WINTER-16 EXAMINATION

Model Answer

Important Instructions to examiners:

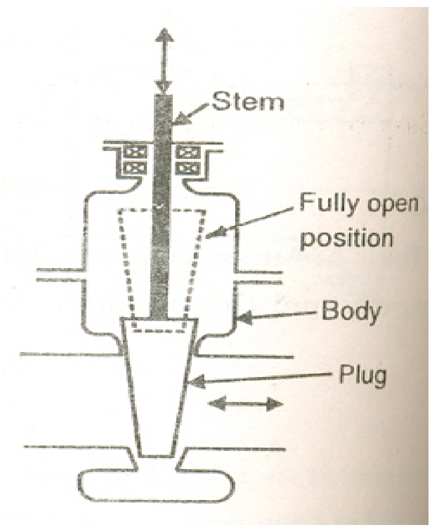
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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
1a	**Attempt any SIX of the following**	12
1a-i	**Expression for kinematic viscosity(ν) :** ν = μ / ρ where μ is the viscosity of the fluid and ρ is the density of the fluid	2
1a-ii	Water is incompressible fluid.	2
1a-iii	Flow is laminar since NRe is less than 2100	2
1a-iv	**Expression to calculate friction factor for laminar flow** For laminar flow :f = $\frac{16}{NRe}$	2
1a-v	**Schedule number:** **Definition:**They are American Standard Association designation for classifying the strength of the pipe. It indicates the wall thickness of the pipe.	 1 1
1a-vi	**Specific application of centrifugal pump:** It is used for handling abrasive, corrosive and dirty fluids. Used in refineries, power plants, fire protection sprinkler system, boiler feed application, sugar refining, pharmaceuticals, paints etc	1 mark each for any two
1a-vii	**Equipment used for producing vacuum without a moving part.** Jet ejector.	2
1b	**Attempt any TWO of the following**	8
1b-i	**Differentiate average velocity and point velocity**	2 marks each

	average velocity	**point velocity**
Formula	v = Q / A Where Q is volumetric flow rate and A is area of pipe. v = $\dot{m}$/ ρAWhere $\dot{m}$is	$V_{P=}c_p\sqrt{2gH}$

	mass flow rate and ρ is density of fluid.	
Variation in the value	constant	Velocity changes with position (location)

1b-ii **Diagram of Gate valve:** 4



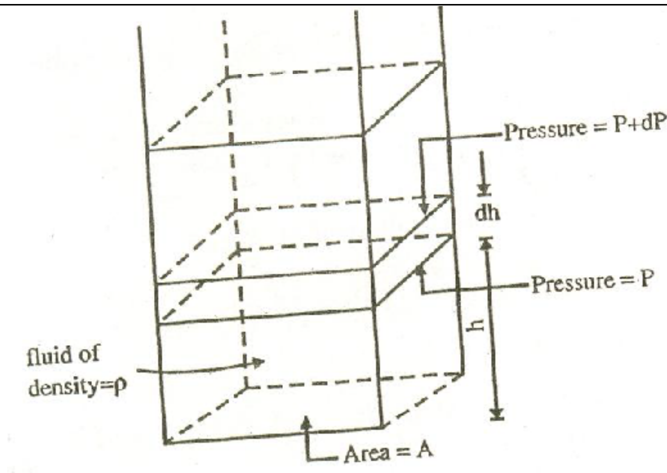
1b-iii **Differentiate between variable head meter and variable area meter:** 4

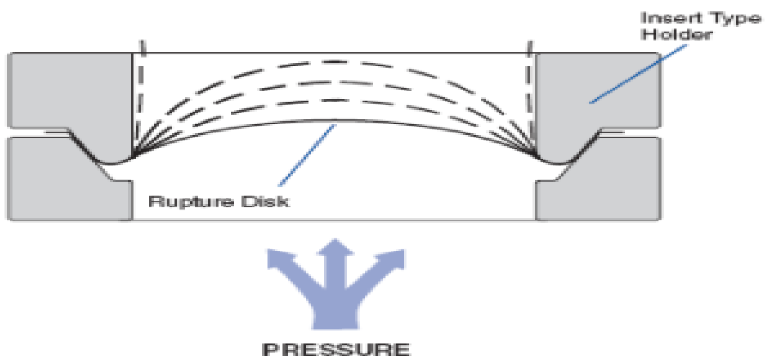
	Variable head meter	Variable area meter
Variation in pressure	Pressure drop varies with flow rate	Pressure drop is constant with flow rate
Ease of handling	difficult	easy
Cost	cheap	costly

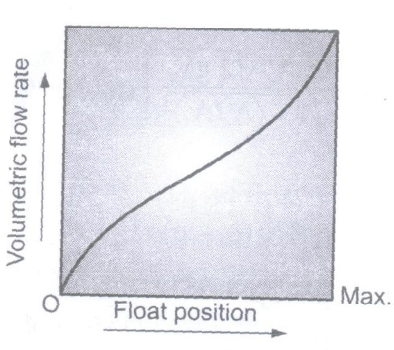
2 **Attempt any FOUR of the following** 16

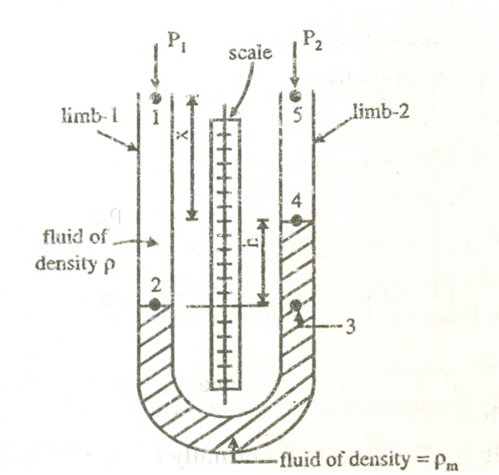
2-a **Expression to calculate pressure**

1

		
	Consider a vertical column of liquid of height h1cm. Let us considera 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 thecolumn in m^2. ρis the density of the liquid in g/cm^3.	1
	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.	1
	At equilibrium, sum of all these forces is zero. PA-(P+dP)A- Adhρg = 0 dP + dhρg = 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) P_2	1

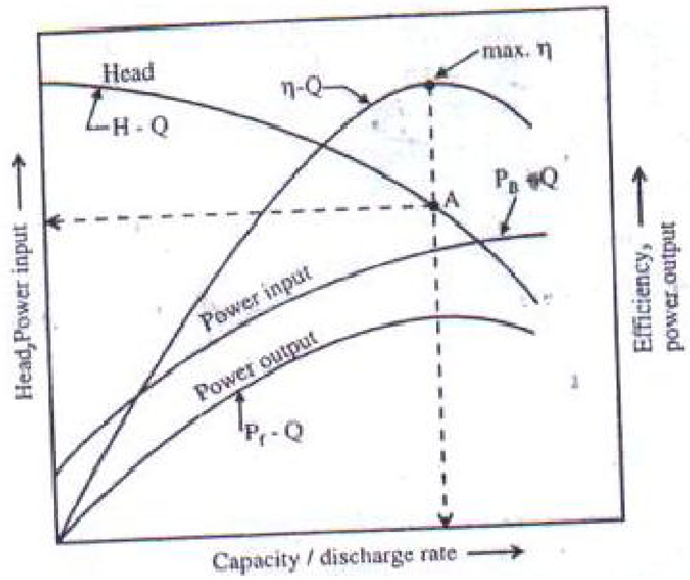
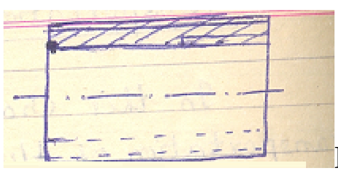
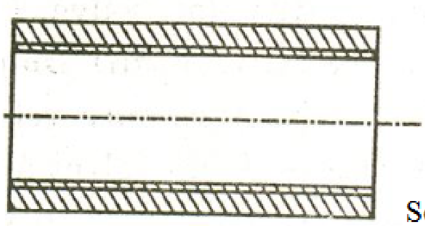
	$\int dP + g\rho\int dh = 0$ P_1 P_1 is the pressure at the base of the column where h = 0 $P_2 – P_1 + \rho gh = 0$ $P_1 – P_2 = \rho g h$	
2-b	**Necessity to calculate friction in a pipe.** As fluid flows through the pipe, it has to overcome some resistance due to friction in the pipe, change in cross sectional area and some obstruction in the flow path. For overcoming this resistance, the fluid has to spend some energy. So there will be loss of energy or head for the fluid in the direction of flow. Hence calculation of friction is a necessity. Yes, it changes with the nature of fluid (friction factor changes as density and viscosity of fluid changes).	3 1
2-c	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	1 3

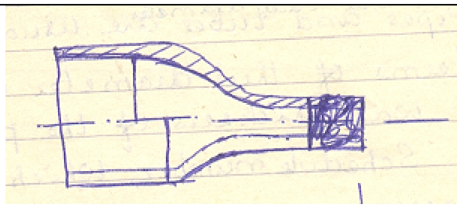
	safety relief valves, isolating the valves from the process, thereby saving on valve maintenance and creating a leak-tight pressure relief solution. The membrane is generally made up of metal.	
2-d	**NPSH** Net Positive Suction Head is the amount by which the pressure at the suction point of the pump (sum of velocity head and suction head) is in excess of the vapour pressure of the liquid **Expression for NPSH** NPSH = $(Ps - Pvap)/\rho g - hfs - Zs$ Where Zs = height of pump from suction points. Ps = Suction pressure Pvap = Vapour pressure of liquid transported. hfs = head loss due to friction.	2 2
2-e	Since NRe is greater than 4000, flow is turbulent For turbulent flow: $f = 0.078/(N_{Re})^{0.25}$ F= **$9.276 * 10^{-3}$**	2 2
2-f	**Calibration:** Calibration of a flow meter is comparing the flow rate measured by the flow meter with a standard value. **Calibration curve for rotameter:**  	2 2

3	**Attempt any FOUR of the following**	16
3-a	**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 – $x\rho g$ $P_2 = P_1 + (x+h)\rho g - h\,\rho_m g - x\rho g$ $= P_1 + hg(\rho - \rho_m)$ $(P_1 - P_2) = \Delta P = h(\rho_m . \rho)g$ $\Delta P = h(\rho_m . \rho)g$	1 2 1
3-b	**Reason for globe valve producing more pressure drop than gate valve:** In gate valve, the diameter of opening through which the fluid flows is nearly same as that of pipe. In the open position, the disk rises into the bonnet, completely out of the path of the fluid. As a result a wide open gate valve introduces only a small pressure drop. In globe valve even in fully open position, the fluid has to take several turns which results in higher pressure	4

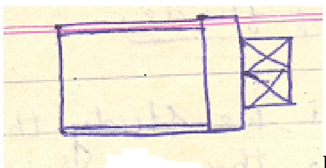
<table>
<tr><td></td><td>drop.</td><td></td></tr>
<tr><td>3-c</td><td>Differentiate reciprocating pump and centrifugal pump
<table>
<tr><th></th><th>centrifugal pump</th><th>Reciprocating pump</th></tr>
<tr><td>i) Category to which they belong</td><td>Non positive displacement</td><td>Positive displacement</td></tr>
<tr><td>ii) Cost</td><td>cheap</td><td>costly</td></tr>
<tr><td>iii)pressure developed</td><td>Very high pressure</td><td>moderate</td></tr>
<tr><td>iv) efficiency</td><td>Less</td><td>More</td></tr>
</table></td><td>1 mark each</td></tr>
<tr><td>3-d</td><td>Pressure range developed by fan, blower and compressor
Fans - <30KPa
Blowers – discharge pressure upto90KPa, centrifugal with multistage construction 275 to 700 Kpa
Compressor – Centrifugal compressor: 2 MPa,
Reciprocating compressor: 240MPa</td><td>4</td></tr>
<tr><td>3-e</td><td>Newtonian fluid:
Newtonian fluid is that fluid which obeys Newton’s law of viscosity. Newton’s law of viscosity states that shear stress is proportional to shear rate and the proportionality constant is the viscosity of the fluid.
Relation between shear stress and shear strain:
$\tau = \mu \frac{dv}{dx}$ where τ is the shear stress , $\frac{dv}{dx}$ is the shear rate and μ is the viscosity of the fluid</td><td>2

2</td></tr>
<tr><td>3-f</td><td>Diagram to relate head developed, efficiency and BHP</td><td></td></tr>
</table>

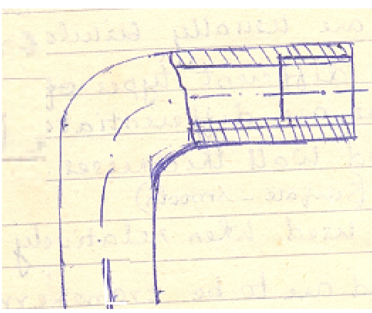
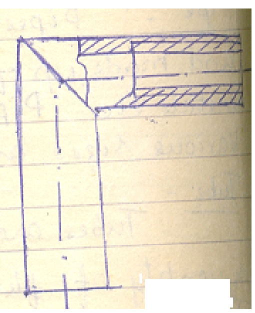
		4
4	**Attempt any FOUR of the following**	16
4-a	**Pipe fittings (any two)** Nipple Use: For joining pipes of same diameter Socket Use: For joining pipes of same diameter	1 mark for diagram and 1 mark for use


Reducer

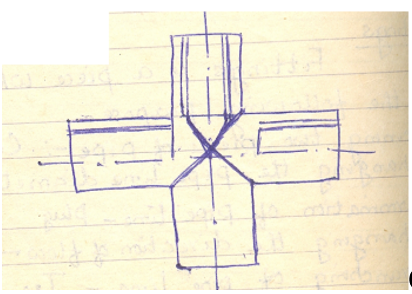
Use: Changing the size of pipe line


plug

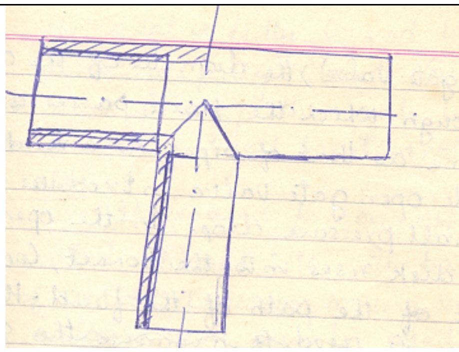
Use: termination of pipe line.

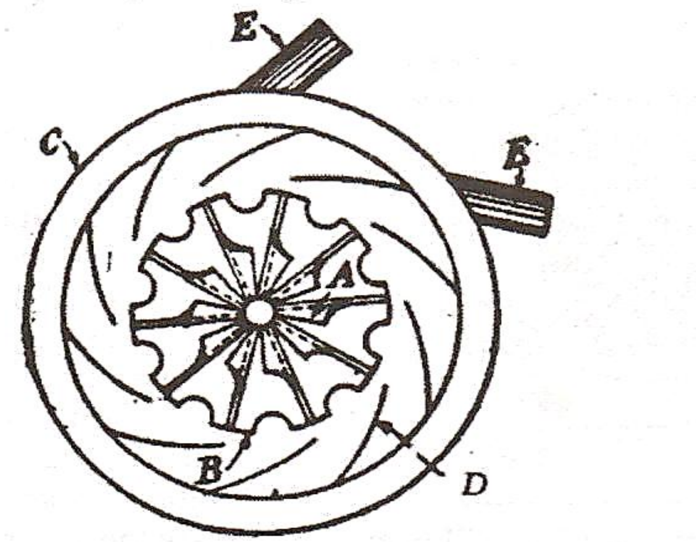
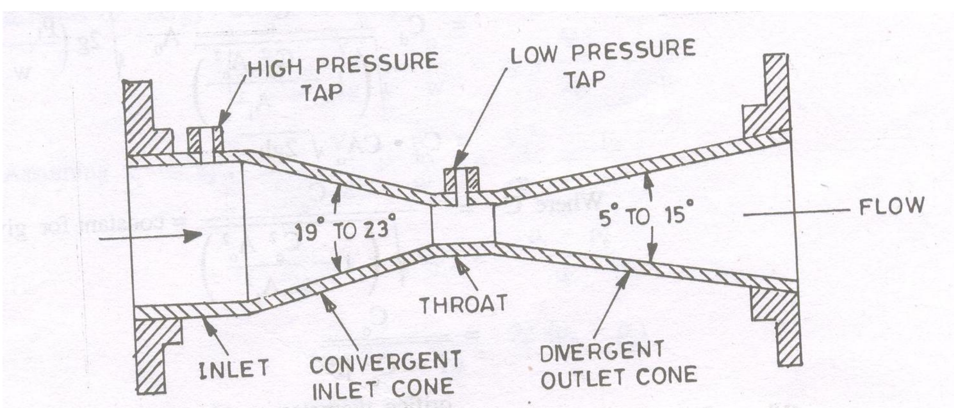


Bend Elbow

Use: changing direction of flow.


Cross

Use: Branching of pipe line

	 Tee Use: Branching of pipe line	
4-b	**Name of dimensionless number:**Reynolds number $N_{Re}= \frac{D\,u\,\rho}{\mu}$ Where D = diameter in m u = Velocity in m/s ρ = density in kg/m^3 μ = Viscosity in Kg / ms $N_{Re}= \frac{D\,u\,\rho}{\mu} = \frac{m * \frac{m}{s} * \frac{Kg}{m^3}}{\frac{Kg}{ms}}$ All the units are getting cancelled. So it is dimensionless	1 3
4-c	**Diagram of centrifugal compressor:**	4

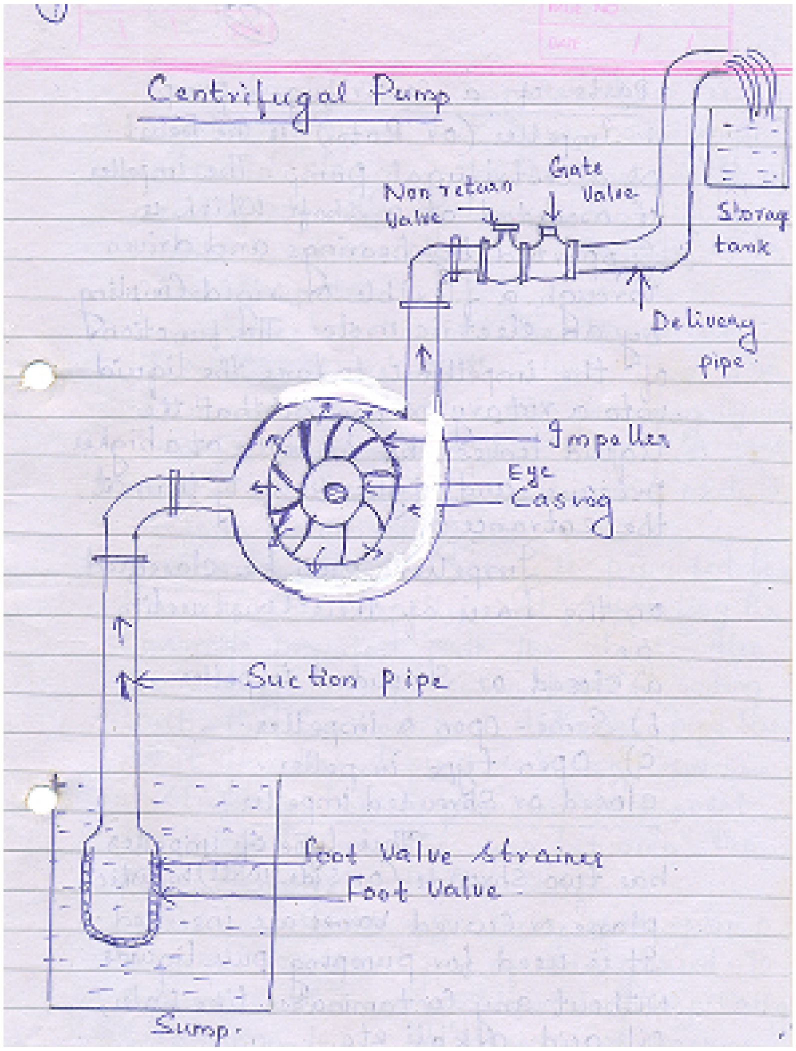
	 – Components of a Centrifugal Compressor **A : Inlet Bucket / Inlet Guide Vane** **B : Rotating Impeller** **C : Casing** **D : Diffusers** **E : Outlet Ducts**	
4-d	**Diagram of Venturimeter** 	4
4-e	Q = 100 cm^3 / s $A_a = \pi Da^2 / 4 = 3.14 * 4^2 / 4 = 12.56\ cm^2$	1

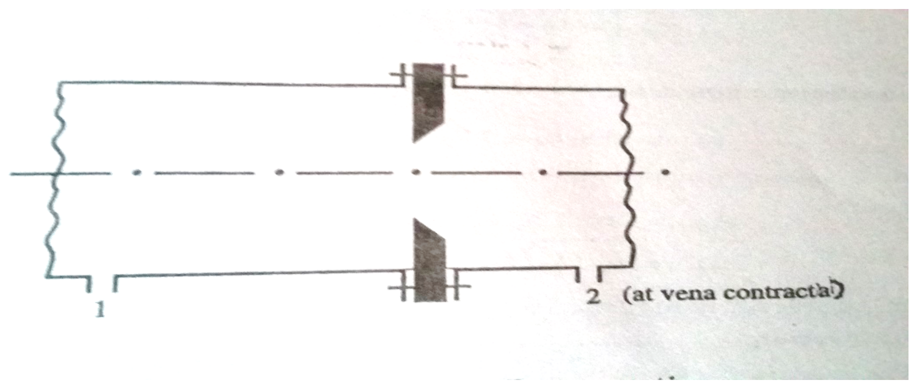
	V_a = 100 / 12.56 = 7.96 cm / s	1
	From equation of continuity, $\dot{m}$ = ρvA =constsant	
	A_b = πD_b^2 / 4 = 3.14 *2^2 / 4 = 3.14 cm^2	1
	Since ρ_A = $\rho_{B,}$	
	V_b = $V_a * A_a$ / A_b =7.96 *12.56 / 3.14 = **31.84cm / s**	1
4-f	**Δ**hm = 1.4cm of Hg ρm =ρ Hg = 13.6 g / cm^3 ρf =ρ H_2O = 1 g / cm^3 ΔHf= **Δ**hm (ρm-ρf) / ρf = 1.4 (13.6-1) / 1 = **17.64 cm of water**.	4
5	**Attempt any TWO of the following**	16
5-a	Data: Specific gravity of oil = 0.8 Density of oil= Specific gravity * Density of water Density of oil= ρ =0.8 * 1000 = 800 kg / m^3 Viscosity of oil =μ= 0.08 Poise = 0.008 kg/m.s Diameter of pipe =d=12.5 mm =0.0125 m Length of pipe =L= 20 m Velocity = u = 50 cm/s =0.5 m/s Pressure drop = ΔP = ? Let's find out Reynolds number $$N_{Re} = \frac{Du\rho}{\mu}$$ $$N_{Re} = \frac{0.0125 * 0.5 * 800}{0.008}$$ $$N_{Re} = \mathbf{625}$$	2
	N_{Re} < 2000,flow is laminar. Fanning Friction factor $f = \frac{16}{N_{Re}}$	

	The pressure drop through a pipe is given by	2 3 1
5-b	Data: Q = 20 lit/s D= 2 cm =0.02m ρ = 870 kg /m^3 = 0.87 kg/lit i)Mass flow rate ($\dot{m}$) in kg/s $\dot{m}$ = Q. ρ $\dot{m}$ = 20 * 0.87 OR Q= 20 lit/s = 20 *10^{-3} m^3/s , ρ = 870 kg /m^3 $\dot{m}$ = **17.4 kg/s** $\dot{m}$ = 20* 10^{-3}*870 = 17.4 kg/s ii))Volumetric flow rate in m^3/s Q = 20 lit/s Q = 20 * 10^{-3} = **2 X 10^{-2} m^3/s** 3) Average velocity(u)in m/s Q = u * A u=Q/A	2 2

	Area of pipe = $\pi/4 * D^2$ A = $\pi /4 * (0.02)^2$ =0.000314 m^2 u=2 X 10^{-2} / 0.000314 u=**63.69 m/s**	 2
	4) Mass velocity (G) in kg /m^2.s G = Mass flow rate / Area of pipe G = 17.4 / 0.000314 =**55414 kg /m^2.s**	 2

5-c	Data: Diameter of pipe= D = 75 mm = 0.075 m Diameter of throat = D_T =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_v= 0. 97 Δh = Difference in levels in mercury manometer	
	The flow equation of venturimeter $$Q = \frac{C_v A_T \sqrt{2 * g * \Delta H}}{\sqrt{1-\beta^4}}$$	1
	Area of throat = $A_T = \pi/4 * D_T^2$ $A_T = \pi/4 *(0.025)2$ A_T = **0.00049 m^2**	2
	$\beta = \frac{DT}{D}$ = 0.025 /0.075 = **0.333**	1
	ΔH= Difference in levels in terms of water $$\Delta H = \Delta h \frac{(\rho_{Hg} - \rho_{H2O})}{\rho_{H2O}}$$ $$\Delta H = 0.18 \frac{(13600 - 1000)}{1000}$$ $$\Delta H = \mathbf{2.268\ m\ of\ water}$$	2
	The flow equation becomes $$Q = \frac{0.97 * 0.000314\sqrt{2 * 9.81 * 2.268}}{\sqrt{1 - 0.334^4}}$$ Q = 0.00319 m^3/s Q =**0.00319 * 10^3 lit/s** Q = 3.19 lit/s	2

6	**Attempt any TWO of the following**	16
6-a	**Centrifugal pump** **Diagram:**  **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 rotates in casing, produces a forced vortex which imparts a centrifugal head to the liquid and pressure is	4

	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.	4
6-b	**Derivation for finding out Velocity of liquid flowing through an Orifice**:  Let P_1 , P_2 & u_1 ,u_2 be the pressures and velocities at stations 1 and 2 respectively. For incompressible fluids applying Bernoulli's equation between stations 1 (at upstream of meter)and at 2 (at vena contracta).Neglect frictional losses and assuming α1 = α2 = 1 Bernoulli's equation at points 1 and 2 Pressure energy at pt.1 + Potential energy at pt.1 + kinetic energy at pt.1 = Pressure energy at pt.2 + Potential energy at pt.2 + kinetic energy at pt.2 — — — —	2

As orifice meter is installed in a horizontal pipeline :

2

eq II

The mass flow rates at stations 1 and 2 are equal ,therefore

$\dot{m}$= $_1.u_1.A_1$ = $_2.u_2.A_2$

As density $\rho = \rho_1 = \rho_2$

$.u_1.A_1 = .u_2.A_2$

eqIII

Where A_1 is the area of pipe and A_2 is area at vena contracta

Putting the value of from eqIII in eq.II ,

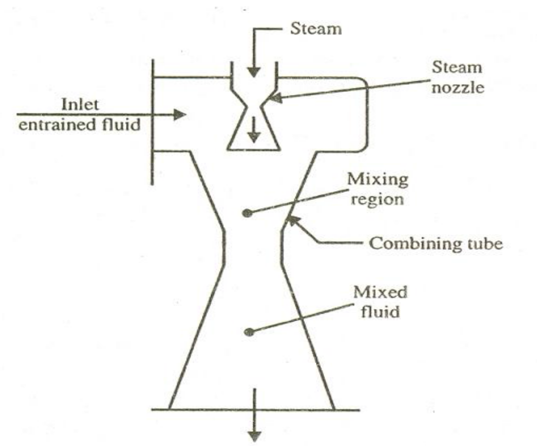
From the continuity equation ,we also have

$\dot{m}$= $.u_0.A_0$ = $.u_2.A_2$

Where u_0 is velocity through orifice

A_0 is area of orifice

		$u_2 = u_0 \frac{A_o}{A_2}$ eq.V The area of the vena contracta (A_2) can be related to area of orifice (A_0)by the coefficient of contraction (Cc) $Cc = \frac{A_2}{A_o}$ $A_2 = Cc.\ A_0$ eq.VI Putting the value of A_2 from eq.VI in eq.V $u_2 = \frac{A_o.u_o}{Cc.A_o}$ $u_2 = \frac{u_o}{C_c}$ $eq.VII$ Putting value of u_2 from eq.VII and A_2 from eq.VI into eq. IV $\frac{u_o}{C_c} = \left[\frac{2(P_1 - P_2)}{\rho\left[1-\left(\frac{Cc.A0}{A_1}\right)^2\right]}\right]^{\frac{1}{2}}$ $u_o = C_c\left[\frac{2(P_1 - P_2)}{\rho\left[1-\left(\frac{Cc.A0}{A_1}\right)^2\right]}\right]^{\frac{1}{2}}$ Eq VIII Considering frictional losses in the meter and the parameters Cc, α_1 , α_2 ,the coefficient of discharge of orificemeter .C_o can be introduced into the above equation and the can be written as $u_o = C_c\left[\frac{2(P_1 - P_2)}{\rho\left[1-\left(\frac{A_o}{A_1}\right)^2\right]}\right]^{\frac{1}{2}}$ $eq.IX$ Let $\beta = \frac{D_o}{D}$ $\left(\frac{A_o}{A_1}\right)^2 = \left(\frac{D_o}{D}\right)^4 = \beta^4$ $u_o = C_o\sqrt{\frac{2(P_1 - P_2)}{\rho(1-\beta^4)}}$ The above equation gives the velocity of liquid flowing through the orifice meter.	2 2

6-c	**Vacuum pump**: A vacuum pump is any compressor which takes the suction at a pressure below the atmospheric and discharges at atmospheric pressure. Example of vacuum pump: Steam Jet Ejector **Steam Jet Ejector** An ejector is a pumping device. It has no moving parts. Instead, it uses a fluid or gas as a motive force. Very often, the motive fluid is steam and the device is called a "steam jet ejector." Basic ejector components are the steam chest, nozzle, suction, throat, diffuser and the discharge.  Steam at about 7 atm is admitted to a converging-diverging nozzle, from which it issues at supersonic velocity into a diffuser cone. The air or other gas to be moved is mixed with the steam in the first part of the diffuser, lowering the velocity to acoustic velocity or below. In the diverging section of the diffuser, the kinetic energy of the mixed gas is converted to pressure energy so that the mixture can be discharged directly to atmosphere.	4 4