SUMMER – 13 EXAMINATION

Subject Code:12093 **Model Answer**

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills).
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. 1 a)

i) Density: Density is defined as ratio of the mass of a liquid to its volume.

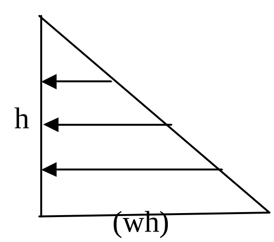
$$\text{Density, } \rho = \frac{Massoffluid}{Volumeoffluid}$$

ii) Specific gravity :

$$(Speaficgravity) = \frac{Weightdensityofliquid}{Weightdenstyofwater}$$

(01 mark for each definition)

b) Pressure : Is defined as force acting per unit area..



Consider a vessel containing the liquid of depth "h".mertes.

Let A= Area of base

w = Specific weight of the liquid Kg/m3.

h = Height of water.

Total pressure on bottom of vessel is weight of water contained in that vessel.

Total force = w x A x h

If 'p' is pressure intensity

Then force = p x A

p x A = w x A x h

P = w x h

h = p/w

(01 mark for definition , 01 mark for relation)

c) Total Pressure : It is defined as the force exerted by a static fluid on surface either plane or curved area when the fluid comes in contact with the surface.

This force always acts normal to the surface.

Centre of pressure : Defined as the point of application of the total pressure on the surface. **(01 mark for each definition**)

d) Steady flow:

A flow in which fluid characteristics like velocity, pressure, density etc at a point do not change with time.

Turbulent flow :

Fluid particles move in zig-zag way. No definite path for fluid particle flow. Reynolds number > 4000. **(01 mark for each definition**)

e) Uniform flow :

A type of flow in which velocity at any given time does not change with respect to space (Length of direction of flow).

$\left(\frac{\delta v}{\delta s}\right)_{t=const} = 0$ dv= Change of velocity.

δs = Length of flow in directions.

Non uniform flow

: A flow in which velocity at any given time changes with respect to space.

(**01 mark for each definition**)

f) i) Darcy – weisbatch formula/equation

Loss of head due to friction = $hf = \frac{4flv^2}{2gd}$

f = coefficient of friction

l = Length of pipe

v = mean velocity of flow

d = diameter of pipe

ii) chezys equation

$$v = c\sqrt{mi}$$

Where $c = \sqrt{\frac{\rho g}{f'}}, i = \frac{hf}{l}$

v = mean velocity of flow.

(01 mark for each equation)

g) Equation for

i) Loss due to sudden expansion

$$he = \frac{(v_1 - v_2)^2}{2g}$$

he = head loss due to sudden enlargement.

V_1 = velocity of flow at inlet

V_2 = velocity of flow at exit.

ii) Loss of head due to sudden contraction

$$hc = 0.5\frac{v_2^2}{2g}$$ **(01 mark for each equation)**

h) Impact of jet :- Force exerted by the jet on plate which may be stationary or moving.

Jet Propulsion :- The propulsion or movement of bodies such as rockets, ships, aircrafts with the help of jet.The reaction of jet coming out from the orifice provided in the bodies is used to move the bodies. **(01 mark for each definition)**

i)

Force exerted by a jet as flat vertical plate moving in the direction of jet.

$F = \rho a (v-u)^2$

ρ = Density of fluid

v = Absolute velocity of jet.

a = cross section area of jet.

u = velocity of flat plate. **(01 mark for formula & 01 mark for terms)**

j) Principle of working of impulse turbine.

- At the inlet of turbine energy available is only kinetic energy.
- Water strike the bucket along the tangent of runner.
- The pressure at inlet and out let of turbine is atmosphere.

(02 marks for appropriate answer)

k) Cavitation:- It is defined as phenomenon of formation of vapour bubbles of flowing liquid in a region where.

Pressure of the liquid falls below its vapour pressure and the sudden collapsing of these vapour bubbles in a region of high pressure.

When vapour bubble collapse, a very high pressure is created.

l)

i) Suction head (hs)

The vertical height of the centre line of the centrifugal pump above the water surface in the tank or pump from which water is to be lifted.

ii) Delivery head (hd)

The vertical distance between the centre line of the pump and the water surface in the tank to which water is delivered. (**01 mark for each definition**)

m)

i) **Static head** (Hs):

The sum of suction head and delivery head Hs = hs + hd.

ii) **Manometric Head** (Hm)

Head against which a centrifugal pump has to work.

Hm = Head imparted by the impeller to the wheel - Loss of head in the pump.

(**01 mark for each definition**)

n) Priming of pumps :

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

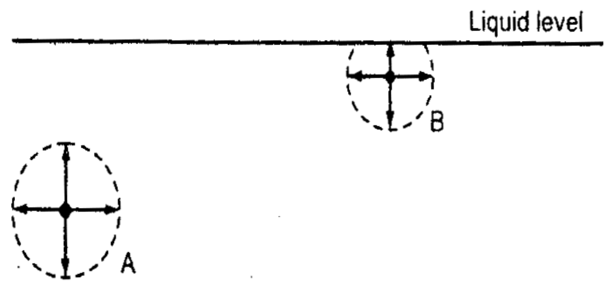
(02 marks for appropriate answer)

Q. 2 a) (01 mark for each point)

Dynamic viscosity		**Kinematic viscosity**	
i)	Shear stress required to produce unit rate of angular deformation	i)	Ratio of dynamic viscosity and density of fluid.
ii)	Represented as μ	ii)	Represented as ν
iii)	$\mu = \tau / \frac{\delta u}{\delta y}$	iii)	$(\nu) = \frac{\mu}{\rho}$
iv)	Unit Ns/m^2 or poise	iv)	Unit : stokes or m^2/sec

Q. 2 a) ii) Surface Tension:

SURFACE TENSION



Let us consider the two molecules of liquid at points A and B. Molecule at point A is equally attracted from all sides since it has molecules from all sides and therefore the forces acting at this point are in equilibrium condition. However, at point B, there is no liquid molecule at above side and consequently there is a net downward force on the molecule due to the attraction of the molecule below it. This force on the molecules at the surface of liquid is normal to the liquid surface, due to this a special layer seems to form on a liquid at the surface, which is in tension and small loads can be supported over it e.g. a small needle placed gently upon the water will not sink but will be supported by the tension at the water surface.

The property of the liquid surface film to exert the tension is called as '*Surface tension*'. It is denoted by letter 'σ' (sigma).

Definition of surface tension : It is the force required to maintain unit length of the film in equilibrium condition.

Units : In metric system, it is expressed as kg (f)/cm or kg (f)/m

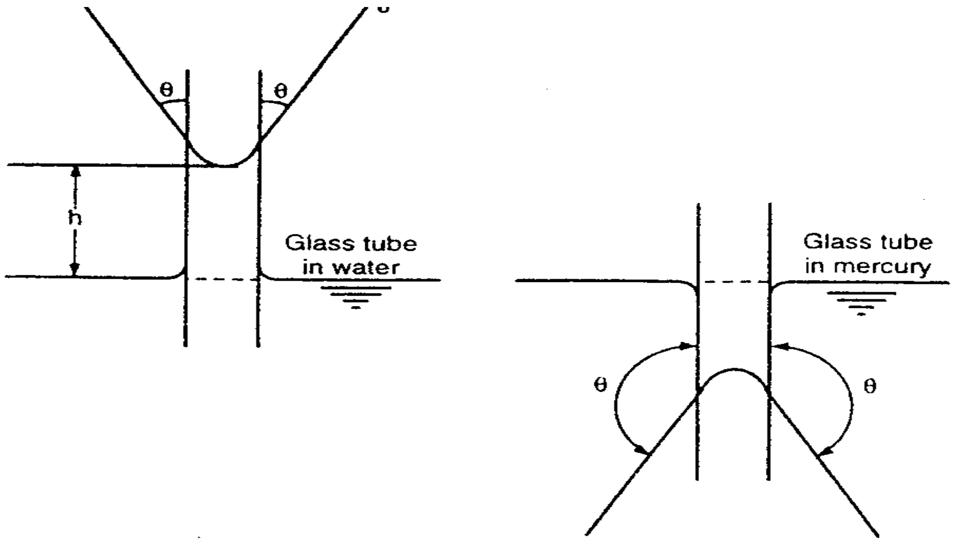
In S.I. units, N/cm or N/m.

Capillarity :

When the liquid molecules possess relatively greater affinity for solid molecules or, in other words, liquid has adhesion greater than cohesion then it will wet the solid surface in contact and will tend to rise at the point of contact. This results concave upwards and the angle of contact θ which is less than 90°. This is also known as 'Capillary Rise'

If the liquid has less attraction for solid molecules or, in other words, 'Cohesion Predominates', then liquid will not have tendency to wet the solid surface in contact and this will result in depression of liquid at that point in the concave downward shape and at the angle θ more than 90° e.g. glass tube is inserted inside the mercury.

This phenomenon of rise or fall of liquid surface relative to the adjacent general level of liquid is known as 'Capillarity'.



(a) Capillary rise
Adhesion > Cohesion

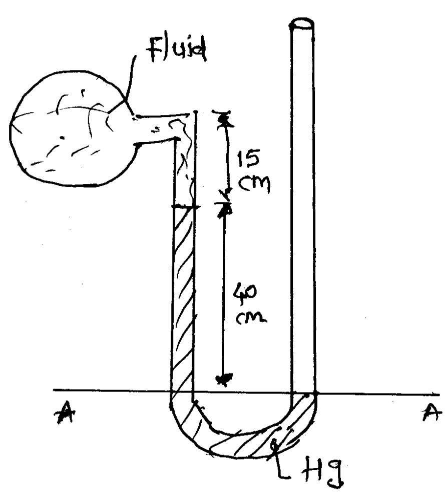
(b) Capillary depression
Cohesion > Adhesion

(02 marks for surface tension & 02 marks for capillarity)

Q.2 b) Given data :

Specific gravity of fluid = $S_1 = 0.8$

- Sp gravity of Hg = $S_2 = 13.6$
- Density of fluid = $\rho_1 = 800$
- Density of Hg = 13.6 x 1000 = ρ_2
- Difference of Hg level = h_2 = 40cm = 0.4m.
- Height of liquid in left limb = h_1 = 15cm = 0.15m



Let pressure in the pipe = p. equating pressure above datum line A-A we get.

$\rho_2 g h_2 + \rho_1 g h_1 + p = 0$

$p = -[\rho_2 g h_2 + \rho_1 g h_1]$ 04**marks.**

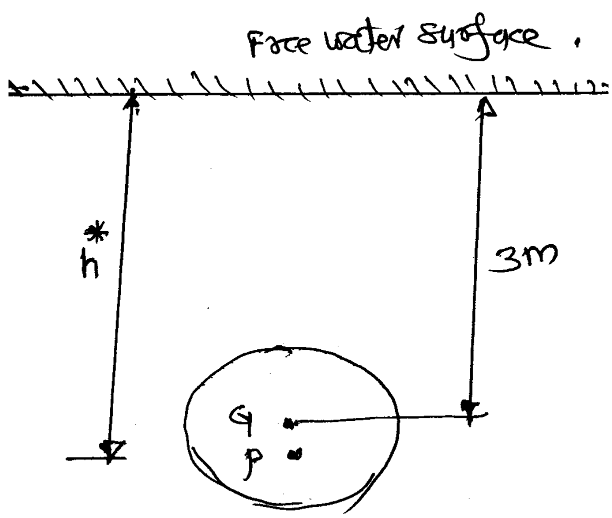
$= -[13.6 \times 1000 \times 9.81 \times 0.4 + 800 \times 9.81 \times 0.15]$

$= -54543.6 N/m^2$

$p = -5.454 N/cm^2$ 0**4 marks.**

Q. 2 C) Given data:

- Diameter of plate = 1.5m
- Area of plate = $= \frac{\pi}{4}(1.5)^2 = 1.767 m^2$ **01 marks.**
- $\bar{h} = 3.0$



Total pressure = $f = \rho g A \bar{h}$

$= 1000 \times 9.81 \times 1.767 \times 3.0$

$= 52002.81 N$ **02 marks.**

Position of centre of pressure (h^*)

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

$$IG = \frac{\pi}{4} d^4 = \frac{\pi}{4}(1.5)^4 = 3.976 m^4$$

05 marks.

$$h^* = \frac{3.976}{1.767 \times 3.0} + 3.0 = 0.75 + 3$$

$$h^* = 3.75 m$$

Que No 3.

a) Given –
Horizontal venturimeter
inlet diameter $= d_i = 30\text{ cm} = 0.3\text{ m}$
throat diameter $= d_t = 15\text{ cm} = 0.15\text{ m}$
coef. of discharge $= C_d = 0.98$
pressure drop across inlet & throat $= h_{hg}$
$= 20\text{ cm}$
$= 0.2\text{ m}.$

Find – rate of flow.

Solution.

$$a_1 = \frac{\pi}{4} d_i^2 = \frac{\pi}{4} 0.3^2 = 0.0706858\text{ m}^2 \quad — (1)$$

$$a_2 = \frac{\pi}{4} d_t^2 = \frac{\pi}{4} 0.15^2 = 0.0176714\text{ m}^2 \quad — (1)$$

pressure drop $= h_w$

$$h_w = h_{hg}\left(\frac{\rho_{hg}}{\rho_w} - 1\right) \quad — (1)$$

$$= 0.2\left(\frac{13600}{1000} - 1\right)$$

$$= 2.52\text{ m of water} \quad — (2)$$

Actual discharge $= Q_a$

$$Q_a = C_d \times \frac{a_1 \times a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh_w} \quad — (1)$$

$$= 0.98 \times \frac{0.0706858 \times 0.0176714}{\sqrt{(0.0706858)^2 - (0.0176714)^2}} \times \sqrt{2 \times 9.81 \times 2.52}$$

$$= 0.1151\text{ m}^3/\text{s}$$

$$= 115.1\text{ lit/sec}. \quad — (2)$$

note – Areas in 'cm²' & / OR discharge in 'lit/s' may also be given full marks for correct numerical values.

Que. NO 3.

b) Given.

Oil flow through pipe; pitot tube with U tube manometer

pressure drop = $h_{hg} = 100$ mm $= 0.1$ m

coef of discharge = $C_d = 0.98$

sp. gravity of oil = $S_o = 0.8$

Find V_{actual}.

Solution.

$$h_{oil} = h_{hg}\left[\frac{S_{hg}}{S_{oil}} - 1\right] \quad — ①$$

$$= 0.1\left[\frac{13.6}{0.8} - 1\right]$$

$$= 1.6 \text{ m of oil.} \quad — ②$$

$$V_{TH} = \sqrt{2 g h_{oil}} \quad — ①$$

$$= \sqrt{2 \times 9.81 \times 1.6}$$

$$= 5.6029 \text{ m/s} \quad — ①$$

$$V_{act} = C_d \times V_{TH}. \quad — ①$$

$$= 0.98 \times 5.6029$$

$$= 5.4908 \text{ m/s} \quad — ②$$

Note – if V_{actual} is directly calculated by using formula then total marks of ($V_{TH} + V_{act}$) as shown above may be given.

Que No 3 (3)

c Given

pipe diameter $= d = 200\ mm = 0.2\ m$

Length of pipe $= l = 500\ m$

pressure loss due to friction $= h_f = 4\ m$

coefficient of friction $= f = 0.009$

Determine discharge.

Solution.

To determine velocity

$$h_f = \frac{4flv^2}{2gd} \qquad \text{— (1)}$$

$$\therefore \quad v = \sqrt{\frac{2gdh_f}{4fl}}$$

$$= \sqrt{\frac{2 \times 9.81 \times 0.2 \times 4}{4 \times 0.009 \times 500}}$$

$$= 0.9338094\ m/s \qquad \text{— (1)}$$

To determine area of pipe.

$$a = \frac{\pi}{4} d^2 \qquad \text{— (1)}$$

$$= \frac{\pi}{4} 0.2^2$$

$$= 0.03142\ m^2 \qquad \text{— (1)}$$

To determine discharge.

$$Q = a \cdot v \qquad \text{— (2)}$$

$$= 0.03142 \times 0.9338094$$

$$= 0.02934\ m^3/s \qquad \text{— (2)}$$

Note. If discharge is directly calculated by using formula such as $h_f = \frac{32flQ^2}{\pi^2 g d^5}$ OR

$$Q = \sqrt{\frac{h_f \pi^2 g d^5}{32 f l}}$$

then appropriately marks may be given.

Que No 4. (4)

a Given

Horizontal pipe

diameter of pipe = d_p = 0.2 m.

velocity of water = V = 3 m/s

Obstruction plate diameter = 150 mm = d_0 = 0.15 m

$C_c = 0.62$

Solution.

Cross sectional area of pipe = A

$= \frac{\pi}{4} d_p^2$ — (1)

$= \frac{\pi}{4} 0.2^2$

$= 0.0314159 m^2$ — (1)

Cross sectional area of obstruction = a

$= \frac{\pi}{4} d_0^2$ — (1)

$= \frac{\pi}{4} 0.15^2$

$= 0.0176714 m^2$ — (1)

Head loss due to obstruction $= \frac{V^2}{2g}\left[\frac{A}{C_c(A-a)} - 1\right]^2$ — (2)

$= \frac{3^2}{2 \times 9.81}\left[\frac{0.0314159}{0.62(0.314159 - 0.0176714)} - 1\right]^2$

= 3.311 m of water — (2)

5

Que. 4. b

Given

Pipe with nozzle; jet on fixed vertical plate

diameter of nozzle $= d = 100 \text{ mm} = 0.1 \text{ m}$

head of water $= h_w = 100 \text{ m}$

Coefficient of velocity $= C_v = 0.95$

Determine force acting on plate.

Solution.

Area of jet $= a$

$= \frac{\pi}{4} d^2$ — 1

$= \frac{\pi}{4} 0.1^2$

$= 0.007855 \text{ m}^2$ — 1

Theoretical velocity of jet $= V_{TH}$

$= \sqrt{2gh_w}$ — 1

$= \sqrt{2 \times 9.81 \times 100}$

$= 44.2945 \text{ m/s}$ — 1

Actual velocity of jet $= C_v \times V_{TH}$ — 1

$V_a = 0.95 \times 44.2945$

$= 42.0798 \text{ m/s}$ — 1

Force acting on plate [fixed vertical] $= F$

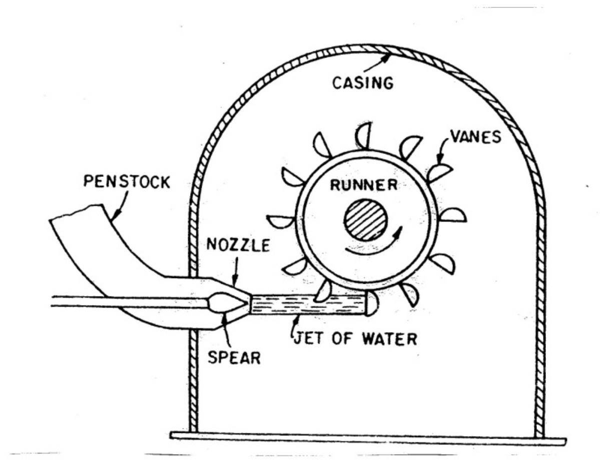
$= \rho a V_a^2$ — 1

$= 1000 \times 0.007855 \times (42.0798)^2$

$= 13.907 \text{ kN}$ — 1

Note: if actual velocity is directly calculated by using formula $V_{act} = C_v \sqrt{2gh_w}$ then appropriate marks may be given.

Q4
—
C



Pelton wheel sketch

As shown in the figure, pelton wheel has following components.

1) Nozzle & flow regulating arrangement – spear.
2) Runner and buckets.
3) Casing.

Working :

1) Nozzle and spear : The water from penstock is supplied to pelton wheel through nozzle and spear. The spear is either manually or automatically controlled to regulate flow rate of water.
2) Runner with buckets : Runner is a circular disc mounted on a shaft. The buckets are mounted on the disc. The jet of water is impinged on the buckets. Each bucket is divided into two halves, by splitter. The jet strikes on the splitter and two equal streams of water glide over the bucket.
3) Casing : The role of casing is to avoid splashing of water. Pelton wheel is impulse type of turbine. The conversion of pressure energy into kinetic energy takes place in nozzle ie. Outside the turbine casing.

It is high head, low discharge type of turbine.

Note : The above given description may vary. Kindly note the distribution of marks.

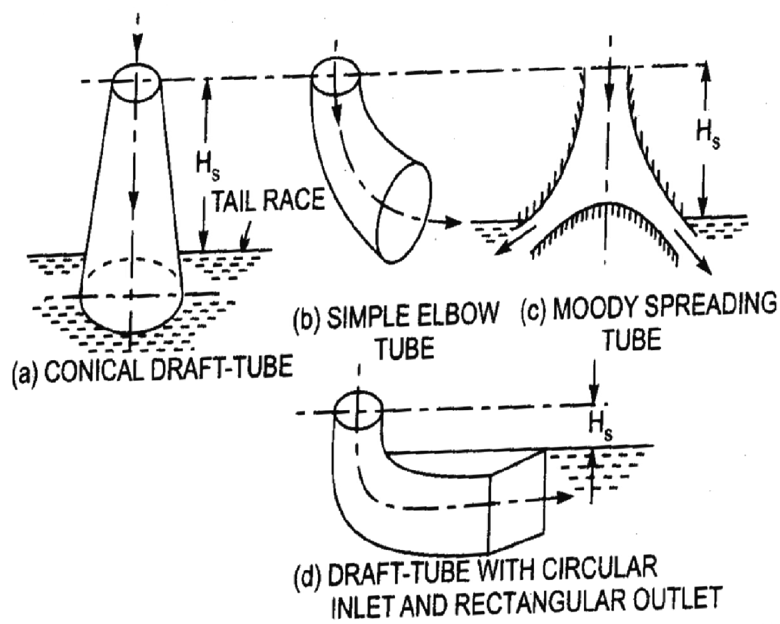
(Sketch – 03 Marks. Construction – 02 Marks Working – 03 Marks.)

Que 5 a) What is the function of draft tube? Explain with neat sketches, the various types of draft tubes. **(02 marks for function, 03 marks each for sketches and description)**

Answer:- The draft tube is an integral part of a reaction turbine. The function of draft tube is as below

1. To reduce velocity/ kinetic energy of water making exit thereby converting kinetic energy to pressure head allowing turbine to be installed above tail pool level.
2. To create negative suction head.
3. Provide added head.

Different types of draft tubes incorporated in reaction turbines are



Conical draft tube

The shape of this tube is that of frustum of a cone. It is usually employed for low specific speed, vertical shaft Francis turbine. The cone angle is restricted to 8^0 to avoid the losses due to separation. The tube must discharge sufficiently low under tail water level. The maximum efficiency of this type of draft tube is 90%. This type of draft tube improves speed regulation of falling load.

Simple elbow type

The vertical length of the draft tube should be made small in order to keep down the cost of excavation, particularly in rock. The exit diameter of draft tube should be as large as possible to recover kinetic energy at runner's outlet. The cone angle of the tube is again fixed from the definite length. Simple elbow type draft tube will serve such a purpose. Its efficiency is, however, low(about 60%). This type of draft tube turns the water from the vertical to the horizontal direction with a minimum depth of excavation

Draft tube with circular inlet and rectangular outlet

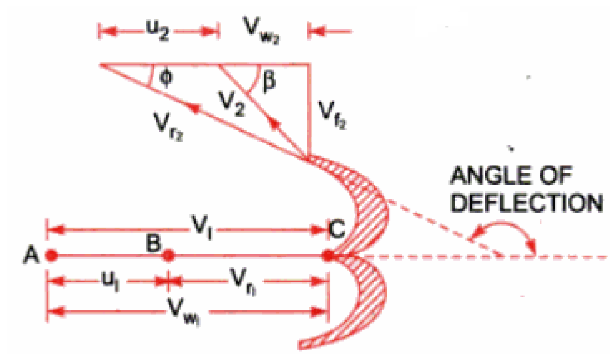
Sometimes, the transition from a circular section in the vertical portion to a rectangular section in the horizontal part is incorporated in the design to have a higher efficiency of the draft tube. The horizontal portion of the draft tube is generally inclined upwards to lead the water gradually to the level of the tail race and to prevent entry of air from the exit end.

Moody spreading tube

The exit diameter of draft tube should be as large as possible to recover kinetic energy at runner's outlet thus the flow is divided into two streams.

Que 5 b) A Pelton wheel is supplied with water under a head of 35 m at the rate of 40.5 kilo litre / min. The bucket deflects the jet through an angle of 160^0 and the mean bucket speed is13 m/s. Calculate the power and efficiency of the turbine.

Solution :- (Velocity diagram not essential)



Speed of bucket = $u=u_1= u_2=13$ m/s

Discharge Q= 40.5/60 = 0.675 m^3/s

Head of water = 35 m

Angle of deflection = 160^{0}

Angle = $180-160=20^0$

The velocity of the jet = $v_1 = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 35}$

= 26.20 m/s **02 marks**

$V_{r1} = V_1 - u_1 = 26.20-13$

$= 13.20$ m/s

$V_{w1} = V_1 = 26.20$ m/s

From outlet velocity triangle

$V_{w2} = V_{r2}$ COS Ø - u_2

= 13.20 COS 20-13

= -0.59 m/s

Work done by the jet/sec. on the runner = ρ a V_1 ($V_{w1} + V_{w2}$)x u

=1000x0.675x(26.20+(-0.59)) x 13

=224727.75 Nm/s **02 marks**

Thus power given to turbine = 224727.75/1000

= 224.72 kw

The hydraulic efficiency of the turbine= V_1^2

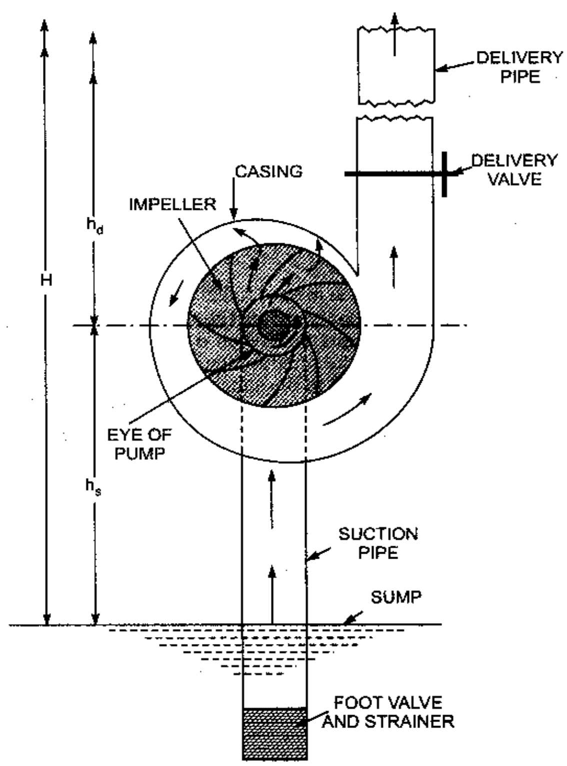
= 2x(26.20+ (-0.59))x 13/(26.20)^2

= 0.969

= 96.9 % **02 marks**

Que 5 c) Explain with a neat sketch, the principle and working of a centrifugal pump.

(04marks for sketch, 04 marks for working principle)



Principle and working of centrifugal pump:-

The hydraulic machines which convert the mechanical energy into hydraulic energy are called pumps. The hydraulic energy is in the form of pressure energy. If the mechanical energy is converted, into pressure energy by means of centrifugal force acting on the fluid, the hydraulic machine is called centrifugal pump.

The centrifugal pump acts as a reversed of an inward radial flow reaction turbine. This means that the flow in centrifugal pumps is in the radial outward directions. The centrifugal pump works on the principle of forced vortex flow which means that when a certain mass of liquid is rotated by an external torque, the rise in pressure head of the rotating liquid takes place. The rise in pressure head at any point of the rotating liquid is proportional to the square of tangential velocity of the liquid at that point (*i.e.*, rise in pressure head $= \frac{V^2}{2g}$ or $\frac{\omega^2 r^2}{2g}$). Thus at the outlet of the impeller, where radius is more, the rise in pressure head will be more and the liquid will be discharged at the outlet with a high pressure head. Due to this high pressure head, the liquid can be lifted to a high level.

Que 6 a) Explain with neat sketches the types of casings and impellers of a centrifugal pump

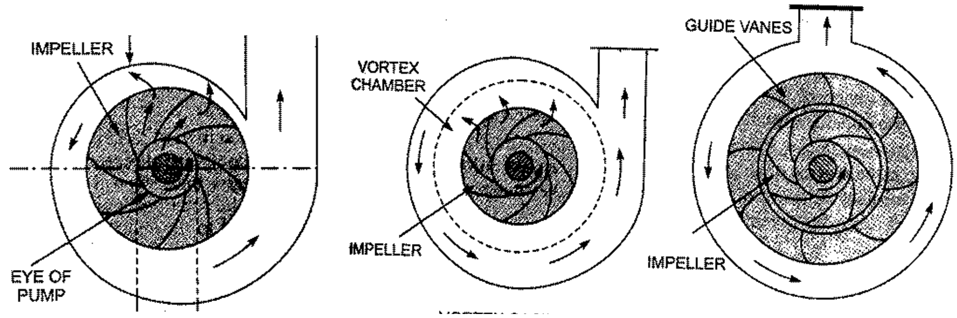
Answer – Casing is an air tight passage surrounding the impeller. It is designed in such a way that the kinetic energy of the water discharged at the outlet of the impeller is converted into pressure energy before the water leaves the casing and enters the delivery pipe.

Types of casing:- **(02 marks each for sketches and description)**

a) Volute casing: – It is spiral type of casing in which area of flow increase gradually. The increase in area of flow decreases the velocity of flow and increases the pressure of water.

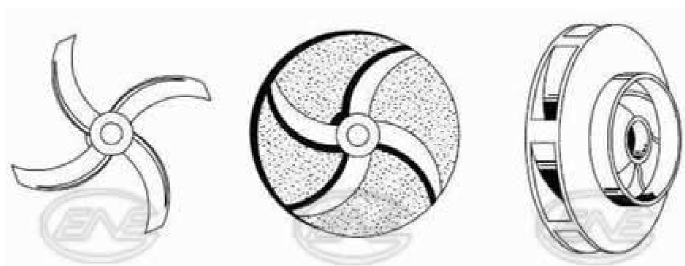
b) Vortex casing: – if a circular chamber is introduced between casing and the impeller, the casing is known as vortex casing.

c) Casing with guide blades:- in this 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 such a way that the water from the impeller enters the guide vanes without stock. Also the area of guide vane increases, thus reducing the velocity of flow through guide vanes and consequently increasing the pressure of water.



Types of impellers :- **(02 marks each for sketches and description)**

Impellers of pumps are classified based on the number of points that the liquid can enter the impeller and also on the amount of webbing between the impeller blades. Impellers can be open, semi-open, or enclosed. The open impeller consists only of blades attached to a hub. The semi-open impeller is constructed with a circular plate (the web) attached to one side of the blades. The enclosed impeller has circular plates attached to both sides of the blades. Enclosed impellers are also referred to as shrouded impellers.

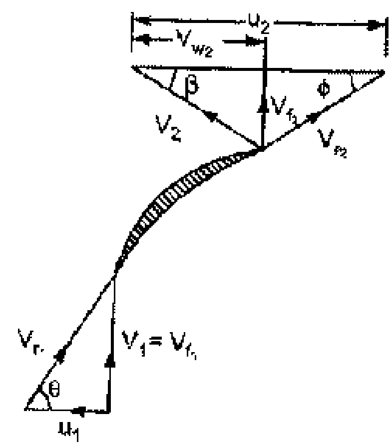


Open Impeller Semi-open Impeller enclosed or shrouded Impeller

Question 6 b) (02 marks each for inlet and outlet velocity and 04 marks for workdone)

The internal and external diameters of the impeller of a centrifugal pump are 200 mm and 400 mm respectively. The pump is running at 1200 r.p.m. The vane angles of the impeller at inlet and outlet are 20° and 30° respectively. The water enters the impeller radially and velocity of flow is constant. Determine the work done by the impeller per unit weight of water.

Solution. Given :



Internal diameter of impeller, $D_1 = 200$ mm $= 0.20$ m
External diameter of impeller, $D_2 = 400$ mm $= 0.40$ 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, $V_{f_1} = V_{f_1}$

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, $\tan\theta = \dfrac{V_{f_1}}{u_1} = \dfrac{V_{f_1}}{12.56}$

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

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

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

or

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

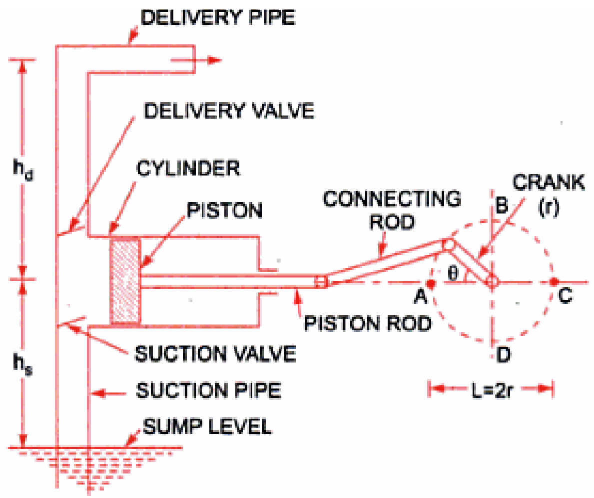
$$\therefore \quad V_{w_2} = 25.13 - 7.915 = 17.215 \text{ m/s.}$$

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

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

Que 6 c) Explain with a neat sketch the principle of a working of a single acting reciprocating pump. Also briefly explain about the phenomenon 'slip'.

Answer:- **(03 marks each for sketch and working principle and 02 marks for slip)**



shows a single acting reciprocating pump, which consists of a piston which moves forwards and backwards in a close fitting cylinder. The movement of the piston is obtained by connecting the piston rod to crank by means of a connecting rod. The crank is rotated by means of an electric motor. Suction and delivery pipes with suction valve and delivery valve are connected to the cylinder. The suction and delivery valves are one way valves or non-return valves, which allow the water to flow in one direction only. Suction valve allows water from suction pipe to the cylinder which delivery valve allows water from cylinder to delivery pipe only.

When crank starts rotating, the piston moves to and fro in the cylinder. When crank is at *A*., the piston is at the extreme left position in the cylinder. As the crank is rotating from *A* to *C*, (*i.e.*, from $\theta = 0$ to $\theta = 180°$), the piston is moving towards right in the cylinder. The movement of the piston towards right creates a partial vacuum in the cylinder. But on the surface of the liquid in the sump atmospheric pressure is acting, which is more than the pressure inside the cylinder. Thus the liquid is forced in the suction pipe from the sump. This liquid opens the suction valve and enters the cylinder.

When crank is rotating from *C* to *A* (*i.e.*, from $\theta = 180°$ to $\theta = 360°$), the piston from its extreme right position starts moving towards left in the cylinder. The movement of the piston towards left increases the pressure of the liquid inside the cylinder more than atmospheric pressure. Hence suction valve closes and delivery valve opens. The liquid is forced into the delivery pipe and is raised to a required height.

SLIP :- slip of a pump is defined as the difference between the theoretical discharge and actual discharge of the pump. The actual discharge of a pump is less than theoretical discharge due to leakage. The difference between theoretical discharge and actual discharge of the pump is known as slip of the pump. Hence mathematically,

$$\text{Slip} = Q_{th} - Q_{act}$$

But slip is mostly expressed as percentage slip which is given by,

$$\text{Percentage slip} = \frac{Q_{th} - Q_{act}}{Q_{th}} \times 100 = \left(1 - \frac{Q_{act}}{Q_{th}}\right) \times 100$$

$$= (1 - C_d) \times 100 \qquad \left(\because \frac{Q_{act}}{Q_{th}} = C_d\right)$$

where C_d = Co-efficient of discharge.