

KATHMANDU UNIVERSITY
End Semester Examination [C]
November/December, 2023

30 NOV 2023

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

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

SECTION "B"

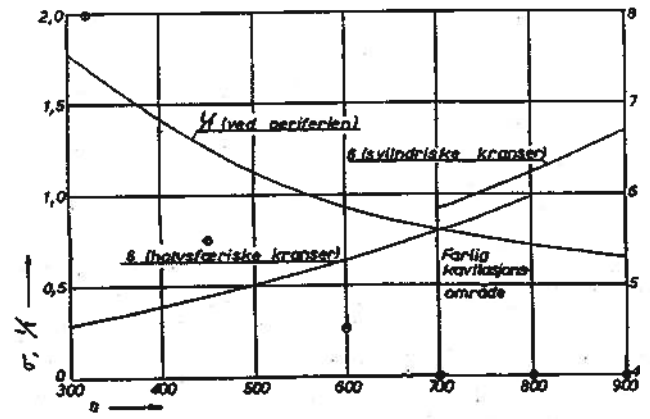
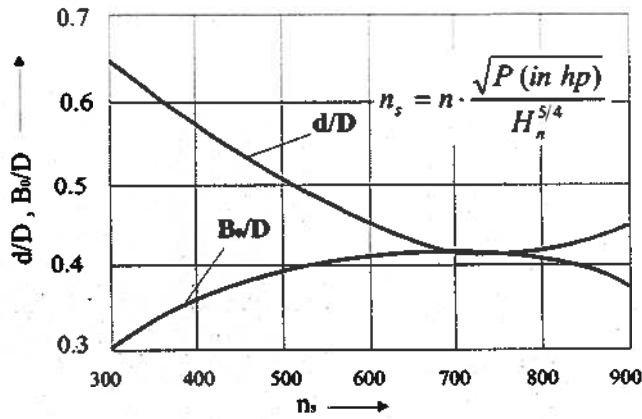
[5 Q. × 11 = 55 marks]

Attempt *ALL* questions. Formula sheet is supplied in this exam along with the question. Assume suitable data if missing/necessary.

1.
 - a. Compare and contrast the different types of installation of Pelton turbine. [2]
 - b. Derive the expression of hydraulic efficiency of Pelton turbine. Also to establish that best bucket speed for maximum efficiency is equal to one-half the jet velocity. [3]
 - c. A Kaplan turbine with a runner diameter of 1.25 m is to have a discharge of $12 \text{ m}^3/\text{s}$. The outlet area of the draft tube is 6 times the inlet area. The pressure head at the entry to the draft tube is limited to 1.5 m of suction pressure head. Estimate the maximum height above the tail water level, at which the turbine can be set. The efficiency of the draft tube can be taken as 0.7 m. [6]
2.
 - a. Sketch the basic geometrical dimensions of the Pelton turbine bucket. What is the role played by the cut-away in the bucket of a Pelton turbine? [3]
 - b. What do you understand by the term velocity triangles as used in the analysis of hydraulic machines? Write the velocity triangles for the inlet and outlet of a flow of a jet of water over a moving curved vane and explain the various notation used. [3]
 - c. A single jet Pelton turbine is required to drive a generator to develop 10,000 kW. The available head at the nozzle is 760 m. Assuming electric generator efficiency 95 %, Pelton wheel efficiency 87 %, co-efficient of velocity for nozzle 0.97, mean bucket velocity 0.46 of jet velocity, outlet angle of the buckets 15 degrees and the relative velocity of the water leaving the buckets 0.85 of that at inlet, find (a) The diameter of the jet, (b) The flow in cumecs and, (c) The force exerted by the jet on the buckets. (d) If the ratio of the mean bucket circle diameter to the jet diameter is not to be less than 10, find the best synchronous speed for generation at 50 cycles per second and the corresponding mean diameter of the runner. [5]
3.
 - a. How do the losses in the draft tube effect the pressure at the runner exit? [2]
 - b. Sketch a Francis turbine showing its different parts and also briefly explain their functions. [3]
 - c. A Francis turbine works under a head of 40 m and discharge $10 \text{ m}^3/\text{s}$ of water. The speed of the runner is 300 rpm. At the inlet tip of the runner vane, the speed ratio is 0.85 and flow ratio is 0.3. If the overall efficiency and hydraulic efficiency of the turbine are 80 % and 90 % respectively. Determine [6]
 - i. the power developed in kW,
 - ii. diameter and width of the runner at inlet,
 - iii. guide vane angle at the inlet,
 - iv. blade angle of the runner at inlet
 - v. specific speed of the turbine and

4. a. Explain the variation of blades angles in Kaplan turbine. Why so? [2]
- b. Describe with neat sketch the working of governing mechanism of Kaplan turbine. How is the governing mechanism of Kaplan turbine differing from the Propeller turbine? [4]
- c. A Kaplan turbine working under a head of 20 m develops 117.72 MW shaft power. The outer diameter of the runner is 3.5 m and hub diameter is 1.75 m. The guide blade angle at the extreme edge of the runner is 35° . The hydraulic and overall efficiencies of the turbines are 88 % and 84 % respectively. If the velocity of whirl is zero at outlet, determine: [5]
- runner vane angles at inlet and outlet at the extreme edge of the runner
 - speed of the turbine, and
 - specific speed of the turbine. Comment on the obtained values.
5. a. Why pumps are generally less efficient than turbines? [2]
- b. What are the operating curves of centrifugal pump? Why does the power curve for pump shall not pass through the origin? [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 the outlet at 45° 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 liter per second. What should be the shaft horse power? [6]

$\eta = \frac{u_1 \cdot v_{u1} - u_2 \cdot v_{u2}}{g \cdot H_n}$	$13^\circ < \beta_2 < 22^\circ$ (lowest value for highest head) $35 < U_2 < 43 \text{ m/s}$ (highest value for highest head)	$H_m = h_s + h_d + h_f + h_{fd} + \frac{v_d^2}{2}$
$h_f = f \cdot \frac{L}{D} \cdot \frac{v^2}{2 \cdot g}$	$v_{m2} = 1.1 \cdot v_{m1}$ $H_m = \left[\frac{p_o}{\rho \cdot g} + \frac{v_o^2}{2 \cdot g} + z_o \right] - \left[\frac{p_i}{\rho \cdot g} + \frac{v_i^2}{2 \cdot g} + z_i \right]$	$n_q = n \cdot \frac{\sqrt{Q}}{H^{3/4}}$ $n_{s,turbine} = 2.97 \cdot n_{q,pump}$
$N_s = \frac{N \cdot \sqrt{P}}{H^{5/4}} \quad (P \text{ in kW})$ 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> $a \quad 1.05 < a < 1.15 \quad 1.6 < a < 2.0$ $b \quad 0.05 < b < 0.15 \quad 0.2 < b < 0.25$ $d_s = \sqrt{\frac{4 \cdot Q}{z \cdot \pi \cdot v_1}}$	Affinity Law 1: $\frac{Q_1}{Q_2} = \frac{n_1}{n_2}$ $\frac{H_1}{H_2} = \left(\frac{u_1}{u_2} \right)^2 = \left(\frac{n_1}{n_2} \right)^2$ $\frac{P_1}{P_2} = \left(\frac{n_1}{n_2} \right)^3$
$n_q = n \cdot \frac{\sqrt{Q}}{H^{0.75}}$	$Q_n = \frac{\pi \cdot (D^2 - d^2)}{4} \cdot \epsilon_{lm}$	Affinity Law 2: $\frac{Q_1}{Q_2} = \left(\frac{D_1}{D_2} \right)^3$ $\frac{H_1}{H_2} = \left(\frac{D_1}{D_2} \right)^2$ $\frac{P_1}{P_2} = \left(\frac{D_1}{D_2} \right)^5$
$\Omega = \omega \cdot \sqrt{Q}$ $\Omega \leq 0.22$ (Pelton) $0.2 < \Omega < 1.25$ (Francis) $\Omega > 1.0$ (Kaplan/Bulb)	$D = \sqrt{\frac{Q_n \cdot 4}{\pi \cdot \epsilon_{lm}}} \quad n = \frac{3000}{z_p}$ $\sigma = \frac{10 - H_s}{H}$	
$H_s = \frac{u_2 \cdot v_{u2}}{g} = \frac{u_2}{g} [u_2 - v_{f2} \cdot \cot \beta_2]$	$\epsilon_{lm} = 0.12 + 0.18 \cdot \Omega$	$P = \rho \cdot Q \cdot g \cdot H_i$
$v_1 = C_d \cdot \sqrt{2 \cdot g \cdot H_n}$ [$C_d = 0.97$ to 0.98]	$\frac{P_2}{\gamma} = \frac{P_a}{\gamma} - h_s - \left(\frac{v_2^2 - v_3^2}{2g} - h_f \right)$	$H_i = \frac{u_2 \cdot v_{u2} - u_1 \cdot v_{u1}}{g}$ $H_i = \frac{u_2^2 - u_1^2}{2 \cdot g} + \frac{v_2^2 - v_1^2}{2 \cdot g} - \frac{w_2^2 - w_1^2}{2 \cdot g}$ $\eta_{man} = \frac{g \cdot H_m}{v_{u2} \cdot u_2}$
$\phi = \frac{u}{v} = 0.45 - 0.48$ 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 $H_n = 1300 \text{ m}$	$\eta_d = \frac{\frac{v_2^2 - v_3^2}{2g} - h_f}{\frac{v_2^2}{2g}}$	$n_{min} = \frac{120 \eta_{man} \cdot v_{u2} \cdot D_2}{\pi (D_2^2 - D_1^2)}$ $D_{Housing} = D + K \cdot B$
$Pr. \text{ rise} = \frac{P_2 - P_1}{\rho g} = \frac{1}{2g} [v_1^2 - v_2^2 + 2v_{u2} \cdot u_2]$	head or lift co-efficient: $\frac{\sqrt{H}}{D \cdot n}$	$\varphi = \frac{v_{m2}}{\sqrt{2 \cdot g \cdot H_m}} [0.1 - 0.25]$
$I = \frac{p}{\rho \cdot g} + \frac{w^2}{2 \cdot g} - \frac{(\omega \cdot r)^2}{2 \cdot g} = const$	flow co-efficient: $\frac{Q}{D^3 n}$	power co-efficient: $\frac{P}{D^5 n^3}$



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

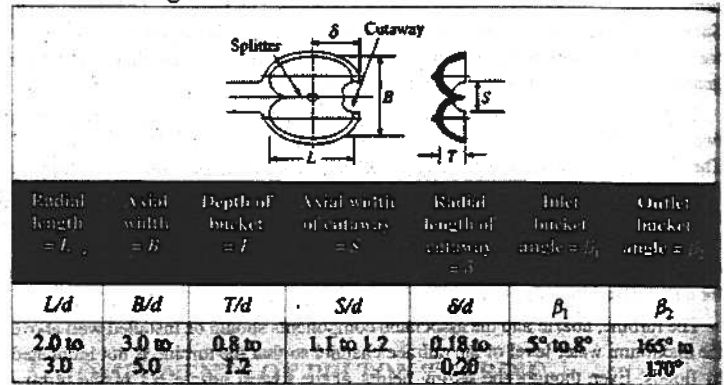
$$(\sigma_c)_{Kaplan} = 0.28 + \left(\frac{1}{7.5} \left(\frac{n_s}{380.78} \right)^3 \right)$$

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

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

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

Basic geometrical dimensions of the Pelton bucket



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SECTION "A"

[20 Q. × 1 = 20 marks]

Choose and mark [X] in the most appropriate option.

- The ratio of forces exerted by water jet when it is made to strike a stationary flat plate held normal to it and a flat plate moving in the direction of jet at one-third the velocity of jet would be
 3:1 9:4 3:2 2:1
- Ratio of absolute velocity of curve plate to absolute velocity of jet when the jet strikes at the center of a moving single curved plate is
 2 0.5 0.33 3
- The power output of Pelton turbine becomes zero when
 the wheel is at rest the wheel runs at runaway speed
 the wheel runs at highest speed all of the above
- Pelton turbine runners are called fast runner when,
 velocities of whirl at outlet is greater than zero
 velocities of whirl at outlet is less than zero
 velocities of flow at inlet and outlet are same
 velocities of whirl at inlet and outlet are same
- At what angle should the wicket gates of a Francis turbine be set to extract 8 MW of power from a flow of 30 m³/s when running at a speed of 200 rpm? The diameter of the runner at the inlet is 3 m and the breadth of the openings at the inlet is 0.9 m.
 22.58 20.58 24.58 18.58
- A Francis turbine has the speed ratio of 0.8 and its flow ratio is 0.25. The width of the runner at the outer periphery is ¼ times the outer diameter. Estimate the specific speed of the turbine. Consider the overall efficiency as 0.85.
 170.1 182.1 192.1 202.1
- Kinematic similarity is said to exist between the model and the prototype, if both of them
 have identical velocities
 are equal in size and shape
 are identical in shape, but differ only in size
 have identical forces
- The cavitation in a hydraulic machine
 causes noise and vibration of various parts
 reduces the discharge of a turbine
 causes sudden drop in power output and efficiency
 all of the above
- If the net positive suction head (NPSH) requirement for the pump is not satisfied, then
 no flow will take place cavitation will be formed
 efficiency will be low excessive power will be consumed

10. Appearance of cavitation damage has
 pit holes with sharp edges shining luster and wavy scales or ripples
 sharp edges with shining luster sharp edges with wavy scales or ripples
11. In a Kaplan turbine runner, the numbers of blades are generally between
 2 to 4 2 to 6 3 to 8 8 to 16
12. A turbine is required to develop 1500 kW at 300 rpm under a head of 150 m. Which of the following turbine should be used?
 Pelton wheel with one nozzle Pelton wheel with two or more nozzles
 Kaplan turbine Francis turbine
13. Selection of turbine in transition zone based upon:
 efficiency in the expected range of flow and head
 initial investment (machinery, equipment and civil works)
 maintenance requirements (normal or extraordinary wear)
 all of the above
14. Runway speed of _____ turbine is higher as compare to other turbines.
 Pelton Pelton turbine with multi jets
 Francis Kaplan
15. A Kaplan turbine has a runner of 4 m diameter. The diameter of the hub is 1.6 m. If the velocity of the flow and the swirl velocity at the inlet side of the blade at the hub are 6 m/s and 10 m/s respectively, the flow and swirl velocities at the inlet side of the tip are, respectively,
 6 m/s and 4 m/s 4 m/s and 6 m/s 3 m/s and 4 m/s 3 m/s and 6 m/s
16. The vertical arrangement of turbine is usually preferred to the horizontal arrangement because
 it will more compact and needs less floor area for power house
 the design of hydraulic passages is simpler in vertical arrangement
 in reaction turbine, the wheels can be placed nearer to the tail water without disturbing the power house arrangement
 all of the above
17. In centrifugal pump casing, the flow of water leaving the impeller is an example of
 rotational flow rectilinear flow free vortex flow force vortex flow
18. The type of centrifugal pump preferred for a specific speed of 20 rpm is
 slow speed pump with radial flow at outlet
 medium speed pump with radial flow at outlet
 high speed pump with radial flow at outlet
 high speed pump with axial flow at outlet
19. It is required to pump $1.3 \text{ m}^3/\text{s}$ of water to a total head of 45 m. How many pumps of specific speed 40 and running at 1450 rpm would be needed when connected in parallel.
 3 4 5 6
20. A Kaplan turbine is to be designed to develop 7.35 MW of power. The net head available is 5.5. Assume the speed ratio as 2.2, flow ratio as 0.68 and overall efficiency as 90 %. The diameter of hub is one-third the diameter of the runner. What is the outlet blade angle of the tip?
 15.7 17.7 19.7 21.7