Important Instructions to examiners:

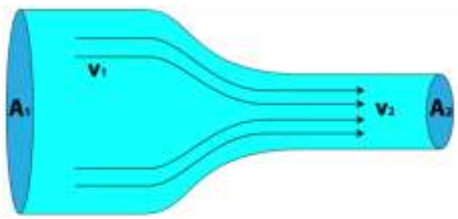
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling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

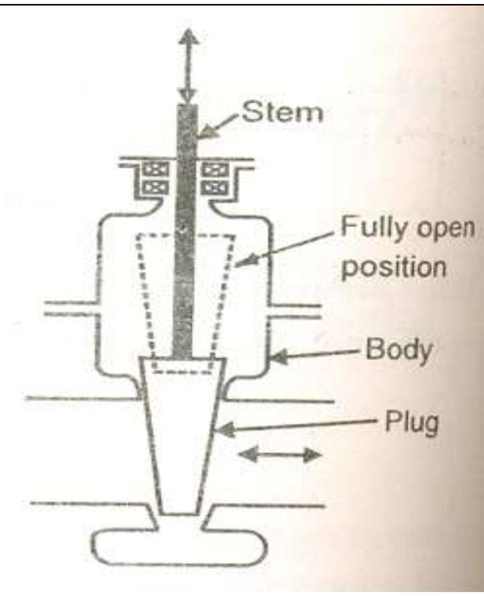
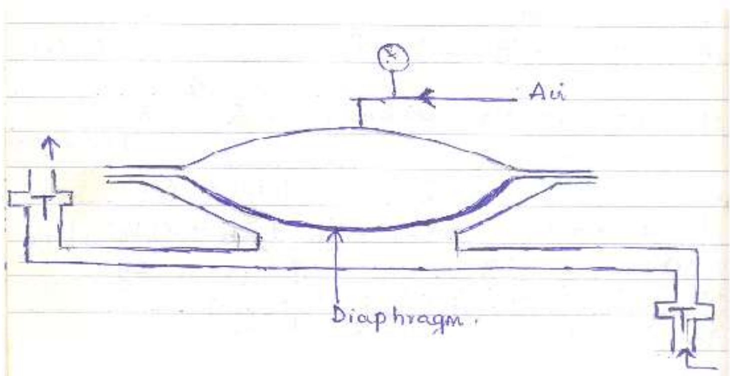
SUMMER-18 EXAMINATION

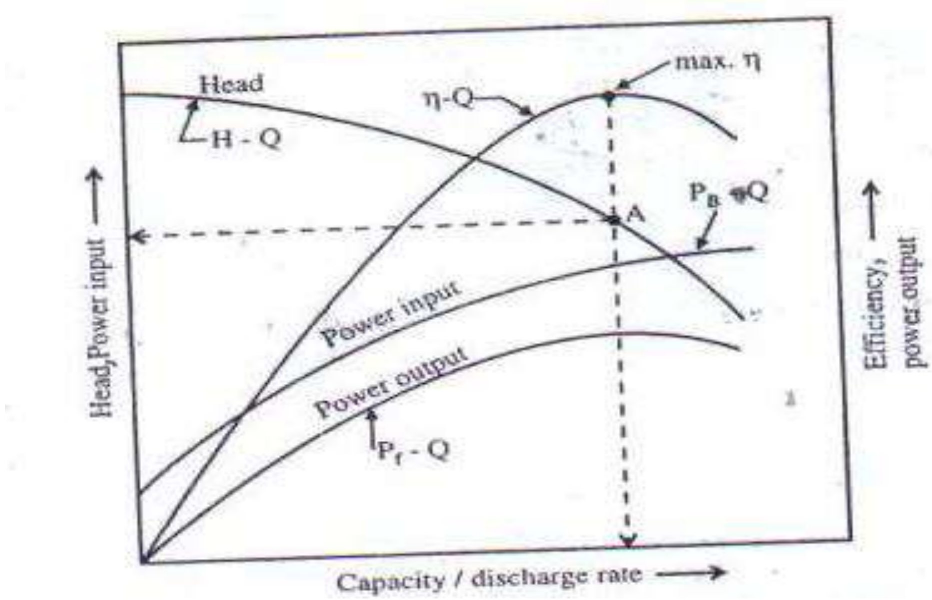
Model Answer

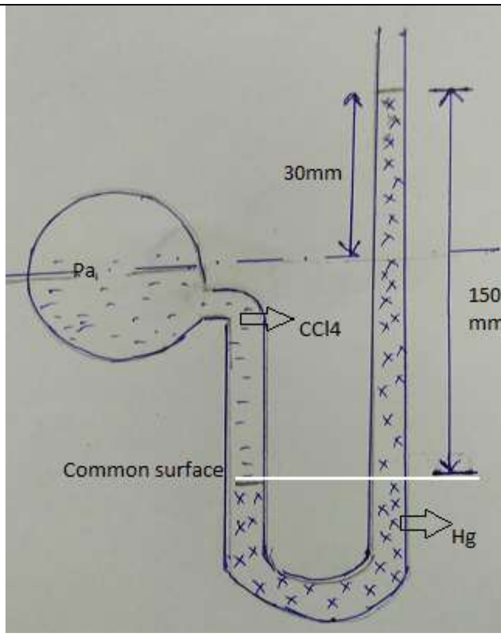
Q No.	Answer	Marks
1A	**Attempt any SIX of the following**	**12**
1A-a	**Newton's law of viscosity** Newton law of viscosity states that shear stress is proportional to shear rate and the proportionality constant is the viscosity of the fluid $\frac{F}{A} = \mu \frac{dv}{dx}$ Where F / A is the shear stress τ $\frac{dv}{dx}$ is the shear rate or velocity gradient. μ = viscosity.	2
1A-b	**Difference between ideal fluid and actual fluid (four points):** <table><tr><th>Ideal fluid</th><th>Actual fluid</th></tr><tr><td>1. Offers no resistance to flow/ deformation ie no viscosity</td><td>1. Offers resistance to flow/ deformation ie it has viscosity</td></tr><tr><td>2. Frictionless</td><td>2. Exhibits friction</td></tr><tr><td>3. Incompressible</td><td>3. Compressible or incompressible</td></tr><tr><td>4. Imaginary fluid</td><td>4. Real fluid</td></tr></table>	½ mark each
1A-c	**Significance of Reynold's Number** t is a dimension less number which indicates the nature of flow. If , $N_{Re} < 2100$ flow is laminar $N_{Re} < 4000$ flow is turbulent $2100 < N_{Re} < 4100$ – flow is transition It is the ratio of inertial force to viscous force.	2
1A-d	**Friction loss due to sudden contraction:** The frictional loss due to sudden contraction is proportional to velocity head of the fluid in the small diameter pipe.	1

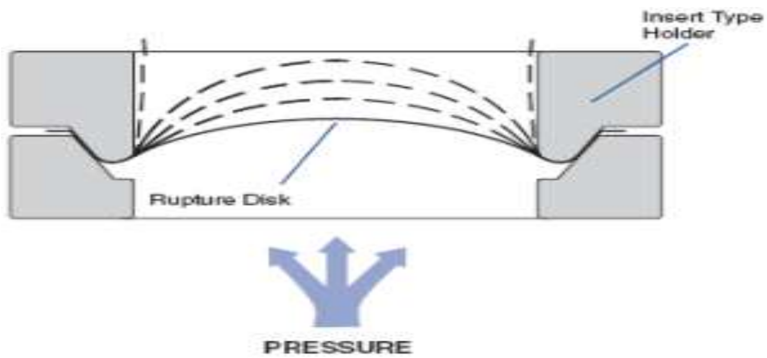
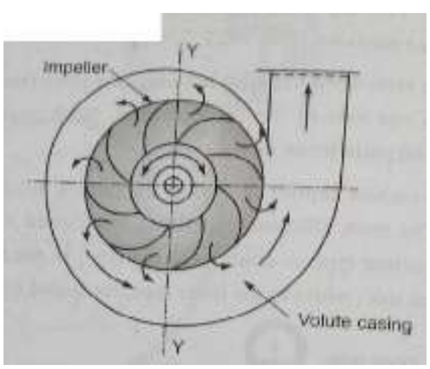
	$h_{fc} = K_c\frac{V_2^2}{2g}$ $K_c = 0.4\left(1 - \frac{A_2}{A_1}\right)$ **Friction loss due to sudden expansion** Friction loss due to sudden expansion (h_{fe}) is contraction is proportional to velocity head of the fluid in the small diameter pipe. $(h_{fe}) = \frac{u_1^2}{2}Ke$ And $K_e = [1 - \frac{A1}{A2}]^2$	1
1A-e	**Equivalent length of pipe fittings** Frictional loss in fittings and valves is expressed as equivalent length of fittings. The equivalent length of fitting is that length of straight pipe of same nominal size as that of fitting which would cause the same fractional loss as that caused by the fitting.	2
1A-f	**Reason for priming in centrifugal pump:** If the pump is initially full of air, air binding occurs and the pump is not capable to deliver the liquid. To avoid air binding, the centrifugal pump needs priming.	2
1A-g	**Application of jet ejectors (4 points):** 1. Used for handling corrosive gases that would damage mechanical vacuum pump. 2. It is used for handling large volume of vapour at low pressure. 3.Crude oil distillation 4. Petrochemical processes 5. Edible oil deodorization 6. Organic motivated systems 7. Fertilizer plant operations	½ mark each

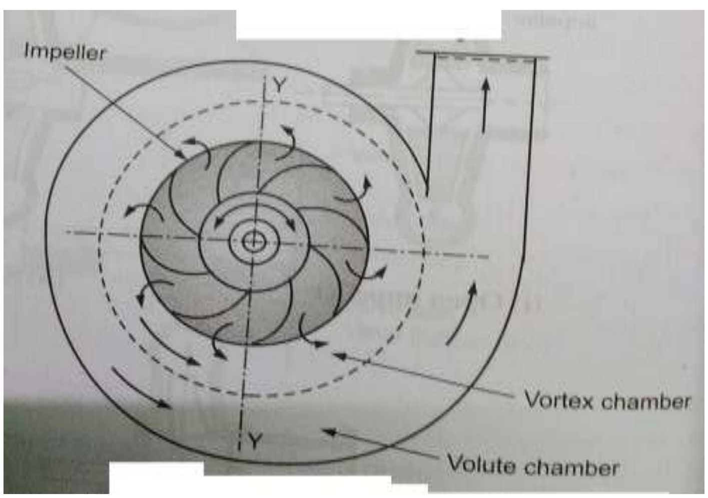
	8. Thermal compressors	
1B	**Attempt any TWO of the following**	**8**
1B-a	**Derivation of equation of continuity:** Mass balance states that for a steady state flow system, the rate of mass entering the flow system is equal to that leaving the system provided accumulation is either constant or nil.  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 $\dot{m} = \rho_1 v_1 A_1 = \rho_2 v_2 A_2$ $\dot{m} = \rho v A$ = constant …….. **Equation of continuity**	2 2
1B-b	**Sketches of (i) Gate valve**	

		2
	(ii) Diaphragm valve 	2
1B-c	**Characteristic curves of a 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 head corresponding to zero or no discharge is known as the shut off head of the pump. From H-Q curve, it is possible to determine whether the pump will handle the necessary quantity of liquid against a desired head or not and the	2

	effect of increase or decrease of head. The η-Q curve shows the relationship between pump efficiency and capacity. It is clear from η-Q curve that efficiency rises rapidly with discharge at low discharge rate, reaches a maximum in the region of the rated capacity 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 P_B- Q curve gives us an idea regarding the size of motor required to operate the pump at the required conditions and whether or not motor will be overloaded under any other operating conditions.  	2
2	**Attempt any TWO of the following**	**16**
2-a	Density of flowing fluid = 1.6*1000= 1600 kg / m^3 Density of manometric fluid = 13.6*1000= 13600 kg / m^3 Pressure along the horizontal plane (common surface) is same.	

		1
	In the left limb, pressure above the common surface is Pa +ρgh = Pa + 1600*9.81*(0.15-0.030) = Pa + 1883.52 ….(i) In the right limb, pressure above the common surface is Pgh = 13600 * 9.81 * 0.15 = 20012.4 …..(ii) Equating (i) and (ii) Pa + 1883.52 = 20012.4 Pa = **18128.88 N / m^2** **Pressure in the pipe = 18128.88 N / m^2**	2 1
2-b	**Hagen-Poiseuille's equation** $$\Delta P = \frac{32\ L\ \mu\ v}{D^2}$$ Where $\Delta P -$ Pressure drop across length L (Pa) μ – Viscosity of fluid (Pa.s) v- Velocity of fluid (m / s) D- Diameter of pipe (m) L – Length of pipe (m)	2 2

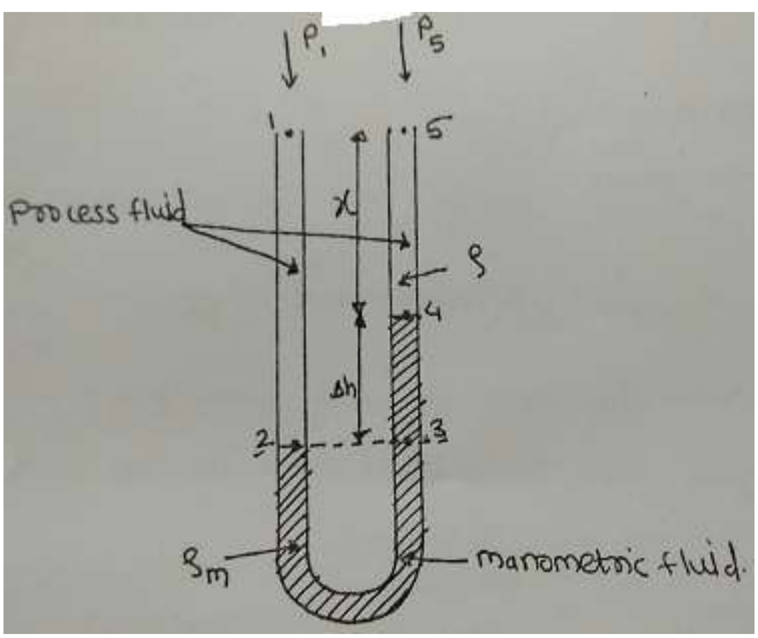
2-c	**Rupture disc:** **Diagram:** 	2
	Construction: The ultimate safety device used in pressure vessel to avoid accident is rupture disc. Rupture disc, is a non-reclosing pressure relief device. A rupture disc is a one-time-use membrane. They can be used as single protection devices or as a backup device 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 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
2-d	**(i) Volute casing**  In this cross section of the casing increases uniformly to the point of discharge	1

	pipe. This casing helps in producing equal velocity flow all around its circumference and to reduce gradually the velocity of liquid as it flows from the impeller to the discharge pipe, thus changing velocity head into pressure head. These casings can convert only a small percentage of velocity head into pressure head and large amount is lost in eddies. Therefore these pumps produce low heads. **(ii) Vortex casing** For better performance, an annular space known as vortex or whirlpool chamber is provided between the impeller and the volute. Since no work is done on the fluid while in the chamber, its energy remains constant. The velocity of whirl varies inversely as its radial distance from the center. This reduction in velocity increases the efficiency of the pump by reducing the formation of eddies  	1 1 1
2-e	**Expression to calculate friction factor** **For laminar flow** For laminar flow : $f = \frac{16}{NRe}$ **For turbulent flow:** $f = 0.078/(N_{Re})^{0.25}$	2 2

2-f	**Difference between venturimeter and orificemeter**	1 mark each for any 4 points

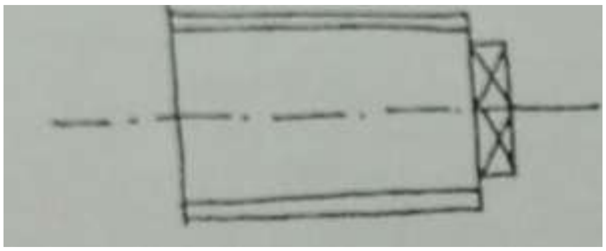
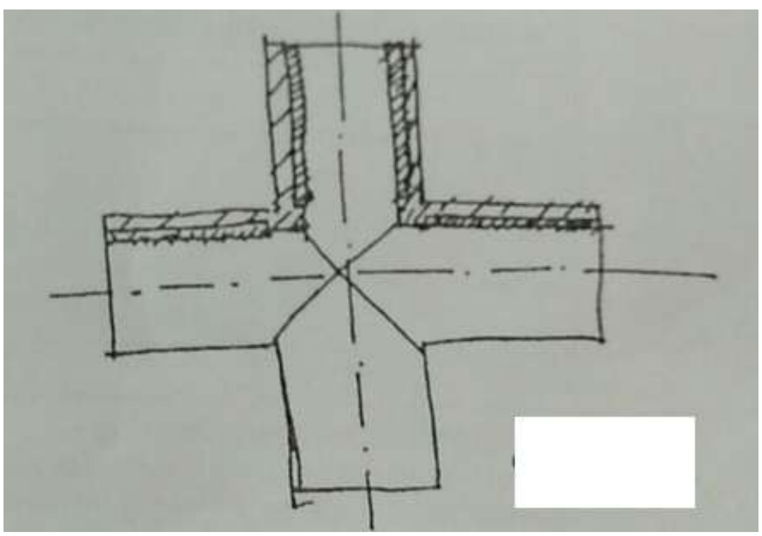
Venturimeter	**orificemeter**
1. Construction is complex	1. Simple
2. Costly	2. Cheap
3. More space	3. Less space
4. Coefficient of discharge Cv > 0.9	4. Coefficient of discharge Co is 0.6
5. Pressure loss is less	5. Pressure loss is more
6. Pressure recovery is more	6. Pressure recovery is less
7. can be used when only small pressure head is available	7. can be used when only small pressure head is available
8. Change of area is gradual.	8. Area changes suddenly

3	**Attempt any FOUR of the following**	16
3-a	**$\Delta P = h(\rho_m - \rho)g$(Derivation)**	1



Let P_1= pressure acting due to process at point 1

	P_2 = Pressure acting due to process at point 2 (if right leg is open to atmosphere, P_5 is atmospheric pressure) ρ_m- density of manometric fluid ρ - Density of flowing fluid The differential pressure acting across the manometer can be determined by using principle of hydrostatic equilibrium. As per this principle, pressure exerted by height of liquid column can be expressed as $P = \rho gh$ ……..(1) Where h is the height of liquid column (m) By applying this principle, pressure acting at point 1 can be expressed as $P= P_1$ …….(2) At point 2 in left limb $P_2 = P_1 + (x+\Delta h)\rho g$ ……(3) By using the principle that fluid exert same pressure at same level, we can write $P_2= P_3$ ……(4) $P_3=P_2= P_1 + (x+\Delta h)\rho g$ ……(5) Similarly pressure exerted at point 4 will be less than P_3 by magnitude equal to pressure exerted by mercury column of height Δh $P_4 = P_3- \Delta h\rho_m g$ …..(6) Using similar procedure, we can write P_5 as $P_5= P_4 - x\rho g$ …(7) Substituting the value of P_3 and P_4 from equation (5) and (6) , $P_5= P_3- \Delta h\rho_m g - x\rho g = P_1 + (x+\Delta h)\rho g - \Delta h\rho_m g - x\rho g$ P_1 is upstream pressure and P_5 is downstream pressure $P_1> P_5$ Simplifying the above equation, we get $P_1 - P_5 = \Delta h (\rho m- \rho)g$ $\Delta P = \Delta h (\rho m- \rho)g$	3

3-b	**Diagram of fittings with their application** **(i) Plug**  Plug is used for termination of pipeline. **(ii) Cross**  It is used to join 4 pipes of same diameter connected to form 4 pipelines at 90^0 to each other. In other word, cross connects 4 pipes of same diameter.	1 1 1 1
3-c	**Working of double acting reciprocating pump :** The working could be explained as follows. (i) Before starting pump, discharge valve is opened. It is important as failure to do so may result in unsafe condition leading to pressure rise.	One mark for each step.

	(ii) Double acting has fluid in contact on both sides of the piston. Due to two suction and two delivery valve, when left chamber of pump is in suction stroke, at the same time discharge of fluid takes place from the right chamber. (iii) During operation, one chamber gets filled and second gets emptied and vice versa. (iv) Fixed rpm of crank and single cylinder gives fixed volume of discharge. The discharge can be varied either by changing the rpm or length of the stroke or by using either duplex or triplex pump.	
3-d	**Comparison between compressor and fan on the basis of following points**	1 mark each

Criteria	Compressor	Fan
Speed	High speed machines	Low speed machines
Pressure developed	Can develop pressure up to several hundred atmospheres.	Pressure developed is low up to 0.04 atmosphere.
Flow rate	Flow rate of gas handled by compressor depends upon pressure developed and requirement; however compressor can handle very large volume of fluid.	Fan can handle large volume of fluid, however due to low pressure developed; the capacity is limited compared to compressor.
Efficiency	Around 80 to 85% for reciprocating compressors and up to 90% for centrifugal	Around 70%

	compressors.	
3-e	**Newtonion fluids:** Fluids which obey Newton's law of viscosity are known as Newtonion fluids. Generally low viscosity fluids exhibit Newtonion flow behavior. Eg : Gases , water and low viscosity liquids. **Non -Newtonion fluids:** Fluids which does not obey Newton's law of viscosity are known as Non - Newtonion fluids. Eg Sewage and sludge, rubber latex, polymer solutions, starch solutions, toothpaste, tomato ketch up.	1 1 1 1
3-f	**NPSH** Net Positive suction Head (NPSH) is the pressure required at the pump inlet in excess of the vapour pressure of the liquid. In order to avoid cavitation in pump, NPSH provides the guideline about positive pressure to be maintained. For small pumps, the required value is around 2 to 3 m; however it can vary with impeller speed, discharge and liquid temperature. **Equation:** The available NPSH is calculated by following formula $NPSH = (Pa – Pv)/\rho g – h^1fs - Za$ Where Pa - Pressure acting on liquid surface in reservoir(N/m^2) ρ - Density of liquid (kg / m^3) g- Acceleration due to gravity (m/s^2) Pv- Vapour pressure at the given temperature (N/m^2) h^1fs = head loss due to friction in suction pipe (m). Za - height difference between level of liquid in the reservoir and pump inlet (m).	2 2
4	**Attempt any FOUR of the following**	16

4-a	**Difference between Pipes and Tubes**	1 mark each for any 4 points

Sr.No.	Pipes	Tubes
1)	Thick walled	Thin walled.
2)	Available in standard length of about 6m.	Available in coils several meter long.
3)	Pipes materials : ferrous	Tubes made from non-ferrous materials like brass, copper , aluminum
4)	Pipe inner surface is usually rough	Tube inner surface is very smooth
5)	Pipe sections are joined by screwing ,flanging or welding	Tube pieces are joined by brazing ,soldering or flared fitting
6)	Pipe sizes are decided by schedule number	Tube sizes are expressed by BWG (Birmingham Wire Gauge)

4-b

D = 25mm = 0.025m

μ = 0.0008 Pa.s

ρ = 1000 kg / m^3

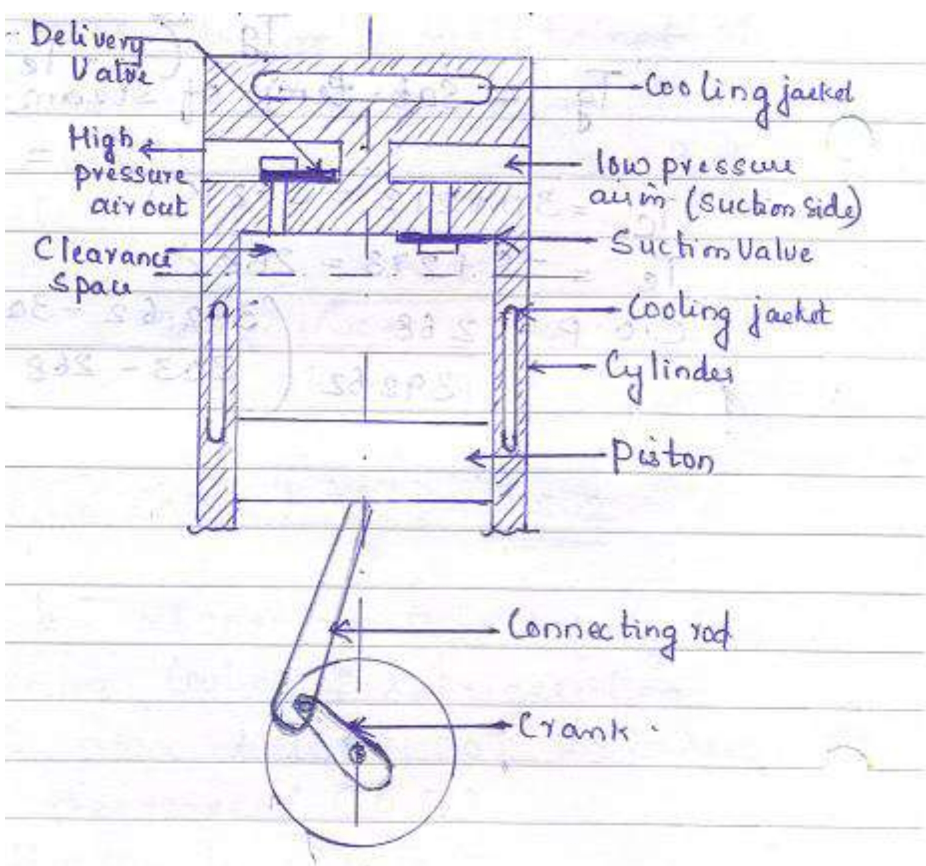
At critical velocity, transition from laminar to turbulent flow starts and value of N_{Re} is taken as 2100.

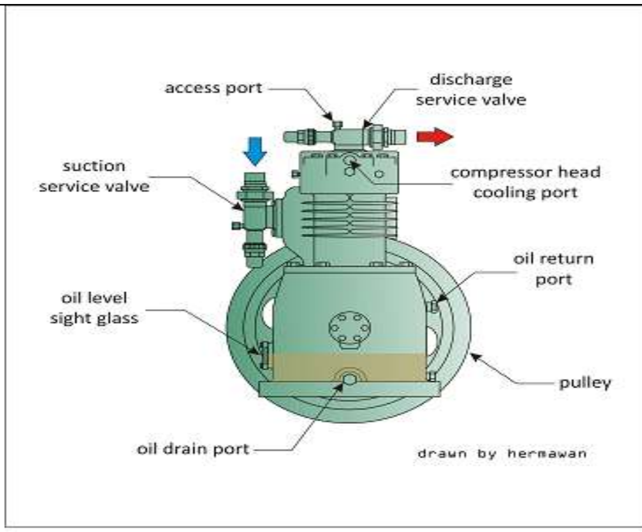
$$N_{Re} = \frac{D u_c \rho}{\mu}$$ 1

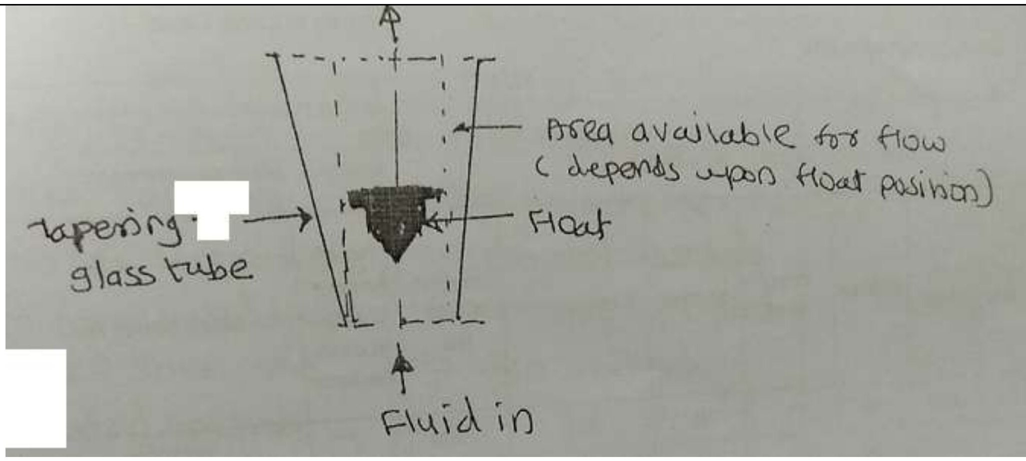
2100 = (0.025 * $u_c * 1000$) / 0.008 2

u_c = 0.0672 m / s

Critical velocity = 0.0672 m / s 1

4-c	**Diagram of reciprocating compressor:**  OR	4

	 ***(Other schematic sketch related to the above figure depicting relevant part should also be considered.)***	
4-d	**Rotameter is called variable area meter** The schematic diagram of rotameter tube is shown in the fig below. From the diagram, it is clear that area available for flow depends upon annular space between float and tapering tube. The area available for flow varies with float position and float position decides flow rate. Therefore as flow rate of fluid flowing through rotameter tube varies with area available for flow (area between float and tube) , it is known as variable area meter.	4



4-e	**Difference between form friction and skin friction:**	2 marks each

Form friction	Skin friction
1. When boundary layer separates and form eddies or wake, then the associated friction is known as form friction.	1. The friction due to unseparated boundary layer is known as skin friction.
2. In turbulent flow, loss due to turbulent flow is dominant	2. In laminar flow or viscous flow, loss due to skin friction is dominant

4-f

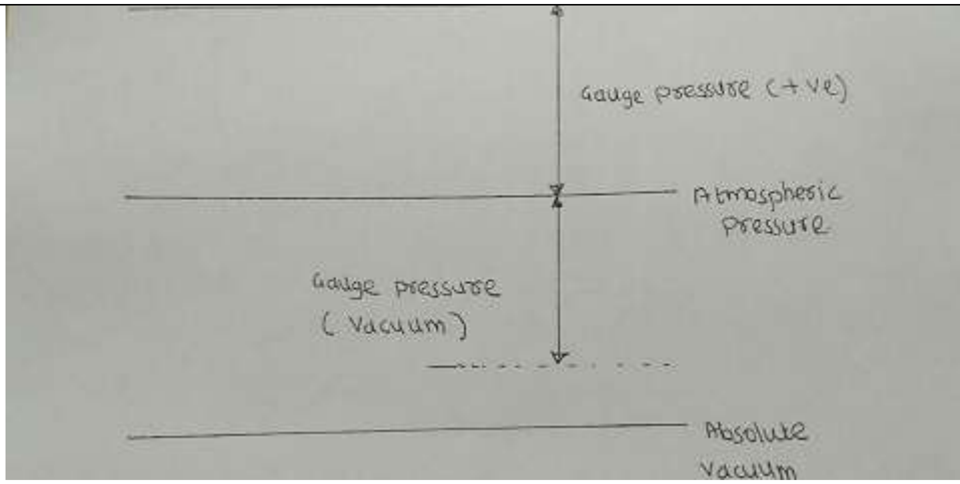
Atmospheric pressure:

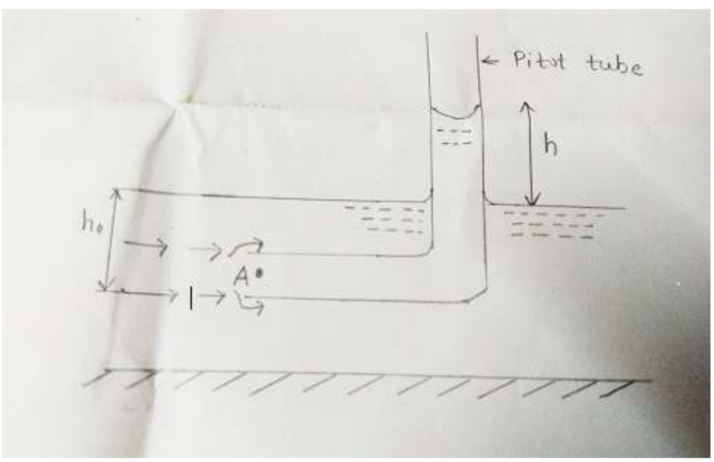
Pressure exerted by 760mm of mercury column at sea level is considered as 1 atmosphere. In equation $P = \rho g h$, by substituting $h = 0.76m$, $\rho = \rho_{Hg}$ and g, we get value of atmospheric pressure in N / m^2 — 1

Gauge pressure:

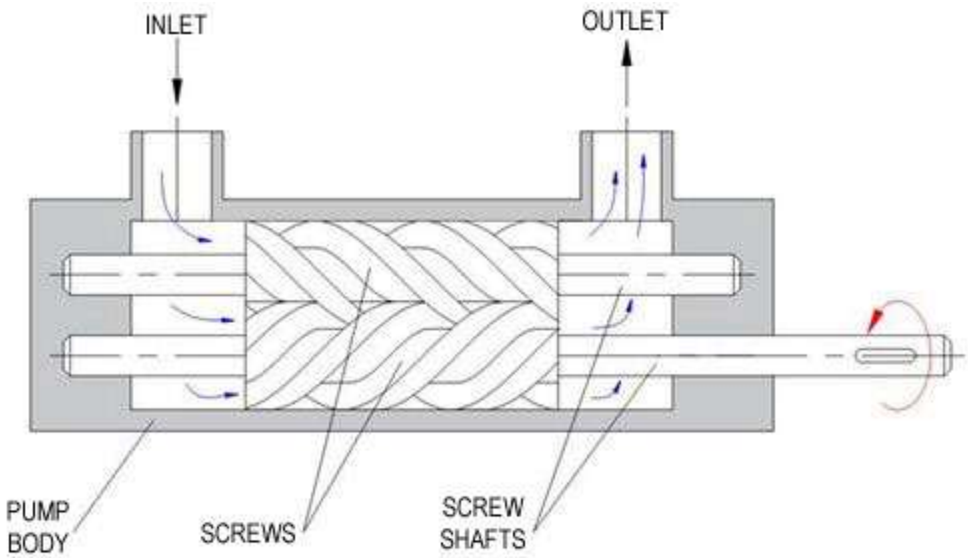
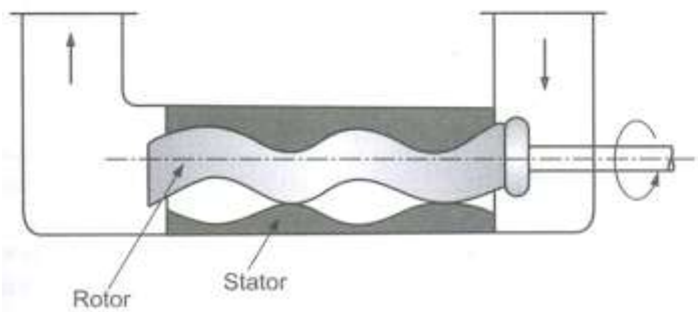
Pressure indicated by a pressure gauge either above or below atmospheric pressure is considered as gauge pressure. — 1

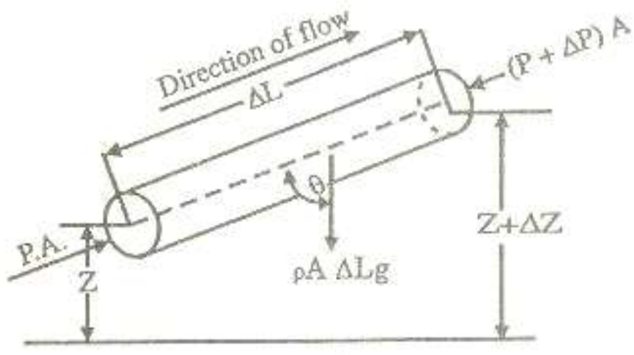
Sketch

	 	2
5	**Attempt any TWO of the following**	16
5-a	D =25mm = 0.025m Density ρ =1000 kg/m^3 Viscosity μ = 8 * 10^{-4} Pa.s Mass flow rate $\dot{m}$ = 1kg /s L = 100 m Area A= $\frac{\pi D^2}{4}$ = $\frac{3.14*0.025^2}{4}$ = 4.906 *10^{-4}m^2 Velocity V = $\frac{\dot{m}}{A\rho}$ = 1/ (1000* 4.906 * 10^{-4})=2.083m/s f =0.0001 h_{fs} = 4flV^2 / 2D = 4*0.0001 *100* 2.083^2 / (2*0.025) = 3.3237 J /kg ΔP = h_{fs} * ρ = 3.3237*1000 = **3323.7 Pa = 3.3237 KPa** **Pressure drop = 3.3237 KPa**	2 2 4
5-b	Data: Q = 12 lit/s D= 3 cm =0.03m ρ = 870 kg /m^3 = 0.87 kg/lit i) Q in m^3/s	

	$Q = 12$ lit/s = $\mathbf{12 * 10^{-3}\ m^3/s}$	2
	ii) ($\dot{m}$) in kg/s	
	($\dot{m}$) = Q * ρ = 12 *10^{-3} *870 = **10.44 Kg / S**	2
	iii) U in m/s Q = u * A Area of pipe = π/4 * D^2 = π /4 * $(0.03)^2$ =7.065 * 10^{-4} m^2 U = 12 X 10^{-3} / 7.065 * 10^{-4} = **16.98 m / S**	2
	iv) G in kg /m^2.s G = Mass flow rate / Area of pipe = 10.44 / 7.065 * 10^{-4} = **14777.07 Kg /m^2.S**	2
5-c	**Pitot Tube** **Diagram:**  **Construction and working:** It consists of glass tube, large enough for capillary effects to be negligible and bent at right angles .The tube is dipped vertically in the flowing stream of fluid with its open end A directed to face the flow & the other open end projecting above the liquid surface. The fluid enter the tube & the level of the fluid in the tube exceeds that of the fluid surface because the end A of the tube is a	2

	stagnation point where the fluid is at rest & the fluid approaching end A divides at this point & passes around the tube. As at stagnation point, the kinetic energy is converted into pressure energy, the fluid in the tube rises above the surrounding fluid surface by a height that corresponds to the velocity of fluid approaching the end A of the tube. Hence, the velocity at any point in the flowing stream can be determined by dipping the pitot tube to the required point and measuring the height h of the fluid raised in the tube above the free surface. Considering loss of energy, the above equation is modified to get actual flow velocity as $$u = C\sqrt{2gh}$$ C = Coefficient of pitot tube (C = 0.98) **Application:** It is used for finding the air speed of an air craft, water speed of a boat, liquid flow in pipes and channels.	4 2
6	**Attempt any TWO of the following**	16
6-a	**Screw pump** **Construction:** It consists of a rotor that rotates in stator made of rubber or other similar Material. The rotor is a true helical metal screw while the stator has a double helical thread pitched opposite to the spiral on the rotor. The liquid to be pumped moves continuously towards a discharge through the voids between the rotor and stator. **Working:** As the rotor rotates, a reduced pressure is created on the inlet side, the liquid is forced into the pump, it is trapped between the rotor and stator and finally is	2 2

	forced out of the discharge side of the pump. **Diagram:**  **Or**  	3
	Application: Screw pump is used to handle highly viscous materials, gritty liquids. It is widely used in chemical industries for feeding slurries containing higher proportions of solids to filtration equipment.	1 mark for any one application
6-b	**Bernoulli's theorem:** **Statement**: For steady, irrotational flow of an incompressible fluid ,the sum of pressure energy, kinetic energy & potential energy at any point is constant.	1



Let us consider an element of length ΔL of a stream tube of constant cross sectional area as shown above.

Let us assume that cross-sectional area of element be A & the density of the fluid be ρ. Let u & P be the velocity & pressure at the entrance & (u + Δu), (P +Δ P) are the corresponding quantities at the exit. 2

The forces acting on the element are

1) The force from upstream pressure = P.A (acting in the direction of flow)
2) The force from downstream pressure normal to the cross-section of the tube = (P +Δ P).A(in opposite direction of flow)
3) The force from the weight of fluid (gravitational force acting downward) = ρ.A.ΔL.g 2

   The component of this force acting opposite to direction of flow = ρ.A.ΔL.gcosθ

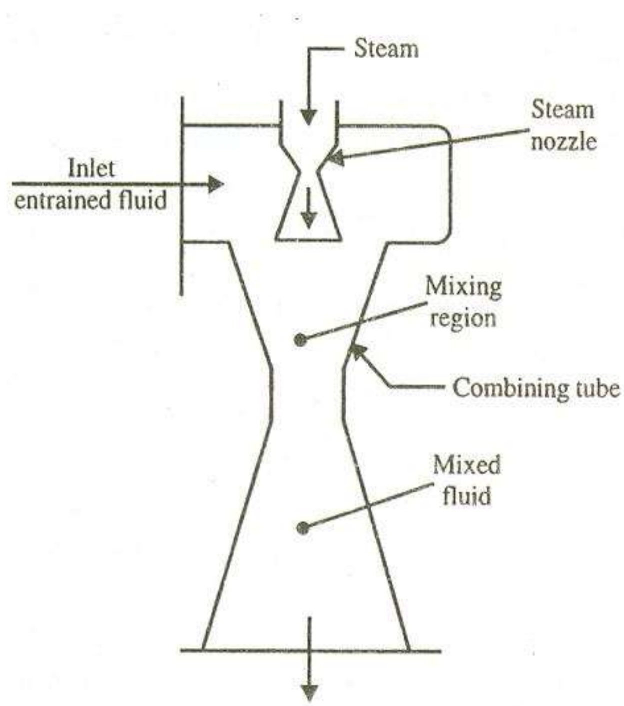
   The rate of change of momentum of the fluid along the fluid element = $\dot{m}$ [u + Δu – u] = $\dot{m}$Δu

   As mass flow rate= $\dot{m}$ = ρ. uA . Δu

According to Newton's Second law of motion

{sum of forces acting in the direction of flow} = {rate of change of momentum of a fluid} 2

	P.A - (P +Δ P).A - ρ.A.ΔL.gcosθ = ρ. uA . Δu -Δ P.A - ρ.A.ΔL.gcosθ = ρ. uA . Δu Δ P.A + ρ.A.ΔL.gcosθ + ρ. uA . Δu = 0 Eq.I Dividing each term of eq.I by A.ΔL. ρ we get $$\frac{\Delta P}{\rho \Delta L} + g.cos\theta + \frac{u.\Delta u}{\Delta L} = 0$$ As cosθ = $\frac{\Delta Z}{\Delta L}$,we can write $$\frac{1}{\rho}\frac{\Delta P}{\Delta L} + g\frac{\Delta Z}{\Delta L} + u\,\frac{\Delta u}{\Delta L} = 0 \qquad Eq.II$$ If we express the changes in the pressure, velocity , height etc. in the differential form ,eq .II becomes $$\frac{1}{\rho}\frac{dP}{dL} + g\,\frac{dZ}{dL} + \frac{d\left(\frac{u^2}{2}\right)}{dL}$$ Which can be written as $$\frac{dP}{\rho} + g\,.dZ + d\left(\frac{u^2}{2}\right) = 0 \qquad Eq.III$$ Eq.III is called as Bernoulli Equation. It is differential form of the Bernoulli Equation. For incompressible fluid, density is independent of pressure & hence ,the integrated form of eq.III is $$\frac{P}{\rho} + gZ + \frac{u^2}{2} = constant$$ Hence proved that low of conservation of energy is applicable for flowing fluid. The Bernoulli Equation relates the pressure at a point in the fluid to its position & velocity.	1
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** **Principle:** A steam jet ejector is a type of pump that uses the venturi effect of a converging-diverging nozzle to convert the pressure energy of a motive fluid (steam)to velocity energy which creates a low pressure zone(vacuum) that draws in and entrains a suction fluid. 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.	2
		3
	Working:	

	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.	3