

KATHMANDU UNIVERSITY
End Semester Examination
May/June, 2022

Marks scored:

Level : B.E.

Course : MEEG 309

Year : III

Semester: II

Exam Roll No. :

Time: 30 mins.

F. M. : 20

Registration No.:

Date :

SECTION "A"

[20Q. × 1 = 20 marks]

Mark [×] in the most appropriate answer box. Formula sheet is not required in this section.

- Which of the following turbines operates at the highest speed for same head and flow?
 Pelton Turgo Francis Kaplan
- A Bulb turbine is an example of:
 Reaction turbine Mixed flow turbine
 Impulse turbine Radial flow turbine
- Which of the following component is used for emergency stopping of Pelton turbine?
 Spear Valve Jet deflector Governor Nozzle
- Which of the following component is not a hydro-mechanical unit of hydropower?
 Gates Penstock Trash rack Main valve
- The guide vane provided in a Francis turbine:
 Increases the circumferential component of velocity of water passing at runner inlet
 Decreases the circumferential component of velocity of water passing at runner
 Increases the radial component of velocity of water passing at runner
 Decreases the radial component of velocity of water passing at runner
- Cavitation in hydraulic turbines occurs when the operating pressure inside turbine is:
 equal to atmospheric pressure below atmospheric pressure
 greater than atmospheric pressure below vapor pressure of water
- The specific speed of a centrifugal pump, delivering 750 liters of water per second against a head of 15 meters at 725 rpm is
 24.8 rpm 48.2 rpm 82.4 rpm 248 rpm
- A hydropower site has available flow of $10 \text{ m}^3/\text{s}$ under a head of 300 m. If the turbine is to be run at a speed of 100 rpm, what type of turbine is suitable based on the speed number?
 Pelton Low head Francis
 Kaplan High Head Francis

17. Which one of the followings is a wrong statement?
- Only the tangential component of absolute velocity is considered in the estimation of theoretical head of a turbo machine
 - A high head turbine has a high value of specific speed
 - For the same power, a turbo machine running at high specific speed will be small in size
 - Pelton wheel is the tangential flow turbine whereas the propeller and Kaplan turbines are axial flow units
18. In a practice, the flow ratio of a Francis turbine is found to lie in the range
- 0.15 to 0.3
 - 0.42 to 0.46
 - 0.55 to 0.65
 - 0.7 to 0.85
19. Two hydraulic turbines are similar and homologous when they are geometrically similar and have the same
- Thoma's number
 - Reynolds number
 - Specific speed
 - Rotational speed
20. Hydraulic efficiency of Francis turbine is
- Directly proportional to velocity of wheel at inlet and inversely proportional to the net head on the turbine
 - Directly proportional to velocity of wheel at inlet and the net head on the turbine
 - Inversely proportional to velocity of wheel at inlet and the net head on the turbine
 - Inversely proportional to velocity of wheel at inlet and directly proportional to the net head on the turbine



KATHMANDU UNIVERSITY
End Semester Examination
May/June, 2022

Level : B.E.
Year : III
Time : 2 hrs. 30 mins.

Course : MEEG 309
Semester: II
F. M. : 55

SECTION "B"

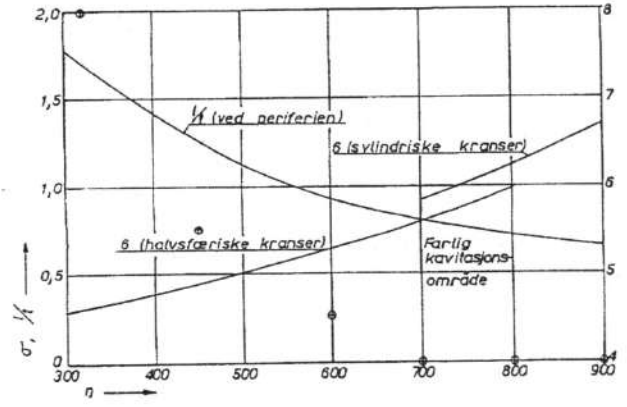
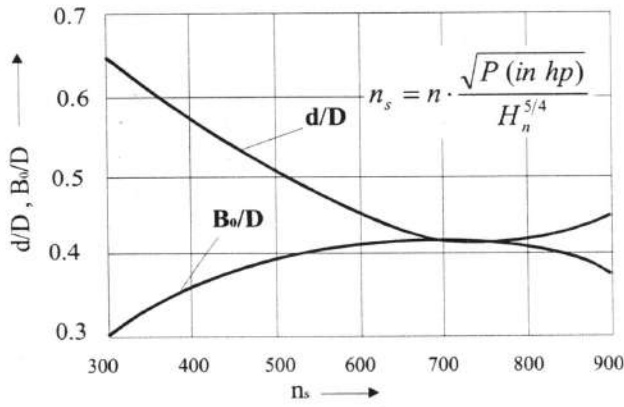
[5Q. \times 11 = 55 marks]

Attempt ALL questions. Assume suitable data if missing/necessary. Formula sheet is provided.

1.
 - a. Discuss the hydraulic conditions where Turgo types of turbines are the best choice. [2]
 - b. With mathematical expression justify that the efficiency of a reaction turbine increases with the draft tube? [3]
 - c. A jet of water 80 mm in diameter and having a velocity of 20 m/s impinges at the center of the hemispherical vane. The linear velocity of the vane is 10 m/s in the direction of the jet. Find the force exerted on the vane. How this force would change if the jet impinges on a series of vanes attached to the circumference of the wheel? [6]
2.
 - a. Justify why the efficiency of a runner with flat plates cannot exceed 50 %? [2]
 - b. Discuss the working principle of a mechanical governor used in hydropower. [3]
 - c. A Pelton wheel of 1.1 m mean bucket diameter works under a head of 500 m. The deflection of the jet is 165° and its relative velocity is reduced over the bucket by 15 percent due to friction. If the diameter of the jet is 100 mm and the water is to leave the bucket without any whirl, determine: (i) Rotational speed of the wheel, (ii) Ratio of bucket speed to jet velocity, (iii) Impulsive force and power developed by the wheel, (iv) Available power (water power), (v) Power input to buckets, and (vi) Efficiency of the wheel with input power to the bucket as reference. Take $C_v = 0.97$. [6]
3.
 - a. What are the different losses in Francis turbines? List out the percentage of those losses in the Francis turbines. [3]
 - b. What is a hill chart? Describe a typical hill chart of a Francis turbine and indicate where it could be used advantageously? [3]
 - c. Find all the information to draw inlet and outlet velocity triangles of a Francis turbine having following data: net head = 150 m, $Q = 2 \text{ m}^3/\text{s}$, speed = 1000 rpm, $D_1 = 0.7 \text{ m}$, $D_2 = 0.3 \text{ m}$, $B_1 = 0.1 \text{ m}$ and hydraulic efficiency = 96 %. [5]

- 4.
- a. Efficiency of model turbines/pumps is generally lower than that of the larger prototype of the turbines/pumps. Comment upon the truth of this statement. [2]
 - b. Describe the variation of the following velocities in a Kaplan runner: [3]
 - Velocity of flow,
 - Tangential velocity, and
 - Whirl velocity
 - c. A Propeller turbine runner has an outer diameter of 4.5 m and an inner diameter of the 2 m. It develops 21 MW when working under a head of 20 m. The turbine is directly coupled to an alternator having 22 pairs of poles. The hydraulic efficiency is 94 % and overall efficiency is 88 %. Find the discharge through the turbine. Find the runner vane angles at inlet and outlet, at the hub and at the edge of the blade. [6]
- 5.
- a. State how the change in speed and diameter of impeller affects the discharge, head and power of centrifugal pumps. [3]
 - b. Why casing is needed in centrifugal pump? With the aid of neat sketches, describe three kinds of casing adopted in centrifugal pumps. [3]
 - c. A three stage centrifugal pump has impellers 40 cm in diameter and 2 cm wide at outlet. The vanes are curved back at outlet at 45 degree and reduce the circumferential area by 10 %. The manometric efficiency is 90 % and the overall efficiency is 80 %. Determine the head generated by the pump when running at 1000 rpm delivering 50 litres per second. What should be the shaft power? [5]

| | | |
|---|---|--|
| $\eta = \frac{u_1 \cdot v_{u1} - u_2 \cdot v_{u2}}{g \cdot H_n}$ | $13^\circ < \beta_2 < 22^\circ$ (lowest value for highest head) $35 < U_2 < 43 \text{ m/s}$ (highest value for highest head) | $H_m = h_s + h_d + h_{fs} + h_{fd} + \frac{v_d^2}{2}$ |
| $h_f = f \cdot \frac{L}{D} \cdot \frac{v^2}{2 \cdot g}$ | $v_{m2} = 1.1 \cdot v_{m1}$ $H_m = \left[\frac{p_o}{\rho \cdot g} + \frac{v_o^2}{2 \cdot g} + z_o \right] - \left[\frac{p_i}{\rho \cdot g} + \frac{v_i^2}{2 \cdot g} + z_i \right]$ | $n_q = n \cdot \frac{\sqrt{Q}}{H^{3/4}}$ $n_{s,turbine} = 2.97 \cdot n_{q,pump}$ |
| $N_s = \frac{N \cdot \sqrt{P}}{H^{5/4}}$ (P in kW) Pelton, 1 jet: 12 - 30 Pelton, 2 jet: 17 - 50 Pelton, 4 jet: 24 - 70 High head Francis: 80 - 150 Medium head Francis: 150 - 250 Low head Francis: 250 - 400 Propeller/ Kaplan: 300 - 1000 Bulb or Tubular: 1000 - 2000 | $H_s = 10 - NPSH_R$ $NPSH_R = a \cdot \frac{v_{m2}^2}{2 \cdot g} + b \cdot \frac{u_2^2}{2 \cdot g}$ <i>Turbines</i> <i>Pumps</i> a 1.05 < a < 1.15 1.6 < a < 2.0 b 0.05 < b < 0.15 0.2 < b < 0.25 $d_s = \sqrt{\frac{4 \cdot Q}{z \cdot \pi \cdot v_1}}$ | Affinity Law 1: $\frac{Q_1}{Q_2} = \frac{n_1}{n_2}$ $\frac{H_1}{H_2} = \left(\frac{u_1}{u_2} \right)^2 = \left(\frac{n_1}{n_2} \right)^2$ $\frac{P_1}{P_2} = \left(\frac{n_1}{n_2} \right)^3$ Affinity Law 2: $\frac{Q_1}{Q_2} = \left(\frac{D_1}{D_2} \right)^3$ $\frac{H_1}{H_2} = \left(\frac{D_1}{D_2} \right)^2$ $\frac{P_1}{P_2} = \left(\frac{D_1}{D_2} \right)^5$ |
| $n_q = n \cdot \frac{\sqrt{Q}}{H^{0.75}}$ | $\underline{Q}_n = \frac{\pi \cdot (D^2 - d^2)}{4} \cdot c_{1m}$ $D = \sqrt{\frac{\underline{Q}_n \cdot 4}{\pi \cdot c_{1m}}} \quad n = \frac{3000}{z_p}$ $\sigma = \frac{10 - H_s}{H}$ | |
| $\Omega = \omega \cdot \sqrt{Q}$ $\Omega \leq 0.22$ (Pelton) $0.2 < \Omega < 1.25$ (Francis) $\Omega > 1.0$ (Kaplan/Bulb) | | |
| $H_e = \frac{u_2 \cdot v_{u2}}{g} = \frac{u_2}{g} [u_2 - v_{f2} \cdot \cot \beta_2]$ | $c_{1m} = 0.12 + 0.18 \cdot \Omega$ | $P = \rho \cdot Q \cdot g \cdot H_t$ $H_t = \frac{u_2 \cdot v_{u2} - u_1 \cdot v_{u1}}{g}$ $H_t = \frac{u_2^2 - u_1^2}{2 \cdot g} + \frac{v_2^2 - v_1^2}{2 \cdot g} - \frac{w_2^2 - w_1^2}{2 \cdot g}$ $\eta_{man} = \frac{g \cdot H_m}{v_{u2} \cdot u_2}$ |
| $v_1 = C_d \cdot \sqrt{2 \cdot g \cdot H_n}$ [$C_d = 0.97$ to 0.98] | $\frac{P_2}{\gamma} = \frac{P_1}{\gamma} - h_s - \left(\frac{v_2^2 - v_3^2}{2g} - h_f \right)$ | |
| $\phi = \frac{u}{v} = 0.45 - 0.48$ Pelton $\phi = \frac{u}{v} = 0.62 - 0.82$ Francis | $\frac{1 - \eta_M}{1 - \eta_P} = \left(\frac{D_P}{D_M} \right)^{1/5}$ $\frac{0.94 - \eta_M}{0.94 - \eta_P} = \left(\frac{Q_P}{Q_M} \right)^{0.32}$ | |
| $3.1 > \frac{B}{d_s} \geq 3.4$ $D = 10 \cdot d_s$, for $H_n \leq 500 \text{ m}$ $D = 15 \cdot d_s$, for $H_n = 1300 \text{ m}$ | $\eta_d = \frac{\frac{v_2^2 - v_3^2}{2g} - h_f}{\frac{v_2^2}{2g}}$ | $n_{min} = \frac{120 \cdot \eta_{man} \cdot v_{u2} \cdot D_2}{\pi (D_2^2 - D_1^2)}$ $D_{Housing} = D + K \cdot B$ |
| $Pr. \text{ rise} = \frac{P_2 - P_1}{\rho g} = \frac{1}{2g} [v_1^2 - v_2^2 + 2v_{u2} \cdot u_2]$ | head or lift co-efficient: $\frac{\sqrt{H}}{D \cdot n}$ | $\phi = \frac{v_{m2}}{\sqrt{2 \cdot g \cdot H_m}} [0.1 - 0.25]$ |
| $I = \frac{p}{\rho \cdot g} + \frac{w^2}{2 \cdot g} - \frac{(\omega \cdot r)^2}{2 \cdot g} = const$ | flow co-efficient: $\frac{Q}{D^3 \cdot n}$ | power co-efficient: $\frac{P}{D^5 \cdot n^3}$ |



$$(\sigma_c)_{Francis} = 0.625 \cdot \left(\frac{n_s}{380.78} \right)^2 \approx 431 \cdot 10^{-8} \cdot n_s^2$$

$$(\sigma_c)_{Kaplan} = 0.28 + \left(\frac{1}{7.5} \left(\frac{n_s}{380.78} \right)^3 \right)$$

$$(\sigma_c)_{CP} = 1.03 \cdot 10^{-3} \cdot n_s^4$$

$\sigma \geq \sigma_c$ Or $NPSH \geq \sigma_c H \Rightarrow$ no cavitation

$$NPSH_{min} = \sigma_c H$$

Basic geometrical dimensions of the Pelton bucket

