SUMMER – 15 EXAMINATION

Subject Code: 17411 (FMM) 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 judgment 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. 1 a) Attempt any Six of the following.

i) Dynamic viscosity: (1 Mark)

The dynamic (shear) viscosity of a fluid expresses its resistance to shearing flows, where adjacent layers move parallel to each other with different speeds.

The magnitude F of this force or resistance is found to be proportional to the speed u and the area A of each plate, and inversely proportional to their separation y:

$$F = \mu A \frac{u}{y}.$$

The proportionality factor μ in this formula is the viscosity (specifically, the dynamic viscosity) of the fluid.

Kinematic viscosity: (1 Mark)

The kinematic viscosity (also called "momentum diffusivity") is the ratio of the dynamic viscosity μ to the density of the fluid ρ. It is usually denoted by the Greek letter nu (ν).

$$\nu = \frac{\mu}{\rho}$$

ii) Total pressure: **(1 Mark)**

It is the force exerted by a static fluid on a surface either plane or curved when the fluid comes in contact with the surfaces. This force is always normal to the surface.

Center of pressure: **(1 Mark)**

It is defined as the point of application of the total pressure on the surface.

iii) Laminar flow: **(1 Mark)**

It is the type of flow in which fluid particles move along the well defined paths or stream line and all the stream lines are straight and parallel. Thus the particles move in lamina or layers gliding smoothly over the adjacent layer.

Steady flow: **(1 Mark)**

It is defined as the type of flow in which the fluid characteristics like velocity, pressure, density etc at appoint do not change with time.

iv) Impact of jet: **(2 Marks)**

The liquid comes out in the form of jet from the outlet of the nozzle, which is fitted to a pipe through which the liquid is flowing under pressure. If some plate, which may be fixed or moving, is placed in the path of the jet, a force is exerted by the jet on the plate. This force is called as impact of jet.

v) Bernoulli's theorem: **(1 Mark)**

It states that in a steady, ideal flow of an incompressible fluid, the total energy per unit weight of the fluid at any point or total head remains constant.

$P/w + v^2/2g + z = constant$ **(1 Mark)**

Where P/w….pressure head.

$v^2/2g$… kinetic head

z …… potential head

vi) Advantages of air vessel in reciprocating pump **(Any Two)** **(1 Mark each)**

1. It gives continuous supply of liquid at a uniform rate
2. Saves considerable amount of work in overcoming the frictional resistance in the suction and delivery pipes.
3. Pump can be run at higher speed without separation.

vii) Principle of reaction turbine: **(2 Marks)**

In Reaction turbine the water at the inlet of the turbine possesses kinetic energy as well as pressure energy. As the water flows through the runner, a part of pressure energy is converted into kinetic energy. This causes a reaction to rotate the turbine runner. Thus water through the runner is under pressure. The runner is completely enclosed in an air tight casing and the runner is always full of water.

viii) Priming: **(2 Marks)**

It is defined as the operation in which the suction pipe, casing of the pump and the portion of the delivery pipe up to the delivery valve is completely filled up from outside source with the liquid to be raised by the pump before the starting the pump.

Q. 1b) Attempt any Two of the following

i) Difference between simple manometer and differential manometer

(04 marks, 1 Mark each)

Sr. No.	Simple Manometer	Differential manomater
1	Simple manometers have single column and the other end is open to atmosphere.	Differential manometers have two columns connected two pipes.
2	Simple manometer is used for measuring pressure of a fluid at a point in the pipe	Differential manometer is used for measuring difference of pressure at two points in a pipe or in two different pipes.
3	Simple manometer may or may not require mercury.	This requires at least one manometric fluid i.e. mercury for measuring pressure difference
4	Inverted type design is not possible	Inverted U-tube differential manometer is available.

ii) P= 25 N/cm^2, mm of Hg = ? , mm of water = ?

$P = 25 \times 10^4 = 2.5 \times 10^5\ N/m^2$ or Pa

We know, 760 mm of Hg = 1.01325×10^5 **(1 Mark)**

h in mm of Hg $= [(2.5 \times 10^5) / (1.01325 \times 10^5)] \times 760$

$= 1875.15$ mm of Hg **(1 Mark)**

For water, $\rho = 1000\ Kg/m^3$ **(1 Mark)**

$P = \rho \times g \times h$

h in meters of water = $2.5 \times 10^5 / 1000 \times 9.81$ **(1 Mark)**

= 25.484 m

i) Darcy's equation

$hf = 4\,f\,L\,v^2 / 2\,g\,d$ **(1 Mark)**

where hf – loss of head due to friction **(1 Mark)**

f - Coefficient of friction

L- length of pipe

v- velocity of flow

d- diameter of pipe

Chezi's equation

$V = C\sqrt{m\,i}$ **(1 Mark)**

Where V – velocity of flow **(1 Mark)**

C – Chezy's constant

M – hydraulic mean depth = (Area of flow/ Perimeter) = A / P

i – loss of head per unit length of pipe = hf / L

Q. 2 Attempt any four of the following

a) Concept of Absolute pressure, atmospheric, gauge and vacuum relation between them.

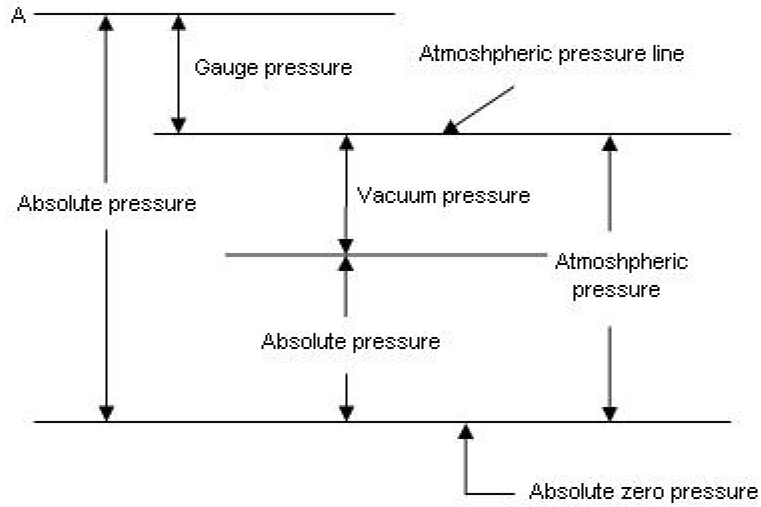
Pressure on a fluid is measured in two different systems. One is absolute zero or complete vacuum. This is called absolute pressure. The other is pressure measured above the atmospheric pressure. It is called as gauge pressure. **(1 Mark)**

Absolute pressure is the pressure measured with reference to absolute zero line.

Gauge pressure is measured above and with reference to atmospheric pressure.

Vacuum pressure is the pressure measured below the atmospheric line **(1 Mark)**

Figure shows the relation between them….



(1 Mark)

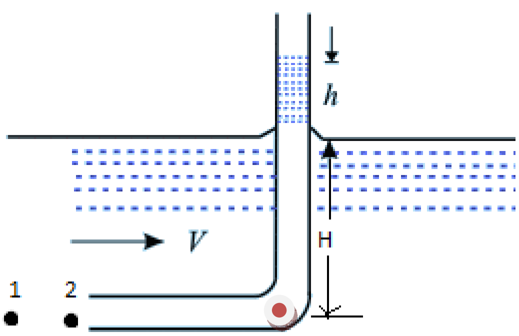
Mathematically, the absolute pressure is given by…

Pabs = Patm ± Pgauge **(1 Mark)**

where +ve sign is for gauge pressure is above atmospheric line and

–ve sign is for pressure is below atmospheric line

b) Derivation for actual velocity of fluid flow for pitot tube.



(1 Mark)

Figure shows a Pitot tube, lower end which is bent through 90^0, is directed in the upstream direction. The liquid rises up in the tube due to the conversion of kinetic energy into pressure energy. The velocity is determined by measuring the rise of liquid in the tube.

Consider two points at the same level in such a way that point 2 is just at the inlet of the Pitot tube and point 1 is far away from the tube.

Let P1 and P2 be the pressure at point 1 and 2 respectively

V1 and V2 be the velocities at point 1 and 2 respectively

H be the depth of tube in the liquid and h be rise of liquid in the tube above free surface.

Applying Bernoulli;s theorem, at point 1 and 2

We get, $P_1 / \rho g + V_1^2 / 2g + Z_1 = P_2 / \rho g + V_2^2 / 2g + Z_2$ **(1 Mark)**

But $Z_1 = Z_2$ and $V_2 = 0$

$P_1 / \rho g = H$ $P_2 / \rho g = h + H$

$H + V_1^2 / 2g = h + H$

$\mathbf{h} = V_1^2 / 2g$

Velocity of liquid $V_1 = \sqrt{2gh}$ **(2 Marks)**

c) d = 7 cm, v = 30 m/s, flat plate angle = 45^0 Normal pressure =? Stationary / moving plate at a velocity 15 m/s

$a = \pi d^2/4 = 0.0038 \text{ m}^2$

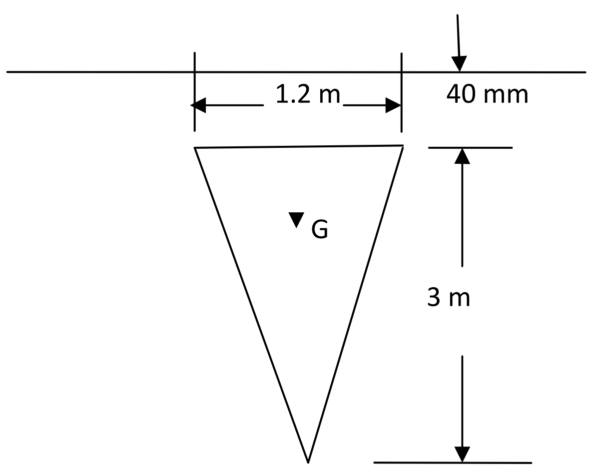
Stationary plate:

Force $F = \rho a V_1^2 = 1000 \times 0.0038 \times (30)^2 = 3420$ N **(2 Marks)**

Moving Plate

Force $F = \rho a (v - u)^2 = 1000 \times 0.0038 \times (30 - 15)^2 = 855$ N **(2 Marks)**

d) Isosceles triangular plate base 'b' = 1.2 m, height 'h' = 3 m vertical, apex is downward, base parallel and 40 mm below free water surface level. Total pressure =? Center of pressure=?



Area 'A' = b x h /2 = 1.2 x 3 / 2 = 1.8 m

Density of water 'ρ' = 1000

Distance of C.G. from free surface of water =

$\bar{h} = x + h/3 = 0.040 + 3/3 = 1.04$ m **(1 Mark)**

Total pressure $F = \rho g A \bar{h} = 1000 \times 9.81 \times 1.8 \times 1.04 = 18364.32$ N **(1 Mark)**

Center of pressure = $h^* = I_G / A\bar{h} + \bar{h}$

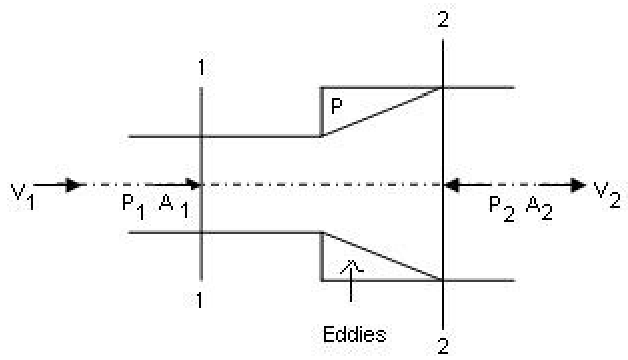
MOI about its C.G. $I_G = b\,h^3/36 = 1.2 \times 3 \times 3 \times 3 / 36 = 0.9\ m^4$ **(1 Mark)**

Center of pressure = $h^* = (0.9 / 1.8 \times 1.04) + 1.04$

$= 1.52$ m **(1 Mark)**

e) Different types of minor losses in flow through pipes (any four)

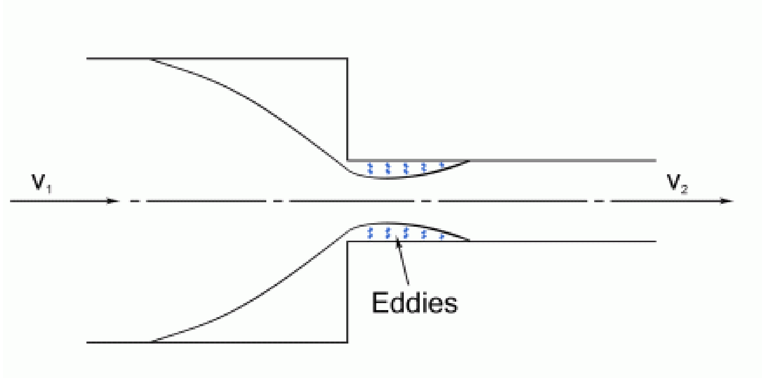
1. **Loss of head due to sudden enlargement** **(1 Mark)**



The Equation gives head loss due to sudden expansion.

$h_c = (V_1 - V_2)^2 / 2g$

2. **Loss of head due to sudden contraction** **(1 Mark)**



The coefficient of Contraction is defined as :

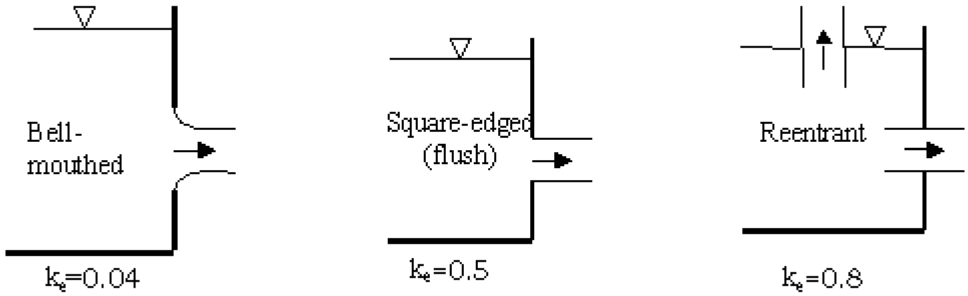
$= \frac{a_C}{a}$

where a_C is the area of the choke and a is the area of the pipe

The head lost is given by:

$$h_L = \frac{v^2}{2g}\left(\frac{1}{C_C} - 1\right)^2 = k \times \frac{v^2}{2g}$$

3. **Loss of head at the entry of a pipe** **(1 Mark)**



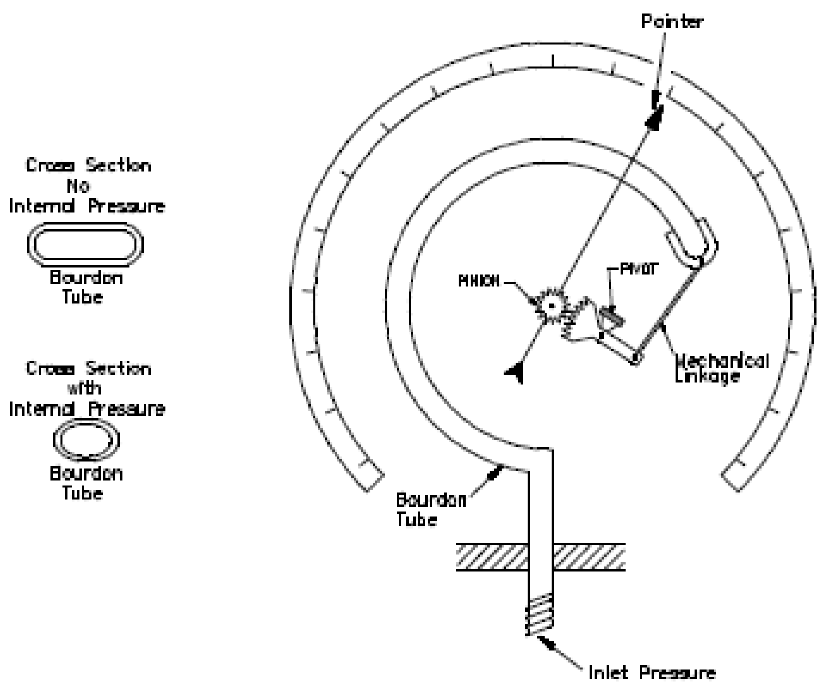
k = loss coefficient which is unit less and is used in the following cases:

Head loss due to entrance: $h = K * V^2 /2g$ values of 'K' for different types of entry are given in figure

4. Loss of head at the exit of a pipe **(1 Mark)**

   Loss of head $h_0 = V^2 / 2 g$
5. Loss of head due to bend in the pipe
6. Loss of head in various pipe fittings

f) Bourdon's pressure gauge:



Sketch: **(2 Marks)**

Construction and working: **(2 Marks)**

- The most commonly used mechanical gauge is Bourdon type pressure gauge.
- It is a stiff, flattened metal tube bent into a circular shape.

- The fluid whose pressure is to be measured inside the tube.
- One end of the tube is fixed and other end is free to move inward or outward.
- The inward and outward movement of free end moves a pointer, though a linkage and gear arrangement, a dial graduated in pressure unit i.e. bar.
- The movement of the free end of the Bourdon tube is proportional to the difference between the external atmospheric pressure and internal fluid pressure.
- Bourdon gauge records the gauge pressure which is the different between fluid pressure and outside atmospheric pressure.
- As soon as the pressure is applied the shape of elliptic spring tube becomes circular. Due to this the closed end moves, the movement of which is given to a sector and pinion through a linkage. Pinion mounted on the shaft rotates the pointer over the scale to indicate the pressure

Q.3 (04 Marks for any four difference)

a)

Impulse Turbine	Reaction Turbine
1. The available water energy is converted into kinetic energy	1. Only a part of available energy of water is converted into kinetic energy.
2. The water flows through the nozzle and strikes on the buckets, which are fixed to the outer periphery of the wheel.	2. The water is guided by guide blades to flow over the moving curved vanes.
3. Water strikes on the bucket with kinetic energy.	3. Water glides over the moving curved vanes with pressure energy.
4. The pressure of flowing water is constant and is equal to atmospheric pressure.	4. **The pressure goes on decreasing as water passes through the turbine**
5. It is not essential that wheel should run full.	5. Wheel should always run full and kept full of water.
6. Water is admitted over a part of circumference of the wheel.	6. Water must be admitted over whole circumference of wheel.
7. It is possible to regulate the flow of water without loss.	7. It is not possible to regulate flow of water without loss.
8. Work is done purely by change in kinetic energy of jet.	8. Work is done by partly change in kinetic energy and partly by change in pressure energy.
9. Example is Pelton wheel turbine.	9. Examples are Francis, Kaplan, Propeller turbine.

Q 3 b)

Q.3
(b) Given Data,

$D = 90\,cm = 0.9\,m$

$D_1 = 40\,cm = 0.40\,m$

$\boxed{\text{Assuming } \eta_{hyd} = 80\%}$

For Francis turbine $\beta = 90^\circ$

$\therefore V_{w_1} = 0, \quad V_f = V_{f_1}$

$V_f = 12\,m/sec$

Diameter of runner to inside,

velocity at inlet, $u = \dfrac{\pi D N}{60}$

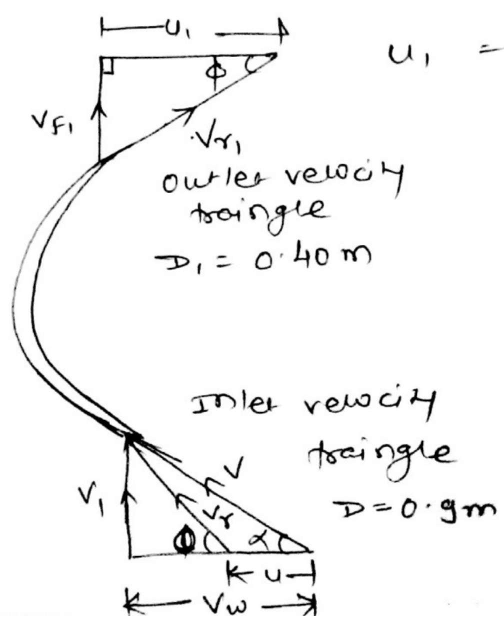
$= \dfrac{\pi \times 0.9 \times 420}{60}$

$= 19.8\,m/s$

velocity at outlet, $u_1 = \dfrac{\pi D_1 N}{60}$

$= \dfrac{\pi \times 0.40 \times 420}{60}$

$u_1 = 8.796\,m/s$



Hydraulic efficiency

$\eta_{hyd} = \dfrac{V_w u \pm V_{w_1} u_1}{gH}$

$V_{w_1} = 0$

$\therefore \eta_{hyd} = \dfrac{V_w u}{gH}$

$$0.8 = \frac{V_w \times 19.8}{9.81 \times 60}$$

$$V_w = 23.78 \text{ m/s}$$

From Inlet velocity triangle,

$$\tan\theta = \frac{V_F}{V_w - u} = \frac{12}{23.78 - 19.8}$$

$$= 3.01$$

$$\theta = 71.65^\circ$$

From outlet velocity traingle

$$\tan\phi = \frac{V_{F1}}{u_1} = \frac{12}{8.796}$$

$$\phi = 53.758^\circ$$

Q 3 c) Pelton wheel:-

(Sketch 02 marks, Explanation 02 marks)

The pelton wheel is a tangential flow impulse turbine. The water strikes the bucket along the tangent of the runner. The main parts of the pelton wheel are:

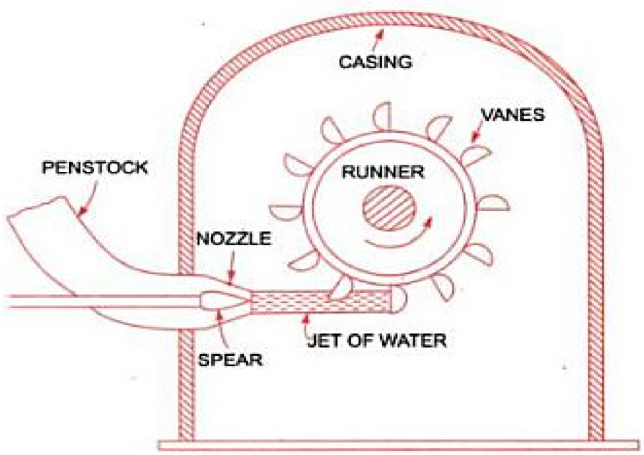


Fig. 18.4 *Pelton turbine.*

Nozzle and flow regulating arrangement:-The amount of water striking the buckets of the runner is controlled by providing a spear in the nozzle. The spear is a conical needle which is operated either by hand wheel or automatically in an axial direction depending upon the size of the unit. when the spear is pushed forward into the nozzle the amount of water striking the runner is reduced. On the other hand if the spear is pushed back, the amount of water striking the runner is increases.

Runner and Buckets:- It consists of a circular disc on the periphery of which a number of buckets evenly spaced are fixed. The shape of the bucket is double hemispherical cup or bowl. Each bucket is divided into two symmetrical parts by a dividing wall which is known as splitter.

Casing:-the function of the casing is to prevent the splashing of the water and to discharge water **to tail** race. It also acts as safeguard against accidents. It is made of cast iron or fabricated steel plates. The casing of the Pelton wheel does not perform any hydraulic function.

Breaking Jet: - when the nozzle is completely closed by moving the spear in the forward direction, the amount of water striking the runner reduces to zero. But the runner due to inertia goes on revolving for a long time. To stop the runner in a short time, a small nozzle is provided which directs the jet of water on the back of the vanes. The jet of water is called breaking jet.

Q 3 d)

Sol.: $\because$ Head of water H = 40 m. Velocity of jet $v = C_v\sqrt{2gH}$.

$\because$ C_v is not given, therefore assume $C_v = 1$.

$$\therefore \quad v = \sqrt{2gH} = \sqrt{2 \times 9.81 \times 40}$$

$$\therefore \quad v = 28.014 \text{ m/sec.}$$

$$\theta = \text{Angle at outlet} = 180^\circ - 165^\circ = 15^\circ$$

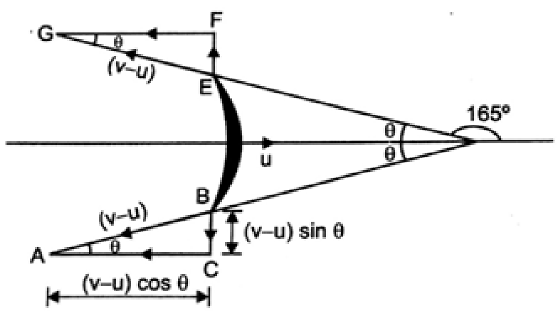
Force exerted by jet on series of curved vanes

$$F_x = \rho \cdot a(v - u)^2 \cdot (1 + \cos\theta)$$

For maximum efficiency of series of curved vanes, the condition is

$$\text{Velocity of vane } u = \frac{v}{2} = \frac{28.014}{2}$$

$$\therefore \quad u = 14.007 \text{ m/sec.}$$



$\therefore$ Force exerted by jet

$$F_x = \rho \cdot a\,(v - u)^2\,(1 + \cos\theta)$$

$$\therefore \quad \text{Work done by jet per sec} = F_x\,u = \rho \cdot a\,(v-u)^2\ (1 + \cos\theta) \cdot u) \text{ N-m/sec.}$$

$$\therefore \quad \text{Work done per sec} = \boxed{[\rho \cdot a\,(v - u)\,]}[(v - u)\,(1 + \cos\theta) \cdot u]$$

$$= [\text{Mass of water through jet in kg}]\ [(v - u)\,(1 + \cos\theta)\,u$$

$\therefore$ Work done on vane per kg of water

$$= [(v - u)\,(1 + \cos\theta) \cdot u]$$

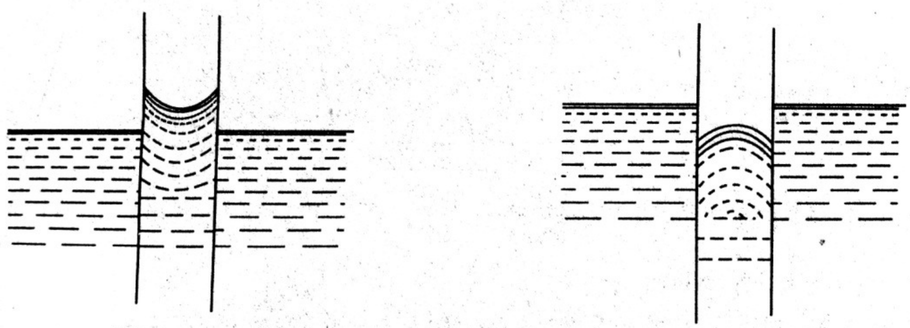
$$= [28.014 - 14.007] \times [1 + \cos 15^\circ] \times 14.007$$

$$= \textbf{385.7068 N-m per kg of water}$$

Q 3 e)

Capillarity:-

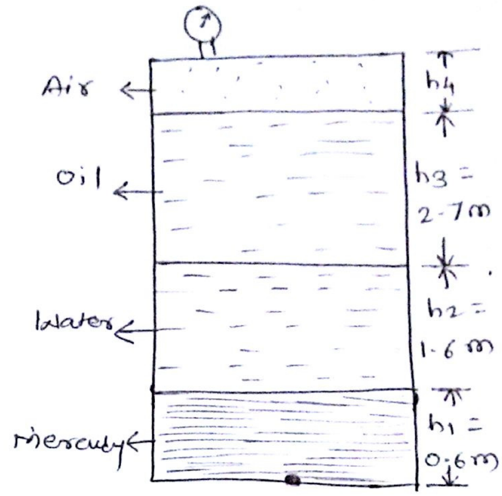
The surface tension of a liquid is its property, which enables it to resist tensile stress. It is due to the cohesion between the molecules at the surface of a liquid. The effect of surface tension may be easily seen in the case of tubes of smaller diameters, open to the atmosphere. When a glass tube of small diameter is dipped in water, the water rises up in the tube with upward concave surface as shown in fig. (a).But when the same tube is dipped in mercury the mercury depresses down in the tube with an upward convex surface as shown in fig.(b). the upward rise in the tube is due to the reason that the adhesion (between the tube and water molecule) is more than the cohesion between the water molecules. But when the same tube is dipped in mercury, the mercury depresses down in the tube with an upward convex surface. This is due to the reason that the adhesion (between the tube and mercury molecules) is less than the cohesion between the mercury molecules.



(a) in water *(b)* in mercury

Q. 3

(F) Given Data,



Pressure at bottom of the tank $= 4\ kg/cm^2$

$= 4 \times 9.81 \times 10^4\ N/m^2$

$P_{bottom} = 392400\ N/m^2$

Let,

ρ_o — Density of oil

ρ_w - Density of water

ρ_A - Density of Air

ρ_{Hg} - Density of mercury

$$P_{bottom} = \rho_{Hg} g h_1 + \rho_w g h_2 + \rho_o g h_3 + \rho_A g h_4$$

$$392400 = (0.9 \times 9.81 \times 2.7 \times 1000) + (1000 \times 9.81 \times 1.6) + (13.6 \times 1000 \times 9.81 \times 0.6) + \rho_A g h_4$$

$\therefore\ \rho_A g h_4 = 272816.1\ N/m^2$

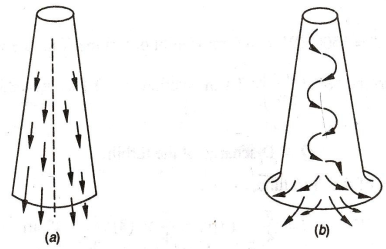
$\therefore\ \rho_A g h_4 = 2.781\ kg/cm^2$

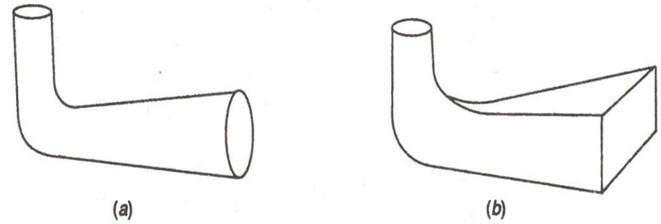
$\therefore$ Pressure at the TOP of the tank $= 2.781\ kg/cm^2$

Q.3. (F) ***As in the given problem data is insufficient, so candidates may solve the problem by assuming suitable data. Pl consider the other possible solution also. Examiners can take such decisions at their end.***

Q 4. a) **Function 02 marks, sketches 03 marks and explanation 03 marks**

Conical Draft Tubes





Elbow draft tubes.

Draft tube is a pipe which connects the turbine outlet to the tail race through which the water exhausted from the turbine runner flows to the outlet channel.

Types of Draft Tubes:-

a. Conical b. Bell mouth type b. Simple elbow tube c.Moody spreading tubes

d. Elbow draft tubes with circular inlet and rectangular outlet.

(a) Conical draft tube : The shape of this tube is like a frustum of a cone. It is used for low specific speed, vertical shaft Francis turbine. The angle of cone is limited to 8° to avoid losses due to separation. It is submerged well below the tail race level. It provides maximum efficiency as 90%.

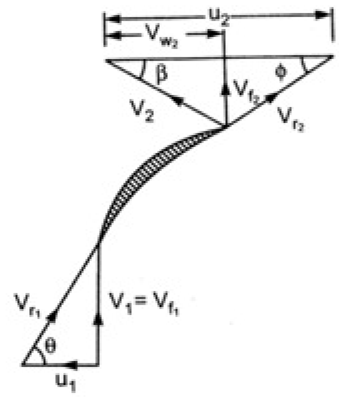
(b) Bell mouth type draft tube : It is suitable for vertical shaft Francis turbine. It is used when the velocity of water at exit of runner has velocity of whirl.

(c) Simple elbow type draft tube : It has circular cross-section at inlet with enlarged circular cross-section area at outlet at right angles. It is used for horizontal shaft Francis turbine. It provides less efficiency, upto 60%.

(d) Draft tube with circular inlet and rectangular outlet : Vertical portion of tube has circular cross-section at inlet and horizontal part of tube has rectangular cross-section area at outlet which provides higher efficiency of draft tube. It is used for any type of Francis turbines.

(e) Moody spreading tube or hydracone : It is used for Kaplan turbine. The exit diameter of draft tube should be large to recover kinetic energy of water at exit of runner. The flow is divided into two streams.

b) Correct answer 08 marks



Solution. Given :

Internal diameter of impeller, $D_1 = 200\text{ mm} = 0.20\text{ m}$

External diameter of impeller, $D_2 = 400\text{ mm} = 0.40\text{ m}$

Speed, $N = 1200$ r.p.m.

Vane angle at inlet, $\theta = 20°$

Vane angle at outlet, $\phi = 30°$

Water enters radially* means, $\alpha = 90°$ and $V_{w_1} = 0$

Velocity of flow, $V_{f_1} = V_{f_2}$

Tangential velocity of impeller at inlet and outlet are,

$$u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 0.20 \times 1200}{60} = 12.56\text{ m/s}$$

and

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.4 \times 1200}{60} = 25.13\text{ m/s.}$$

From inlet velocity triangle, $\tan\theta = \frac{V_{f_1}}{u_1} = \frac{V_{f_1}}{12.56}$

$$\therefore \quad V_{f_1} = 12.56\tan\theta = 12.56 \times \tan 20° = 4.57\text{ m/s}$$

$$\therefore \quad V_{f_2} = V_{f_1} = 4.57\text{ m/s.}$$

From outlet velocity triangle, $\tan\phi = \frac{V_{f_2}}{u_2 - V_{w_2}} = \frac{4.57}{25.13 - V_{w_2}}$

or

$$25.13 - V_{w_2} = \frac{4.57}{\tan\phi} = \frac{4.57}{\tan 30°} = 7.915$$

$$\therefore \quad V_{w_2} = 25.13 - 7.915 = 17.215\text{ m/s.}$$

The work done by impeller per kg of water per second is given by equation as

$$= \frac{1}{g} V_{w_2} u_2 = \frac{17.215 \times 25.13}{9.81} = \mathbf{44.1\ Nm/N.\ Ans.}$$

c) MULTISTAGE CENTRIFUGAL PUMPS **04 marks**

If a centrifugal pump consists of two or more impellers, the pumps is called a multiple centrifugal pumps. The impellers may be mounted on the same shaft or on different shafts. A multistage pumps having the following two important function:

1. To produce a high head and 2. To discharge a large quantity of liquid.

   If a high head is to be developed, the impellers are connected in series (or on the same shaft) while for discharging large quantity of liquid, the impellers (or pumps) are connected in parallel.

Multistage centrifugal pumps for High Heads:

For developing a high head, number of impellers are mounted in series or on the same shaft as shown in fig.

The water from suction pipe enters the 1st impeller at inlet and is discharge at outlet with increased pressure. The water with increased pressure from the outlet of the 1st impellers taken to the inlet of the 2nd impellers with the help of a connecting pipe as shown in fig. At the outlet of the 2nd impellers, the pressure of water will be more than the pressure of water at the outlet of 1st impeller. Thus if more impeller are mounted on the same shaft, the pressure at the outlet will be increased further.

Let, n=Number of identical impeller mounted on the same shaft,

Hm= Head developed by each impeller.

Then total head developed=n*Hm

The discharge passing through each impeller is same.

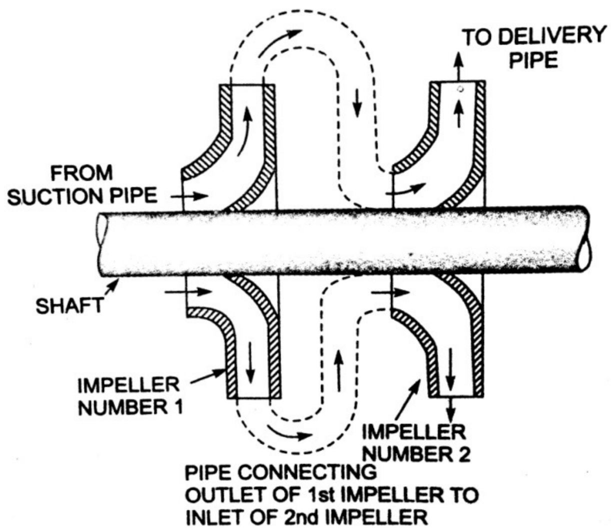


Fig. 19.12 *Two-stage pumps with impellers in series.*

Multistage Centrifugal Pumps for High Discharge: **04 marks**

For obtaining high discharge, the pumps should be the connected in parallel as shown in fig. Each of the pumps lifts the water from a common pumps and discharge water to a common pipe to which the delivery pipes of each pumps is connected. Each of the pumps is working against the same head.

Let, n= Number of identical pumps arranged in parallel.

Q= Discharge from one pumps.

Total discharge= n*Q

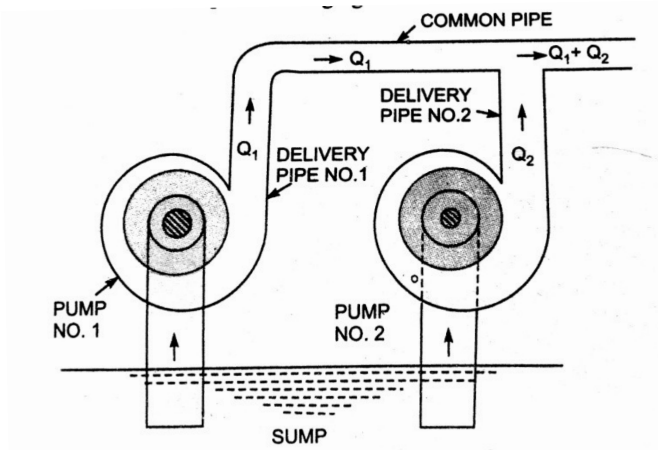


Fig. 19.13 *Pumps in parallel.*

Q. 5 a) i) **Manometric Head (H_m) :-** It is the head against which centrifugal pump has to work. It is actual head available in centrifugal pump i.e. head given by the impeller minus losses. It is measured in meters of water.

02 marks

ii) **NPSH:** NET POSITIVE SUCTION HEAD is defined as the net head in meters of liquid required to force the liquid into the pump though suction pipe. It is given as the atmospheric pressure head minus vapour pressure head minus frictional head minus velocity head in the suction pipe.

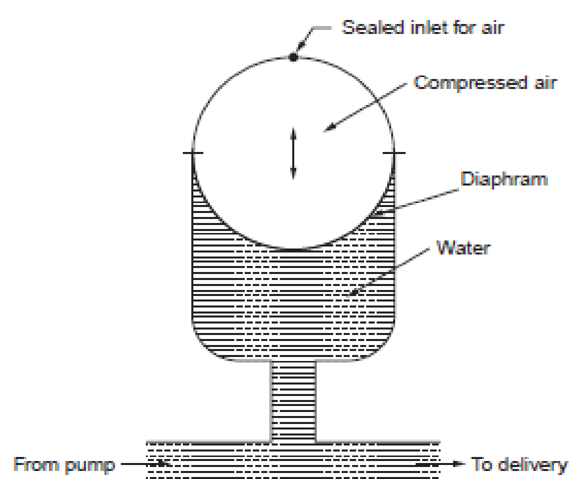
Mathematically

NPSH = Atmospheric pressure head- vapour pressure head- frictional head- velocity head

$= H_a - H_v - h_s - h_{fs}$ **02 marks**

Q. 5 b)

Air vessel is a strong closed vessel as shown in figure. The top half contains compressed air and the lower portion contains water or the fluid being pumped. Air and water are separated by a flexible diaphragm which can move up or down depending on the difference in pressure between the fluids. The air charged at near total delivery pressure/suction pressure from the top and sealed. The air vessel is connected to the pipe lines very near the pump, at nearly the pump level. On the delivery side, when at the beginning and up to the middle of the delivery stroke the head equals *hs* + *hf* + *ha* , higher than the static and friction heads.



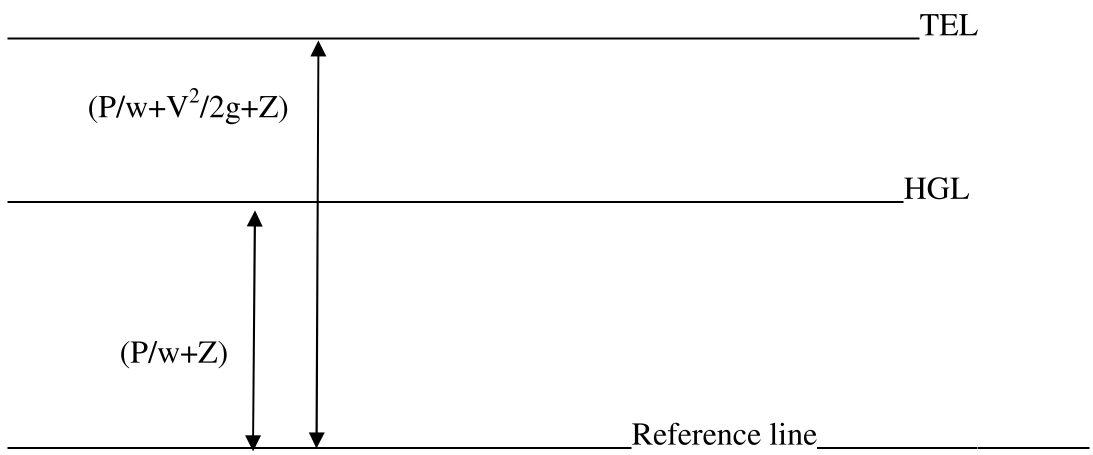
Air vessel

At this time part of the water from pump will flow into the air vessel and the remaining will flow through the delivery pipe. This will increase the compressed air pressure. At the middle stroke position the head will be sufficient to just cause flow. The whole of the flow from pump will flow to the delivery pipe. At the second half of the stroke the head will be equal to *hs* + *hf* – *ha.* At the position the head will be not sufficient to cause flow. The compressed air pressure will act on the water and water charged earlier into the air vessel will now flow out. Similar situation prevails on the suction side. At the start and up to the middle of the suction stroke the head at the pump is higher than static suction head by the amount of acceleration head. The flow will be more and part will flow into the air vessel. The second half of the stroke water will flow out of the air vessel. In this process the velocity of water in the delivery pipe beyond the air vessel is uniform, and lower than the maximum velocity if air vessel is not fitted. Similar situation prevails in the suction side also. The effect is not only to give uniform flow but reduce the friction head to a considerable extent saving work. Without air vessel the friction head increases, reaches a maximum value at the mid stroke and then decreases to zero. With air vessel the friction head is lower and is constant throughout the stroke. In this way continuous supply of water at a uniform rate in reciprocating pump is obtained.

04 marks

Q. 5 c)

i) **Hydraulic gradient line** : It is defined as the line which gives the sum of pressure head (p/w) and datum head (z) of flowing fluid in a pipe with reference to some reference line. HGL may rise or fall depending upon the pressure changes.



ii) **Total Energy Line : (TGL/TEL)**

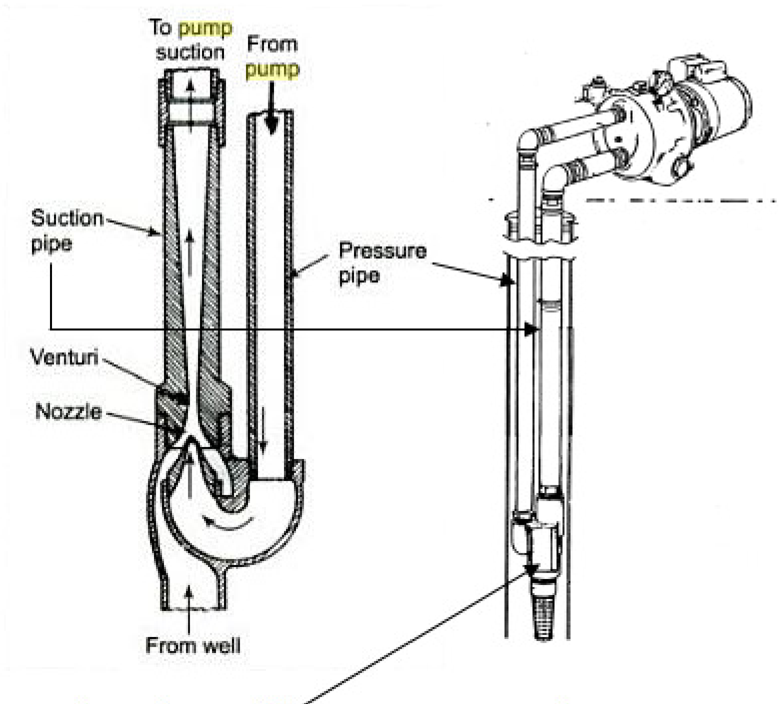
Total energy line is the line which gives sum of pressure head, datum head and kinetic head of flowing fluid in a pipe with respect to some reference line. When fluid flows along the pipe, there is loss of head and total energy decreases in the direction of flow.

$$TEL = \frac{P}{W} + \frac{v^2}{2g} + z$$

(Sketch 1M Description 3 M.)

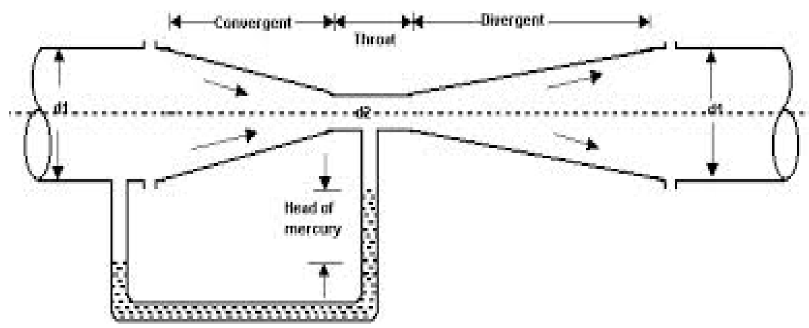
Q 5 d) Jet pump: **(any one Sketch-02 marks, Explanation- 02 marks)**

Fig. shows a jet pump set up which consists of jet unit, suction pipe, pressure pipe and a centrifugal pump. A jet unit is consists of a pipe having a convergent end at the bottom. The upper end of the pipe leads to the required height. Now water under pressure is introduced from pressure pipe through a nozzle as shown in fig. The pressure energy of water is converted into kinetic energy, as it passes through the nozzle. As a result of this, the pressure in the convergent portion of the pipe is considerably reduced and water is sucked into the pipe. This sucked water after coming in contact with the jet is carried into the pump suction pipe.



Jet unit assembly **Jet pump set up**

Q 5 e) **Sketch-02 marks, Explanation- 02 marks**



In convergent cone because of gradual decrease in diameter there is increase in velocity and decrease in pressure and in divergent section decrease in pressure is again increased to its original value and then liquid is reached in the pipe. In convergent cone velocity of fluid is increased. This acceleration of flowing fluid may be allowed to take place rapidly in relatively small length, without resulting in appreciable loss of energy. However if decrease in velocity of fluid is allowed to take place rapidly in a small length, then the flowing fluid will not remain in contact with the boundary of diverging flow passage , flow will separate from walls and eddies are formed to avoid this the length of divergent cone is 2 to 3 times that of convergent cone.

Q 5 f) i) **Explanation- 02 marks**

Condition for Maximum Transmission of Power Through the Pipe:

$\because$ Power transmitted through pipe is given by

$$\text{Power} = W(H - h_f)$$

differentiate the above equation w.r.t. velocity v and equate it to zero.

$$\therefore \quad \frac{d\,(\text{Power})}{dv} = 0$$

$$\therefore \quad \frac{d}{dv}[W(H - h_f)] = 0$$

$$\therefore \quad W \cdot \frac{\pi}{4} d^2 \frac{d}{dv}\left[H \cdot v - \frac{4flv^3}{2gd}\right] = 0$$

$$\therefore \quad W \cdot \frac{\pi}{4} d^2 \left[H - \frac{4 \times 3\, flv^2}{2gd}\right] = 0$$

$$\therefore \quad H - 3 \times \frac{4flv^2}{2gd} = 0$$

$$\therefore \quad H - 3 h_f = 0$$

$$\therefore \quad H = 3 h_f$$

$$\therefore \quad \boxed{h_f = \frac{H}{3}}$$

$\therefore$ Condition for maximum transmission of power is $h_f = \frac{H}{3}$ i.e. power transmitted through a pipe is maximum when the head lost due to friction is one third of total heat at inlet.

ii) Laws of fluid frictional for turbulent flow. **(Stating laws 2 M)**

- Frictional resistance is proportional to square of velocity of flow.
- Frictional resistance is independent of pressure.
- Frictional resistance is proportional to density of fluid.
- Frictional resistance slightly varies with temperature.
- Frictional resistance is proportional to surface area of contact.

Q 6 a) **i)**

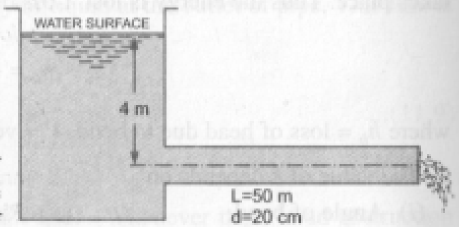
Solution. Dia. of pipe, $d = 20$ cm $= 0.20$ m

Length of pipe, $L = 50$ m

Height of water, $H = 4$ m

Co-efficient of friction, $f = .009$

Let the velocity of water in pipe $= V$ m/s.



Applying Bernoulli's equation at the top of the water surface in the tank and at the outlet of pipe, we have [Taking point 1 on the top and point 2 at the outlet of pipe].

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + \text{all losses}$$

Considering datum line passing through the centre of pipe

$$0 + 0 + 4.0 = 0 + \frac{V_2^2}{2g} + 0 + (h_i + h_f)$$

or

$$4.0 = \frac{V_2^2}{2g} + h_i + h_f$$

But the velocity in pipe $= V$, $\therefore V = V_2$

$$\therefore \quad 4.0 = \frac{V^2}{2g} + h_i + h_f \quad \ldots(i)$$

$$h_i = 0.5\,\frac{V^2}{2g}$$

Substituting these values, we have

$$4.0 = \frac{V^2}{2g} + \frac{0.5\,V^2}{2g} + \frac{4\,.\,f\,.\,L\,.\,V^2}{d \times 2g}$$

$$= \frac{V^2}{2g}\left[1.0 + 0.5 + \frac{4 \times .009 \times 50}{0.2}\right] = \frac{V^2}{2g}\,[1.0 + 0.5 + 9.0]$$

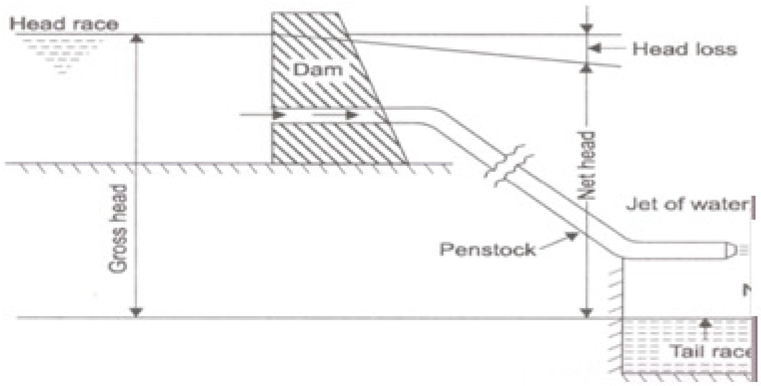
$$= 10.5 \times \frac{V^2}{2g}$$

$$\therefore \quad V = \sqrt{\frac{4 \times 2 \times 9.81}{10.5}} = 2.734 \text{ m/sec}$$

$\therefore$ Rate of flow, $Q = A \times V = \frac{\pi}{4} \times (0.2)^2 \times 2.734 = 0.08589 \text{ m}^3\text{/s}$

$= 85.89$ **litres/s. Ans.**

ii) Layout of hydraulic power plant



- The general layout of a hydraulic power plant consist of :
- Dam- constructed across a river to store water.
- Penstock – Pipes of a large diameters called penstocks which carry water under pressure from the storage reservoir to the turbines of pipe)
- Turbine- different types of vanes fitted to the wheels.
- Tail race – a channel which carries water away from the turbine after the water has worked on the turbines. (**Description 2 M Sketch 2M.)**

Q 6 b) i)

<u>Solution</u>

Given

$V = 2.7$ m/sec.

gauge difference $x = 30$ mm of Hg.

∴ Difference of pressure

head $h = x\left(\frac{S_{g}}{S_{w}} - 1\right)$

$= 30\left(\frac{13.6}{1} - 1\right)$

$= 378$ mm of water

$= 0.378$ m of water

Velocity of flow

$V = C_v\sqrt{2gh}$

∴ coefficient of velocity

$C_v = \frac{V}{\sqrt{2gh}} = \frac{2.7}{\sqrt{2 \times 9.8 \times 0.378}}$

$= \frac{2.7}{2.72}$

$= 0.99.$

Q 6 b) ii)

Dia. of orifice, $d_0 = 10$ cm

$\therefore$ Area, $a_0 = \frac{\pi}{4}(10)^2 = 78.54 \text{ cm}^2$

Dia. of pipe, $d_1 = 20$ cm

$\therefore$ Area, $a_1 = \frac{\pi}{4}(20)^2 = 314.16 \text{ cm}^2$

$$p_1 = 19.62 \text{ N/cm}^2 = 19.62 \times 10^4 \text{ N/m}^2$$

$$\therefore \quad \frac{p_1}{\rho g} = \frac{19.62 \times 10^4}{1000 \times 9.81} = 20 \text{ m of water}$$

Similarly

$$\frac{p_2}{\rho g} = \frac{9.81 \times 10^4}{1000 \times 9.81} = 10 \text{ m of water}$$

$$\therefore \quad h = \frac{p_1}{\rho g} - \frac{p_2}{\rho g} = 20.0 - 10.0 = 10 \text{ m of water} = 1000 \text{ cm of water}$$

$$C_d = 0.6$$

02 marks

The discharge, Q is given by equation

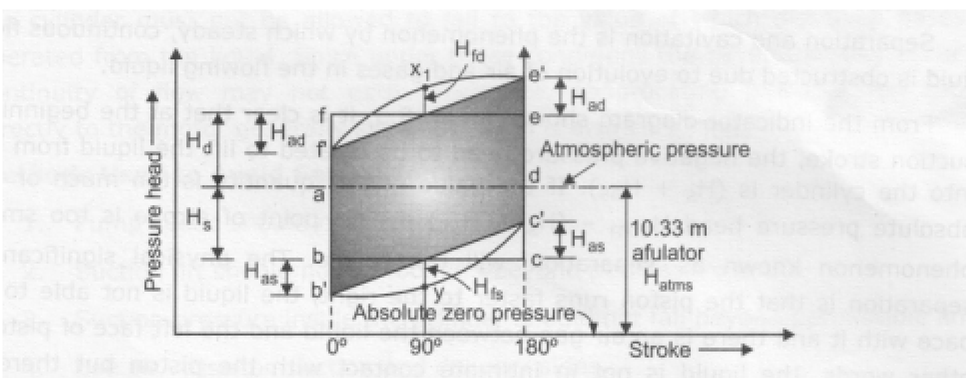
$$Q = C_d \frac{a_0 a_1}{\sqrt{a_1^2 - a_0^2}} \times \sqrt{2gh}$$

$$= 0.6 \times \frac{78.54 \times 314.16}{\sqrt{(314.16)^2 - (78.54)^2}} \times \sqrt{2 \times 981 \times 1000}$$

$$= \frac{20736838.09}{304} = 68213.28 \text{ cm}^3/\text{s} = \mathbf{68.21 \text{ litres/s.}}$$

02 marks

Q 6 c) **Sketch-04marks, Explanation- 04 marks**



Indicator Diagram Showing Effect of Acceleration Head and Friction Head

The water in the delivery pipe is accelerated at the beginning of the stroke and retarded at the end of the delivery stroke. The indicator diagram modified for the acceleration head is shown in figure.

The new diagram is represented by a b'c'e'f' a. It will be noted that the area of the indicator diagram remains unaffected. Thus the total work done remains the same.

When water flows in the suction and delivery pipes, there will be loss of head due to friction. This loss of head reduces the height of water by which this water is to be lifted. Therefore to compensate for the frictional head loss, it is added in the indicator diagram. This modified diagram is shown in Fig.

Loss of head due to friction :

$$H_f = \frac{4fL}{d} \cdot \frac{v^2}{2g} = \frac{4fL}{2g \cdot d}\left(\frac{A}{a}\,\omega r \sin\theta\right)^2$$

At the beginning of stroke, $\theta = 0°$ then $H_f = 0$

At the mid stroke, $\theta = 90°$, $\sin\theta = 1$, then H_f becomes maximum.

$$H_f \cdot \max = \frac{4fL}{2gd}\left(\frac{A}{a}\,\omega r\right)^2$$

At the end of stroke $\theta = 180°$, then $H_f = 0$, as the velocity of water is zero.