MODEL ANSWER

SUMMER– 17 EXAMINATION

Subject Title: FMM Subject Code: 17411

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.	Sub Q. N.	Answer	Marking Scheme
Q No. 1 (A)		**Attempt any six of the following**	
	a)	**Define vapour pressure** It is the equilibrium pressure of a vapour above the liquid. OR The pressure of the vapour resulting from evaporation of a liquid above a sample of liquid in a closed container.	02 Marks
	b)	**Define specific weight** It is defined as the ratio of weight of the fluid to the volume of the fluid. It is generally denoted by letter 'w' SI Unit of Specific weight is N/m^3 It is also called as Weight density Mathematically, Weight density = Weight/ Volume	02 Marks

	c)	**State various types of fluid flows** The types of fluid flows are as follows i) Steady flow ii) Unsteady flow iii) Uniform flow iv) Non- uniform flow v) Compressible flow vi) In compressible flow vii)Laminar flow viii) Turbulent flow ix) Rotational flow x) Irrotational flow xi) Vortex flow	02 Marks
	d)	**State various losses of energy of fluid flowing in a pipe** When a fluid is flowing through a pipe, the fluid experiences some resistance due to which some energy of the fluid is lost. This loss of energy is classified as i) Major loss ii) Minor loss i) Major loss- These losses are due to friction ii) Minor losses- These losses are caused on account of changes in the velocity of flowing fluid either in magnitude or direction	02 Marks
	e)	**State the formula for force exerted by a jet on the curved plate, when jet strikes the plate at the center.** **Case i) When the plate is fixed** Force exerted by the jet in the direction of jet is F = pav^2 (1+ Cos θ) **Case ii) When plate is moving** Force exerted by the jet in the direction of jet is F = $pa(v - u)^2$ (1 + Cos θ)	02 Marks
	f)	**State the principle of reaction turbine** In reaction turbine, the water enters the wheel under pressure & flows over the vane. Therefore energy at inlet is kinetic energy as well as pressure energy. Example - Francis turbine, Kaplan turbine	02 Marks
	g)	**State the concept of priming of centrifugal pumps** Priming of Centrifugal pump is the operation in which the suction pipe, casing of the pump & a portion of the delivery pipe up to the delivery valve is completely filled by the liquid. Thus the air from these parts is removed and whole space is filled with the liquid to be pumped.	02 Marks

h) **State the advantage of using air vessel in reciprocating pumps**

Advantages of Air vessel are as below

i) It reduces the possibility of separation & cavitation

ii) It allows the pump to run at higher speed

iii) Suction head can be increased by increasing the length of pipe below the air vessel

iv) Large amount of power is saved due to lesser acceleration head

v) It's use gives uniform discharge

1/2 Marks each any four

1(B) **Attempt any two of the following**

a) **Define**

i) Absolute pressure- It is the algebraic sum of gauge pressure & atmospheric pressure. It is a zero referenced against a perfect vacuum

i.e. $P_{ab} = P_{gauge} + P_{atm}$

ii) Gauge pressure- When pressure is measured with the help of pressure measuring instrument, either above or below atmospheric pressure, it is called as gauge pressure

iii) Vacuum pressure- It is the pressure of fluid which is measured below atmospheric pressure. It is measured by vacuum gauge.

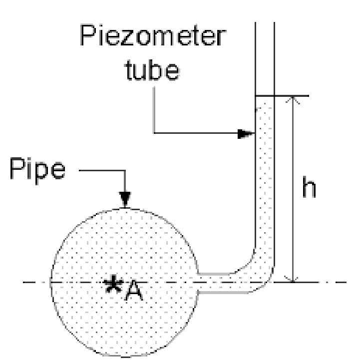
iv) Atmospheric pressure- The atmospheric air exerts a normal pressure upon all the surfaces with which it is in contact, & it is called as atmospheric pressure.

It varies with altitude & can be measured by means of a barometer.

Hence it is also called as barometric pressure

01 Marks for each

b) **Explain the concept of piezometer for pressure measurement**



02 Marks

Piezometer- It is made up of a glass tube whose one end is inserted in the wall of a pipe or vessel, containing a liquid whose pressure is to be measured. While other end extends vertically upward to such a height that liquid can freely rise in it without overflowing. The rise of liquid gives pressure head at that point.

If at point A the height of liquid is h in tube then pressure at A is

$P = \rho gh = wh$

Piezometer is used to measure moderate gauge pressure

02 Marks

c) **Explain various energies possessed by a flowing fluid**

The energies possessed by flowing fluid are as

i) Pressure energy- It is the energy possessed by a fluid particle by virtue of its existing pressure. It is measured as P/w

04 Marks

ii) Kinetic energy- It is the energy possessed by a fluid particle by virtue of its motion or velocity. It is measured as $V^2/2g$

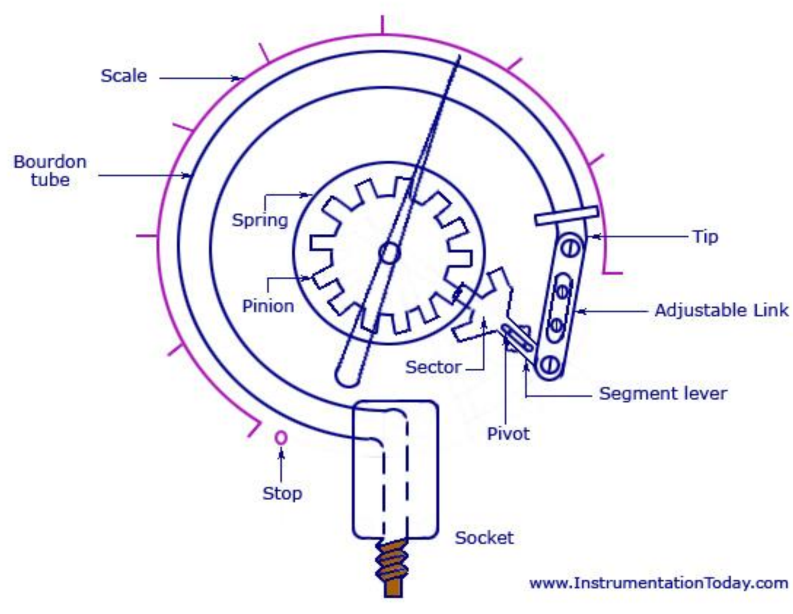
iii) Potential energy- It is the energy possessed by a fluid particle by virtue of its position. It is measured as z

Q No. 2

Attempt any Four of the following

a) **Explain the construction & working of Bourdons pressure gauge for pressure measurement**

These gauges are used to measure pressure above or below the atmospheric pressure.



Bourdon Tube Pressure Gauge

02 Marks

Construction- The steel or bronze tube elliptical in cross section, curved in to a circular arc used as the pressure sensing element. The outer end of the tube is closed and is free to move. While the other end is rigidly fixed to the frame, through the unknown pressure is applied, which is to be measured. A link, small sector and simple pinion is used to magnify the movement of tube and also transfer it to the pointer which is moving in clockwise rotation on a calibrated circular scale indicates the pressure intensity of the fluid.

Working- When the fixed end of the tube is connected to the gauge points, the fluid under pressure enters the elliptical cross section tube. The increase in internal pressure inside the tube causes it to become circular in cross section, thus causing the tube to be straighten slightly at the free end. This small outward movement of free end is mechanically magnified by means of a link, sector and pinion which also transfer it to the pointer. The pointer moves over a circular calibrated scale, indicated the pressure intensity of the fluid.

02 Marks

b) **Explain pressure measurement using differential U- tube manometer**

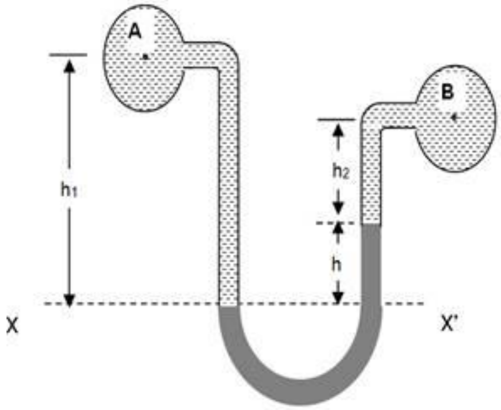


Fig (a)

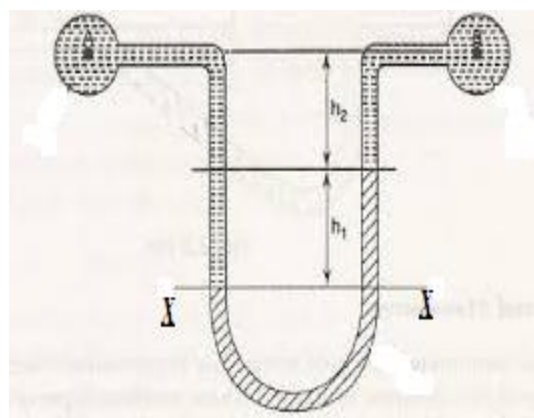


Fig (b)

02 Marks

(Any one)

U- tube differential manometer- (any one case)

It uses glass tube bent in U shape, whose two ends are connected to the two gauge points between which pressure difference is required to be measured. The manometer contains a liquid which is heavier than liquids for which pressure difference is required to be measured.

When two limbs are connected to gauge point A & B, then due to difference in pressures, the level of manometer liquid in two limbs will get displaced through distance h.

02 Marks

(Any one)

Let X - X be the datum,

Let p_1 , p_2 & p be the density of liquid at A, B & heavy liquid

Case- i) For figure (a) Gauge points A& B are at different levels

Pressure above datum X - X in left limb

$= p_{1*} g (h + x) + P_A$

Pressure above datum X - X in right limb

$= p*g*h + p_{2*} g*y + P_B$

Equating two pressures for equilibrium condition

$p_{1*} g (h + x) + P_A = p* g *h + p_{2*} g *y + P_B$

$P_A - P_B = p*g*h - p_1 g(h + x) + p_{2*} g*y$

(any one case)

Case- ii) For figure (b) Gauge points are at same level

Pressure above datum X-X in left limb = $p_{1*} g (h+x) + P_A$

Pressure above datum X-X in right limb = $p*g*h + p_{2*} g*x + P_B$

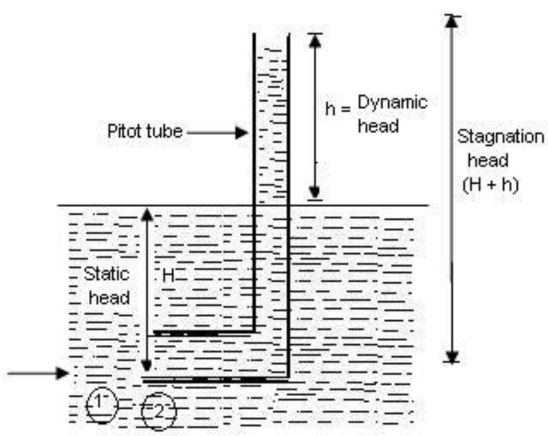
Equating two pressures for equilibrium condition

$P_A - P_B = p*g*h - p_1 g (h + x) + p_{2*} g*x$

$P_A - P_B = p*g (p - p_1) – g*x (p_1- p_2)$

c) **Explain construction & working of Pitot tube**

Pitot tube- It is used for measuring velocity of flow of fluid flowing through the channel



02 Marks

Construction-

It consists of a glass tube, bent at right angle as shown in figure. The diameter of glass tube is large enough to nullify the effect of capillary action.

The tube dipped vertically in the flowing fluid with its lower end which is bent at 90^0, facing the flow & other open end projecting above fluid surface.

02 Marks

Working-

		The fluid enters the tube from lower end facing the stream & the level of liquid in the tube rises above the level of fluid in surrounding stream. This is due to the fact that lower end of tube is a stagnation point where fluid is at rest. At a stagnation point the kinetic energy will get converted in to pressure energy causing the fluid in the tube to rise above the surrounding fluid surface by a height which corresponds to the velocity of flow of fluid approaching the lower end of tube. This pressure at stagnation point is called as stagnation pressure**.**	
	d)	**Calculate the velocity at the end of the pipes of diameter 150 mm & 220 mm connected in series having discharge of 60 lpm** **Given Data-** d_1 = 150 mm = 0.15 m d_2 = 220 mm = 0.22 m Cross sectional area of pipe of diameter 0.15 m $a_1 = \pi/4 * (d_1^2) = \pi/4 * (0.15)^2 = 0.0176\ m^2$ Cross sectional area of pipe of diameter 0.22m $a_2 = \pi/4 * (d_2^2) = \pi/4\ (0.22)^2 = 0.0380\ m^2$ $Q = 60$ Lit/min. $= 60 * 10^{-3}/60 = 1 * 10^{-3}\ m^3/s$ $Q = a_1 v_1$ $V_1 = Q/a_1 = 1 * 10^{-3} / 0.0176 = 0.0566$ m/s ………….ANS. $V_2 = Q/a_2 = 1 * 10^{-3} / 0.0380 = 0.0263$ m/s ……………ANS	02 Marks 02 Marks
	e)	**Explain Darcy's equation for loss of head due to friction.** When a fluid is flowing through a pipe, the fluid experiences some resistance due to which some energy or head of the fluid is lost. This loss of energy or head is classified as i) Major loss ii) Minor losses Major loss can be calculated by using Darcy's equation. $h_f = 4*f*L*V^2 / 2*g*d$ Where, $h_f =$ Head loss of head due to friction in m f = coefficient of friction. L = Length of pipe in m	04 Marks

V = Velocity of fluid in m/Sec

d = Diameter of pipe in m

f) **A pipe is used for energy transmission. Length and diameter of pipe are 80 m and 45 cm respectively, flow rate is 105 Lit/s. Calculate friction loss. Neglect minor losses. Take**

f = 0.03

Given data:

L = 80 m.

d = 45 cm. = $45 * 10^{-2}$ m

Q = 105 Lit/s = $105 * 10^{-3}\ m^3/s$

f = 0.03

Find - Head loss due to friction h_f

To Find velocity of flow, v

As Discharge Q = a * v

$Q \;=\; \pi/4 * d^2 * v$

$v \;=\; Q / \pi/4 * d^2 \;=\; 105 * 10^{-3} / \; \pi/4\,(45 * 10^{-2})^2$ — 02 Marks

v = 0.6603 m/sec

To find head loss due to friction.

It can be calculated by using Darcy's Weisbach equation**.**

$h_f \;=\; 4*f*L*V^2 / 2*g*d$

$= 4 * 0.03 * 80 * (0.6603)^2 / \; 2 * 9.81 * 45 * 10^{-2}$. — 02 Marks

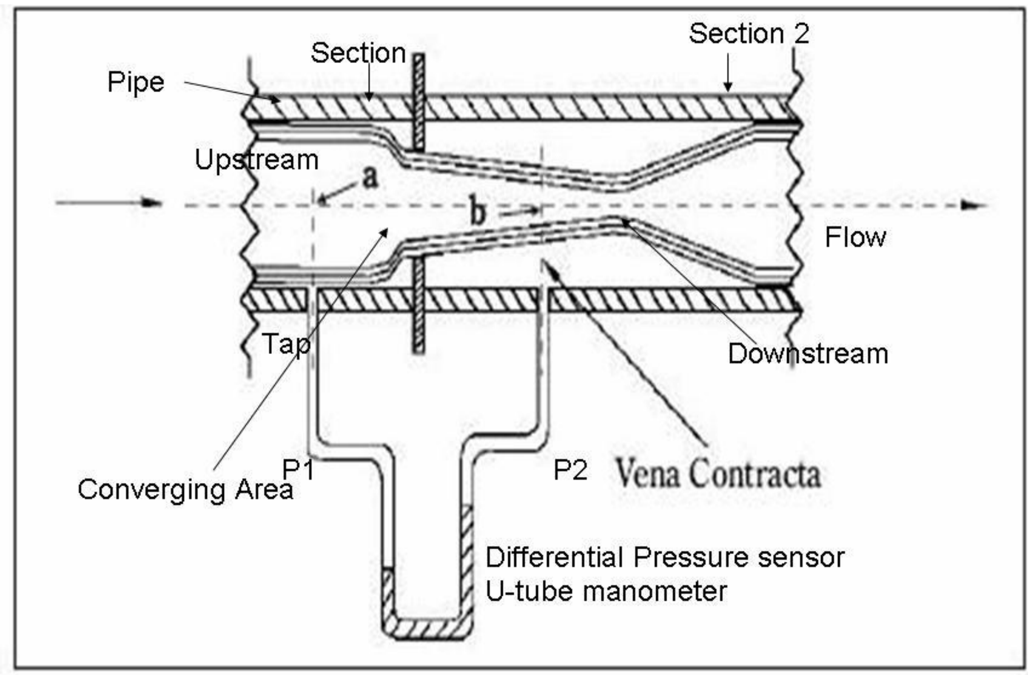
h_f = 0.4740 m of water ………………ANS.

03 Attempt any THREE of the following :

a) **A Rectangular plate 3 m x 2 m is immersed horizontal in a liquid of specific gravity 1.2. surface level. Calculate the total pressure on the plate, if it is immersed at a distance of 2**

		m from fluid surface level. - Given : Area of Plate A= 3 x 2 = 6 m^2, Sp Gravity =1.2, **Density of fluid** = ρ = 1.2 x 1000 =1200 kg/m^3, h = height from of C. G. of plate = $\bar{h}$ = 2 m, Total Pressure P = ? **Total pressure** = P = $\rho.g.A.\bar{h}$ = 1200 x 9.81 x 6 x 2 = 141264 N = **141.264 kN**	**01 Mark** **01 Mark** **02 Mark**
	b)	**Define total pressure and center of pressure.** - **Total pressure**: It is defined as the force exerted by the static fluid on the surface either plane or curve when the fluid comes in contact with the surface. **Center of pressure**: It is defined as the point of application of total pressure acting on the surface of object immersed in the fluid.	02 Marks 02 Marks
	c)	**Explain construction and working of orifice meter.** **Construction:** The main parts of an orifice flow meter are as follows: 1. A stainless steel orifice plate which is held between flanges of a pipe carrying the fluid whose flow rate is being measured. 2. It should be noted that for a certain distance before and after the orifice plate fitted between the flanges, the pipe carrying the fluid should be straight in order to maintain laminar flow conditions. 3. Openings are provided at two places 1 and 2 for attaching a differential pressure sensor (**U-tube manometer**, differential pressure gauge etc) as shown in the diagram. **Working of Orifice Meter** 1. The detail of the fluid movement inside the pipe and orifice plate has to be understood. 2. The fluid having uniform cross section of flow converges into the orifice plate's opening in its upstream. When the fluid comes out of the orifice plate's opening, its cross section is minimum and uniform for a particular distance and then the cross section of the fluid starts diverging in the downstream. 3. At the upstream of the orifice, before the converging of the fluid takes place, the pressure of he fluid (P1) is maximum. As the fluid starts converging, to enter the orifice opening its pressure drops. When the fluid comes out of the orifice opening, its pressure is minimum (p2) and this minimum pressure remains constant in the minimum cross section area of fluid flow at the downstream.	02 Marks (Const / working)

4. This minimum cross sectional area of the fluid obtained at downstream from the orifice edge is called **VENA-CONTRACTA.**
5. The differential pressure sensor i.e. U- tube manometer attached between points 1 and 2 records the pressure difference (P1 – P2) between these two points which can be used to determine the flow rate of the fluid through the pipe when calibrated.



02 Marks sketch

d) **State and explain Bernoulii's theorem. Obtain Bernoulli's equation.**

"For a perfect incompressible liquid, flowing in a continuous stream, the total energy of a particle remains the same, while the particle moves from one point to another."

This statement is based on the assumption that there are no losses due to friction in the pipe. Mathematically,

$$\frac{P}{\rho g} + \frac{v^2}{2g} + z = Constant$$

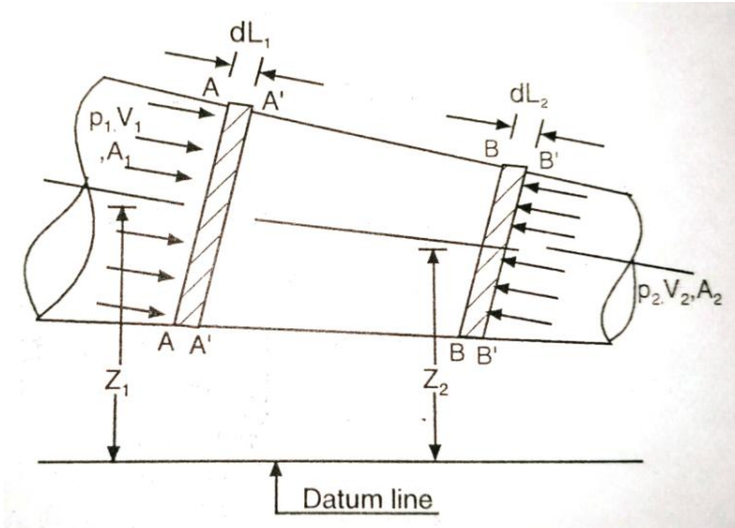
01 Marks statement

where,

z = Potential Energy

$v^2/2g$ = Kinetic Energy

$P/\rho g$ = Pressure Energy

		Derivation of Bernoulli"s equation:  Let us consider two sections **AA** and **BB** of the pipe and assume that the pipe is running full and there is a continuity of flow between the two sections. Let, z_1= Height of **AA** above the datum P_1= Pressure at **AA** v_1= Velocity of liquid at **AA** a_1= Cross sectional area of the pipe at **AA**, and z_2, P_2, v_2, a_2= Corresponding values at **BB** Let the liquid between the two sections **AA** and **BB** move to **A'A'** and **B'B'** through very small lengths dl_1 and dl_2 as shown in fig. This movement of liquid between **AA** and **BB** is equivalent to the movement of the liquid between **AA** and **A'A'** to **BB** and **B'B'**, the remaining liquid between **A'A'** and **BB** being unaffected. Let, *W* be the weight of the liquid between **AA** and **A'A'**. Since the flow is continuous, therefore $W = \rho g a_1 dl_1 = \rho g a_2 dl_2$ or $a_1.dl_1 = \frac{W}{\rho g}$ Similarly, $a_2.dl_2 = \frac{W}{\rho g}$ $\therefore a_1 dl_1 = a_2.dl_2$ We know that the work done by pressure at **AA**, in moving the liquid to **A'A'** $= Force * Distance = P_1.a_1.dl_1$ Similarly, the work done by pressure at **BB**, in moving the liquid to **B'B'** $= -P_2.a_2.dl_2$	01 Marks Sketch Derivation 02 Mark

Total work done by the pressure

$= P_1.a_1.dl_1 - P_2.a_2.dl_2$

$= P_1.a_1.dl_1 - P_2.a_1.dl_1$

$= a_1.dl_1(P_1 - P_2)$

$$= \frac{W}{\rho g}(P_1 - P_2)$$

Loss of potential energy = $W(z_1 - z_2)$

and again in Kinetic Energy = $W(v_2^2/2g - v_1^2/2g) = \frac{W}{2g}(v_2^2 - v_1^2)$

We know that, Loss of potential energy + Work done by pressure = Gain in kinetic energy

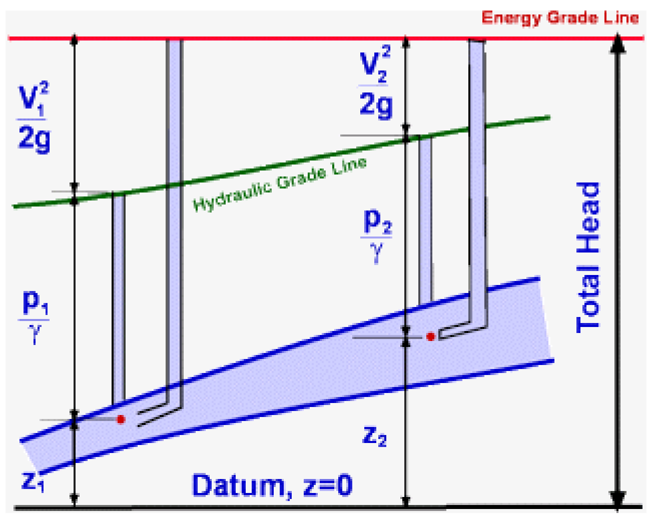
$$\therefore W(z_1 - z_2) + \frac{W}{\rho g}(P_1 - P_2) = \frac{W}{2g}(v_2^2 - v_1^2)$$

$$(z_1 - z_2) + \frac{P_1}{\rho g} - \frac{P_2}{\rho g} = \frac{v_2^2}{2g} - \frac{v_1^2}{2g}$$

$$\therefore z_1 + \frac{v_1^2}{2g} + \frac{P_1}{\rho g} = z_2 + \frac{v_2^2}{2g} + \frac{P_2}{\rho g}$$

This is Bernoulli's Equation.

e) Define Hydraulic gradient line and Total energy line.



Hydraulic Gradient Line and Total Energy Line are the graphical representation for the longitudinal variation in piezometric head and total head.

Consider two points 1 and 2 in a pipe line having 'l' meters apart with the reference to this potential datum line, z1, p1/w and $v^2/2g$ represent datum head, pressure head, velocity head at section 1. Similarly the corresponding values at 2.

Hydraulic gradient line (HGL): The sum of potential and pressure head.ie, [z+p/w] at any point is called the piezometric head. If a line joining the piezometric levels at varies points, the lines so obtain

2 Marks for each point,

is called hydraulic gradient line (HGL).

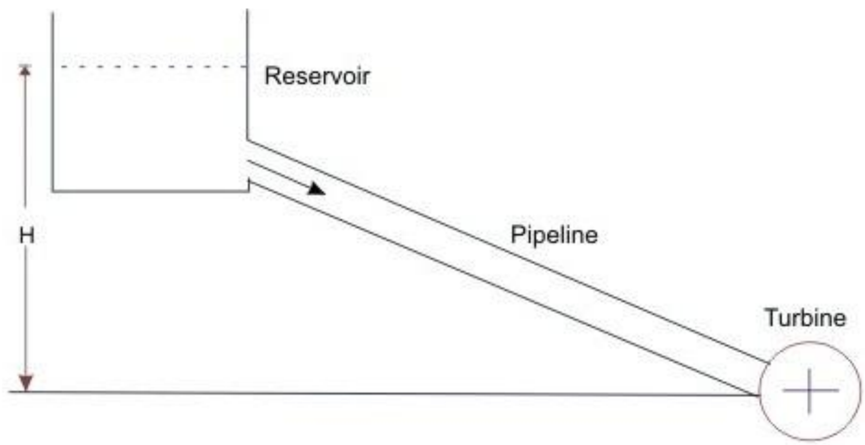
Total energy gradient line (TEL): The sum of potential head, pressure head and velocity head is known as total head. If a line joining the total heads at various points, the line so obtained is called total energy gradient line (TEL).

f) **Explain the concept of power transmission through pipes.**

In certain cases, hydraulic power is transmitted by conveying fluid through a pipeline. For example, as shown in figure below, water from a reservoir at a high altitude is often conveyed by a pipeline to an impulse hydraulic turbine in a hydroelectric power station. Thus the hydrostatic head of water or power is transmitted by the pipeline. During this transmission, certain amount head is lost in friction.

Explanation – 2 M.

Sketch – 2M.



Let us analyze the efficiency of power transmission.

If potential head of water in reservoir = H

Head available at the pipe exit, He = H – hf

Where hf is head loss due to friction in the pipeline.

$$hf = f\,l\,Q^2 / 3d^5$$

Assuming all the coefficients constant,

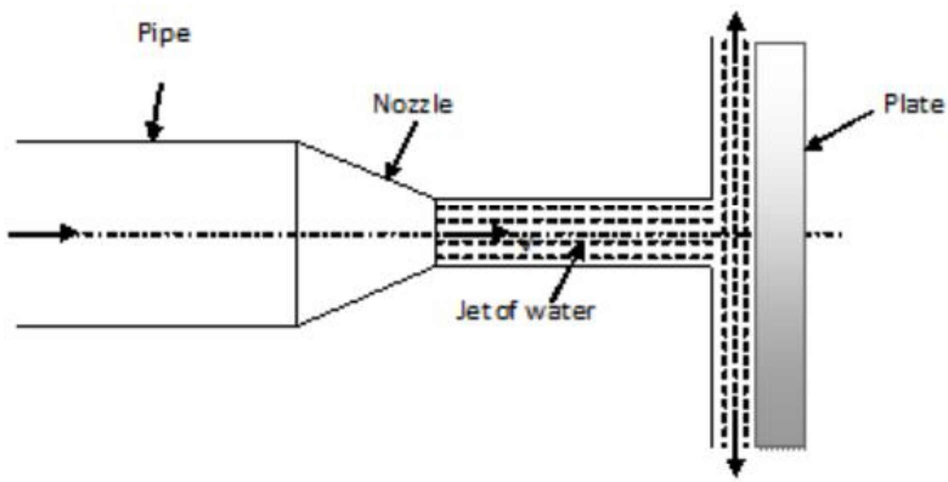
$$hf = R\,Q^2$$

Where R is constant

Power available at the exit of the pipeline,

$$P = \rho\,g\,Q\,He = \rho\,g\,Q\,(H - hf) = \rho\,g\,Q\,(H - R\,Q^2)$$

This is actual amount of power transmitted at the exit of pipeline.

4		**Attempt any TWO of the following**:	
	a)	**Obtain an expression for force exerted by jet of water on fixed vertical plate.** **Force exerted by the jet on a stationary vertical plate:** Consider a jet of water coming out from the nozzle strikes the vertical plate.  Let V = velocity of jet, d = diameter of the jet, a = area of x – section of the jet The force exerted by the jet on the plate in the direction of jet. Fx = Rate of change of momentum in the direction of force Rate of change of momentum in the direction of force = initial momentum – final momentum / time = mass x initial velocity – mass x final velocity / time = mass/time (initial velocity – final velocity) = mass/sec x (velocity of jet before striking mass/sec x (velocity of jet before striking – final velocity of jet after striking) $= \rho aV\ (V - 0) = \rho aV^2$ This is force exerted by the jet on a vertical plate.	Explanation 02 Mark Sketch 02 Mark Expression 04 Mark

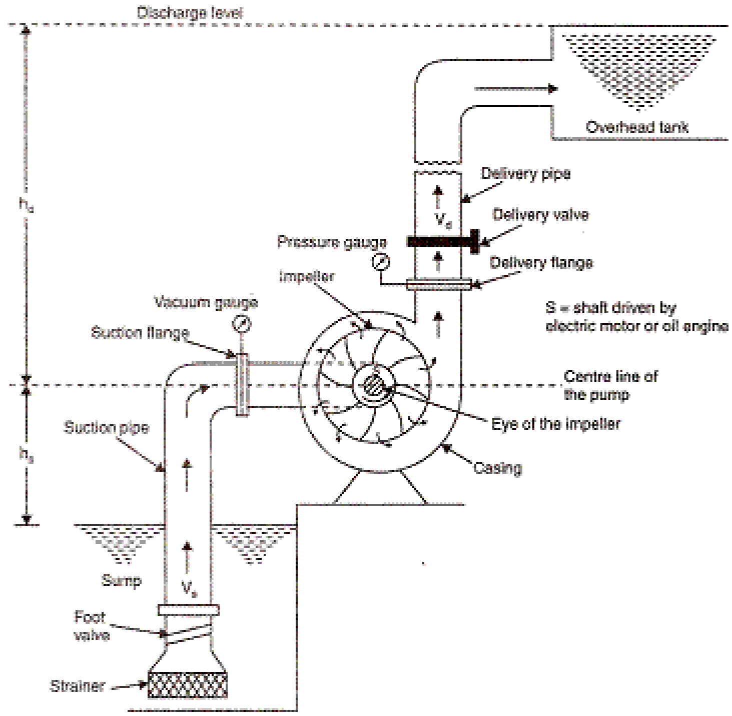
b) **Differentiate between Impulse and Reaction turbine.**

Impulse Turbine	Reaction Turbine
1. All the available energy of the fluid is converted into kinetic energy by an efficient nozzle that forms a free jet.	1. Only a portion of the fluid energy is transformed into kinetic energy before the fluid enters the turbine runner.
2. The jet is unconfined and at atmospheric pressure throughout the action of water on the runner, and during its subsequent flow to the tail race.	2. Water enters the runner with an excess pressure, and then both the velocity and pressure change as water passes through the runner.
3. Blades are only in action when they are in front of the nozzle.	3. Blades are in action all the time.
4. Water may be allowed to enter a part or whole of the wheel circumference.	4. Water is admitted over the circumference of the wheel.
5. The wheel does not run full and air has free access to the buckets.	5. Water completely fills the vane passages throughout the operation of the turbine.
6. Casing has no hydraulic function to perform; it only serves to prevent splashing and to guide the water to the tail race.	6. Pressure at inlet to the turbine is much higher than the pressure at outlet ; unit has to be sealed from atmospheric conditions and, therefore, casing is absolutely essential.
7. Unit is installed above the tail race.	7. Unit is kept entirely submerged in water below the tail race.
8. Flow regulation is possible without loss.	8. Flow regulation is always accompanied by loss.
9. When water glides over the moving blades, its relative velocity either remains constant or reduces slightly due to friction.	9. Since there is continuous drop in pressure during flow through the blade passages, the relative velocity does increase.

08 points 01 for each

c) **Explain the construction and working of centrifugal pump.**

Centrifugal pump raises liquid from a lower level to a higher level by the action of centrifugal force. The pressure head developed by centrifugal action is entirely due to the velocity imparted to the liquid by the rotating impellor. Therefore it is also known as roto-dynamic pump.



Sketch 02 Marks

Construction of a centrifugal pump: It consists of following main parts.

1) Impellor: It consists of number backwardly curved vanes. Impellor is mounted on a shaft which is connected to the shaft of a prime mover.
2) Casing: Casing is air tight passage surrounding the impellor. As water passes through the casing, kinetic energy is converted into pressure energy before water leaves and enters the delivery pipe.
3) Suction pipe: It is a pipe whose upper end is connected with the pump on suction side and the lower end is submerged in the source of liquid.
4) Foot valve with Strainer: A foot valve is one way valve which is fitted at the lower end of the suction pipe. The lower end of the pipe is also is fitted with a strainer which acts as a filter to prevent the entry of foreign unwanted matter in the suction pipe. Foot valve helps the pump in starting which otherwise priming.
5) Delivery pipe: The lower end of the pipe is connected to the outlet of the pump and pipe takes water up to the required head and then delivers it.
6) Prime mover: It is used to rotate the impellor of the pump. Usually an electric motor is provided for this purpose. The impellor shaft is coupled with the motor shaft.

Construction 04 Marks

Working 02 Marks

Working of centrifugal pump:

To start the pump, the suction pipe, casing and portion of the delivery pipe up to regulating valve is filled with liquid to be pumped so that no air pocket is left. The delivery pipe is kept closed and prime mover is started to rotate the impellor. As the impellor starts rotating, it imparts centrifugal head to the liquid. Low pressure is developed at the center of the impellor. This causes the liquid in the suction pipe to rush into the eye of the pump. The liquid then progressively acquires a high velocity. When the impellor attains its normal speed the delivery valve is opened and continuous supply of liquid is obtained to a certain desired height.

5 a)

Q. 5 (a) 4 Marks

$S = 1.1$

Area $= \frac{b \times h}{2}$ $\quad I_G = \frac{bh^3}{36}$

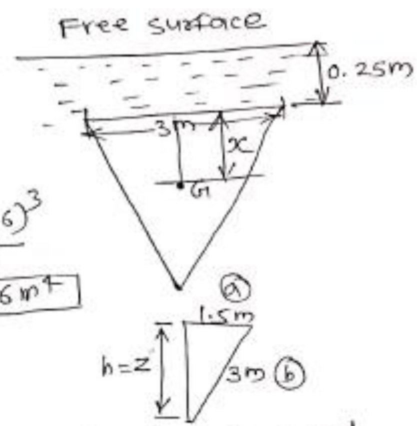
$x = \frac{h}{3}$ $\quad I_o = \frac{bh^3}{12}$

$b = 3\,m$ $\quad I_G = \frac{3 \times (2.6)^3}{36}$

$h = 2.6\,m$ $\quad \boxed{I_G = 1.4646\,m^4}$

$\therefore A = \frac{b \times h}{2} = \frac{3 \times 2.6}{2}$

$\boxed{A = 3.9\,m^2}$



$\therefore$ z is determined by Pythagoras theoram

$b^2 = a^2 + z^2$

$z^2 = b^2 - a^2$

$z = \sqrt{b^2 - a^2}$

$z = \sqrt{9 - 2.25}$

$\boxed{z = 2.6\,m}$

Sp. gravity $s = 1.1$

$\therefore \rho = 1100\,kg/m^3$

$\boxed{\bar{h} = 0.25 + \frac{h}{3} = 1.1166\,m}$

Total pressure

$F = \rho g A \bar{h}$

$= 1100 \times 9.81 \times 3.9 \times 1.1166$

$\boxed{F = 46991.99\,N}$ — 2 marks

centre of pressure

$h^* = \frac{I_G}{A\bar{h}} + \bar{h}$

$h^* = \left(\frac{1.4646}{3.9 \times 2.6}\right) + 1.1166$

$\boxed{h^* = 1.2610\,m}$ — 2 marks

04 Marks

5 b) **Classification of turbines**

The hydraulic turbines are classified according to the type of energy available at the inlet of the turbine, direction of flow through the vanes, head at the inlet of the turbine and specific speed of the turbines. Thus the followings are the important classification of the turbines :

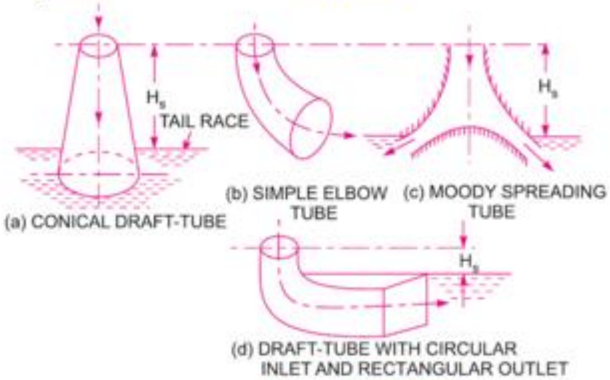
1. According to the type of energy at inlet :
   (*a*) Impulse turbine, and (*b*) Reaction turbine.
2. According to the direction of flow through runner :
   (*a*) Tangential flow turbine, (*b*) Radial flow turbine,
   (*c*) Axial flow turbine, and (*d*) Mixed flow turbine.
3. According to the head at the inlet of turbine :
   (*a*) High head turbine, (*b*) Medium head turbine, and
   (*c*) Low head turbine.
4. According to the specific speed of the turbine :
   (*a*) Low specific speed turbine, (*b*) Medium specific speed turbine, and
   (*c*) High specific speed turbine.

04 Marks

c) **Types of draft tubes**

Types of Draft-Tubes. The following are the important types of draft-tubes which are commonly used :

1. Conical draft-tubes,
2. Simple elbow tubes,
3. Moody spreading tubes, and
4. Elbow draft-tubes with circular inlet and rectangular outlet.



Types of draft-tubes.

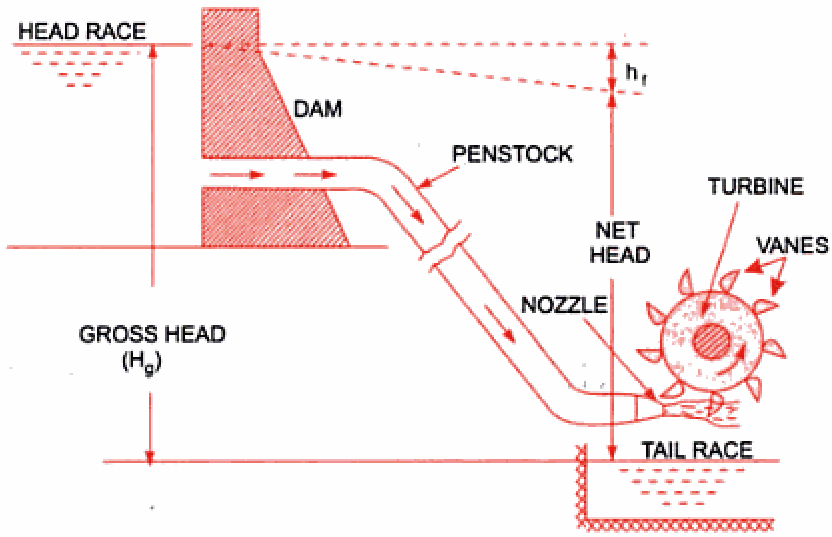
04 Marks

d) **Hydraulic power plant**

The main components of hydraulic power plant are (*i*) The storage system. (*ii*) Conveying system (*iii*) Hydraulic turbine with control system and (*iv*) Electrical generator

The storage system consists of a reservoir with a dam structure and the water flow control in terms of sluices and gates etc. The reservoir may be at a high level in the case of availability of such a location. In such cases the potential energy in the water will be large but the quantity of water available will be small. The conveying system may consist of tunnels, channels and steel pipes called penstocks. Tunnels and channels are used for surface conveyance. Penstocks are pressure pipes conveying the water from a higher level to a lower level under pressure. The penstock pipes end at the flow control system and are connected to nozzles at the end. The nozzles convert the potential energy to kinetic energy in free water jets. These jets by dynamic action turn the turbine wheels. In some cases the nozzles may be replaced by guide vanes which partially convert potential energy to kinetic energy and then direct the stream to the turbine wheel, where the remaining expansion takes place, causing a reaction on the turbine runner. Dams in river beds provide larger quantities of water but with a lower potential energy.

Explanation 2 marks



Layout of a hydro-eletric power plant.

sketch 2 marks

e) **Cavitation:**

CAVITATION

Cavitation is defined as the phenomenon of formation of vapour bubbles of a flowing liquid in a region where the pressure of the liquid falls below its vapour pressure and the sudden collapsing of these vapour bubbles in a region of higher pressure. When the vapour bubbles collapse, a very high pressure is created. The metallic surfaces, above which these vapour bubbles collapse, is subjected to these high pressures, which cause pitting action on the surface. Thus cavities are formed on the metallic surface and also considerable noise and vibrations are produced.

Cavitation includes formation of vapour bubbles of the flowing liquid and collapsing of the vapour bubbles. Formation of vapour bubbles of the flowing liquid take place only whenever the pressure in any region falls below vapour pressure. When the pressure of the flowing liquid is less than its vapour pressure, the liquid starts boiling and vapour bubbles are formed. These vapour bubbles are carried along with the flowing liquid to higher pressure zones where these vapours condense and bubbles collapse. Due to sudden collapsing of the bubbles on the metallic surface, high pressure is produced and metallic surfaces are subjected to high local stresses. Thus the surfaces are damaged.

phenomenon 2 marks

In the case of pumps, the pressure is lowest at the inlet and cavitation damage occurs at the inlet. For cavitation to occur the pressure at the location should be near the vapour pressure at the location.

prevention 2 marks

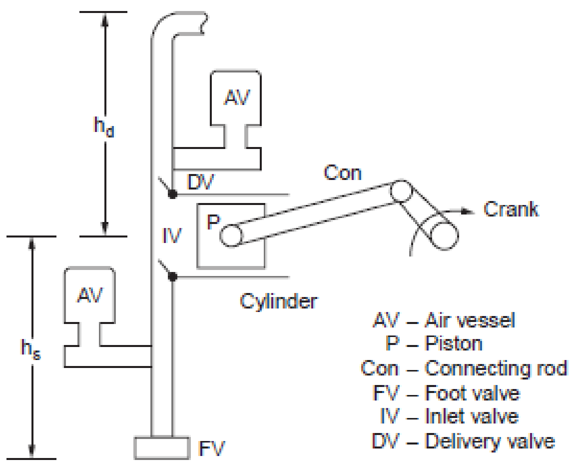
Applying the energy equation between sump surface and the pump suction,

$$\frac{P_s}{\gamma} + \frac{V_s^2}{2g} + Z = \frac{P_a}{\gamma} - h_{fs}$$

where Z is the height from sump surface and pump suction. The other terms have their usual significance. The term h_{fs} should include all losses in the suction line.

Net Positive Suction Head (NPSH) is defined as the available total suction head at the pump inlet above the head corresponding to the vapour pressure at that temperature.

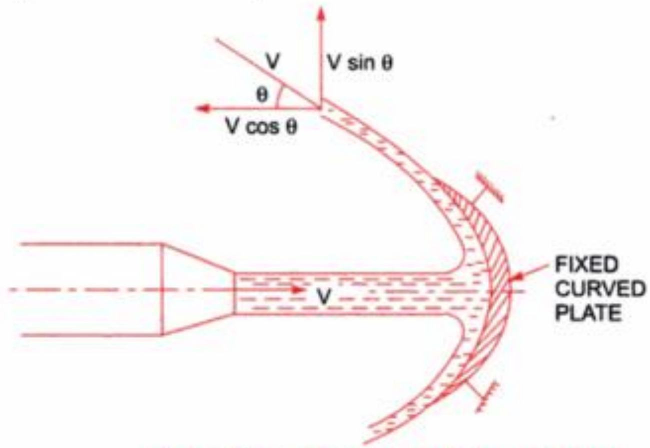
The height of suction, the frictional losses in the suction line play an important role for avoiding cavitation at a location. When pumps designed for one location is used at another location, atmospheric pressure plays a role in the onset of cavitation. Some authors use the term "suction specific speed, 'n_s'". Where H in the general equation is substituted by $NPSH$.

	f	**Reciprocating pump (construction 2 marks working 2 marks)** The main components are: 1. Cylinder with suitable valves at inlet and delivery. 2. Plunger or piston with piston rings. 3. Connecting rod and crank mechanism. 4. Suction pipe with one way valve. 5. Delivery pipe. 6. Supporting frame. 7. Air vessels to reduce flow fluctuation and reduction of acceleration head and friction head. A diagramatic sketch is shown  Diagramatic view of single acting reciprocating pump The action is similar to that of reciprocating engines. As the crank moves outwards, the piston moves out creating suction in the cylinder. Due to the suction water/fluid is drawn into the cylinder through the inlet valve. The delivery valve will be closed during this outward stroke. During the return stroke as the fluid is incompressible pressure will developed immediately which opens the delivery valve and closes the inlet valve. During the return stroke fluid will be pushed out of the cylinder against the delivery side pressure. The functions of the air vessels will be discussed in a later section. The volume delivered per stroke will be the product of the piston area and the stroke length. In a single acting type of pump there will be only one delivery stroke per revolution. Suction takes place during half revolution and delivery takes place during the other half. As the piston speed is not uniform (crank speed is uniform) the discharge will vary with the position of the crank.	**construction 2 marks** **working** **2 marks**

6	A i)	**Impact of jet on fixed curved plate at centre**	

Jet strikes the curved plate at the centre. Let a jet of water strikes a fixed curved plate at the centre as shown in Fig. The jet after striking the plate, comes out with the same velocity if the plate is smooth and there is no loss of energy due to impact of the jet, in the tangential direction of the curved plate. The velocity at outlet of the plate can be resolved into two components, one in the direction of jet and other perpendicular to the direction of the jet.

Component of velocity in the direction of jet = $-V\cos\theta$.



Jet striking a fixed curved plate at centre.

complete derivation 4 marks

(– ve sign is taken as the velocity at outlet is in the opposite direction of the jet of water coming out from nozzle).

Component of velocity perpendicular to the jet = $V\sin\theta$

Force exerted by the jet in the direction of jet,

$$F_x = \text{Mass per sec} \times [V_{1x} - V_{2x}]$$

where V_{1x} = Initial velocity in the direction of jet = V

V_{2x} = Final velocity in the direction of jet = $-V\cos\theta$

$\therefore$ $$F_x = \rho aV[V-(-V\cos\theta)] = \rho aV[V+V\cos\theta]$$
$$= \rho aV^2[1+\cos\theta]$$

Similarly, $$F_y = \text{Mass per sec} \times [V_{1y} - V_{2y}]$$

where V_{1y} = Initial velocity in the direction of $y = 0$

V_{2y} = Final velocity in the direction of $y = V\sin\theta$

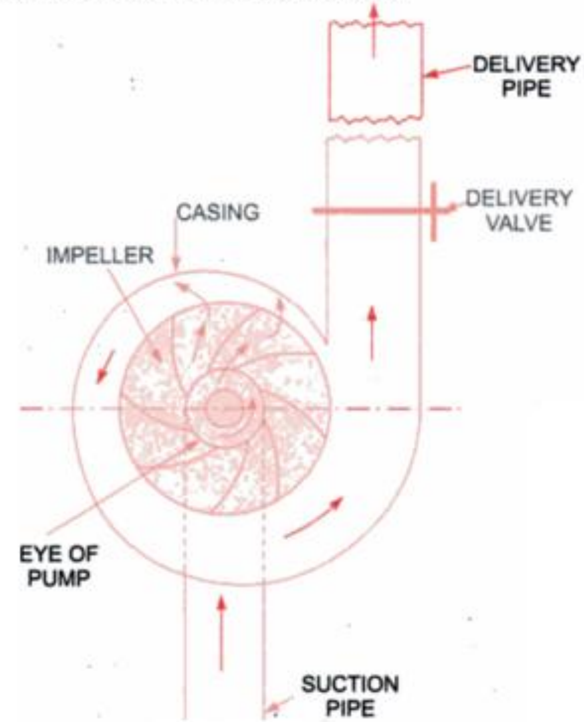
$\therefore$ $$F_y = \rho aV[0 - V\sin\theta] = -\rho aV^2\sin\theta$$

–ve sign means the force is acting in the downward direction. In this case the angle of deflection of the jet $= (180° - \theta)$

	ii)	**Turbine Efficiency** **1. Hydraulic efficiency :** It is defined as the ratio of the power produced by the turbine runner and the power supplied by the water at the turbine inlet. $$\eta_H = \frac{\text{Power produced by the runner}}{\rho\, Q\, g\, H}$$ where Q is the volume flow rate and H is the net or effective head. Power produced by the runner is calculated by the Euler turbine equation $P = Q\rho\ [u_1\ V_{u1} - u_2\ V_{u2}]$. This reflects the runner design effectiveness. **2. Volumetric efficiency :** It is possible some water flows out through the clearance between the runner and casing without passing through the runner. Volumetric efficiency is defined as the ratio between the volume of water flowing through the runner and the total volume of water supplied to the turbine. Indicating Q as the volume flow and ΔQ as the volume of water passing out without flowing through the runner. $$\eta_v = \frac{Q - \Delta Q}{Q}$$ To some extent this depends on manufacturing tolerances. **3. Mechanical efficiency :** The power produced by the runner is always greater than the power available at the turbine shaft. This is due to mechanical losses at the bearings, windage losses and other frictional losses. $$\eta_m = \frac{\text{Power available at the turbine shaft}}{\text{Power produced by the runner}}$$ **4. Overall efficiency :** This is the ratio of power output at the shaft and power input by the water at the turbine inlet. $$\eta_0 = \frac{\text{Power available at the turbine shaft}}{\rho\, QgH}$$ Also the overall efficiency is the product of the other three efficiencies defind $$\eta_0 = N_H\ N_m N_v$$	**four definitions 4 marks**
	b ii)	**Slip** There can be leakage along the valves, piston rings, gland and packing which will reduce the discharge to some extent. This is accounted for by the term slip. Percentage of slip $= \dfrac{Q_{th} - Q_{ac}}{Q_{th}} \times 100$ Where Q_{th} is the theoretical discharge and Q_{ac} is the measured discharge. Coefficient of discharge, $C_d = \dfrac{Q_{ac}}{Q_{th}}$ It has been found in some cases that $\mathbf{Q_{ac} > Q_{th}}$, due to operating conditions. In this case the slip is called **negative slip**. When the delivery pipe is short or the delivery head is small and the accelerating head in the suction side is high, the delivery valve is found to open before the end of suction stroke and the water passes directly into the delivery pipe. Such a situation leads to negative slip. Theoretical power $= mg(h_s + h_d)\ W$ where m is given by $Q \times \delta$.	**definition 2 marks** **types 2 marks**

Casings of centrifugal pump:

(*a*) **Volute Casing.** Fig (*a*) shows the volute casing, which surrounds the impeller. It is of spiral type in which area of flow increases gradually. The increase in area of flow decreases the velocity of flow. The decrease in velocity increases the pressure of the water flowing through the casing. It has been observed that in case of volute casing, the efficiency of the pump increases slightly as a large amount of energy is lost due to the formation of eddies in this type of casing.

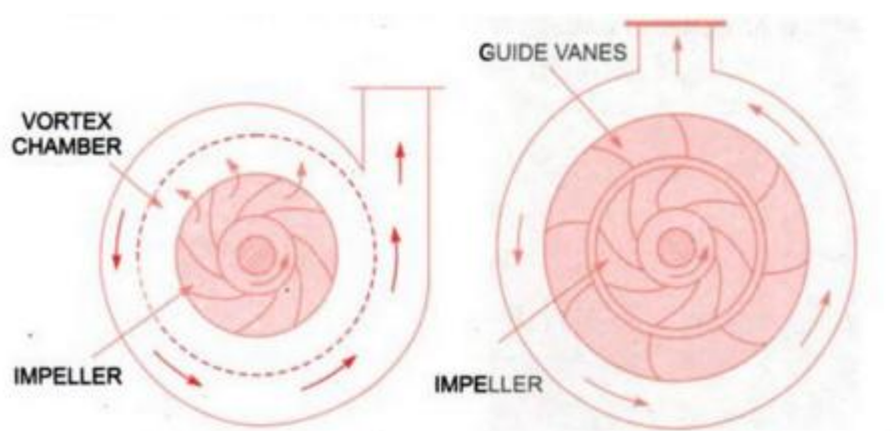


(*a*) **Volute Casing.**

sketches 2 marks explanation 2 marks

(*b*) **Vortex Casing.** If a circular chamber is introduced between the casing and the impeller as shown in Fig. (*b*) the casing is known as Vortex Casing. By introducing the circular chamber, the loss of energy due to the formation of eddies is reduced to a considerable extent. Thus the efficiency of the pump is more than the efficiency when only volute casing is provided.

(*c*) **Casing with Guide Blades.** This casing is shown in Fig. (*c*) in which the impeller is surrounded by a series of guide blades mounted on a ring which is known as diffuser. The guide vanes are designed in which a way that the water from the impeller enters the guide vanes without stock. Also



(b) VORTEX CASING (*c*) CASING WITH GUIDE BLADES the area of the guide vanes increases, thus reducing the velocity of flow through guide vanes and consequently increasing the pressure of water. The water from the guide vanes then passes through the surrounding casing which is in most of the cases concentric with the impeller as shown in Fig. (c).

C

Indicator diagram :

Effect of Acceleration in Suction and Delivery Pipes on Indicator Diagram.

The pressure head due to acceleration in the suction pipe is given by equation as

$$h_{as} = \frac{l_s}{g} \times \frac{A}{a_s} \omega^2 r \cos\theta$$

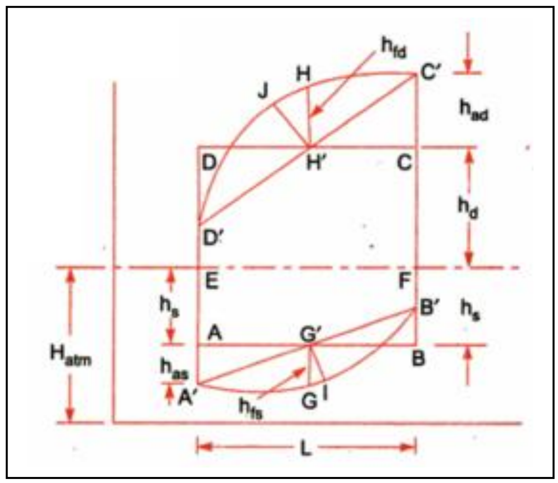
When $\theta = 0°$, $\cos\theta = 1$, and $h_{as} = \frac{l_s}{g} \times \frac{A}{a_s} \omega^2 r$

When $\theta = 90°$, $\cos\theta = 0$, and $h_{as} = 0$

When $\theta = 180°$, $\cos\theta = -1$, and $h_{as} = -\frac{l_s}{g} \times \frac{A}{a_s} \omega^2 r$.

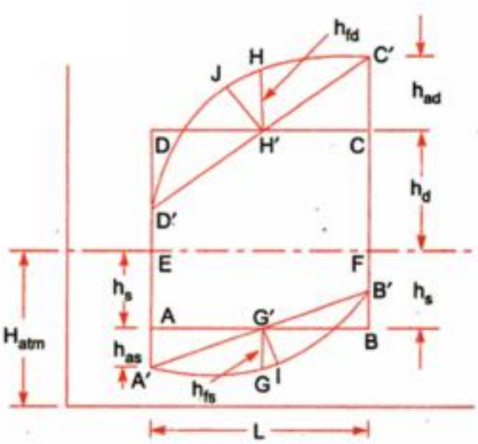
Sketches 2 marks ;

Thus, the pressure head inside the cylinder during suction stroke will not be equal to 'h_s', as was the case for ideal indicator diagram, but it will be equal to the sum of 'h_s' and 'h_{as}'. At the beginning of suction stroke $\theta = 0°$, 'h_{as}' is +ve and hence the pressure head in the cylinder will be $(h_s + h_{as})$ below the atmospheric pressure head. At the middle of suction stroke $\theta = 90°$ and $h_{as} = 0$ and hence pressure head in the cylinder will be h_s below the atmospheric pressure head. At the end of suction stroke, $\theta = 180°$ and h_{as} is – ve and hence the pressure head in the cylinder will be $(h_s - h_{as})$ below the atmospheric pressure head. For suction stroke, the indicator diagram will be shown by $A'GB'$. Also the area of $A'AG$ = Area of BGB'.



Explanation acceleration head 3 marks

Similarly, the indicator diagram for the delivery stroke can be drawn. At the beginning of delivery stroke, h_{ad} is +ve and hence the pressure head in the cylinder will be $(h_d + h_{ad})$ above the atmospheric pressure head. At the middle of the delivery stroke, $h_{ad} = 0$ and hence pressure head in the cylinder is equal to h_d above the atmospheric pressure head. At the end of the delivery stroke, h_{ad} is – ve and hence pressure in the cylinder will be $(h_d - h_{ad})$ above the atmospheric pressure head. And thus the indicator diagram for delivery stroke is represented by the line $C'HD'$. Also, the area of $CC'H$ = Area of $DD'H$.

		Effect of Friction in Suction and Delivery Pipes on Indicator Diagram. The loss of head due to friction in suction and delivery pipes is given by equations as $$h_{fs} = \frac{4fl_s}{d_s \times 2g} \times \left(\frac{A}{a_s}\omega r \sin\theta\right)^2 \text{ and } h_{fd} = \frac{4fl_d}{d_d \times 2g} \times \left(\frac{A}{a_d}\omega r \sin\theta\right)^2.$$ It is clear from the above equations that the variation of h_{fs} or h_{fd} is parabolic with θ. During the suction or delivery stroke, the pressure head inside the cylinder will change as given below : (*i*) At the beginning of the suction or delivery stroke, $\theta = 0$ and hence $\sin\theta = 0$. This means h_{fs} and $h_{fd} = 0$. (*ii*) At the middle of the suction or delivery stroke, $\theta = 90°$ and hence $\sin\theta = 1$. This means $$h_{fs} = \frac{4fl_s}{d_s \times 2g} \times \left(\frac{A}{a_s}\omega r\right)^2 \text{ and } h_{fd} = \frac{4fl_d}{d_d \times 2g} \times \left(\frac{A}{a_d}\omega r\right)^2.$$ the indicator diagram with acceleration and friction in suction and delivery pipes will become as shown in Fig. Area of the indicator diagram $A'GB'C'HD'$ $= $ Area of $A'G'B'C'H'D'$ + Area of parabola $A'GB'$ + Area of parabola $C'HD'$ But area of $A'G'B'C'H'D'$ $=$ Area of $ABCD$ $= (h_s + h_d) \times L$ Area of parabola $A'GB'$ $$= A'B' \times \frac{2}{3} \times G'I = \frac{2}{3} \times (A'B' \times G'I)$$ $$= \frac{2}{3} \times (AB \times GG') = \frac{2}{3} \times L' h_{fs}$$ Similarly, area of parabola $C'HD'$ $$= C'D' \times \frac{2}{3} H'J = \frac{2}{3} (C'D' \times H'J)$$ $$= \frac{2}{3} \times (CD \times H'H) = \frac{2}{3}(L \times h_{fd}) = \frac{2}{3} L \times h_{fd}$$  *Effect of acceleration and friction on indicator diagram.*	**Explanation friction head 03 marks**

$\therefore$ Area of indicator diagram

$$= (h_s + h_d) \times L + \frac{2}{3} \times L \times h_{fs} + \frac{2}{3} \times L \times h_{fd}$$

$$= \left(h_s + h_d + \frac{2}{3} h_{fs} + \frac{2}{3} h_{fd} \right) \times L$$

But we know that work done by pump is proportional to the area of the indicator diagram.

$$\therefore \quad \text{Work done by pump per second} \propto \left(h_s + h_d + \frac{2}{3} h_{fs} + \frac{2}{3} h_{fd} \right) \times L$$

$$= KL \left(h_s + h_d + \frac{2}{3} h_{fs} + \frac{2}{3} h_{fd} \right)$$

where K = a constant of proportionality

$$= \frac{\rho g A N}{60}$$
