1	
3-e	**Use of fan as a pumping device :** 1) For removal of fumes. 2) For ventilation work. 3) For supplying air to dryers **4)** Suppling draft to boilers.	1 mark each	4
3-f	Pressure at A = Pressure at B = 101.325 kPa Density of liquid = ρ = 1150kg/m^3 h_f = Frictional losses = 1 J / Kg Volumetric flow rate = 500 cm^3/s = 500 × 10^{-6} m^3/s D = 40 mm = 0.04 m Area of pipe A = $\frac{\Pi}{4} D^2 = \frac{\Pi}{4} (0.04)^2$ = = 1.26 × 10^{-3} m^2 Velocity at B = $u_2 = \frac{500\times10^{-6}}{1.26\times10^{-3}}$ = 0.40 m/s Velocity at A = u_1 = 0 Pressure at A = P_1 ; Pressure at B = P_2 The Bernoulli's equation between stations 1 and 2 is $\frac{P_1}{\rho} + gZ_1 + \frac{u_1^2}{2} + \eta\, W_p = \frac{P_2}{\rho} + gZ_2 + \frac{u_2^2}{2} + h_f$	1 1 1	4

	Let A be the datum level. $\therefore Z_1 = 0, Z_2 = 5m, P_1 = P_2$ $\therefore \eta Wp = pump\ work = \frac{u_2^2}{2} + h_f + gZ_2$ $= \frac{(0.4)^2}{2} + 1 + (9.81 \times 5) =$ **50.13 J/kg**	1	
4-a	**Diagram and application of** **i) Socket**  For joining pipes of same diameter **ii) Elbow(any one diagram)**  (a) 90° elbow (b) 45° elbow (c) long radius elbow For Changing the direction of flow.	1 mark each for diagram and application.	4
4-b	**Given :** S = 0.9 μ = 20 poise d = 20 cm Q = 10 lit/sec Q = AV		4

<table>
<tr><td></td><td>∴ Flow velocity V = $\frac{10*1000}{\frac{\Pi}{4}*400}$= 31.83 cm/sec∴ Reynold's number R_e = $\frac{\rho V d}{\mu}$ = $\frac{0.9*31.83*20}{20}$ == 28.64
Thus the flow is laminar</td><td>1
2
1</td><td></td></tr>
<tr><td>4-c</td><td>

	Reciprocating Compressor	Centrifugal Compressor
1	These compressors cannot be directly coupled with the drive unit.	These compressors are directly coupled with the drive unit.
2	The compression process is isothermal because coolers are used.	The compression process is adiabatic because of high speed operation.
3	Slow speed machine.	High speed machine.
4	Can develop pressure upto $1MN/m^2$	Can develop pressure upto $1000N/m^2$

</td><td>1 mark each</td><td>4</td></tr>
<tr><td>4-d</td><td>Pitot Tube
Construction :The pitot tube consist of an impact tube, the opening of which facing to the direction of flow and static tube, the opening of which is perpendicular to the direction of flow. The impact tube measures the impact / dynamic pressure and the static tube measures the static pressure. The two tubes may be connected to the arms of manometer for measuring the pressure difference.</td><td>2</td><td>4</td></tr>
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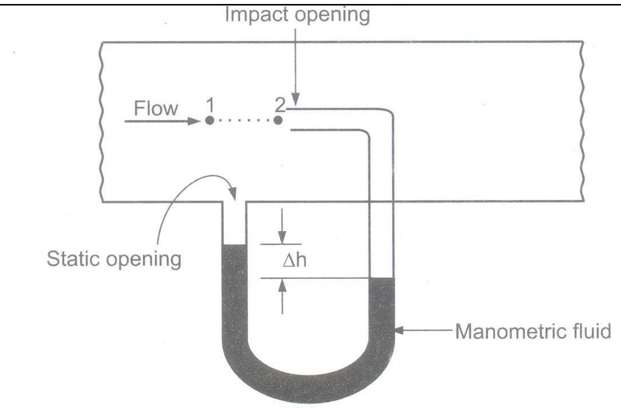
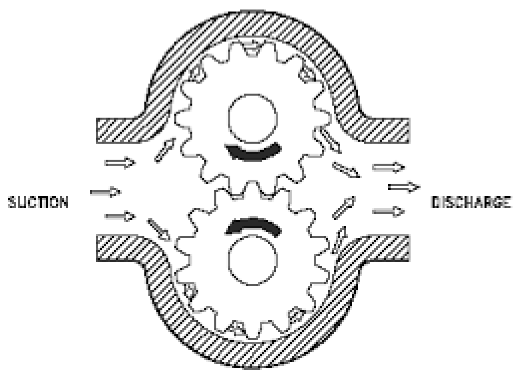
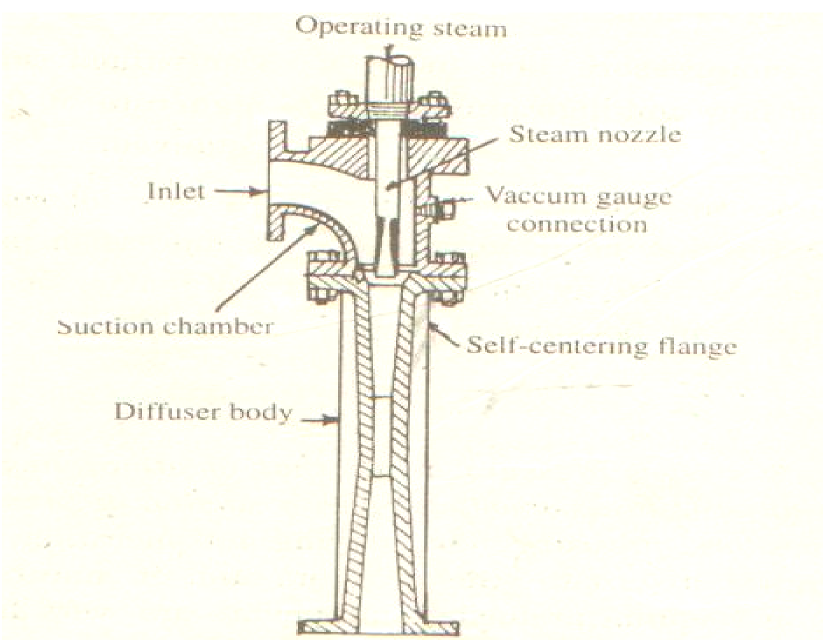
		2	
4-e	**Given :** D_1 = 200 mm = 0.2m D_2 = 400mm = 0.4m Q = 250lit/sec = $0.25 m^3/sec$ A_1 = cross sectional are of smaller pipe $= \frac{\pi}{4}(D_1)^2 = \frac{\pi}{4}(0.2)^2 = 0.0314 m^2$ A_2 = cross sectional are of larger pipe $= \frac{\pi}{4}(D_2)^2 = \frac{\pi}{4}(0.4)^2 = 0.1256 m^2$ U_1 = velocity of flowing fluid through smaller pipe $U_1 = \frac{Q}{A_1} = \frac{0.25}{0.0314} = 7.9617$ m/sec ∴ Loss of head $h_{fe} = \frac{U_1^2}{2}(1 - \frac{A_1}{A_2})^2$ $h_{fe} = \frac{(7.9617)^2}{2}(1 - \frac{0.0314}{0.1256})^2$ **h_{fe} = 17.8280 J/kg.**	1 1 1 1	4
4-f	**Given :** Specific gravity of oil = 0.80		4

	Density of oil = ρ = 0.80× 1000 = 800 kg/m^3 Density of manometric fluid = ρ_m = 13600 kg/m^3 h_m= height of manometric fluid above the datum line = 150 mm = 150 × 10^{-3} m h_m= height of flowing fluid (oil) above the z-z datum = 150 – 90 = 60 mm = 60 × 10^{-3} m Pressure of oil in the pipeline or guage pressure at A is $P_A = h_m \rho_m g - h_m \rho_m g$ = 150 × 10^{-3}× 13600 × (9.81-60) × 10^{-3}× 800 × 9.81 = 19541.5 N/m^2 = **19.54 kN/m^2**	2 2	
5-a	Data: Viscosity of oil = 0.97 poise = 0.097 kg/m.s Specific gravity of oil = 0.9 Density of oil = sp.gravity of oil x density of water = 0.9 x1000 =900kg / m^3 Mass flow rate =1000 /30 = 3.334 kg/s Diameter of pipe: D = 100 mm = 0.1 m Length of pipe = 10 m Area of pipe = A = π /4 D^2 = π (0.1)^2 / 4 = 7.85 *10^{-3}m^2 $\dot{m}$ = ρ vA V = $\dot{m}$ / ρA = 3.334 / (900 * 7.85 * 10^{-3}m^2)= 0.4713 m / s Hagen Poiseille's equation is $\Delta P = 32\ \mu VL / D^2$ ΔP = 32 * 0.097*0.4713*10 / 0.1^2 = **1462.9N /m^2**	1 1 1 2 3	8
5-b	Data D1 = 30 cm = 0.3 m Area of pipe 1 = $A_1 = \pi /4\ D_1^2 = \pi /4*(0.3)^2$ = 0.0706 m^2 D2 = 20 cm = 0.2 m Area of pipe 2 = $A_2 = \pi /4\ D_2^2 = \pi /4*(0.2)^2$ = 0.0314 m^2	2	8

	D3 = 15 cm = 0.15m Area of pipe 3 = $A_3 = \pi/4\ D_3^2 = \pi/4*(0.15)^2 = 0.0176\ m^2$ Volumetric flow rate of water in a pipe1(dia.30 cm) = $Q_1 = u_1A_1$ Q_1 = 2.5 * 0.0706 = **0.1765 m^3/s** Volumetric flow rate of water in a pipe2(dia.20 cm) = $Q_2 = u_2A_2$ = 2 * 0.0314 = 0.0628 m^3/s From continuity equation mass flow in system = mass flow from the system mass flow in pipe 1 = mass flow in pipe2 + pipe flow in pipe 3 $\dot{m}_1 = \dot{m}_2 + \dot{m}_3$ $0.1765 = 0.0628 + 0.0176U_3$ u_3 = 0.1137/ 0.0176 = **6.46 m/s**	2 2 2	
5-c	Diameter of pipe: D= 50 mm = 0.05 m Orifice diameter: Do = 10 mm =0.01 m Δh = 10 cm = 0.10 m Density of mercury : ρHg = 13,600 kg/m^3 ρH_2SO_4 =Sp.gravity of acid x density of water = 1.3 x 1000 =1300 kg/m^3 Differential pressure on mercury manometer = 10 cm of mercury $\Delta H = \Delta h\left[\frac{\rho_{Hg}-\rho_{H2O}}{\rho_{H2O}}\right] = 0.1\left[\frac{13600-1300}{1300}\right]$ =0.946 m of acid β= Diameter of orifice /Diameter of pipe = 0.01 /0.05 = 0.2 Area of orifice = $A_o = \frac{\pi}{4}D_o^2 = \frac{\pi}{4}(0.01)^2$ = 7.85*$10^{-5}m^2$ The flow equation of orifice meter $Q = \frac{C_oA_o\sqrt{2g\Delta H}}{\sqrt{1-\beta^4}} = \frac{0.63*7.85*10^{-5}\sqrt{2*9.81*0.946}}{\sqrt{1-(0.2)^4}}$ Q =0.000212 m^3/s Approximate loss of pressure = $\Delta P = h.\rho g$	2 1 1 1 3	8

	$\Delta P = 0.946 x 1300 x 9.81$ $\Delta P = \mathbf{12064}$ **N /m²**		
6-a	**Gear Pump:** **Diagram:**  **Gear pump** **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. Used in chemical industry for handling high viscosity liquids like molasses,paints&greases.But not suitable for liquids having suspensions due to closed clearance between the gear wheels & teeth.	4 4	8
6-b	Data: Velocity of water = 25 m/s (constant , $u_1 = u_2$) $P_2 = 29.43$ N /cm^2 = 29.43×10^4 N /m^2	2	8

	$P_2 = 22.563$ N /cm^2 = 22.563 x 10^4 N /m^2 Z_1= 28 m Z_2= 30 m Total head at point 1 = — — = ——— ——— =89.35 m of water Total head at point 2 = — — = ——— ——— = 23 +31.85 +30 =84.85 m of water Loss of head = Total head at point 1 – Total head at point 2 = 89.35-84.85 = **4.5 m**	2 2 2	
6-c	**STEAM JET EJECTOR** **Diagram**  Steam jet ejector	4	8

	Working : 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.	4	