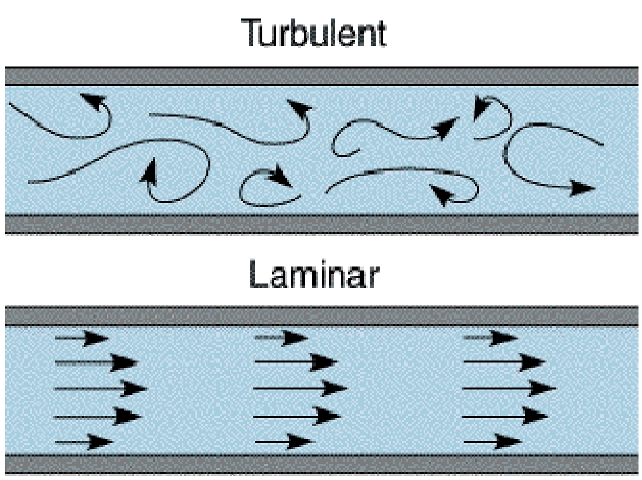
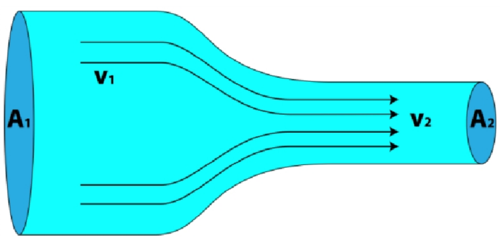
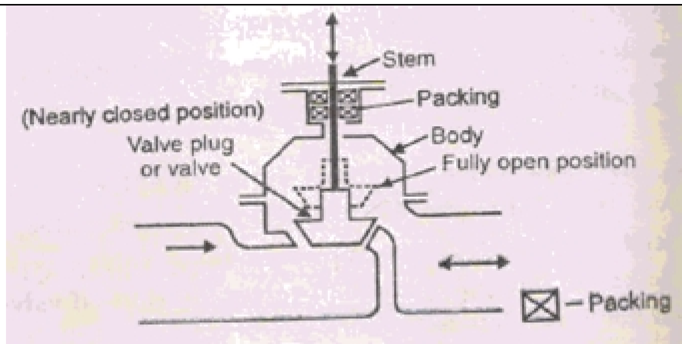
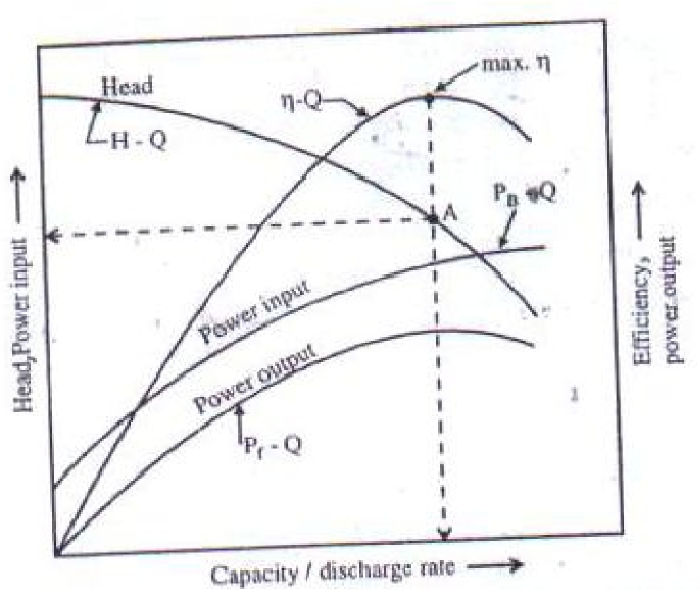
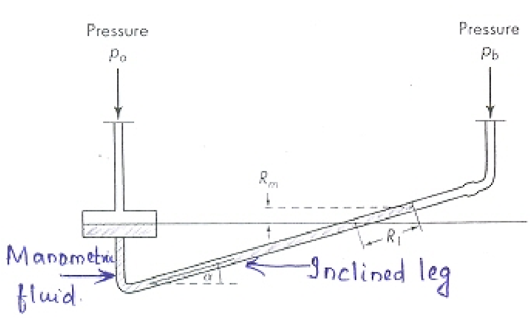
Important Instructions to examiners:

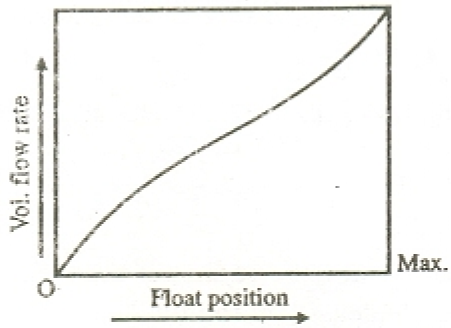
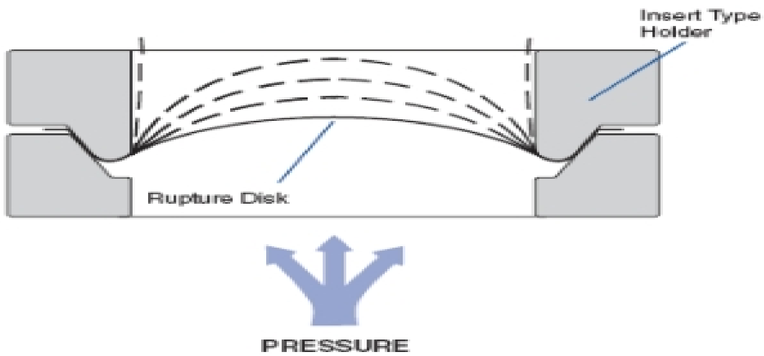
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling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

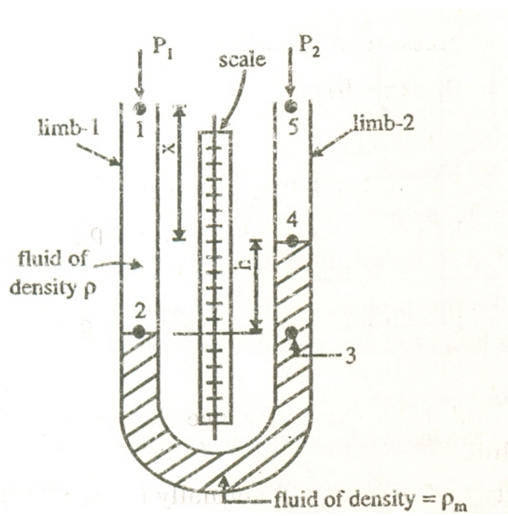
Q No.	Answer	marks	Total marks
1A-a	**Kinematic viscosity with its unit:** Kinematic viscosity: It is the ratio of viscosity of the fluid to its density Unit in SI is m^2/s	 1 1	2
1A-b	**Newtonian fluid :** Newtonian fluid is that fluid which obeys Newton's law of viscosity. $\frac{F}{A} = \mu \frac{dv}{dx}$ ie $\tau = \mu \frac{dv}{dx}$	2	2
1A-c	**Sketch of laminar and turbulent flow:** 	1 mark each	2
1A-d	NRe = 144054 $f = 0.079 / NRe^{0.25}$ = **0.0040037**	2	2
1A-e	**Material of construction for pipes and tubes:** Pipes and tubes are generally made from cast iron, wrought iron, mild steel, stainless steel, copper, brass, bronze, aluminium etc	2	2
1A-f	**Application of screw pump:**	2 marks	2

	1. Used in irrigation system and agricultural machinery 2. Used for pumping raw water that contain solids and debris 3. used in machinery lubrication 4.used in fuel oil transport 5. used to transport high temperature refinery products such as asphalt	for any one application	
1A-g	**Pumping device for gases:** Fans, blowers and Compressors	2	2
1B-a	**Derivation:** 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**	1 2 1	4
1B-b	**Diagram of Globe valve:**	4	4

			
1B-c	**Characteristic curve of centrifugal pump:** 	4	4
2-a	**Diagram of inclined tube manometer:** 	2	4

	Equation to calculate pressure drop: $P_a - P_b = \Delta P = R_1 \sin\alpha\,(\rho_m - \rho)g$ where ρ_m is the density of manometric fluid and ρ is the density of flowing fluid.	2	
2-b	**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. It has no unit.	2 2	4
2-c	**Equation for calculating friction loss due to sudden contraction:** 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 1 1	4
2-d	**Calibration of rotameter:** 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

		2	
2-e	**Rupture disc:** **Diagram:**  A 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 has 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	2 2	4

	is generally made up of metal		
2-f	**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. **Priming:** Removal of air from the suction line and pump casing and filling it with the liquid to be pumped is called priming.	2 2	4
3-a	**Derivation**  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 ρ_mg = $P_1 + (x+h)\rho g - h \rho_m g$ Pressure at the point 5 P_2 = Pressure at the point 4 – $x\rho g$ $P_2 = P_1 + (x+h)\rho g - h \rho_m g - x\rho g$	01 03	04

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

$$= P_1 + hg(\rho - \rho_m)$$

$$(P_1 - P_2) = \Delta P = h(\rho_m . \rho)g$$

$$\Delta P = h(\rho_m . \rho)g$$

</td><td></td><td></td></tr>
<tr><td>3-b</td><td>

Classification of Fluids:

(i)Ideal fluid

(ii)Real fluid

(iii)Newtonian fluid

(iv)Non Newtonian fluid

</td><td>1 mark for each point</td><td>04</td></tr>
<tr><td>3-c</td><td>

Difference between Diaphragm valve & Ball valve:

<table>
<tr><th></th><th>Diaphragm Valve</th><th>Ball Valve</th></tr>
<tr><td>Pressure Drop</td><td>More</td><td>less</td></tr>
<tr><td>Application</td><td>Corrosive Liquids</td><td>Complete(shut-off)on /off service</td></tr>
</table>

</td><td>2 marks for each point</td><td>04</td></tr>
<tr><td>3-d</td><td>

The following factors which influence the choice of pump:

1.Reciprocating Pump: a)High Pressure
b) Clear liquid only

2.Plunger Pump **:** a) Very High Pressure & high dellivery.

3.Rotary Pump **:** a) Gear pump transporting clear,viscous liquid.

</td><td>1 marks for each point</td><td>04</td></tr>
</table>

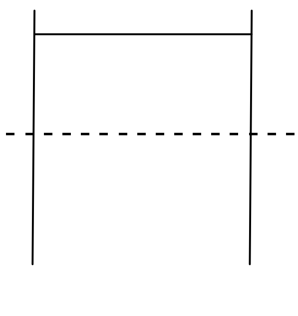
<table>
<tr><td></td><td>b) Lobe pump also transporting clear liquid.

**4.Centrifugal Pump : ** a)Transporting slurries & liquid Suspension.
Quantity of liquid to be handled, nature of liquid, head against which liquid is to be pumped, cost, efficiency etc also plays a role in the selection of the pump</td><td></td><td></td></tr>
<tr><td>3-e</td><td>**Comparision between Reciprocating compresssor & centrifugal compressor:**

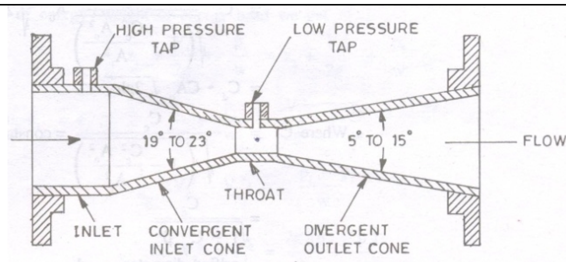
<table><tr><th></th><th>Reciprocating Compressor</th><th>Centrifugal Compressor</th></tr><tr><td>**Speed**</td><td>Slow speed</td><td>High speed</td></tr><tr><td>**Rate of flow**</td><td>low</td><td>high</td></tr></table></td><td>2 marks for each point</td><td>04</td></tr>
<tr><td>3-f</td><td>**N.P.S.H** – Net Positive Suction Head: It 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

$$NPSH = Zs + (Ps - Pvap)/\rho - hfs$$
Where, Zs = height of pump from suction points.
Ps = Suction pressure
Pvap = Vapour pressure of liquid transported.
hfs = frictional head loss</td><td>02

02</td><td>04</td></tr>
<tr><td>4-a</td><td></td><td></td><td></td></tr>
</table>

	 A $\rho_L = 1250\ kg/m^3$ $P_A = 32.424\ KN/m^2\ g$ $= 32.424 \times 1000\ N/m^2\ g$ $= 32424\ N/m^2$ $\therefore P_A = h\rho g$ $32424 = h \times 1250 \times 9.8$ $\therefore h = 32424/(1250 \times 9.8)$ **= 2.64 meter**	01 01 01 01	4
4-b	Specific gravity of liquid =0.95 gm/cm^3 Q = Volumetric flowrate = 600 lit/sec = 600 x 1000 cm^3/sec Diameter of Pipe = 200 mm = 20 cm		4

	$\therefore$.Area of Pipe = ∏ /4 d^2 = ∏/4 $(20)^2$ = ∏/4 (400) cm^2 $\therefore$. Velocity of liquid = (600 x1000 x 4)/(∏ x400) = 600 x 10/∏ cm/sec Nre = Duρ /μ = [20 x(6000/3.14) x 0.95]/μ ***Since 'μ' is not given so we can't find out numerical value.***	01 01 01 01	
4-c	**The purpose of following fittings:** **1.Union** **:** Joining two pipes of same diameter of very high length. **2.Plug** **:** It is used for closing a pipe line. **3.Cross** **:** It is used to bypass the fluid flowing through Straight pipe length(for changing the flow in 4 different directions). **4.Reducer:** It is used for connecting pipes of different Diameters(from large diameter pipe to small diameter pipe).	1 mark each	04
4-d	**Venturimeter**		4



02

02

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.

4-e

$he = (1 – A_1/A_2)^2 V_1^2 /2g$ — 01

$= [1 – (0.05^2/0.1^2)^2]2^2/(2 \times 9.8)$ — 02

$= 0.5625(2/ 9.81)=$ **0.114678 Kg_f-m/ kg** — 01

or 0.114678m of flowing fluid = 1.125 J/Kg

Total: 04

4-f **Comparision between Blower & Compressor:**

2 marks for each point — Total: 04

	Blower	**Compressor**
Presssure	40 – 100 psi	Very high pressure
Application	Supplying air to furnaces,cooling & drying purposes vents action purpose.	Compressor are used in petroleum industry for getting very high comp.ratio

5-a Data: — 8

Volumetric flow rate of toluene = Q = 12 lit/sec

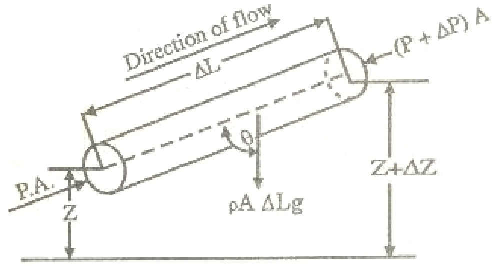
Diameter of pipe = d = 3 cm = 0.03 m

	Density of toluene = 870 kg/ m^3		
	1) Volumetric flow rate(Q) in m^3/s		
	As 1 litre = 10^{-3} m^3	1	
	1 lit/sec = 10^{-3} m^3/s	1	
	Q = 12 lit/sec = 12 x 10^{-3} m^3/s = **0.012 m^3/s**		
	2) Velocity (u in m/s)		
	As volumetric flow rate (Q) = Average velocity(u) x Area of pipe(A)	1	
	u = Q/A		
	Area of pipe = =A= $\pi/4\ D^2 = \pi/4\ (0.03)^2 = 0.7065 \times 10^{-3}\ m^2$	1	
	As u = Q/A		
	$u = \frac{1.2 \times 10^{-2}}{7.065 \times 10^{-4}}$		
	u = **16.98 m/s**	1	
	3) Flow rate ṁ in kg/sec		
	As ṁ = ϱ u A	1	
	ṁ = 870x16.98 x0.7065 x 10^{-3}		
	ṁ = **10.44 kg/sec**.		
	4)Mass velocity through pipe : G		
	$G = \frac{mass\ flow\ rate}{cross\text{-}sectional\ area\ of\ pipe}$	1	
	G = ṁ/A		

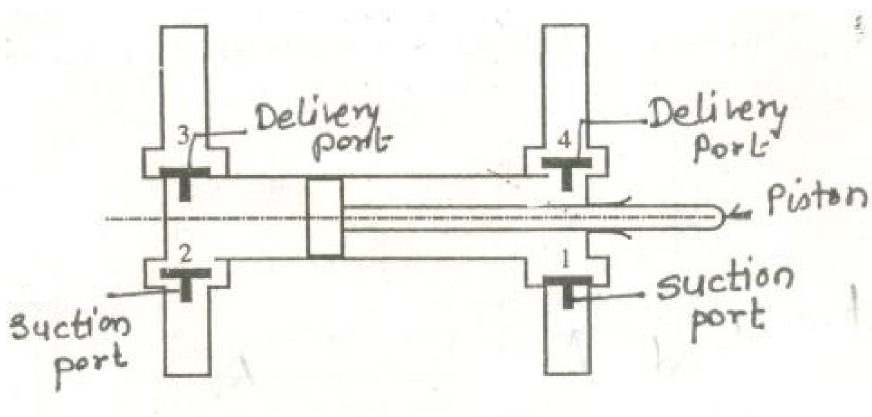
	G = 10.44 /0.7065 x 10^{-3} G = **14777 kg/m^2.s**	1	
5-b	Data: Density of acetic acid = 1060 kg/ m^3 Viscosity of acetic acid = 0.0025 N.s/m^2 Volumetric flow rate of acetic acid = Q = 0.02 m^3/s Inside diameter of pipe = D = 0.075 m Area of pipe =A= π/4 D^2 = π/4 $(0.075)^2$ = 4.418 x 10^{-3} m^2 Average velocity of acid through pipe = u = Q / A u = $\frac{0.02}{4.418\ x\ 10^{-3}}$ u = 4.53 m/s To calculate pressure drop,we need to calculate the value of Reynolds no. & hence friction factor As N_{Re}= $\frac{D.u\rho}{\mu}$ N_{Re} = $\frac{0.075x4.53x1060}{0.0025}$ N_{Re} = 144054 As N_{Re} > 4000,flow is turbulent Friction factor for tuebulent flow $$f = \frac{0.078}{(N_{Re})^{0.25}}$$	 1 1 1 1	8

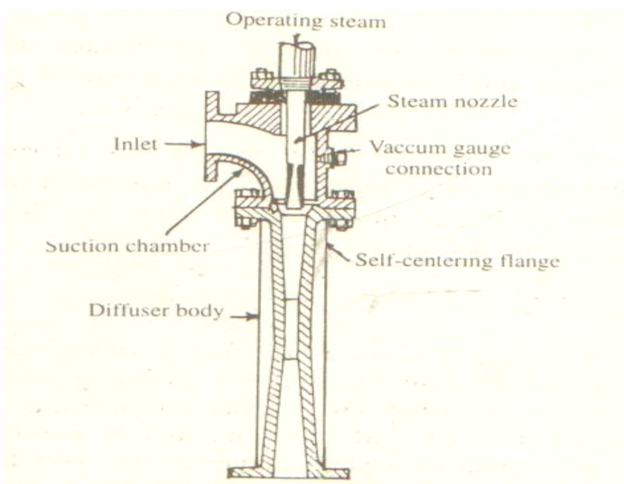
	$$f = \frac{0.078}{(144054)^{0.25}}$$ $$f = 0.004$$	1	
	For calculation of pressure drop due to friction in a pipe due to turbulent flow ,the equation used is $$\Delta P = \frac{4 f \rho L u^2}{2D}$$	2	
	$$\Delta P = \frac{4x0.004x1060x70x(4.53)^2}{2x0.075}$$		
	$$\Delta P = 162416.08 \frac{N}{m^2} = 162.416 \frac{kN}{m^2}$$	1	
5-c	Data : Diameter of orifice: d_0 = 25 mm = 0.025 m Diameter of pipe: D= 50 mm = 0.05 m Coefficient of orifice = C_o = 0.62 Density of water = 1000 kg/m^3 Density of mercury = 13000 kg/m^3	1	8
	Area of orifice = $A_o = \pi/4\ d_0^2 = \pi/4\ (0.025)^2 = 4.909 \times 10^{-4} m^2$	1	
	β= Diameter of throat / Diameter of pipe = 25/50 = 0.5	1	
	Pressure drop across the meter = Δh = 11 cm= 0.11 m of mercury	1	

	Let's find out the value of pressure drop in terms of process fluid(water)= ΔH $$\Delta H = \Delta h \left[\frac{\rho_{Hg-}\rho_{H_2O}}{\rho_{H_2O}}\right]$$ $$\Delta H = 0.11 \left[\frac{13600-1000}{1000}\right]$$ $\Delta H = 1.386$ m of water The flow equation of orificemeter $$Q = \frac{C_o A_o}{(1-\beta^4)} . \sqrt{2g\Delta H}$$ $$Q = \frac{0.62x4.909x10^{-4}}{(1-0.5^4)} . \sqrt{2x9.81x1.386}$$ $$\boldsymbol{Q = 1.691\ x\ 10^{-3}\ m^3/s}$$	2 1 1	
6-a	**Derivation for Bernoulli Equation**: It is an energy balance. Statement:" For steady, irrotational flow of an incompressible fluid ,the sum of pressure energy, kinetic energy & potential energy at any point is constant". Bernoulli theorm is derived on the basis of Newton's Second law of motion.(Force = Rate of change of momentum.)	2 1	8

	 Force balance for potential flow Let us consider an element of length ΔL of a stream tube of constant c/s 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. 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 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	1 1	

	{sum of forces acting in the direction of flow} = {rate of change of momentum of a fluid} $P.A - (P + \Delta P).A - \rho.A.\Delta L.g\cos\theta = \rho.\ uA\ .\ \Delta u$ $-\Delta P.A - \rho.A.\Delta L.g\cos\theta = \rho.\ uA\ .\ \Delta u$ $\Delta P.A + \rho.A.\Delta L.g\cos\theta + \rho.\ uA\ .\ \Delta u = 0$ Eq.I	1	
	Dividing each term of eq.I by $A.\Delta L.\ \rho$ we get $\frac{\Delta P}{\rho \Delta L} + g.\cos\theta + \frac{u.\Delta u}{\Delta L} = 0$ As $\cos\theta = \frac{\Delta Z}{\Delta L}$,we can write $\frac{1}{\rho}\frac{\Delta P}{\Delta L} + g\frac{\Delta Z}{\Delta L} + u\frac{\Delta u}{\Delta L} = 0$ $Eq.II$	1	
	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 $\frac{dP}{\rho} + g\ .dZ + d\left(\frac{u^2}{2}\right) = 0$ $Eq.III$ 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 $\frac{P}{\rho} + gZ + \frac{u^2}{2} = constant$	1	

	The Bernoulli Equation relates the pressure at a point in the fluid to it's position & velocity.		
6-b	Double acting reciprocating pump:  Double acting reciprocating pump	4	8
	Working: Reciprocating pump consists of a piston or plunger which reciprocates in stationary cylinder.Suppose the piston is initially at extreme left position and when crank rotates thro 180 ^{0} ,piston moves to extreme right position. Therefore due to outward movement of piston,a partial vacuum is created in cylinder,which enables the atmospheric pressure acting on the liquid surface in the sump below to force the liquidup the suction pipe & fill the cylinder by forcingly opening the suction valve. (it is called as a suction stroke).When the crank rotates thro further 180 ^{0} ,piston moves inwardly from it's extreme right position towards left.The inward movement of piston causes the pressure of liquid in the cylinder to rise above atmospheric pressure,because of which the suction valve closes & delivery valve opens .the liquid is then forced up the delivery valve & raised to the required height.(Delivery stroke) .	4	

	In case of double acting pump,the liquid is in contact with both the sides of a piston or plunger.This pump has two suction pipes & two delivery pipes.During each stroke ,the suction takes place on one side of piston & other side delivers the liquid .The liquid is drawn into the pump & discharged from the pump during backward & as well as forward stroke.In the backward stroke ,the liquid is drawn into the pump thro the suction port (1) & liquid is discharged thro the delivery port(3) & in the forward stroke,the liquid is drawn into the pump thro suction port (2) and liquid is discharged thro the delivery port (4) .So in case of double acting pump in one complete revolution of the crank there are two suction strokes & two delivery strokes.	2	
6-c	**STEAM JET EJECTOR**  Steam jet ejector 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	4	8

	discharged thro the ejector.it handles large volumes of vapour at low pressures.it is suitable for corrosive fumes or vapours.	4	