HYDRAULIC MACHINES

1. The specific speed of a pump has dimensions of

(a) $L^{3/4}T^{-3/2}$

(b) $L^{3/4}T^{-1/2}$

(c) $M^{o}L^{\circ}T^{\circ}$

(d) $M^{-1/2}L^{1/2}\ T^{14}$

Solution:

$$N_s = \frac{Nx\sqrt{Q}}{H^{3/4}}$$

Dimension of N (rpm) = T^{-1}
Dimension of Q (Nm/s) = $L^{3}.T^{-1}$
Dimension of H(m) = L

$N_s = \frac{T^{-1}(L^3T^{-1})^{1/2}}{L^{3/4}}$=$L^{3/4}T^{-3/2}$

2. The net head (H) on the turbine is given by:

(a) H = Gross head + Head lost due to friction

(b) H= Gross head - Head lost due to friction

(c) H = Gross head + $\frac{V^2}{2g}$ - Head lost due to friction

(d) None of the above

Solution:

The net or effective head is the head of water available at the point of entry to the turbine.

The difference between the gross and net heads is evidently equal to the loss of head due to friction and other causes in the conveyance system

3. The specific speed for a turbine has the dimension of

(a) $F^{1/2}L^{3/4}T^{3/2}$

(b) T^{-1}

(c) $T^{1/2}L^{-5/2}T^{-3/2}$

(d) $FL^{-3/4}T^{-3/2}$

Solution:

Solution:

It is defined as the speed of a similar turbine working under a head of 1 m to produce a power output of 1 kW. The specific speed is useful to compare the performance of various type of turbines. The specific speed differs for different type of turbines and is same for the model and actual turbine.

$$N_s = \frac{Nx\sqrt{P}}{H^{5/4}}$$

Dimension of N (rpm) = T^{-1}

Dimension of P (Nm/s) = $F.L.T^{-1}$

Dimension of H(m) = L

Dimension of $N_s = F^{1/2}\ L^{-3/4}\ T^{-3/2}$

4. A surge tank is provided in hydropower schemes to

(a) Reduce water hammer pressure

(b) Reduce frictional losses

(c) Increase the net head

(d) Strengthen the penstock

Solution:

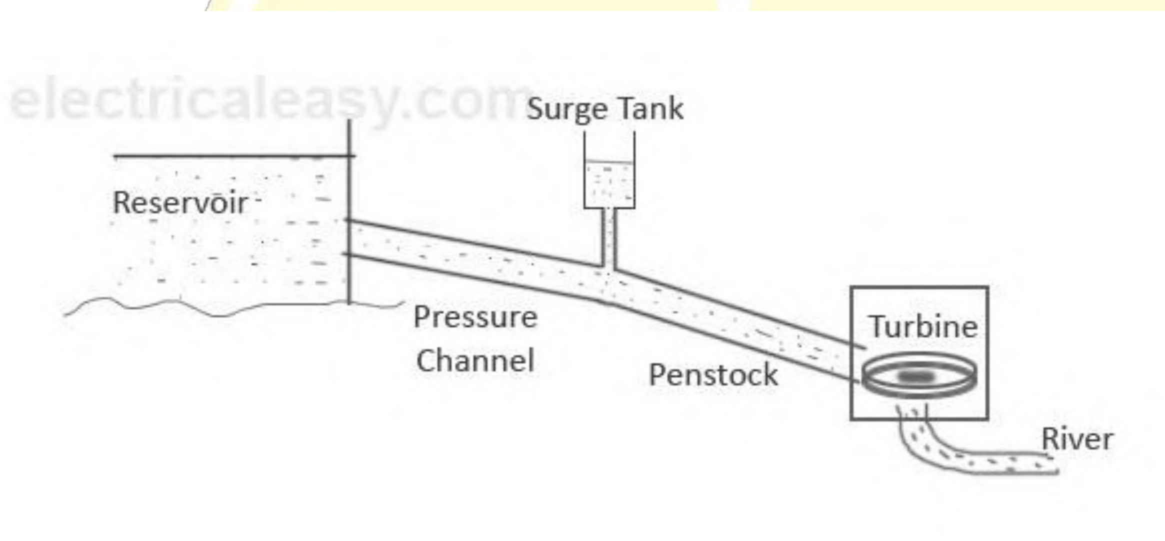
Surge Tank:

Surge tanks are usually provided in high or medium head power plants when considerably long penstock is required. A surge tank is a small reservoir or tank which is open at the top. It is fitted between the reservoir and the power house.

The water level in the surge tank rises or falls to reduce the pressure swings in the penstock. When there is sudden reduction in load on the turbine, the governor closes the gates of the turbine to reduce the water flow.

This causes pressure to increase abnormally in the penstock. This is prevented by using a surge tank, in which the water level rises to reduce the pressure.

On the other hand, the surge tank provides excess water needed when the gates are suddenly opened to meet the increased load demand.



5. For producing electricity, following combination of machines will be required:

(a) Electric Motor + Pump

(b) Hydraulic Turbine + Generator

(c) Hydraulic Turbine + Electric Motor

(d) Generator + Pump

Solution:

Water Turbine: Water from the penstock is taken into the water turbine. The turbine is mechanically coupled to an electric generator. Kinetic energy of the water drives the turbine and consequently the generator gets driven. There are two main types of water turbine; (i) Impulse turbine and (ii) Reaction turbine. Impulse turbines are used for large heads and reaction turbines are used for low and medium heads.

Generator: A generator is mounted in the power house and it is mechanically coupled to the turbine shaft. When the turbine blades are rotated, it drives the generator and electricity is generated which is then stepped up with the help of a transformer for the transmission purpose.

6. Typically, hydroelectric plant will have following hydraulic machine.

(a) Hydraulic Turbine

(b) Hydraulic Pump

(c) Electric Motor

(d) None of the above

Solution:

Hydraulic turbines: Hydraulic turbines may be considered as hydraulic motors or prime movers of a water—power development, which convert water energy (hydropower) into mechanical energy (shaft power).

The shaft power developed is used in running electricity generators directly coupled to the shaft of the turbine, thus producing electrical power. The hydraulic turbine is a rotary machine actuated by the impulse and/or reaction of a water current attacking the rotor (called the runner), which consists of a series of buckets or curved vanes or blades.

7. Francis turbine is

(a) A reaction turbine

(b) An impulse turbine

(c) A tangential flow impulse turbine

(d) An axial flow turbine

Solution:

Reaction Turbine: Turbine for which both pressure energy and kinetic energy is available at the inlet is a reaction turbine.

E.g. **Francis** Turbine, Kaplan Turbine and Propeller Turbine.

They are useful for **low head and high discharge.**

Impulse Turbine: Turbine for which only kinetic energy is available at the inlet is an impulse turbine.

E.g. Pelton Turbine and Turgo Impulse Turbine.

They are useful for **high head and low discharge.**

8. The specific speed of a pump is defined as the speed of a unit of such a size that it discharges

(a) Unit discharge at unit power

(b) Unit work at unit head loss

(c) Unit discharge at unit head

(d) Unit volume at unit time

Solution:

The specific speed of a centrifugal pump is defined as the speed of a geometrically similar pump which would deliver one cubic metre of liquid per second against a head of one metre or we can say that it delivers unit discharge at unit head.

9. In the selection of turbine by specific speed or head, which one of the following statements is not correct?

(a) For specific speed 10-35, Kaplan turbines

(b) For specific speed 60-300, Francis turbines

(c) For head 50-150 m, Francis turbines

(d) For head above 300 m, Pelton wheel

Solution:

Following are the range of specific speed of different turbines

The specific speed of Pelton wheel turbine (single jet) is in the range of 10-35

The specific speed of Pelton wheel turbine (multiple jets) is in the range of 35-60

The specific speed of Francis turbine is in the range of 60-300.

The specific speed of Kaplan/propeller turbine is greater than 300.

So the Kaplan turbine has the highest specific speed.

The classification of the turbine based on the basis of operating head

Type of turbine	Operating head (m)
Pelton	**300 m and above**
Francis	60 m to 300 m
Kaplan	20 m to 60 m
Bulb	2 m to 20 m

The specific speed of a turbine is in the range of

Turbine	N_s
Pelton wheel	10 - 60
Francis	60 - 300
Kaplan	> 300

10. The maximum number of jets generally employed in an impulse turbine without jet interference is -

(a) 2

(b) 6

(c) 4

(d) 8

Solution:

Number of Jets: obtained by dividing the total rate of flow through the turbine by the rate of flow through single jet. The number of jets is not more than two for horizontal shaft turbines and is limited to six for vertical shaft turbines.

11. In a Kaplan turbine runner, the number of blades is generally

(a) 2 to 4

(b) 8 to 16

(c) 4 to 8

(d) 16 to 24

Solution:

Kaplan turbine has adjustable runner blades. Kaplan Turbine has very small number of blades 4 to 8. France Turbine has very large number of blades 16 to 24

12. A Pelton wheel working under a constant head and discharge, has maximum efficiency when the speed ratio is -

(a) 0.26

(b) 0.46

(c) 0.36

(d) 0.56

Solution:

In the case of a Pelton turbine, an additional requirement for its operation at the condition of maximum efficiency is that the ratio of the bucket to initial jet velocity has to be kept at its optimum value of about 0.46.

Pelton turbine --> 0.43 - 0.48.

Francis turbine --> 0.60 - 0.90.

Kaplan turbine --> 1.5 - 2.

13. Which of the following statements is INCORRECT?

(a) The reaction turbines are used for low head and high discharge

(b) The angle of taper on draft tube is less than 8

(c) A Francis turbine is an impulse turbine

(d) None of these

Solution:

Reaction Turbine: Turbine for which both pressure energy and kinetic energy is available at the inlet is a reaction turbine.

E.g. **Francis** Turbine, Kaplan Turbine and Propeller Turbine.

They are useful for **low head and high discharge.**

Impulse Turbine: Turbine for which only kinetic energy is available at the inlet is an impulse turbine.

E.g. Pelton Turbine and Turgo Impulse Turbine.

They are useful for **high head and low discharge.**

14. The specific speed of a turbine is speed of an imaginary turbine, identical with the given turbine, which

(a) Delivers unit discharge under unit head

(b) Delivers unit discharge under unit speed

(c) Develops unit horse power under unit head

(d) Develops unit horse power under unit speed

Solution:

Specific speed of the turbine is the speed at which unit power delivered at the unit head. ∴ The specific speed of a turbine is the speed of an imaginary turbine, identical with the given turbine, which develops unit horsepower under the unit head.

15. In a centrifugal pump casing, the flow of water leaving the impeller is -

(a) Radial

(b) Centrifugal

(c) Rectilinear

(d) Free vortex

Solution:

A centrifugal pump is a machine which converts the kinetic energy of the water into pressure energy before the water leaves its casing. The flow of water leaving the impeller is free vortex. The impeller of a centrifugal pump may have volute casing, vortex casing and volute casing with guide blades.

16. The runway speed of a turbine is ………..

(a) The actual running speed at design load

(b) The synchronous speed of the generator

(c) The speed attained by the turbine under no load condition

(d) The speed of the wheel when governor fails

Solution:

The runaway speed is the maximum speed that the turbine can theoretically attain. It is achieved during load rejection. The runaway speed of a water turbine is its speed at full flow and no shaft load. The turbine will be designed to survive the mechanical forces of this speed. The manufacturer will supply the runaway speed rating.

17. Identify the false statement from the following.

The specific speed of the pump increases with ………..

(a) Increase in shaft speed

(b) Increase in discharge

(c) Decrease in gravitational acceleration

(d) Increase in head

Solution:

$$N_s = \frac{N\sqrt{Q}}{H_m^{3/4}}$$

Clearly from the formula it can be stated that

$$N_s \propto \frac{1}{H_m^{3/4}}$$

Specific speed will decrease with H increses

18. Which of the following inferences is not drawn by studying performances curves of centrifugal pumps?

(a) Discharge increases with speed

(b) Power decrease with speed

(c) Head increases with speed

(d) Manometric head decreases with discharge

Solution:

$Q \propto N;\ P \propto N^3; H \propto N^2$

Power increases with cube of speed

19. The centrifugal pump should be installed above the water level in the sump such that

(a) Its height is not more than 1.03 m at room temperature of liquid

(b) Its height is not allowed to exceed 6.7 m

(c) The negative pressure does not reach as low as the vapour pressure

(d) None of these

Solution:

The centrifugal pump converts the mechanical energy into fluid energy. Also, it increases manometric head by converting the pressure head into manometric head. Hence, during its operation there is a chance that the pressure at the eye of the impeller may reaches to zero or negative pressure which may lead to the cavitation effect (if it reaches below vapour pressure). Hence to reduce this effect, it must be placed at certain height from the sump level called as suction height.

This minimum manometric head is required to make possible the suction which is represented by NPSH (net positive suction head). Hence, the centrifugal pump height is such that the negative pressure does not reaches below vapour pressure.

20. The 'surcharge storage' in a dam reservoir is the volume of water stored between ………..

(a) Minimum and maximum reservoir levels

(b) Minimum and normal reservoir levels

(c) Normal and maximum reservoir levels

(d) None of these

Solution:

Surcharge Storage: The volume of water stored between the maximum pool level and normal pool level is called surcharge storage.

Bank Storage: When the reservoir is filled, a certain amount of water seeps into the permeable reservoir bank. This water comes out when the reservoir gets depleted. This volume of water is known as bank storage.

Useful storage: The volume of water stored in the reservoir between normal and minimum pool level is called useful storage.

Valley Storage: Before the construction of the dam, a variable amount of water is stored in the stream channel is called valley storage.

21. Which one of the following is correct for impulse turbine?

(a) Always operates in submerged condition

(b) Converts pressure head into velocity with the help of vanes.

(c) Operates by initial complete conversion of kinetic energy.

(d) Operates by initial complete conversion to potential energy.

Solution:

Impulse Turbine: If at the inlet of the turbine, the energy available is only kinetic energy, the turbine is known as impulse turbine. e.g. a Pelton wheel turbine.

In the impulse turbine, the pressure head of the incoming steam is converted into a large velocity head at the exit of the supply nozzle. That is the entire available energy of the steam is converted into kinetic energy.

22. Which of the following turbine is suitable to generate the power of 10000 hp, working at the speed of 500 rpm under a head of 81 m?

(a) Propeller

(b) Francis

(d) Pelton

(c) Kaplan

Solution:

Power developed in kW

= 10,000 x 0.756 = 7560 kW

$$N_s = \frac{Nx\sqrt{P}}{H^{5/4}} = \frac{500x\sqrt{7460}}{81^{5/4}} = 179\ in\ SI\ Units$$

Turbine	Specific speed (SI units)
Pelton	8-30
Francis	40-420
Kaplan and Propeller	380-950

23. The head developed by the centrifugal pump is 40 m while operating at the speed of 750 rpm. If the rated capacity is given as 50 cumec. What is the specific speed of centrifugal pump?

(a) 150

(b) 300

(c) 333

(d) 500

Solution:

$$N_s = \frac{Nx\sqrt{Q}}{H^{3/4}}$$

N = No. of revolutions in rpm,

Q = Discharge, and

H = Head developed by cent. Pump

Given:

N = 750 rpm, Q = 50 m3/s, and H = 40

$$N_s = \frac{750x\sqrt{50}}{40^{3/4}} = 333$$

24. The power of the pump is given as 30 HP. What is the equivalent power expressed in watts?

(a) 20000

(b) 22380

(c) 25742

(d) 30500

Solution:

I hp=746 watts

30 hp =30x746=22380 watts

25. A turbine generates the power of 150000 kW while working at the speed of 300 rpm at the head of 100 m. What is the specific speed of the turbine?

(a) 300

(b) 340

(c) 367

(d) 452

Solution:

It is defined as the speed of a similar turbine working under a head of 1 m to produce a power output of 1 kW. The specific speed is useful to compare the performance of various type of turbines. The specific speed differs for different type of turbines and is same for the model and actual turbine.

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

Where N = speed of turbine,
P = power generated,
H = head generated

$N_s = \frac{300x\sqrt{150000}}{100^{5/4}}$=367.42=367

26. Which of the following is CORRECT to maximize the efficiency of all reaction turbine?

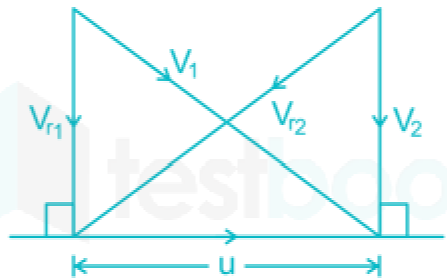
(a) Angle of absolute velocity vector at outletis 90°.

(b) Blade angle is 90° at inlet

(c) Blade angle is 90° at outlet.

(d) Guide vane angle is 90

Solution:



Velocity diagram for maximum efficiency

In case of Maximum efficiency

$$\alpha_2 = 90^0 \textit{where } \alpha_2 \textit{ is the angle of absolute velocity vector at the outlet}$$

27. Which of the following statement is correct?

(a) Pumps connected in parallel are used to boost the head, whereas pump operating in series boosts the discharge.

(b) Pumps operating in series, boosts the heads, whereas pump operating in parallel boosts the discharge.

(c) Pump either in parallel or series always boost only discharge.

(d) Pump either in parallel or series always boast only head.

Solution:

According to Gorman-Rupp,

When two pumps are connected in series at the same flow rate the series pump yield high heads as compared to the individual heads produce by each pump. • While in parallel, two pumps can simultaneously discharge a greater amount of water than the individual one.

Hence boost the discharge, if two pumps are connected in parallel.

28. Draft tube at the exit of a reaction turbine used for hydroelectric project is _

(a) Above or below the water surface, depends on unit speed of the turbine.

(b) Always above the water surface.

(c) Always immersed in water

(d) May either be below or above the water

Solution:

It is a conduit which connects the runner exit to the tailrace where the water is being finally discharged from the turbine. Hence, Draft tube at the exit of a reaction turbine used for the hydroelectric project is always immersed in water.

29. In the hydel system, a forebay is used at the junction of

(a) Penstock and turbine.

(b) Power channel and penstock

(c) Power channel and tail race channel

(d) Tailrace channel and penstock.

Solution:

In the hydel system, a forebay is used at the junction of the headrace channel and penstock.

As the name suggests forebay is an enlarged body of water in front of the intake. The reservoir acts as a forebay when the penstock takes water directly from it. When the canal leads water to the turbines the section of the canal in front of turbines is enlarged to create forebay. The forebay temporarily stores water for supplying the same to the turbines.

30. What is the specific speed of centrifugal pump, which has a rated capacity of 44 cumec and a head of 36 m when operated at the speed of 725 rpm?

(a) 45

(b) 225

(c) 327

(d) 350

Solution:

Specific Speed of centrifugal pump Ns=$\frac{(NxQ^{0.5})}{H^{0.75}}$

Given

Q= 44 cumecs

H=36 m

N=725rpm

$$Ns = \frac{(NxQ^{0.5})}{H^{0.75}} = \frac{(725x44^{0.5})}{36^{0.75}} = 327.2 = 327$$

31. If the two exactly same pumps are running at the same speed and lift the water at the head of 20 m and 30 mi respectively. What is the diameter of impeller of second pump if the diameter (mm) of impeller of first pump is 500 mm?

(a) 430.2

(b) 500.5

(c) 612.5

(d) 714.3

Solution:

For Pump No. 1

Head (H_{M1}) = 20 m and Diameter (D_1) = 500 mm

For Pump No. 2

Head (H_{M2}) = 30 m and Diameter (D_2) = ?

For same pumps: $H_m / N^2 D^2$ = Constant

$\Rightarrow H_{m1} / N_1^2 D_1^2 = H_{m2} / N_2^2 D_2^2$

Given that N is constant for both pumps

$\Rightarrow H_{m1} / D_1^2 = H_{m2} / D_2^2$

$\Rightarrow 20/500^2 = 30/ D_2^2$

$\Rightarrow D_2 = 612.38$ mm

32. What will be the capacity factor of hydro- power if a plant with a capacity of 10000 kW is to produce 400000 kWh when operating for 100 hours?

(a) 25%

(b) 30%

(c) 50%

(d) 40%

Solution:

Capacity Factor = (Load/Total Hours)/Plant Capacity

Capacity Factor = (400000/100)/10000

Capacity Factor = 0.4 or 40%

33. In a turbine, the ratio of power available at the shaft of the turbine to the power supplied by the water at inlet of the turbine is called

(a) Mechanical efficiency

(b) Volumetric efficiency

(c) Overall efficiency

(d) Hydraulic efficiency

Solution:

Overall efficiency (η_o) is defined as the ratio of the power available at the shaft of the turbine to the power supplied by the water at the inlet of the turbine.

34. Which of the following is a positive displacement pump?

(a) Reciprocating pump

(b) Centrifugal pump

(c) Propeller pump

(d) Jet pump

Solution:

Positive displacement pumps are those pumps in which the liquid is sucked and then it is pushed or displaced to the thrust exerted on it by a moving member, which results in lifting the liquid to the required height.

Reciprocating pump, Vane pump, Lobe pump are the examples of positive displacement pump whereas the centrifugal pump is the non-positive displacement pump.

35. The flow ratio of a Francis turbine, if it is working under a head of 62 m and velocity at inlet 7 m/s ($g = 10\ m/s^2$) is:

(a) 0.4

(b) 0.3

(c) 0.2

(d) 0.1

Solution:

Flow ratio of Francis turbine is defined as the ratio of the velocity of flow at inlet to the theoretical jet velocity

$$flow\ ratio = \frac{V}{\sqrt{2gH}}$$

$In\ the\ caseof\ Francis\ turbine\ flow\ raio\ varies\ from 0.15\ to 0.3$

Speed ratio varies from 0.6 to 0.9

Flow ratio =$\frac{7}{\sqrt{2x10x62}} = 0.2$

36. The overall efficiency of a centrifugal pump when head is 25 m, discharge = 0.04 m3/s and output p = 16 kW (take g = 10 m/sec^2 and p = 1000 kg/m^3) is:

(a) 65%

(b) 52.5%

(c) 62.5%

(d) 55%

Solution:

Overall efficiency of a centrifugal pump

η =$\frac{water\ power}{shaft\ power} = \frac{\omega QH}{P}$

$$P = \frac{\omega QH}{\eta}$$

$$\eta = \frac{\rho gQH}{P} = \frac{1000x9.81x0.04x25}{16000} = 0.625 = 62.5\%$$

37. If three centrifugal pumps identical in all respects and each capable of delivering a discharge Q against a head H are connected in parallel, the resulting discharge is:

(a) 3Q against a head 3H

(b) Q against a head 3H

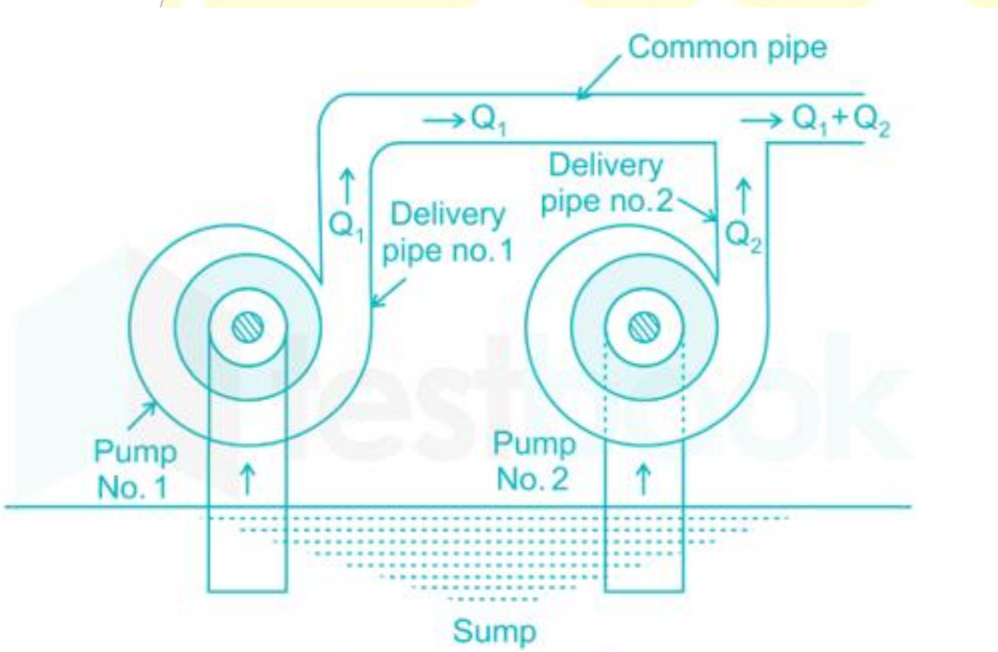
(c) 3Q against a head H

(d) 3Q against a head $\sqrt{3}$ H

Solution:

Pumps arranged in parallel increase the flow, but the head remains that of one pump working

With pumps in parallel, the flow rates are additive with a common head.



Pumps in parallel

38. A Pelton wheel is to be designed for a pitch diameter of 1 m and jet diameter of 0.1m. The number of buckets on the runner computed by Taygun's formula is:

(a) 25

(b) 15

(c) 20

(d) 10

Solution:

Number of buckets on a runner Z=15+$\frac{D}{2d}$

Jet ratio=12

i.e 12=$\frac{D}{d}$

Number of buckets on a runner =15 +6 =21

Here take the answer as 20

39. Two centrifugal pumps P and R are available for use in a pipe flow system and their head-discharge characteristics are as follows:

Pump P		Pump R	
Discharge (cumecs)	Head (m)	Discharge (cumecs)	Head (m)

0	40	0	45
0.12	35	0.14	40
0.2	28	0.24	35
0.3	18	0.36	21

The following statements (S1, S2 and 53) pertain to the head and discharge values during actual operation. Neglect losses in the system.

Which of the following statements are correct?

S1:When the two pumps P and Rare connected in parallel, the discharge is 0.36 cumecs corresponding to a head of35 m.

S2:When the two pumps P and R are connected in series, the discharge is 0.3 cumec corresponding to a head of 46 m.

S3: When the two pumps P and R are connected in series, the discharge is 0.3 cumec corresponding to a head of 46 m.

(a) S2 only

(b) S1 and S3

(c) S1 and S2

(d) S2 and S3

Solution: