SUMMER-15 EXAMINATION

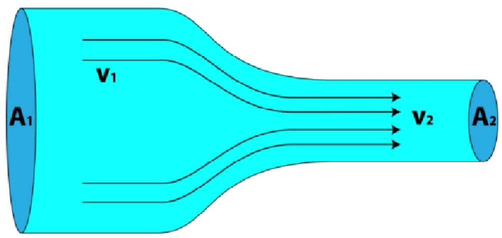
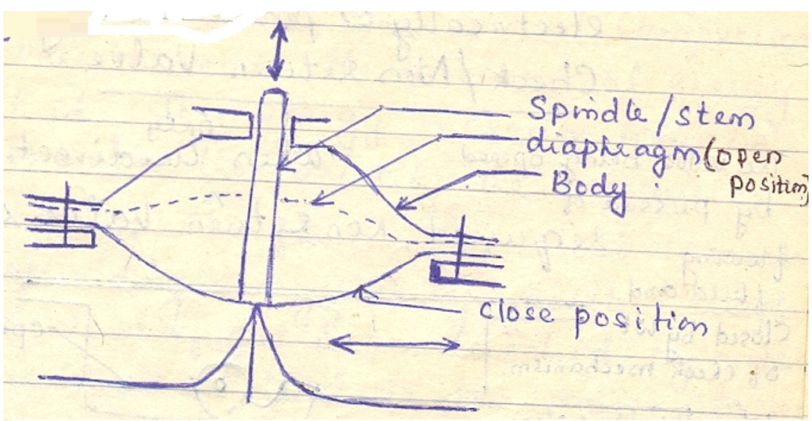
Model Answer

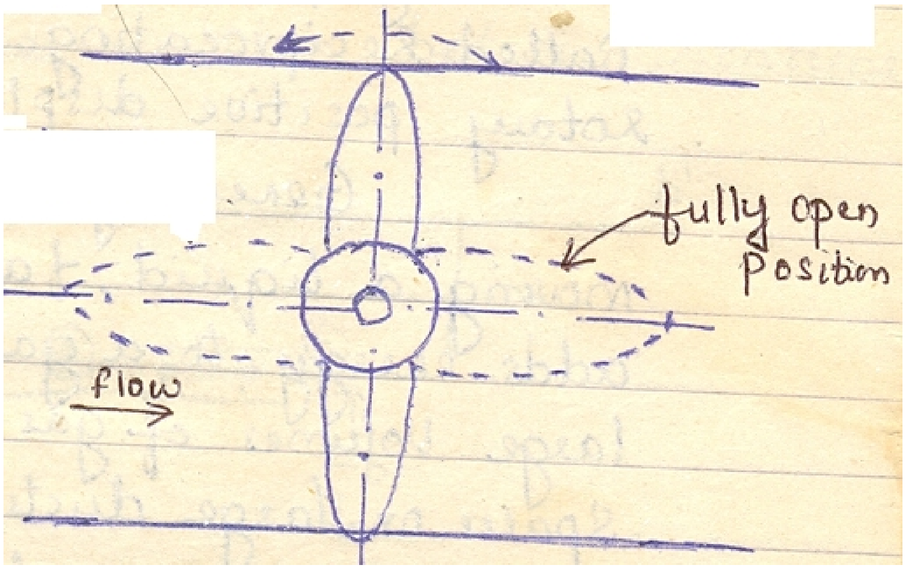
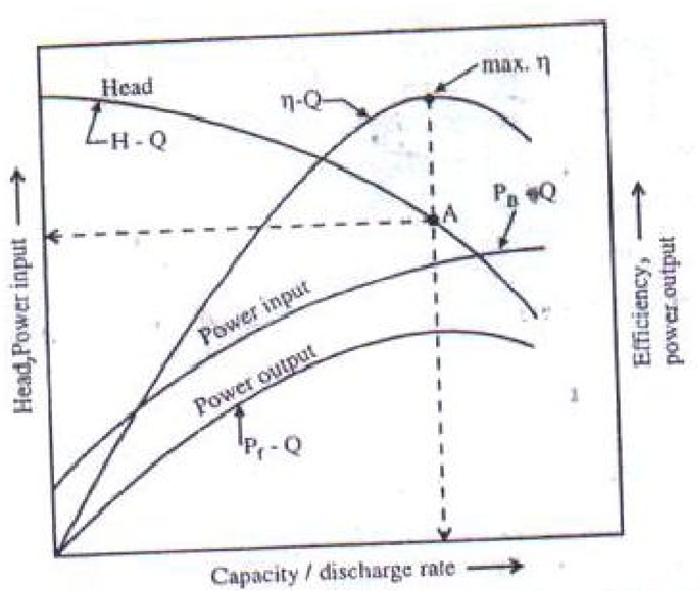
Subject code :(17426)

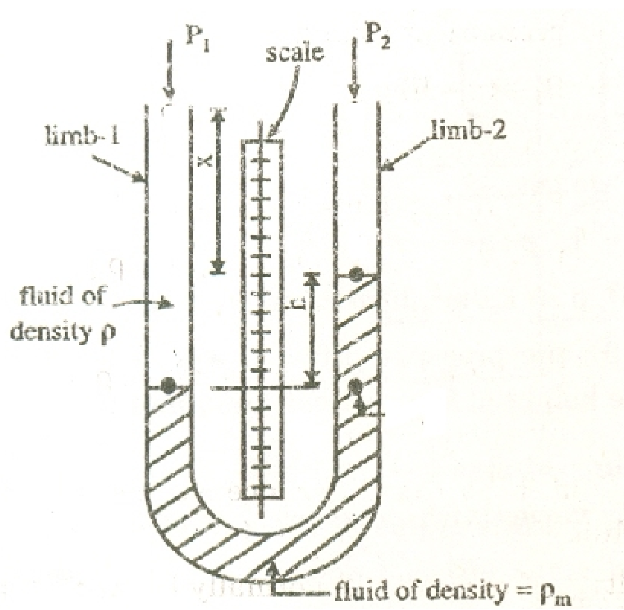
Important Instructions to examiners:

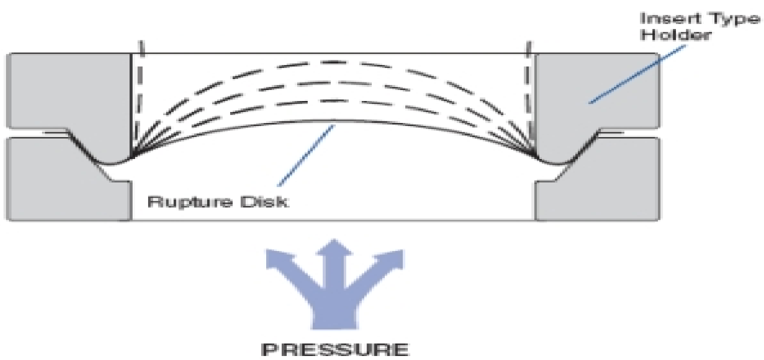
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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.

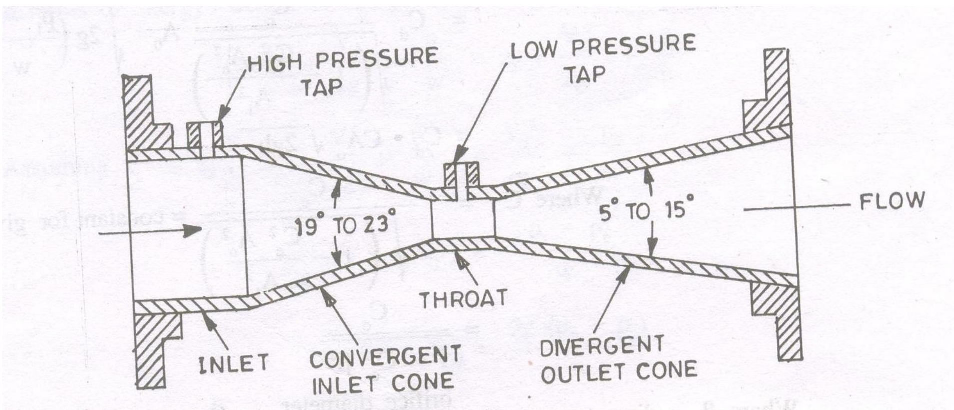
Q No.	Answer	marks	Total marks
1A-a	**Density:** It is the mass per unit volume of a substance **Weight density:** It is the weight of unit volume of fluid.	 1 1	2
1A-b	**Classification of fluids based on** **Density:** Compressible fluids and incompressible fluids **Viscosity:** Ideal and actual (real) fluid.	 1 1	2
1A-c	**Critical velocity**. It is the velocity at which the flow changes from laminar to transition.	2	2
1A-d	NRe=10000 $f = 0.078/(N_{Re})^{0.25} = 0.0078$	2	2
1A-e	**Different types of pipe fittings:(any four)** Union, coupler, plug, reducer, expander, bend, elbow, tee, cross	½ mark each	2
1A-f	**Merits of positive displacement pump:** 1. It does not need priming. 2. Can be used for low capacity and high heads. 3. Efficiency is high. 4. Designed for higher heads. 5. Can develop high pressure.	1mark each for any 4 points	2
1A-g	**Application of steam jet ejector**: 1, used for handling corrosive gases that would damage mechanical vacuum pump.	2	2

	2. It is used for handling large volume of vapour at low pressure.		
1B-a	**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 = $v_2 \rho_2 A_2$ 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**	1 2 1	4
1B-b	**DiaphragmValve:**  	2	4

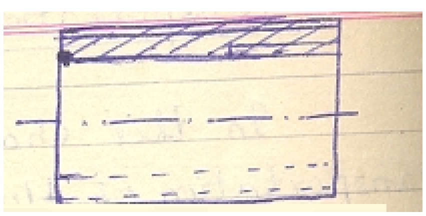
	Butterfly valve:  	2	
1B-c	**Characteristics curve of centrifugal pump:**  The characteristics curve shows the relationship between discharge and the various parameters like head, power and efficiency. From the H-Q curve, it is clear that head increases continuously as the capacity is decreased. The η-Q	2 2	4

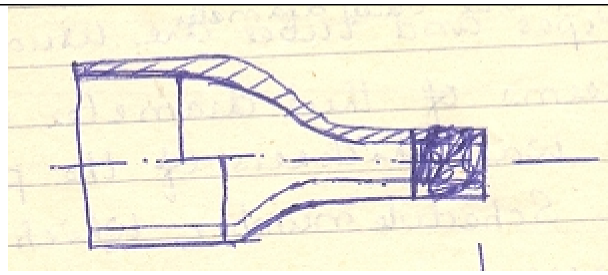
	curve shows that η reaches a maximum and then falls. The duty point ie the point where the H-Q curve cuts the ordinate through the point of maximum efficiency shows the optimum operating conditions. The difference between power input and power output represents the power lost in the pump due to friction , leakages etc.		
2-a	**U tube manometer:** **Diagram:**  **Expression to calculate pressure difference:** $\Delta P = h\,(\rho_m . \rho)g$ Where h=difference in level of manometric fluid in the two limbs of manometer. ρ = density of flowing fluid ρ_m = density of manometric fluid.	2 2	4
2-b	**Form friction:**		4

	Friction caused by eddies when an obstruction is present in the line of flow. **Skin friction:** Friction between a moving fluid and wall of pipe. It is due to the roughness of the pipe. When fluid is flowing through a straight pipe, only skin friction exists.	2 2	
2-c	**Diagram of Rupture disc:**  	4	4
2-d	**Priming:** Removal of air from the suction line and pump casing and filling it with the liquid to be pumped is called priming **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.	2 2	4
2-e	**Relation between friction factor and Reynold's number** **For laminar flow :** $f = \frac{16}{NRe}$ **for turbulent flow:**	2	4

	$f = 0.078/(N_{Re})^{0.25}$ or $1/\sqrt{f} = 4\log(N_{Re}\sqrt{f}) - 0.4$	2	
2-f	**Venturimeter**  **PRINCIPLE:** It works on the Bernoulli's principle. It is a variable head meter. Venturi reduces the flow area thus creating differential pressure across it. Any changes in fluid flow rate through venturi are measured in terms of differential pressure across it.	2 2	4
3-a	$P = h \rho g$ $P = h_1 \rho_1 g = h_2 \rho_2 g$ $60 \times 13.6 = h_2 \times 1$ $\therefore h_2 = \frac{60 \times 13.6}{1}$ **= 816.0 cm of H_2O Column**	1 1 1 1	4
3-b	**Types of valves used in industry :** i) Globe Valve ii) Gate Valve iii) Needle Valve iv) Ball Valve v) Diaphragm Valve vi) Check Valve	1 mark each for any 4	4

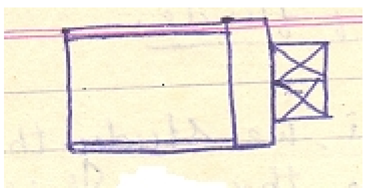
<table>
<tr><td></td><td>vii)) Butterfly Valve
viii) Pressure Release Valve</td><td></td><td></td></tr>
<tr><td>3-c</td><td>Classification of Pumps with Examples :
i) Positive Displacement Pump
a) Reciprocating eg : Piston pump, Plunger pump
b) Rotary eg : Gear pump, lobe pump, screw pump
ii) Non - Positive Displacement Pump
a) Centrifugal eg : Volute diffuser
b) Regeneration
c) Turbine
iii) Special Pump</td><td>1
1
1
1</td><td>4</td></tr>
<tr><td>3-d</td><td><table>
<tr><td></td><td>Compressor</td><td>Blower</td><td>Fan</td></tr>
<tr><td>Speed</td><td colspan="3">All 3 can run at low/ medium/ high speed depending upon discharge.</td></tr>
<tr><td>Pressure</td><td>High</td><td>Medium</td><td>low</td></tr>
<tr><td>Flow rate</td><td>low</td><td>Medium</td><td>High</td></tr>
<tr><td>Efficiency</td><td>Low since heat of compression is more</td><td>medium</td><td>High since heat of compression is low</td></tr>
</table></td><td>4</td><td>4</td></tr>
<tr><td>3-e</td><td>Newton’s law of viscosity:
Newton law of viscosity states that shear stress is proportional to shear rate and the proportionality constant is the viscosity of the fluid.
Mathematical expression:
$\frac{F}{A} = \mu\frac{dv}{dx}$
Where,
$\frac{F}{A}$ = Shear stress</td><td>2
2</td><td>4</td></tr>
</table>

	μ = Coefficient of viscosity $\frac{dv}{dx}$ = Shear rate.		
3-f	**NPSH for a system with suction lift –** is the necessary suction for lifting of liquid from a reservoir which is below the central line of pump. 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. Formula used for NPSH is, $$NPSH = -Z_s + \frac{Ps.Pvap}{\rho} - h_{fs}$$ Where, Z_s = height of pump from the level of liquid in the tank (for lift suction Z_s = -ve) P_s = Pressure at the eye of impeller P_{vap} = Vapour pressure of liquid h_{fs} =Head lost due to friction on suction side.	02 02	4
4-a	**Sketches of Pipe fittings with their uses :** i)Joining two pipes.,e.g., Coupling /socket, union, nipple  Nipple ii) Changing pipeline diameter .,e.g.,reducer, expander	1 mark each for any 4 pipe fitting with its use	4

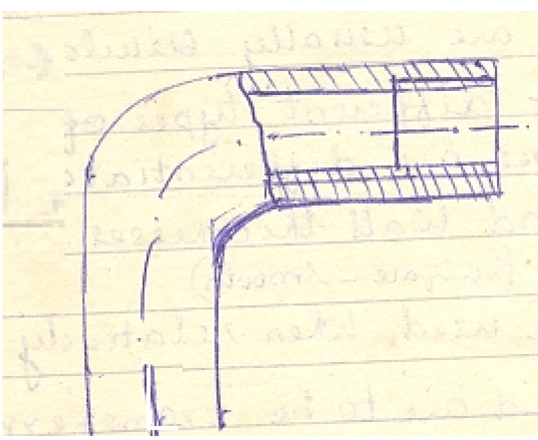


Reducer

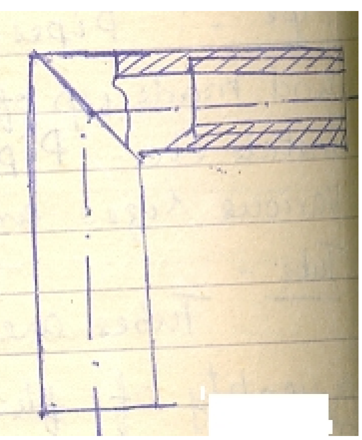
iii) Termination of pipe line., e.g.,plug



iv) Changing direction of flow .e.g.,elbow, bend

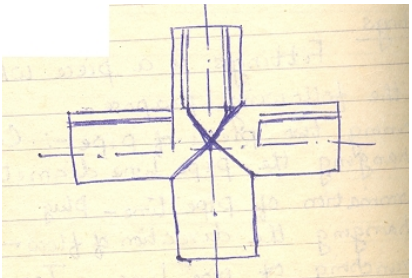
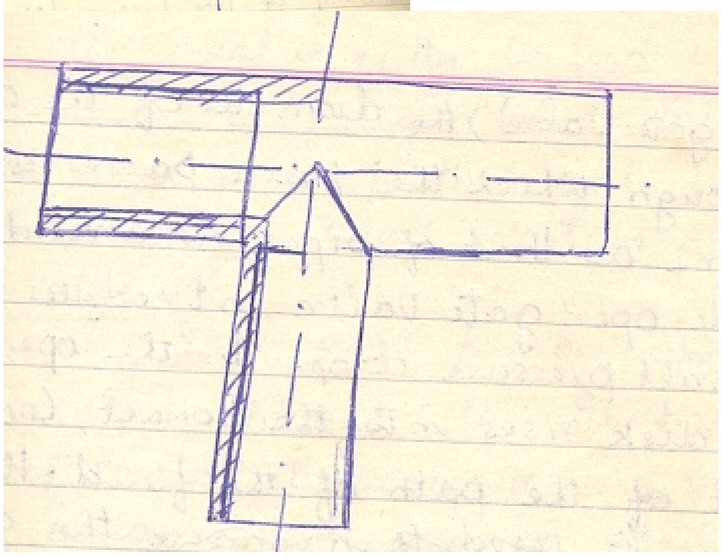


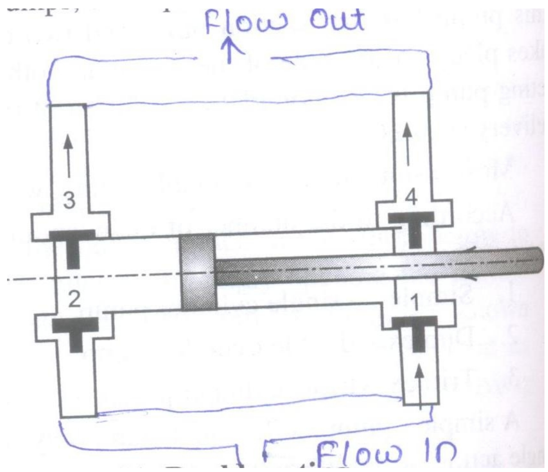
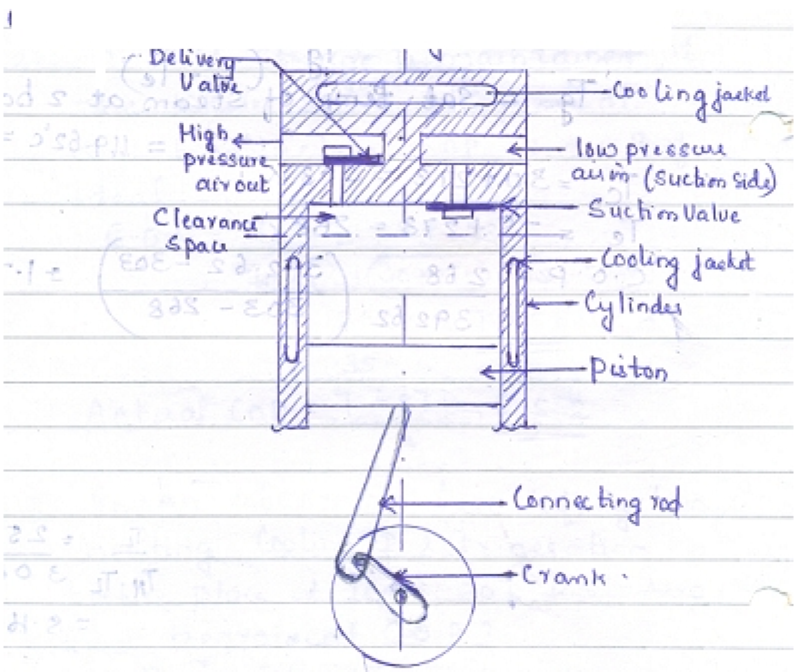
Bend



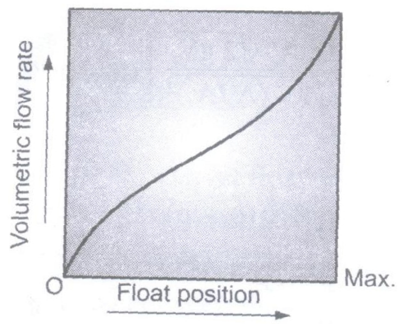
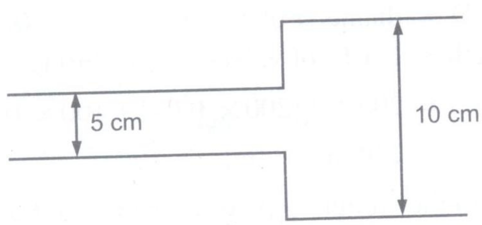
Elbow

v) Branching of the line: tee cross

	 		
4-b	**Reynold's Number** is a dimension less number which indicates the nature of flow. It is the ratio of inertial force to viscous force. $N_{Re} = \frac{D\,u\,\rho}{\mu}$ Where, D = diameter in cm u = Velocity in cm/s ρ = density gm/cm^3 μ = Viscosity $\frac{gm}{cm\ x\ sec}$ **Useful information:** If , $N_{Re} < 2100$, flow laminar	01 01 02	4

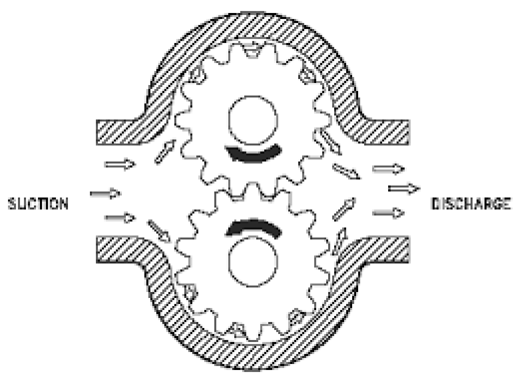
	$N_{Re} > 4000$, flow turbulent $2100 < N_{Re} < 4000$, flow transition.		
4-c	**Reciprocating compressor:**  **Or**  	2	4

	Construction: Reciprocating compressors are available either as a single-stage or multistage units for pressures as high as 240 Mpa.A reciprocating compressor incorporates a piston,a cylinder with intake & exhaust valves and a crank shaft with a drive. These units operate mechanically in the same manner as the reciprocating pumps and are usually double acting. The cylinder of the compressor is usually water jacketed to remove heat of compression. The reciprocating compressors are usually belt driven from an electric motor. When it is not possible to achieve the required compression ratio with single stage units, multistage units are used. In case of multistage compressors, it is general practice to cool the gas between the stages. For cooling purpose, coolers are employed.	2	
4-d	**Calibration of rotameter:** The calibration chart for a given rotameter prepared over its entire range is a relationship between the rotameter reading (i.e.,height of float,float position) and the volumetric flow rate. For calibrating a given rotameter, the flow of fluid (liguid e.g.,Water) through the meter is started by slightly opening a valve at the inlet to the meter. Time is allowed to attain steady state & for this valve opening, the float position is noted & the liquid is collected in a measuring tank over a known period of time. The volumetric flow rate is obtained from the volume collected & the time noted. This procedure is repeated for several valve positions to cover the entire range of the meter & the calibration chart is prepared. On the calibration chart,we should provide information such as : name,density & temperature of the fluid handled. Volumetric flow rate = $\frac{\text{volume of liquid collected}}{\text{time}}$ **Calibration chart for rotameter**	2	4

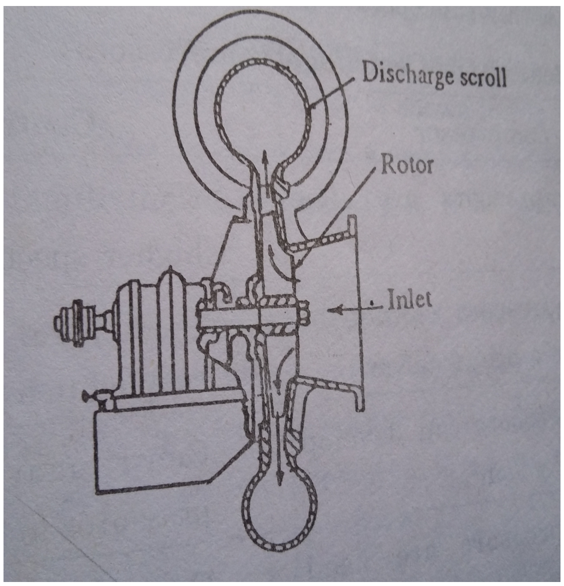
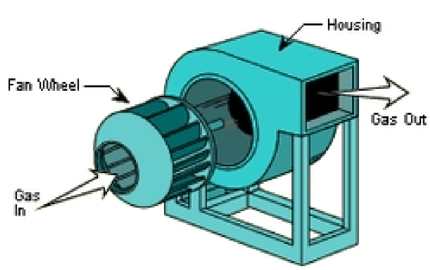
	 	2	
4-e	**Solution:**  Friction loss due to sudden expansion (h_{fe}) is given by the equation $(h_{fe}) = \frac{{u_1}^2}{2} \quad [1 - \frac{A1}{A2}]^2$ Where, u_1= Velocity of flowing fluid through the smaller pipe A_1 = Cross-sectional area of the smaller pipe A_2 = Cross-sectional area of the larger pipe $A_1 = \frac{\Pi}{4} {D_1}^2$, where D_1 = 5 cm = 0.05 m $A_1 = \frac{\Pi}{4} (0.05)^2 = 1.963 \times 10^{-3}\ m^2$ $A_2 = \frac{\Pi}{4} {D_2}^2$, where D_2 = 10 cm = 0.1 m $A_2 = \frac{\Pi}{4} (0.10)^2 = 7.854 \times 10^{-3}\ m^2$	1 1	4

	$u_1 = 2$ m/s Substituting values of the terms involved in the above equation of h_{fe},we get $h_{fe} = \frac{(2)2}{2}\ [1 - \frac{(1.963\ x\ 10-3)}{(7.854\ x\ 10-3)}]^2$ **1.125 J/kg**	1 1	
4-f	$P_1 = 101.325$ KN / m^2 $P_2 = 101.325 + 32.424 = 133.749$ KN / m^2 $\Delta P = P_2 - P_1 = \rho g h$ $32.424 * 10^3 = 1250 * 9.81 * h$ h =**2.644 m**	1 2 1	4
5-a	Data: Volumetric flow rate: Q= 5 m^3/hr Diameter of pipe: D = 78 mm = 0.078 m Viscosity of water = $\mu = 8 X 10^{-4}$Pa.s = $8 X 10^{-4}$kg/m.s Length of pipe = 50 m Area of pipe = A = $\pi /4\ D^2 = \pi /4\ (0.078)^2$ $A = 4.776 X 10^{-3}\ m^2$ As Q = 5 m^3/hr = 5 /3600 = $1.39 X 10^{-3}\ m^3/s$ $u = Q/A = \frac{1.39 X 10-3}{4.776 X 10-3}$ u = 0.3 m/s $NRe = \frac{Du\rho}{\mu} = \frac{0.078*0.3*1000}{8 X 10-4} = 29250$ As NRe> 4000, flow is turbulent For turbulent flow ,$f = \frac{0.078}{NRe^{0.25}} = \frac{0.078}{29250^{0.25}} = 0.00596$ Pressure drop can be calculated from Fanning equation: $\Delta P = \frac{4f\rho Lu^2}{2D} = \frac{4*0.0059*1000*50*0.3^2}{2*0.078} =$ **687.6 N/m²**	1 1 1 1 1 2	8

	Frictional loss $hfs = \frac{\Delta P}{\rho}$ = 687.6/1000= $\mathbf{0.6807\ J/kg}$	1	
5-b	Data: D1 = 30 cm = 0.3 m Area of pipe 1 = $A_1 = \pi/4\ D_1^2 = \pi/4*(0.3)^2 = 0.07065\ m^2$ D2 = 20 cm = 0.2 m Area of pipe 2 = $A_2 = \pi/4\ D_2^2 = \pi/4*(0.2)^2 = 0.0314\ m^2$ D3 =15 cm = 0.15 mArea of pipe 3 = $A_3 = \pi/4\ D_3^2 = \pi/4*(0.15)^2 = 0.01766\ m^2$ Volumetric flow rate of water in a pipe1(dia.30 cm) = $Q_1 = u_1A_1$ $Q_1 = 2.5 * 0.07065$ $\mathbf{Q_1 = 0.1765\ m^3/s}$ From continuity equation mass flow rate in pipe 1 = mass flow rate in pipe2 + mass flow rate in pipe 3 $\dot{m}_1 = \dot{m}_2 + \dot{m}_3$ $\rho_1V_1A_1 = \rho_2V_2A_2 + \rho_3V_3A_3$ $1000*2.5*0.07065 = 1000*2*0.0314 + 1000*V_3*0.01766$ $\mathbf{V_3 = 6.46\ m/s}$	1 1 1 1 1 1 1 1	8
5-c	Diameter of pipe: D= 78 mm = 0.078 m Orifice diameter: Do = 15 mm =0.015 m Δh = 18 cm = 0.18 m Discharge = Q =719 cm^3/s $Q = 7.19 \times 10^{-4}\ m^3/s$ Density of mercury : $\rho_{Hg} = 13,600\ kg/m^3$ Density of water : $\rho_{H2O} = 1000\ kg/m^3$ $\Delta H = \Delta h\left[\frac{\rho_{Hg}-\rho_{H2O}}{\rho_{H2O}}\right] = 0.18\left[\frac{13600-1000}{1000}\right]$ = 2.268 m of water β= Diameter of orifice /Diameter of pipe = 0.015 /0.078 = 0.192 Area of orifice = $A_o = \frac{\pi}{4}D_o^2 = \frac{\pi}{4}(0.015)^2 = 0.000176\ m^2$ The flow equation of orifice meter	1 1 1 1 1	8

	$Q = \frac{C_o A_o \sqrt{2g\Delta H}}{\sqrt{1-\beta^4}}$	1	
	$7.19 * 10^{-4} = \frac{C_o * 0.000176\sqrt{2 * 9.81 * 2.268}}{\sqrt{1-(0.192)^4}}$	1	
	$7.19 * 10^{-4} = \frac{C_o * 0.000176 * 6.67}{0.9999}$		
	$\boldsymbol{C_o = 0.6099}$	1	
6-a	**Gear Pump**: Most commonly used positive displacement pump. **Diagram:**  **Gear pump**	4	8
	Construction: It consists of two toothed gear wheels , enclosed in a casing provided with inlet & outlet connections for liquid to be pumped. Of the two gear wheels ,one is driven by an electric drive & other rotates in mesh with the first. The gap/clearance between the gear wheels as well as between the surface of the gear wheels &the casing is very small. The number of teeth on each gear may be three,four or more. The discharge rate of liquid is independent of the pressure. It has no valves & it does not require priming.	2	

	Working: The liquid to be pumped enters in pump through the inlet connection. As one of the gear wheel is driven by the electric motor, the other gear wheel also rotates inside the casing. Due to rotation of both the gear wheels, there is reduction in pressure at the inlet. Therefore the liquid entered in casing is carried round in the space between the gear teeth & the casing during the rotation of the gear wheels & after further rotation the liquid is pumped out of the discharge side as the teeth come into mesh. 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.	2	
6-b	Data: Velocity of water = 24 m/s (constant , $u_1 = u_2$) $P_1 = 361$ kN /m^2 = 361 *1000 N /m^2 $P_2 = 288$ kN /m^2 = 288 *1000 N /m^2 Z_1= 30 m Z_2= 33.5 m Total energy at point A = $\frac{P_1}{\rho g} + \frac{u_1^2}{2g} + Z_1 = \frac{361 * 1000}{1000 * 9.81} + \frac{(24)^2}{2 * 9.81} + 30$ = 36.79 +29.35 +30 =96.14 m of water Total energy at point B = $\frac{P_2}{\rho g} + \frac{u_2^2}{2g} + Z_2 = \frac{288 * 1000}{1000 * 9.81} + \frac{(24)^2}{2 * 9.81} + 33.5$ = 29.35 +29.35 +33.5 = 92.2 m of water Loss of head = Total energy at point A - Total energy at point B = 96.14 – 92.2	1 1 1 1 1 1	8

	= **3.94 m** of water.	2	
6-c	**Centrifugal Blower**: **Diagram:**  Or  **Construction :** It consists of a vaned impeller keyed to a shaft connected to external source of electricity (electric drive).The casing is narrower & diameter of casing,	4	8

	discharge scroll are relatively larger than in the centrifugal pump. These units need high speed of operation & large impeller diameter as very high heads in terms of low density fluids are required to generate moderate pressure ratios. When the shaft rotates ,the impeller blades are driven inside the casing .The impeller is surrounded by diffuser .The function of the diffuser is to convert the kinetic energy of gas leaving the impeller into pressure energy. The section of each impeller &it's diffuser forms a stage construction. These units can be used to develop pressures of 275kPa to 700 kPa.	2	
	Working : As the impeller rotates due to rotation of shaft, pressure is reduced & therefore gas/air flows inside the casing. The gas is thrown out by centrifugal action along the blades. Therefore kinetic energy is imparted to gas due to high speed of rotation of impeller blades. This K.E.is then converted to an increase in static pressure by slowing the flow through the diffuser.	2	