



ZONE TECH
Best Institute For Assistant & Junior Engineer

RPSC-AEn Mains

Work Book Solution

for

Hydraulic Mechanic



Visit Our Website
www.zonetech.in



DOWNLOAD NOW

<https://zonetech.in/downloads>

PART - A

2 Marks Questions

1.

Sol.

Cavitation means bubbles are forming in the liquid.

- To avoid Cavitation, we have to increase the Pump size to One or Two Inch;
- To increase the pressure of the Suction Head, or
- Decrease the Pump Speed.

2.

Sol.

Centrifugal pump. Because flow rate is higher compared to reciprocating pump. Flow is smooth and it requires less space to install. Lower initial cost and lower maintenance cost.

3.

Sol.

In a radialflow turbine, steam flows outward from the shaft to the casing. The unit is usually a reaction unit, having both fixed and moving blades.

4.

Sol.

Topping and superposed turbines are highpressure, noncondensing units that can be added to an older, moderatepressure plant. Topping turbines receive highpressure steam from new highpressure boilers. The exhaust steam of the new turbine has the same pressure as the old boilers and is used to supply the old turbines.

5.

Sol.

Positive displacement pumps are those that operate by forcing a fixed volume of fluid from the inlet pressure section of the pump into the discharge zone of the pump.

6.

Sol.

Governing of a turbine is defined as the operation by which the speed of the turbine is kept constant under all conditions of working. It is done by oilpressure generator.

7.

Sol.

When the nozzle is completely closed, 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 direct the jet of water on the back of vanes. This jet of water is called breaking jet.

8.

Sol.

Propeller Turbines have non-adjustable propeller vanes. They are used in where the range of head is not large. Commercial products exist for producing several hundred watts from only a few feet of head. Larger propeller turbines produce more than 100 MW.

9.

Sol.

The Kaplan turbine is a propeller-type water turbine which has adjustable blades. It was developed in 1913 by the Austrian professor Viktor Kaplan, who combined automatically - adjusted propeller blades with automatically-adjusted wicket gates to achieve efficiency over a wide range of flow and water level.

10.

Sol.

Bulb or Tubular turbines are designed into the water delivery tube. A large bulb is centered in the water pipe which holds the generator, wicket gate and runner. Tubular turbines are a fully axial design, whereas Kaplan turbines have a radial wicket gate.

11.

Sol.

The wetted perimeter (p) is the length of the line of intersection of the channel wetted surface with the cross section plan normal to the direction of flow.

12.

Sol.

1. Increase suction pressure if possible.
2. Decrease liquid temperature if possible.
3. Throttle back on the discharge valve to decrease flow-rate.
4. Vent gases off the pump casing.

13.

Sol.

It is defined as the ratio of power delivered to the runner to the power supplied at the inlet.

14.

Sol.

It is defined as the ratio of power at the shaft of the turbine to the power delivered by the water to runner.

15.

Sol.

It is defined as the ratio of volume of water actually striking the runner to the Volume of water supplied to the runner.

16.

Sol.

It is defined as the ratio of shaft power by water power

17.

Sol.

If the water flows radially from inwards to outwards the turbine is known as outward radial flow turbine.

18.

Sol.

If the water flows through the runner along the direction parallel to the axis of rotation of the runner the turbine is called axial flow turbine.

19.

Sol.

It is the ratio of pitch diameter (D) to the diameter of jet (d).

20.

Sol.

A tube or pipe of gradually increasing area is used for discharging water from the exit of the turbine to the tail race is called draft tube.

21.

Sol.

1. The net head on the turbine increases.
2. Due to increase in net head the power and efficiency of the turbine also increases.
3. The large amount of rejected kinetic energy is converted into useful pressure energy

22.

Sol.

1. Conical draft tube
2. Simple elbow tube
3. Moody spreading tube
4. Draft tube with circular inlet and rectangular outlet.

23.

Sol.

It is defined as the ratio of change of pressure energy inside the runner to the change of total energy outside the runner.

24.

Sol.

It is defined as the speed of the turbine under unit head

$$N_u = N / \sqrt{H}$$

where N_u = unit speed
 N = number of rotations
 H = head of the turbine

25.

Sol.

It is defined as the discharge passing through the turbine which is working under unit head.

$$Q_u = Q / \sqrt{H}$$

Where Q_u = Unit discharge
 Q = Total discharge
 H = Head of the turbine

26. Define unit power?

Sol.

It is defined as the power developed by the turbine working under unit head.

$$P_u = \frac{P}{(H)^{3/2}}$$

Where P_u = Unit power
 P = Total power
 H = Head of the turbine

27.

Sol.

1. To obtain a continuous supply of liquid at a uniform rate.
2. To save a considerable amount of work in overcoming the frictional resistance in the suction and delivery pipes, and
3. To run the pump at a high speed with out separation.

28.

Sol.

It is defined as the speed of the turbine which is geometrically similar and it will develop unit power when working under unit head.

$$N_s = \frac{N\sqrt{P}}{(H)^{5/4}}$$

29.

Sol.

The specific speed of a centrifugal pump is defined as the speed of a geometrically similar pump which would deliver 1 m³/s against a head of 1 m.

$$N_s = \frac{N\sqrt{Q}}{(H)^{3/4}}$$

30.

Sol.

The manometric head is defined as the head against which a centrifugal pump has to work.

H_m = head imparted by the impeller to the water - loss of head

$$H_m = \frac{Vw_2u_2}{g} - \text{loss of head}$$

$$H_m = h_s + h_d + h_{fs} + h_{fd} + \frac{v_d^2}{2g}$$

31.

Sol.

Priming of a centrifugal pump is defined as the operation in which the suction pipe, casing of the pump and a 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 starting the pump.

32.

Sol.

For Single acting Reciprocating Pump

$$\text{Discharge } Q_{th.} = \frac{ALN}{60}$$

For Double acting Reciprocating Pump

$$\text{Discharge } Q_{th.} = \frac{2ALN}{60}$$

where, A = Area of the Cylinder (m^2)

L = Length of Stroke (m)

N = Speed of Crank (rpm)

33.

Sol.

The difference between the theoretical discharge ($Q_{th.}$) and actual discharge (Q_{act}) is known as slip of the pump.

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

$$\% \text{ Slip} = [(Q_{th.} - Q_{act}) / Q_{th.}] \times 100$$

If Q_{act} is more than the $Q_{th.}$ then slip will be -ive.

If Q_{act} lesser than $Q_{th.}$ then the slip will be +ive.

34.

Sol.

It is defined as the ratio of actual discharge to theoretical discharge of reciprocating pump.

$$C_d = \frac{Q_{act}}{Q_{th.}}$$

If $C_d > 1$ then negative slip occurs and if $C_d < 1$ then positive slip occurs.

35.

Sol.

The indicator diagram for a reciprocating pump is defined as the graph drawn between the pressure head in the cylinder and the distance traveled by the piston for one complete revolution of the crank.

36.

Sol.

It is defined as the graph between pressure head in the cylinder and stroke length of the crank under ideal condition is known as ideal indicator diagram.

During the suction stroke, the pressure in the cylinder is below atmospheric pressure.

During the delivery stroke, the pressure in the cylinder is above atmospheric pressure.

37.

Sol.

An air vessel is a closed chamber containing compressed air in the top portion and liquid at the bottom of the chamber. At the base of the chamber there is an opening through which the liquid may flow into the vessel or out from the vessel. When the liquid enters the air vessel, the air gets compressed further and when the liquid flows out of the vessel, the air will expand into the chamber.

38.

Sol.

Due to cavitation process the continuous flow of fluid will get affected and separation takes place. The pressure at which separation takes place is known as separation pressure and the head corresponding to separation pressure is called separation pressure head.

For water the limiting value of separation pressure head is,

$$h_{\text{sep}} = -7.8 \text{ m (Gauge pressure)}$$

$$h_{\text{sep}} = 10.3 - 7.8 = 2.5 \text{ m (Absolute pressure)}$$

39.

Sol.

When vaporization takes place, the molecules start accumulating over the free liquid surface exerting pressure on the liquid surface. This pressure is known as Vapour pressure of the liquid.

PART - B

5 Marks Questions

40.

Sol. Specific Speed: It is defined as the speed of a turbine which is identical in shape, blade angles, gate opening etc., with the actual turbine but of such a size that it will develop unit power when working under unit head. It is denoted by the symbol N_s . The specific speed is used in comparing the different types of turbine as every type of turbine has different specific speed.

In M.K.S. units, unit power is taken as one horse power and unit head as one metre. But in S.I. units, unit power is taken as one kilowatt and unit head as one metre.

Significance of Specific speed: Specific speed plays an important role for selecting the type of the turbine. Also the performance of turbine can be predicted by knowing the specific speed of the turbine. The type of turbine for different specific speed is given in Table:

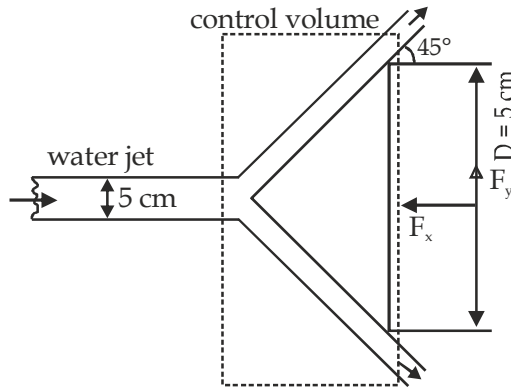
S. No.	Specific Speed (M.K.S.)	Specific Speed (S.I.)	Types of Turbine
1	10 to 35	8.5 to 30	Pelton wheel with single jet
2	35 to 60	30 to 50	Pelton wheel with two or more jets
3	60 to 300	50 to 255	Francis turbine
4	300 to 1000	255 to 860	Kaplan or Propeller turbine

41.

Sol. Assumptions:

- (i) Flow is steady and incompressible.
- (ii) Atmospheric pressure over the cone and jet
- (iii) Gravitational effects are neglected
- (iv) Jet flow is uniform and thus the moment flux correction factor can be taken as unity.





$$m = \rho V = \rho A v = 100 \times \frac{\pi}{4} \times 0.05^2 \times 30 = 58.90 \text{ kg/s}$$

Momentum equation for steady flow

$$\sum \vec{F} = m V_2 \cos \theta - m v_1 = m v (\cos \theta - 1)$$

$F_y = 0$ because of symmetry about 'x' axis:

$$F_x = 58.90 \times 30 (\cos 45^\circ - 1) = -517.59 \text{ N}$$

Here negative sign indicates that a force of 517.59 N must be applied to the cone in the opposite direction of the flow to hold it in place.

42.

Sol. The water flowing through the penstock, from the reservoir, comes out from the nozzle with a velocity V_1 . The expression of V_1 is

$$V_1 = C_v \sqrt{2gH} \quad (i)$$

where,

C_v = Coefficient of velocity of nozzle

H = Net head above the nozzle

1. If the head is less, the velocity of water coming out of the nozzle will be less.

The impulse force on the buckets' of pelton wheel depends on the absolute velocity of water at inlet. The expression of force is given as

$$F = \rho Q (V_1 - u) (1 + k \cos \phi)$$

Where,

Q = Volume flow rate of water

k = Friction coefficient of buckets

ϕ = Blade angle of the outlet

2. If the absolute velocity of the inlet is less, the impulse force generated will also be less. The relationship between the power generated and overall efficiency is

$$P = \eta_0 \rho g Q H \quad \dots (ii)$$

If the diameter of jet coming out of the nozzle is 'd' and absolute velocity is V_1 , then

$$Q = \frac{\pi}{4} d^2 \times V_1$$

Using (i)

$$Q = \frac{\pi}{4} d^2 \times C_v \times \sqrt{2gH}$$

Put in equation (ii),

$$P = \eta_0 \times \rho g \frac{\pi}{4} d^2 C_v \sqrt{2gH} \times H$$



3. If head above the wheel is small, the power generated will also be small.
 $\therefore$ concluding from points 1, 2 and 3, Pelton wheels are unsuitable for low heads.

43.

- Sol.**
- 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 the liquid is flowing, is subjected to these high pressures, which cause pitting action on the surface. The cavities are formed on the metallic surface and also considerable noise and vibrations are produced.

The phenomena of cavitation is more pronounced in pumps. The methods to reduce it are:

- Lower the temperature.
- Raise the liquid level in the suction vessel.
- Reduce motor rpm if possible.
- Increase diameter of the eye of the impeller.
- Use two lower capacity pumps in parallel.
- Use a booster pump to feed the principal pump

Precaution against Cavitation:

The following precautions should be taken against cavitation:

- (i) The pressure of the flowing liquid in any part of the hydraulic system should be not be allowed to fall below its vapour pressure. If the flowing liquid is water, then the absolute pressure head should not be below 2.5 m of water at normal ambient temperature.
- (ii) The special materials or coatings such as aluminium-bronze and stainless steel, which are cavitation resistant materials, should be used.

44.

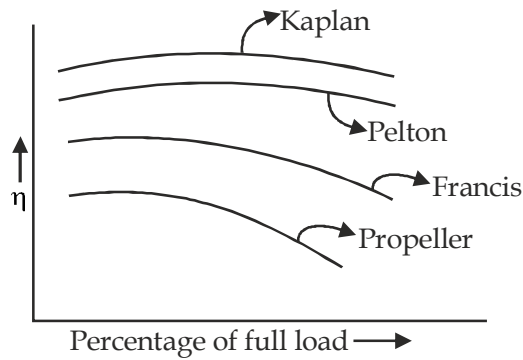
- Sol.** The pressure at the exit of the runner of a reaction turbine is generally less than atmospheric pressure. Thus the water at the exit of the runner cannot be directly discharged to the tail race. A pipe of gradually increasing area is used for discharging water from the exit of the turbine to the tail race. This pipe of gradually increasing area is called a draft tube. One end of the draft tube is connected to the outlet of the runner while the other end is sub-merged below the level of water in the tail race. The draft tube, in addition to serve a passage for water discharge, has the following two purposes also:
1. The turbine may be placed above the tail race and hence turbine may be inspected properly.
 2. The kinetic energy ($V_2^2 / 2g$) rejected at the outlet of the turbine is converted into useful pressure energy.

45.

Sol.

$$\eta_h = \frac{\text{Mechanical Power Output}}{\text{Hydraulic Power Input}} = \frac{\omega T}{\rho g Q H_t}$$

Where, ω is rotational speed of shaft
 T is torque developed by shaft
 Q is discharge



$$H_t = \left(\frac{P}{\rho g} + \frac{\bar{V}^2}{2g} + z \right)_{\text{inlet}} - \left(\frac{P}{\rho g} + \frac{\bar{V}^2}{2g} + z \right)_{\text{outlet}}$$

46.

Sol. Some of the troubles commonly experienced during the operation of the centrifugal pumps and the remedial measures to be taken for the same are listed below:

1. Pump fails to start pumping:

- (i) Pump is probably not properly primed. Reprime the pump, opening the air vent until a steady and unbroken stream of liquid is obtained.
- (ii) Total static head is probably much higher than that for which the pump is designed. Check the same with accurate vacuum and pressure gages, or may be determined by actual measurement, the difference in elevation between pump and suction liquid level, and also between pump and point of discharge. Add to this static head the loss of head due to friction in pipes and that in the other fittings used in the installation.
- (iii) Wrong direction of rotation of the impeller. Arrow on the pump case shows the proper direction of rotation.
- (iv) Impeller may be clogged. Examine carefully for solids or foreign matter lodged in the impeller.
- (v) Suction lift too high. Check with vacuum gauge or by actual measurement where possible, adding to the static suction lift the loss of head in the pipe and fittings.
- (vi) Strainer or suction line may be clogged. This would cause an excessive suction lift.
- (vii) Speed may be too low. Check the speed with a tachometer and compare it with the one given on the name plate of the pump. When the pump is being driven by electric motor, check up to see whether the voltage may not be too low.

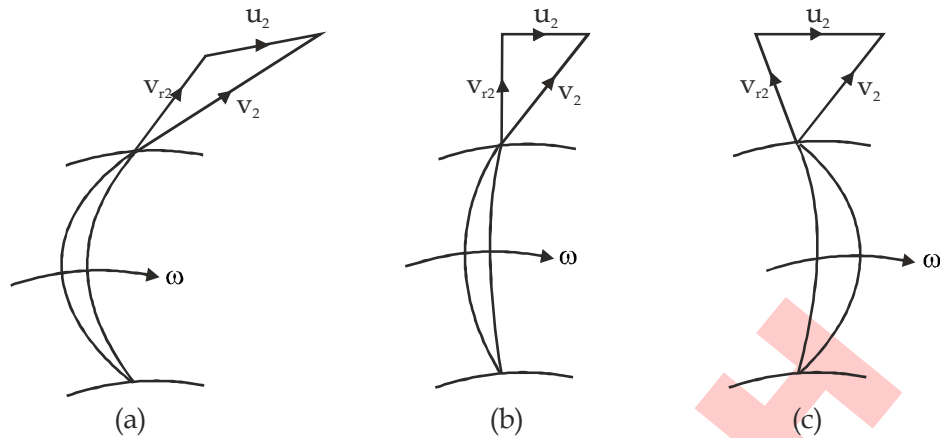
2. Pumps take too much power:

- (i) Speed may be too high
- (ii) Head may be too low and pump delivers too much liquid.
- (iii) Liquid may have too high specific gravity.
- (iv) Pump may be operating in wrong direction.
- (v) Shaft may be bent, impeller may be rubbing on casing, stuffing boxes may be too light, wearing rings may be worn.

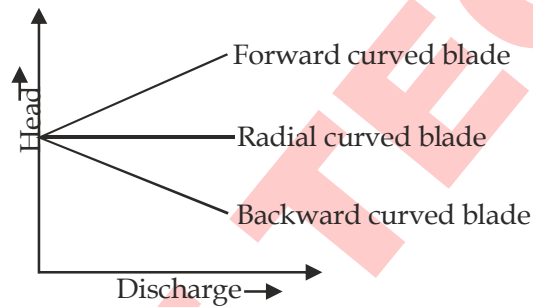
47.

Sol. Velocity triangles at exit are shown below:

- (a) Forward curved blade
- (b) Radial curved blade
- (c) Backward curved blade



'Head vs. discharge' curves for a centrifugal pump is shown below:



48.

Sol. Given: $H_m = 16$ m, $D_2 = 400$ mm, $D_1 = 200$ mm

For the minimum speed for starting the pump, condition is

$$\frac{u_2^2}{2g} - \frac{u_1^2}{2g} \geq H_m$$

$$\therefore u_2 = \frac{\pi D_2 N}{60}, \quad u_1 = \frac{\pi D_1 N}{60}$$

$$\therefore D_2 = 2D_1, \quad \therefore u_2 = 2u_1$$

$$\therefore \frac{(2u_1)^2}{2g} - \frac{u_1^2}{2g} \geq H_m$$

$$\Rightarrow \frac{3u_1^2}{2g} \geq H_m$$

$$\frac{3u_1^2}{2 \times 9.81} \geq 16$$

$$u_1 \geq 10.229$$

$$\therefore \frac{\pi D_1 N}{60} \geq 10.229$$

$$\therefore \frac{\pi \times 0.2 \times N}{60} \geq 10.229$$

$$\therefore N \geq 976.83 \text{ rpm}$$

Minimum speed to start the pump is 976.83 rpm

49.

Sol. **Air Vessel:** An air vessel is a closed chamber containing compressed air in the top portion and liquid (or water) at the bottom of the chamber. At the base of the chamber, there is an opening through which the liquid (or water) may flow into the vessel or out from the vessel. When the liquid enters the air vessel, the air gets compressed further and when the liquid flows out the vessel, the air will expand in the chamber.

An air vessel is fitted to the suction pipe and to the delivery pipe at a point close to the cylinder of a single-acting reciprocating pump.

The advantages of air-vessel are:

1. Suction side:

- (i) To reduce accelerating head
- (ii) Pump can be run at higher speed
- (iii) Length of suction pipe below air-vessel can be increased.

2. Delivery side:

- (i) To reduce accelerating head.
- (ii) A uniform rate of discharge is ensured.



PART - C

20 Marks Questions

50.

Sol.

Basis of Difference	Impulse Turbine	Reaction Turbine
Definition	The type of turbine in which only kinetic energy of water (impulse force) is used to rotate the turbine is known as impulse turbine.	The type of water turbine in which both kinetic energy as well as pressure energy of water is used to turn the turbine is called the reaction turbine.
Water flow	In an impulse turbine, the water flow through a nozzle and strikes to the blades of the turbine.	In reaction turbine, the water is guided by the guide blades (fixed blades) to flow over the turbine.
Force on blades	In impulse turbine, an impulsive force rotates the turbine.	In reaction turbine, a reaction force on the blades is rotation the turbine.
Pressure of water while flowing over Moving blades	In impulse turbine, the pressure of water remains unchanged and is equal to atmospheric pressure when it flows over the moving blades.	In the reaction turbine, the pressure of water continuously decreases when it flows over the blades.
Decrease in pressure of water	In impulse turbine, the pressure of water is reduced in the nozzle before entering the turbine.	In reaction turbine, the pressure of water is decreasing while flowing over the blades.
Change in pressure of water	In impulse turbine, all the pressure of water is converted into kinetic energy before striking the turbine blades.	In reaction turbine, there is no change in the pressure of water before striking the turbine blades.
Water head	The impulse turbines are most suitable for large water heads.	The reaction turbines are suitable for relatively low water heads.
Water flow rate	The impulse turbines are suitable for comparatively low water flow rates.	Reaction turbines are suitable in cases where water flow rates are higher.
Necessity of turbine casing	In impulse turbine, there is no necessity of turbine casing as it has no hydraulic function. It is just provided to prevent splashing of water.	In reaction turbine, the turbine casing is required because the pressure at inlet is very high as compared to pressure at outlet. Therefore, the casing seals it from the atmospheric pressure.
Blades profile	The blades of an impulse turbine are of symmetrical profile.	The blades of a reaction turbine are asymmetrical, having aerofoil profile.
Water discharge	In impulse turbine, the water discharges directly from the turbine wheel to tail race.	In a reaction turbine, the water discharges into a draft tube first and then into the tail race.
Turbine size	For the same power output, the size of impulse turbine is smaller.	The reaction turbine have relatively large size for the same power output.
Examples	Popular examples of impulse turbine are : Pelton wheel turbine, Turgo turbine and cross-flow turbine.	Popular examples of reaction turbines are : Francis turbine and Kaplan turbine.

51.

Sol. SPECIFIC SPEED

It is defined as the speed of a turbine which is identical in shape, geometrical dimensions, blade angles, gate opening etc., with the actual turbine but of such a size that it will develop unit power when working under unit head. It is denoted by the symbol N_s . The specific speed is used in comparing the different types of turbines as every type of turbine has different specific speed.

In M.K.S. units, unit power is taken as one horse power and unit head as one metre. But in S.I. units, unit power is taken as one kilowatt and unit head as one metre.

Derivation of the specific Speed

The overall efficiency (η_0) of any turbine is given by,

$$\Rightarrow \eta_0 = \frac{\text{Shaft power}}{\text{Water power}} = \frac{\text{Power developed}}{\frac{\rho \times g \times Q \times H}{1000}} = \frac{P}{\frac{\rho \times g \times Q \times H}{1000}} \quad \dots(i)$$

where, H = Head under which the turbine is working
 Q = Discharge through turbine
 P = Power developed or shaft power.

From equation (i), we get

$$P = \eta_0 \times \frac{\rho \times g \times Q \times H}{1000}$$

$$P \propto Q \times H \text{ (as } \eta_0 \text{ and } \rho \text{ are constant)} \quad \dots(ii)$$

Now let, D = Diameter of actual turbine
 N = Speed of actual turbine
 u = Tangential velocity of the turbine
 N_s = Specific speed of the turbine
 V = Absolute velocity of water

The absolute velocity, tangential velocity and head on the turbine are related as,

$$u \propto V$$

$$\text{where } V \propto \sqrt{H} \quad \dots(iii)$$

But the tangential velocity u is given by

$$u = \frac{\pi DN}{60} \propto DN \quad \dots(iv)$$

$\therefore$ From equations (iii) and (iv), we have

$$\sqrt{H} \propto DN \text{ or } D \propto \frac{\sqrt{H}}{N} \quad \dots(v)$$

The discharge through turbine is given by

$$Q = \text{Area} \times \text{Velocity}$$

$$\text{But Area} \propto B \times D \quad (\text{where } B = \text{Withd})$$

$$\propto D^2 \quad (\because B \propto D)$$

$$\text{and Velocity} \propto \sqrt{H}$$

$$\therefore Q \propto D^2 \times \sqrt{H}$$

$$\propto \left(\frac{\sqrt{H}}{N} \right)^2 \times \sqrt{H} \quad \left(\because \text{From equation (v), } D \propto \frac{\sqrt{H}}{N} \right)$$

$$\propto \frac{H}{N^2} \times \sqrt{H} \propto \frac{H^{3/2}}{N^2} \quad \dots(\text{vi})$$

Substituting the value of Q in equation (ii), we get

$$P \propto \frac{H^{3/2}}{N^2} \times H \propto \frac{H^{5/2}}{N^2}$$

$$\therefore P = K \frac{H^{5/2}}{N^2}$$

where, K = Constant of proportionality

If P = 1, H = 1, the speed N = Specific speed N_s .

Substituting these values in the above equation, we get

$$1 = \frac{K \times 1^{5/2}}{N_s^2} \text{ or } N_s^2 = K$$

$$\therefore P = N_s^2 \frac{H^{5/2}}{N^2} \text{ or } N_s^2 = \frac{N^2 P}{H^{5/2}}$$

$$\therefore N_s = \sqrt{\frac{N^2 P}{H^{5/2}}} = \frac{N \sqrt{P}}{H^{5/4}} \quad \dots(\text{vii})$$

In equation (vii), if P is taken in metric horse power the specific speed is obtained in M.K.S. units. But if P is taken in kilowatts, the specific speed is obtained in S.I. units.

Significance of Specific Speed

Specific speed plays an important role for selecting the type of the turbine. Also the performance of a turbine can be predicted by knowing the specific speed of the turbine. The type of turbine for different specific speed is given in table as :

S.No.	Specific Speed		Types of Turbine
	(M.K.S.)	(S.I.)	
1.	10 to 35	8.5 to 30	Pelton wheel with single jet
2.	35 to 60	30 to 51	Pelton wheel with two or more jets
3.	60 to 300	51 to 225	Francis turbine
4.	300 to 1000	225 to 860	Kaplan or Propeller turbine

52.

Sol. Given, (i) Shaft power = 11,772 kW

(ii) Head = 380 metres

(iii) Speed = 750 r.p.m.

(iv) Overall efficiency, $\eta_0 = 86\%$ or 0.86

(v) Ratio of jet dia. to wheel dia. = $\frac{d}{D} = \frac{1}{6}$

(vi) Co-efficient of velocity, $K_{v1} = C_v = 0.985$

(vii) Speed ratio, $K_{u1} = 0.45$

Velocity of jet, $V_1 = C_v \sqrt{2gH}$

$$V_1 = 0.985 \sqrt{2 \times 9.81 \times 380} = 85.05 \text{ m/s}$$

The velocity of wheel,

$$u = u_1 = u_2$$

$$= \text{Speed ratio} \times \sqrt{2gH}$$

$$= 0.45 \times \sqrt{2 \times 9.81 \times 380} = 38.85 \text{ m/s}$$

But $u = \frac{\pi DN}{60}$

$$\therefore 38.85 = \frac{\pi DN}{60}$$

or $D = \frac{60 \times 38.85}{\pi \times N} = \frac{60 \times 38.85}{\pi \times 750} = 0.989 \text{ m}$

But $\frac{d}{D} = \frac{1}{6}$

$$\therefore \text{Dia of jet } d = \frac{1}{6} \times D = \frac{0.989}{6} = 0.165 \text{ m}$$

Discharge of one jet,

$$q = \text{Area of jet} \times \text{Velocity of jet}$$

$$= \frac{\pi}{4} d^2 \times V_1 = \frac{\pi}{4} (0.165)^2 \times 85.05 \text{ m}^3/\text{s}$$

$$q = 1.818 \text{ m}^3/\text{s}$$

Now, $\eta_0 = \frac{\text{S.P.}}{\text{W.P.}} = \frac{11772}{\frac{\rho g \times Q \times H}{1000}}$

$$0.86 = \frac{11772 \times 1000}{1000 \times 9.81 \times Q \times 380}$$

where, $Q = \text{Total discharge}$

$\therefore$ Total discharge,

$$Q = \frac{11772 \times 1000}{1000 \times 9.81 \times 380 \times 0.86} = 3.672 \text{ m}^3/\text{s}$$

$$\therefore \text{Number of jets} = \frac{\text{Total discharge}}{\text{Discharge of one jet}} = \frac{Q}{q} = \frac{3.672}{1.818} = 2 \text{ jets}$$

53.

Sol. Given, (i) Speed, $N_1 = 190 \text{ r.p.m.}$

(ii) Power, $P_1 = 5150.25 \text{ kW}$

(iii) Head, $H_1 = 220 \text{ m}$

(iv) Overall efficiency, $\eta_0 = 80\% = 0.80$

(v) Speed ratio = 0.47



(vi) New head of water, $H_2 = 140$ m

Overall efficiency is given by

$$\eta_0 = \frac{P_1}{\rho \times g \times Q_1 \times H_1} = \frac{1000 \times P_1}{\rho \times g \times Q_1 \times H_1} \times 1000$$

$$\therefore Q_1 = \frac{1000 \times P_1}{\eta_0 \times \rho \times g \times H_1} = \frac{1000 \times 5150.25}{0.80 \times 1000 \times 9.81 \times 220} = 2.983 \text{ m}^3/\text{s}$$

Unit speed is given by equation,

$$N_u = \frac{N_1}{\sqrt{H_1}} = \frac{190}{\sqrt{220}} = 12.81 \text{ r.p.m.}$$

Unit discharge is given by equation

$$Q_u = \frac{Q_1}{\sqrt{H_1}} = \frac{2.983}{\sqrt{220}} = 0.201 \text{ m}^3/\text{s}$$

Unit power is given by equation

$$P_u = \frac{P_1}{H_1^{3/2}} = \frac{5150.25}{220^{3/2}} = 1.578 \text{ kW}$$

When the turbine is working under a new head of 140 m, the speed, discharge and power are given by equation as

For speed, $\frac{N_1}{\sqrt{H_1}} = \frac{N_2}{\sqrt{H_2}}$

$$\therefore N_2 = \frac{N_1 \sqrt{H_2}}{\sqrt{H_1}} = N_1 \sqrt{\frac{H_2}{H_1}} = 190 \sqrt{\frac{140}{220}} = 151.56 \text{ r.p.m.}$$

For discharge, $\frac{Q_1}{\sqrt{H_1}} = \frac{Q_2}{\sqrt{H_2}}$

$$\therefore Q_2 = \frac{Q_1 \sqrt{H_2}}{\sqrt{H_1}} = Q_1 \sqrt{\frac{H_2}{H_1}} = 2.983 \sqrt{\frac{140}{220}} = 2.379 \text{ m}^3/\text{s}$$

For power, $\frac{P_1}{H_1^{3/2}} = \frac{P_2}{H_2^{3/2}}$

$$\therefore P_2 = P_1 \frac{H_2^{3/2}}{H_1^{3/2}} = P_1 \left(\frac{H_2}{H_1} \right)^{3/2} = 5150.25 \left(\frac{140}{220} \right)^{3/2} = 2614.48 \text{ kW}$$

54.

Sol.

On the basis of design of casing the centrifugal pumps are classified as volute pump and diffuser pump.

Volute Pump:

- In a volute pump the impeller is surrounded by a spiral shaped casing which is known as volute chamber.



- The area of flow increases gradually in the volute chamber resulting in decrease in the velocity of flow.
- The decrease in velocity increases the pressure of water flowing through the casing.
- It has been observed that in case of volute casing, the efficiency of the pump decreases slightly as a large amount of energy is lost due to the formation of eddies in this type of casing.

Diffuser Pump:

- In the diffuser pump, the impeller is surrounded by a series of guide blades (vanes) mounted on a ring called diffuser ring.
- The diffuser ring and guide vanes are fixed in position.
- The adjacent guide vanes provide gradually enlarged passages for the flow of liquid.
- The liquid after leaving the impeller passes through these passages of increasing area, wherein the velocity of flow decreases and the pressure increases.
- Diffuser pumps are more costly than volute pumps.

On the basis of fluid handling centrifugal pumps are classified as radial flow pump, mixed flow pump and axial flow pump.

Radial Flow Pump:

- In radial flow pump the liquid flows through the impeller in the radial direction only.

Mixed Flow Pump:

- In mixed flow pumps, the liquid flows through the impeller axially as well as radially.
- A mixed flow impeller discharges more than the radial impeller.
- These are used where a large quantity of liquid is to be discharged to low heights.

Axial Flow Pump:

- In axial flow pumps, the flow of liquid through the impeller is in axial direction only.
- The axial flow pumps are designed to deliver large quantities of liquid at relatively low heads.
- However, it is not justified to call axial flow pumps as centrifugal pumps as there is hardly any centrifugal action in their operation.

Net Positive Suction Head (NPSH)

It is defined as the absolute pressure head at the inlet to the pump minus the vapour pressure head (in absolute units) corresponding to the temperature of the liquid pumped, plus the velocity head at this point.

Thus,

$$\text{NPSH} = \left(\frac{P_a}{\gamma} + \frac{P_s}{\gamma} \right) - \frac{P_v}{\gamma} + \frac{V_s^2}{2g}$$

But
$$\frac{P_s}{\gamma} = - \left(\frac{V_s^2}{2g} + h_s + h_{fs} \right)$$

$$\therefore \text{NPSH} = \frac{P_a}{\gamma} - \frac{V_s^2}{2g} - h_s - h_{fs} - \frac{P_v}{\gamma} + \frac{V_s^2}{2g}$$

$$\Rightarrow \text{NPSH} = \frac{P_a}{\gamma} - \frac{P_v}{\gamma} - h_s - h_{fs}$$

The right hand side of the above equation represents the total suction head (H_{sv})

$$\text{i.e. } H_{sv} = \frac{P_a}{\gamma} - \frac{P_v}{\gamma} - h_s - h_{fs}$$

$$\therefore \text{NPSH} = H_{sv}$$

Where P_a is the atmospheric pressure acting on the free liquid surface in the pump, P_s is the gauge pressure at the inlet to the pump, V_s is the velocity of flow in the suction pipe, h_s is the suction lift and h_{fs} is the head lost in foot valve, strainer and the suction pipe and P_v is the vapour pressure of liquid in absolute units.



55.

- Sol.** **Given:** (i) Net head, $H_m = 14.5$ m
(ii) Speed, $N = 1000$ r.p.m.
(iii) Vane angle at outlet, $\phi = 30^\circ$
(iv) Impeller diameter means the diameter of the impeller at outlet
 $\therefore$ Diameter, $D_2 = 300$ mm = 0.30 m
(v) Outlet width, $B_2 = 50$ mm = 0.05 m
(vi) Manometric efficiency, $\eta_{man} = 95\% = 0.95$
Tangential velocity of impeller at outlet,

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.30 \times 1000}{60} = 15.70 \text{ m/s}$$

Now using equation,

$$\eta_{man} = \frac{gH_m}{V_{w2} \times u_2}$$

$$\therefore 0.95 = \frac{9.81 \times 14.5}{V_{w2} \times 15.70}$$

$$\therefore V_{w2} = \frac{0.95 \times 14.5}{0.95 \times 15.70} = 9.54 \text{ m/s}$$

From outlet velocity triangle, we have

$$\tan \phi = \frac{V_{f2}}{(u_2 - V_{w2})} \text{ or } \tan 30^\circ = \frac{V_{f2}}{(15.70 - 9.54)} = \frac{V_{f2}}{6.16}$$

$$\therefore V_{f2} = 6.16 \times \tan 30^\circ = 3.556 \text{ m/s}$$

$$\therefore \text{Discharge, } Q = \pi D_2 B_2 \times V_{f2}$$

$$Q = \pi \times 0.30 \times 0.05 \times 3.556 \text{ m}^3/\text{s} = 0.1675 \text{ m}^3/\text{s}$$