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CHAPTER

Hydraulic Turbines

Q.1 Consider the following statements:

1. Specific speed uniquely determines the type, shape and design of the turbine.
2. Both unit speed 'n_{11}' and unit discharge 'Q_{11}' are necessary to uniquely determine the type and design of the turbine.

Which of these statements is/are correct in respect of a hydraulic turbine?

(a) 2 alone (b) 1 alone
(c) Both 1 and 2 (d) Neither 1 nor 2

Q.2 A Francis turbine working at 400 rpm has a unit speed of 50 rpm and develops 500 kW of power. What is the effective head under which this turbine operates?

(a) 62.5 m (b) 64.0 m
(c) 40.0 m (d) 100 m

Q.3 For a hydro-electric project with reaction turbine, the draft tube at the exit from the turbine is

(a) always immersed in water
(b) always above the water
(c) may either be above or below the water
(d) above or below the water depending on the unit speed of the turbine

Q.4 The specific speed of a turbine under a head of 150 m to develop 2000 HP while running at 300 rpm is

(a) 10-35 (b) 35-60
(c) 60-300 (d) 300-1000

Q.5 A Pelton wheel operates at 630 rpm taking 3 m³/s of water under a head of 256 m with a speed ratio of 0.48 (Given $\sqrt{19.62} = 4.43$) What is the diameter of the impeller?

(a) 0.90 m (b) 1.03 m
(c) 1.42 m (d) 1.80 m

Q.6 Which one of the following statement is not correct in respect of hydraulic turbines?

(a) (Speed) is proportional to $(\text{Diameter})^{1/2}$
(b) (Power) is proportional to $(\text{Speed})^3$
(c) (Power) is proportional to $(\text{Head})^{3/2}$
(d) (Speed) is proportional to $(\text{Head})^{1/2}$

Q.7 An impulse turbine

(a) always operates submerged
(b) makes use of a draft tube
(c) operates by initial complete conversion to kinetic energy
(d) converts pressure head into velocity throughout the vanes

Q.8 A hydraulic turbine has a discharge of 5 m³/sec, when operating under a head of 20 m with a speed of 500 rpm. If it is to operate under a head of 15 m, for the same discharge, the rotational speed in rpm will approximately be

(a) 433 (b) 403
(c) 627 (d) 388

Q.9 To generate 10,000 HP under a head of 81 m while working at a speed of 500 rpm, the turbine of choice would be

(a) Pelton (b) Kaplan
(c) Bulb (d) Francis

Q.10 Owing to a sudden closure of turbines in a powerhouse:

(a) a positive surge will occur in head race channel with surge front moving downstream
(b) a positive surge will occur in head race channel with surge front moving upstream
(c) a negative surge will occur in head race channel with surge front moving upstream
(d) a negative surge will occur in head race channel with surge front moving downstream

Q.11 Tests were conducted on a Francis turbine of 0.8 m diameter under a head of 9 m. The turbine running at 240 rpm develops 84.5 kW and the water consumption was 1.2 m³/s. If the same turbine operates under a head of 16 m, the new discharge will be

(a) 1.4 m³/s (b) 1.6 m³/s
(c) 1.8 m³/s (d) 2 m³/s

Q.12 In axial flow turbine

(a) inlet is axial outlet is radial
(b) inlet is axial and outlet is axial
(c) inlet is radial and outlet is axial
(d) inlet is radial and outlet is radial

Q.13 If α is the blade angle at the outlet, then the maximum hydraulic efficiency of an ideal impulse turbine is

(a) $\frac{1+\cos\alpha}{2}$ (b) $\frac{1-\cos\alpha}{2}$

(c) $\frac{1-\sin\alpha}{2}$ (d) $\frac{1+\sin\alpha}{2}$

Q.14 The load factor is the ratio of

(a) average load to maximum load during any period
(b) energy consumed in a time t to the maximum demand in that time
(c) maximum demand to connected load
(d) average output of the plant for a given period of time to the plant capacity

Q.15 Indicate the *incorrect* statement:
A surge tank in a penstock

(a) restricts the water hammer pressure to a small length of pipe upstream of it
(b) acts as a storage device to absorb excess flows
(c) restricts the water hammer pressure to a small length of pipe down stream of it.
(d) converts the energy of water hammer into low frequency mass oscillation

Q.16 The Thoma's number is used in connection with

(a) water hammer phenomenon
(b) mass oscillation phenomenon
(c) fluid friction in a boundary layer
(d) cavitation phenomenon

Q.17 The Thoma number is defined as equal to

(a) $\frac{P_a - P_v - \gamma z}{\gamma H_1}$ (b) $\frac{P_a - P_v}{\gamma H_1}$

(c) $\frac{P_a - P_v - \gamma H_1}{\gamma H}$ (d) $\frac{(P_a - \gamma z) + P_v}{\gamma H_1}$

where
P_a = atmospheric pressure
P_v = vapour pressure
H_1 = effective working head, and
z = vertical distance of the turbine runner above the tail race

Q.18 Safe value of critical Thoma's number for a Francis turbine is about

(a) 4.5 (b) 3.0
(c) 1.5 (d) 0.3

Q.19 Typically the value of maximum efficiency for a well designed Kaplan turbine is about

(a) 60% (b) 95%
(c) 70% (d) 82%

Q.20 The Toricelli theorem gives velocity of jet as

(a) $\sqrt{gh}$ (b) $\sqrt{2gh}$

(c) $\frac{1}{\sqrt{2gh}}$ (d) $\sqrt{\frac{2gh}{3}}$

Q.21 Cavitation damage in turbine runner occurs

(a) near the inlet on the concave side of blades
(b) near the outlet on the convex side of blades
(c) near the inlet on the convex side of blades
(d) near the outlet on the concave side of blades

Q.22 For cavitation-free operation of turbines, the runner must be suitably installed with respect to the tail race. The Thoma's coefficient

$\sigma_{inst} = (H_{atm} - H_v - H_s)/H$ for safe operation must satisfy the following relationship with the critical coefficient σ_c

(a) $\sigma_c > \sigma_{inst}$ (b) $\sigma_c = \sigma_{inst}$
(c) $\sigma_{inst} > \sigma_c$ (d) $\sigma_c + \sigma_{inst} = 1$

Q.23 Turbines that can be classified based on the main direction of flow of water in the runner, are:

1. Mixed flow turbine
2. Tangential flow turbine
3. Radial flow turbine
4. Axial flow turbine

Which of these statements are correct?

(a) 1, 2 and 4 (b) 1, 3 and 4
(c) 2, 3 and 4 (d) 1, 2 and 3

Q.24 Consider the following statements:

1. Hydraulic efficiency of the turbine is the ratio of the power developed by the runner to the net power supplied by the water at the entrance to the turbine.
2. Mechanical efficiency of the turbine is the ratio of the power available at the turbine shaft to the power developed by the runner.
3. volumetric efficiency is the ratio of the quantity of water actually striking the runner and the quantity of water supplied to the turbine.

Which of these statements is/are correct?

(a) Only 3 (b) Both 1 and 3
(c) Both 2 and 3 (d) 1, 2 and 3

Q.25 Water enters a turbine steadily at the rate of 100 litres per second with a pressure of 3×10^5 N/m^2 and a velocity of 100 m/s. It leaves the turbine with a pressure of 10^5 N/m^2 and a velocity of 50 m/s. If no losses occur, the power produced by the turbine is

(a) 20 kW (b) 375 kW
(c) 395 kW (d) 770 kW

Q.26 A turbine works at 20 m head and 500 rpm speed. Its 1:2 scale model to be tested at a head of 20 m should have a rotational speed of nearly

(a) 1000 rpm (b) 700 rpm
(c) 500 rpm (d) 250 rpm

Q.27 An impulse turbine of 3 m diameter is rated at 10000 kW at 300 rpm under a head of 500 m. The turbine is operated under the head of 400 m. What is the speed of which it would run?

(a) 324 rpm (b) 336 rpm
(c) 348 rpm (d) 269 rpm

Q.28 An impulse turbine of 3m diameter is rated at 10000 kW at 300 rpm under a head of 500 m. The turbine is operated under the head of 400 m. What is the power developed?

(a) 15000 kW (b) 7200 kW
(c) 13000 kW (d) 12000 kW

Q.29 Given that atmosphere pressure head is 9 m, vapour pressure head (max) is 1 m, failure head is 40 m and cavitation coefficient σ is 0.15. The height at which the turbine can be set above the tailrace level is

(a) 6 m (b) 4 m
(c) 3 m (d) 2 m

Q.30 In all reaction turbines, maximum efficiency is obtained when the

(a) guide vane angle is 90°
(b) blade angle is 90° at the inlet
(c) blade angle is 90° at the outlet
(d) angle of the absolute velocity vector at the outlet is 90°

Q.31 The speed ratio of a Pelton wheel operating under a head of 900 m is 0.45. What is the peripheral velocity of the turbine wheel?

(a) 28 m/s (b) 96 m/s
(c) 42 m/s (d) 60 m/s

Q.32 Assertion (A): Selection of turbine by specific speed criterion is more scientific.

Reason (R): Specific speed depends on dimensions, size of both actual and specific turbine.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

Q.33 Water turbine may be put in the decreasing order of specific speeds as

(a) propeller turbine, reaction turbine, impulse turbine
(b) Pelton wheel, Francis turbine, Kaplan turbine
(c) Reaction turbine, impulse turbine, propeller turbine
(d) None of the above

Q.34 Consider the following statements:

1. An impulse turbine is ideal for high head development.
2. Speed ratio of a reaction turbine is in the range of 0.6 to 0.9
3. Specific speed of a Kaplan turbine is in the range of 50 to 150 m.

Which of these statement/s is/are correct?

(a) only 1 (b) both 1 and 2
(c) both 1 and 3 (d) All of these

Q.35 If a multi-jet Pelton turbine has 'n' number of jets, then its specific speed is directly proportional to

(a) n^0 (b) $n^{1/2}$
(c) $n^{3/4}$ (d) n

Q.36 Consider the following statements:

1. Specific speed uniquely determines the type, shape and design of the turbine.
2. Both unit speed 'n_u' and unit discharge 'Q_u' are necessary to uniquely determine the type and design of the turbine.

Which of these statement/s is/are correct in respect of a hydraulic turbine?

(a) 2 alone (b) 1 alone
(c) 1 and 2 (d) Neither 1 nor 2

Q.37 A turbine discharging 10 m^3/s is to be designed so that a torque of 1600 kg-m is to be exerted on the impeller turning at 200 rpm under the condition that the exiting liquid exerts no moment inspite of its momentum. The tangential component of the velocity at the outer periphery of the impeller of radius 1.0 m is

(a) 0.98 m/s (b) 1.57 m/s
(c) 2.10 m/s (d) 2.26 m/s

Q.38 Two Pelton turbines *A and B* have the same specific speed and are working under the same head. Turbine *A* produces 400 kW at 1000 rpm. If turbine B produces 100 kW, then its rpm is

(a) 4000 (b) 2000
(c) 1500 (d) 3000

Q.39 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I

A. Pelton turbine
B. Francis turbine
C. Kaplan turbine
D. Banki turbine

List-II

1. Mixed flow reaction turbine
2. Operating under low head and large discharge
3. Operating under high head and large discharge
4. No draft tube

Codes:

	A	B	C	D
(a)	4	2	1	3
(b)	3	1	2	4
(c)	4	1	2	3
(d)	3	2	1	4

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Answers Hydraulic Turbines

1. (b)	2. (b)	3. (a)	4. (b)	5. (b)	6. (a)	7. (c)	8. (b)	9. (d)	10. (b)
11. (b)	12. (b)	13. (a)	14. (a)	15. (a)	16. (d)	17. (a)	18. (d)	19. (b)	20. (b)
21. (b)	22. (c)	23. (d)	24. (d)	25. (c)	26. (a)	27. (d)	28. (b)	29. (d)	30. (d)
31. (d)	32. (c)	33. (a)	34. (b)	35. (b)	36. (b)	37. (b)	38. (b)	39. (c)	

Explanations Hydraulic Turbines

1. (b)

Specific speed is independent of dimension or size of the actual turbine and specific turbine.

Further, $N_s = 3.13 N_u \sqrt{Q_u \eta_0}$

Therefore besides unit speed and unit discharge overall efficiency is also required to determine type and design of turbine.

2. (b)

Unit speed of the turbine is given by

$$\frac{N}{\sqrt{H}} = 50$$

$$\Rightarrow \quad \frac{400}{\sqrt{H}} = 50$$

$$\Rightarrow \quad H = 64\ \text{m}$$

3. (a)

Draft tube must be airtight and under all-conditions of its operation, its lower end must be submerged below the level of water in the tail race. It has two purposes:

(i) Permits a negative or suction head to be established at the runner exit.

(ii) Converts a large portion of velocity energy rejected from the runner into useful pressure energy.

5. (b)

$$\text{Speed ratio} = \frac{u}{\sqrt{2gH}}$$

$$\therefore \quad u = 0.48 \times \sqrt{2 \times 9.81 \times 256}$$

$$= 0.48 \times 4.43 \times 16$$

$$= 34.02\ \text{m/s}$$

But $\quad u = \left(\frac{\pi DN}{60}\right)$

$$\therefore \quad D = \frac{60 \times 34.02}{\pi \times 630} = 1.03\ \text{m}$$

6. (a)

$$(DN) \propto H^{1/2}$$

$$\text{Power} \propto D^2 N^3$$

$$\text{Power} \propto D^2 N^{3/2}$$

$$N \propto H^{1/2}$$

9. (d)

Power developed in kW

$$= 10{,}000 \times 0.756 = 7560\ \text{kW}$$

$$\text{Specific speed} = \frac{N\sqrt{P}}{H^{5/4}} = \frac{500 \times \sqrt{7560}}{(81)^{5/4}}$$

$$= 179 \text{ in SI units}$$

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

10. (b)

If the sluice gate of the head race channel is suddenly closed (for closing turbine) positive surge will move upstream. If the sluice gate is suddenly opened (to start turbine) positive surge will move downstream.

11. (b)

$$\frac{H_1}{N_1^2} = \frac{H_2}{N_2^2}$$

$$N_2 = N_1\sqrt{\frac{H_2}{H_1}} = 240\sqrt{\frac{16}{9}} = 320\ \text{rpm}$$

$$Q_2 = Q_1\frac{N_2}{N_1} = 1.2 \times \frac{320}{240} = 1.6\ \text{m}^3/\text{s}$$

12. (b)

In axial flow turbine both inlet and exit of turbine is axial.

If water flows through the runner in the radial direction but leaves in the direction parallel to the axis of rotation of the runner. The turbine is called mixed flow turbine.

13. (a)

For maximum efficiency

$$u = \frac{V_1}{2}$$

$$\eta_{max} = \frac{1 + \cos\alpha}{2}$$

14. (a)

Load factor

$$= \frac{\text{Average load over a given time interval}}{\text{Peak load during the same time interval}}$$

Capacity factor

$$= \frac{\text{Average load}}{\text{Rated capacity of the plant}}$$

If the rated capacity of the plant is equal to the peak load, then the load factor and capacity factor will be numerically equal.

21. (b)

Since cavitation begins when the pressure reaches too low a value, it is likely to occur at points where the velocity or the elevation is high, and particularly at such points where high velocity and high elevation are combined. In a reaction turbine the point of minimum pressure is usually at the out let end of a blade on its convex side. For flow between such a point and the water level in the tail race, the Bernoulli's equation may by written as

$$\frac{p_v}{\gamma} + \frac{V^2}{2g} + z = \frac{p_a}{\gamma}$$

$$\sigma = \frac{V^2}{2gH} = \frac{p_a - p_v - \gamma z}{\gamma H}$$

where σ is Thoma's cavitation number

H: Effective head

To determine the maximum elevation z_{max} of the turbine above the tail water level for cavitation free operation.

$$z_{max} = \frac{p_a}{\gamma} - \frac{p_v}{\gamma} - \sigma_c H$$

σ_c is the critical cavitation parameter which is usually about 0.1.

26. (a)

$$N_m = N_p \frac{D_p}{D_m}\sqrt{\frac{H_m}{H_p}}$$

29. (d)

$$Z = \frac{p_a}{\gamma} - \frac{p_v}{\gamma} - \sigma_c H$$

31. (d)

$$\text{Speed ratio} = \frac{u}{\sqrt{2gH}}$$

$$\Rightarrow \quad \frac{u}{\sqrt{2 \times 9.8 \times 900}} = 0.45$$

$$\Rightarrow \quad u = 60\ \text{m/sec}$$

32. (c)

Specific speed is independent of dimensions size of both actual and specific turbine.

38. (b)

$$N_{S_A} = N_{S_B}$$

$$\frac{N_1\sqrt{P_1}}{H^{5/4}} = \frac{N_2\sqrt{P_2}}{H^{5/4}}$$

$$\Rightarrow \quad 1000 \times \sqrt{400} = N_2 \times \sqrt{100}$$

$$\therefore \quad N_2 = 2000\ \text{rpm}$$

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