KATHMANDU UNIVERSITY
End Semester Examination
June/July, 2023

Marks Scored:

Level : B.E.
Year : III

Course : MEEG 309
Semester : II

Exam Roll No. :

Time: 30 mins.

F. M. : 20

Date 29 JUN 2023

Registration No.:

SECTION "A"
[20 Q. × 1 = 20 marks]

Mark [X] in the most appropriate option.

1. Match the following:

P-Reciprocating pump	1. Plant with power output below 100 kW
Q-Axial flow pump	2. Plant with power output between 100 kW to 1 MW
R-Microhydel plant	3. Positive displacement
S-Backward curved vanes	4. Draft tube
	5. High flow rate, low pressure ratio
	6. Centrifugal pump impeller

[ ] P-3, Q-5, R-6, S-2
[ ] P-3, Q-5, R-2, S-6
[ ] P-3, Q-5, R-1, S-6
[ ] P-4, Q-5, R-1, S-6

2. A water jet 0.0015 m^2 in area issues from a nozzle with 15 m/s velocity. It is made to impinge perpendicular onto a plate that moves away from the jet with a velocity of 5 m/s. The force on the plate due to this impact is
[ ] 150 N [ ] 1470 N [ ] 340 N [ ] 900 N

3. An impulse turbine with a single nozzle which is connected to national grid of Nepal develops 1.865 MW under a head 70 m. What speed would be the best for coupling to an alternator?
[ ] 37.5 rpm [ ] 140.67 rpm [ ] 142.85 rpm [ ] 136.36 rpm

4. Selection of turbine in overlapping zone is mainly done based upon:
[ ] techno-economic studies
[ ] specific speed
[ ] optimum energy generation
[ ] operating criteria

5. If the water flows from inwards to outwards, the turbine is known as ______________
[ ] tangential flow turbine
[ ] turbulent low inward flow
[ ] inward flow turbine
[ ] outward flow turbine

6. For a given conditions, turbines have a wide range of speed. If the speed of the turbine made higher, then,
[ ] the size of the generator will be small, because the number of pair of poles is less
[ ] the size of the generator will be large, because the number of pair of poles is high
[ ] it will occupy large space and the installation and excavation costs are less
[ ] it will occupy large space and the installation and excavation costs are high

7. The runaway speed of a Pelton turbine having a diameter of 2.5 m, jet ratio of 16 and normal speed of 300 rpm is
[ ] 360 rpm [ ] 450 rpm [ ] 525 rpm [ ] 750 rpm

8. The impulse turbine generally fitted
[ ] at the level of tailrace
[ ] little above the level of tailrace
[ ] slightly below the tailrace
[ ] at least 2.5 m above the tailrace

9. At particular hydroelectric station, the available head is 60 m and it is estimated that a discharge of 30 m^3/s will be available. It is proposed to install Francis turbines of specific speed 215 and these are to run at 550 rpm with an overall efficiency of 85 %. The required number of turbines is

[ ] 2 [ ] 3 [ ] 4 [ ] 5

10. The discharge through a reaction turbine with increase in unit speed

[ ] increases [ ] decreases
[ ] remains unaffected [ ] first increases and then decreases

11. The flow ratio of Francis turbine is defined as the ratio of the

[ ] velocity of flow at inlet to the theoretical jet velocity
[ ] theoretical velocity of jet to the velocity of flow at inlet
[ ] velocity of runner at inlet to the velocity of flow at inlet
[ ] the velocity of flow at inlet to velocity of runner at inlet

12. A model of Francis turbine one-sixth of full size develops 3 kW at 320 rev/min under a head of 1.5 m. What is the power of a full size turbine operating under a head of 5 m if the model and full size turbine has an overall efficiency of 75 % ?

[ ] 657.2 kW [ ] 567.2 kW [ ] 757.2 kW [ ] 457.2 kW

13. Two turbines A and B of the same type have the same specific speed and are working under the same head. Turbine A produces 400 kW at 1000 rpm. If the turbine B produces 100 kW then its rpm is

[ ] 4000 [ ] 2000 [ ] 1500 [ ] 1250

14. A Kaplan turbine has a runner of 5 m diameter. The diameter of the hub is 2 m. If the peripheral velocity and the swirl velocity at the inlet side of the blade tip are 40 m/s and 5 m/s respectively, the peripheral velocity and swirl velocity at the inlet side of the mid-radius section are, respectively,

[ ] 40 m/s and 7.1 m/s [ ] 57.1 m/s and 3.5 m/s
[ ] 28 m/s and 5 m/s [ ] 28 m/s and 7.1 m/s

15. Turbines with high speed number (Kaplan) are high speed turbine because

[ ] the circumferential velocity of the runner is high compared to the free jet velocity
[ ] the free jet velocity of the runner is high compared to the circumferential velocity
[ ] the circumferential velocity of the runner is equal to the free jet velocity
[ ] with the high rotational speed of the turbine

16. The angle of taper on draft tube is

[ ] less than 3^0 [ ] greater than 8^0 [ ] greater than 5^0 [ ] less than 8^0

17. The velocity heads of water at the inlet and outlet sections of a draft tube are 3 and 0.2 m respectively. The frictional and other losses in the draft tube are 0.4 m. What is the efficiency of the draft tube?

[ ] 14.4 % [ ] 92.3 % [ ] 86.7 % [ ] 85.7 %

18. In a Bulb turbine runner, the numbers of blades are generally between

[ ] 1 to 2 [ ] 2 to 5 [ ] 3 to 4 [ ] 3 to 6

19. The diameters of an impeller of a centrifugal pump at inlet and outlet are 30 cm and 60 cm respectively. What is the minimum starting speed of the pump if it works against a head of 30 m?

[ ] 691.8 rpm [ ] 791.8 rpm [ ] 891.8 rpm [ ] 991.8 rpm

20. A discharge of 0.4 m^3/s of water is needed to be pumped to a total head of 240 m. How many pumps connected in series and each having a specific speed of 35 and running at a speed of 1500 rpm would be needed for the job?

[ ] 1 [ ] 2 [ ] 3 [ ] 4

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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. Define the term degree of reaction as applied to hydraulic machines. Is it possible to have a turbine with 100 percent degree of reaction? If not why? [3]

b. Show that when a jet strikes at the center of a moving series of curved plates, maximum efficiency is obtained when the vane is semi-circular in section and the velocity is half of that of the jet. [3]

c. At a site on a river, the power potential is 225 MW under a net head of 15 m. It is designed to operate the turbines at a speed of 60 rpm. Two choices of turbines, as follows, are available: (a) Francis turbine having specific speed not exceeding 300, (b) Kaplan turbine having specific speed not exceeding 600 (i) How many units of each type, all of same size, would be required? (ii) The atmospheric pressure is 9.9 m (abs) and vapour pressure head is 0.3 m. Calculate the maximum draft head in each case. The critical Thoma number can be taken as 0.36 for Francis and 0.73 m for Kaplan turbine. [5]

2.

a. What is main characteristics curve of Pelton turbine? Why is the discharge constant and does not vary with the speed in the Pelton turbine? [3]

b. What is speed number? Why it is important? Prove that the maximum speed number for a Pelton turbine with one nozzle is 0.09. [3]

c. A three-jet Pelton is required to generate 10 MW under a net head of 400 m. The bucket angle at the outlet is 165^0 and the decrease in the relative velocity while passing over the bucket is 5 %. Assume the overall efficiency 80 %, coefficient of velocity 0.98. Determine (a) diameter of jet, (ii) the force exerted by the jet on the buckets, (c) if the jet ratio is not to be less than 10, calculate the highest speed of the wheel for a frequency of 50 Hz and the corresponding wheel diameter. [5]

3.

a. Why is it necessary to choose the number of Francis runner blades as odd and the number of guide vanes as even? [2]

b. What do you understand by setting of a turbine? Explain how the installation of draft tube without loss of head is possible for the turbine installed at (a) the tail race level, (b) above tail race level and (c) below tail race level. [3]

c. Why does reaction turbine usually design from outlet? Calculate the main dimension of the Francis turbine having following data: Flow rate = 71.5 m^3/s, head = 543 m. Assume a = 1.10, b = 0.10, $\beta_2 = 22^0$, u_2 = 40 m/s, $\underline{u}_1$ = 0.728, hydraulic efficiency = 96 % and 10 % acceleration. [6]

4.

a. Why is there a gap between the hub and ring and the ring and the runner blades of the Kaplan turbine? How do you fix it? [2]

b. Sketch and explain the energy diagram of Kaplan turbine at BEP and off design conditions in the same diagram. [3]

c. A Propeller turbine has been designed to develop 22 MW under a head of 20 m whilst turning 150 revolutions per minute. The relevant data is: hydraulic efficiency 95 %, overall efficiency 88 %, outer diameter 4.5 m and diameter of hub 2 m. Determine the runner vane angles at the hub and at the outer periphery. Assume that the turbine discharges without whirl at exit. [6]

5.

a. Explain when the hydraulic and manometric efficiencies of a pump become synonymous? [2]

b. Discuss the influence of exit blade angle on the performance and efficiency of a centrifugal pump. Assume radial flow at entrance. [3]

c. A centrifugal pump lifts water under a static head of 36 m of water of which 4 m is suction lift. Suction and delivery pipes are both 150 mm in diameter. The head loss in suction pipe is 1.8 m and in delivery pipe 7 m. The impeller is 380 mm in diameter and 25 mm wide at mouth and revolves at 1200 rpm. It exit blade angle is 35^0. If the manometric efficiency of the pump is 82 %, determine the discharge and the pressure at the suction and delivery branches of the pump. [6]

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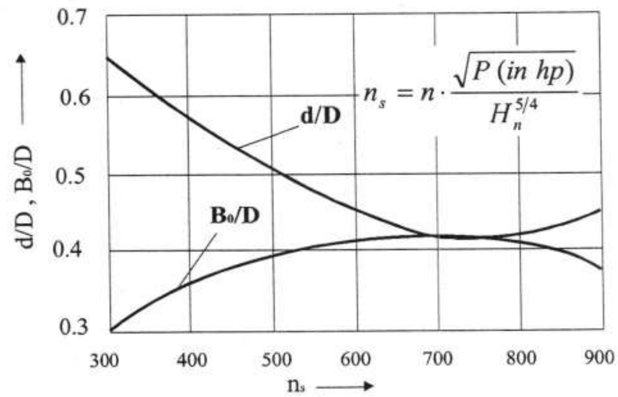
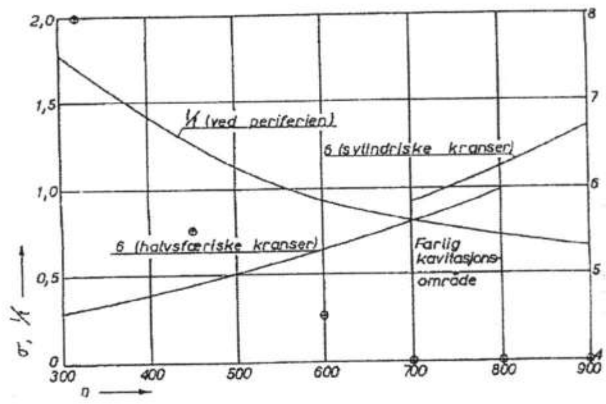
$\eta = \dfrac{u_1 \cdot v_{u1} - u_2 \cdot v_{u2}}{g \cdot H_n}$	$13^0 < \beta_2 < 22^0$ (lowest value for highest head) $35 < U_2 < 43$ m/s (highest value for highest head)	$H_m = h_s + h_d + h_{fs} + h_{fd} + \dfrac{v_d^2}{2}$
$h_f = f \cdot \dfrac{L}{D} \cdot \dfrac{v^2}{2 \cdot g}$	$v_{m2} = 1.1 \cdot v_{m1}$ $H_m = \left[\dfrac{p_o}{\rho \cdot g} + \dfrac{v_o^2}{2 \cdot g} + z_o\right] - \left[\dfrac{p_i}{\rho \cdot g} + \dfrac{v_i^2}{2 \cdot g} + z_i\right]$	$n_q = n \cdot \dfrac{\sqrt{Q}}{H^{3/4}}$ $n_{s,turbine} = 2.97 \cdot n_{q,pump}$
$N_s = \dfrac{N \cdot \sqrt{P}}{H^{5/4}}$ (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	$H_s = 10 - NPSH_R$ $NPSH_R = a \cdot \dfrac{v_{m2}^2}{2 \cdot g} + b \cdot \dfrac{u_2^2}{2 \cdot g}$ *Turbines* / *Pumps* a: $1.05 < a < 1.15$ / $1.6 < a < 2.0$ b: $0.05 < b < 0.15$ / $0.2 < b < 0.25$ $d_s = \sqrt{\dfrac{4 \cdot Q}{z \cdot \pi \cdot v_1}}$	Affinity Law 1: $\dfrac{Q_1}{Q_2} = \dfrac{n_1}{n_2}$ $\dfrac{H_1}{H_2} = \left(\dfrac{u_1}{u_2}\right)^2 = \left(\dfrac{n_1}{n_2}\right)^2$ $\dfrac{P_1}{P_2} = \left(\dfrac{n_1}{n_2}\right)^3$
$n_q = n \cdot \dfrac{\sqrt{Q}}{H^{0.75}}$	$\underline{Q}_n = \dfrac{\pi \cdot (D^2 - d^2)}{4} \cdot \underline{c}_{1m}$	Affinity Law 2: $\dfrac{Q_1}{Q_2} = \left(\dfrac{D_1}{D_2}\right)^3$ $\dfrac{H_1}{H_2} = \left(\dfrac{D_1}{D_2}\right)^2$ $\dfrac{P_1}{P_2} = \left(\dfrac{D_1}{D_2}\right)^5$
$^*\Omega = {^*\underline{\omega}} \cdot \sqrt{^*\underline{Q}}$ $^*\underline{\Omega} \leq 0.22$ (Pelton) $0.2 < {^*\underline{\Omega}} < 1.25$ (Francis) $^*\underline{\Omega} > 1.0$ (Kaplan/Bulb)	$D = \sqrt{\dfrac{\underline{Q}_n \cdot 4}{\pi \cdot \underline{c}_{1m}}}$ $n = \dfrac{3000}{z_p}$ $\sigma = \dfrac{10 - H_S}{H}$	
$H_e = \dfrac{u_2 \cdot v_{u2}}{g} = \dfrac{u_2}{g}[u_2 - v_{f2} \cdot \cot \beta_2]$	$\underline{c}_{1m} = 0.12 + 0.18\ {^o\Omega}$	$P = \rho \cdot Q \cdot g \cdot H_t$
$v_1 = C_d \cdot \sqrt{2 \cdot g \cdot H_n}$ [C_d= 0.97 to 0.98]	$\dfrac{P_2}{\gamma} = \dfrac{P_a}{\gamma} - h_s - (\dfrac{v_2^2 - v_3^2}{2g} - h_f)$	$H_t = \dfrac{u_2 \cdot v_{u2} - u_1 \cdot v_{u1}}{g}$ $H_t = \dfrac{u_2^2 - u_1^2}{2 \cdot g} + \dfrac{v_2^2 - v_1^2}{2 \cdot g} - \dfrac{w_2^2 - w_1^2}{2 \cdot g}$
$\phi = \dfrac{u}{v} = 0.45 - 0.48$ Pelton $\phi = \dfrac{u}{v} = 0.62 - 0.82$ Francis	$\dfrac{1 - \eta_M}{1 - \eta_P} = \left(\dfrac{D_P}{D_M}\right)^{1/5}$ $\dfrac{0.94 - \eta_M}{0.94 - \eta_P} = \left(\dfrac{Q_P}{Q_M}\right)^{0.32}$	$\eta_{man} = \dfrac{g \cdot H_m}{v_{u2} \cdot u_2}$
$3.1 > \dfrac{B}{d_s} \geq 3.4$ D = 10 · d_s, for $H_n \leq$ 500 m D = 15 · d_s, for H_n = 1300 m	$\eta_d = \dfrac{\dfrac{v_2^2 - v_3^2}{2g} - h_f}{\dfrac{v_2^2}{2g}}$	$n_{min} = \dfrac{120.\eta_{man}.v_{uz}.D_2}{\pi(D_2^2 - D_1^2)}$ $D_{Housing} = D + K \cdot B$
$\text{Pr.}rise = \dfrac{P_2 - P_1}{\rho g} = \dfrac{1}{2g}\left[v_1^2 - v_2^2 + 2v_{u2}.u_2\right]$	head or lift co-efficient: $\dfrac{\sqrt{H}}{D.n}$	$\varphi = \dfrac{v_{m2}}{\sqrt{2.g.H_m}}[0.1 - 0.25]$
$I = \dfrac{p}{\rho \cdot g} + \dfrac{w^2}{2 \cdot g} - \dfrac{(\omega \cdot r)^2}{2 \cdot g} = const$	flow co-efficient: $\dfrac{Q}{D^3 n}$	power co-efficient: $\dfrac{P}{D^5.n^3}$





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

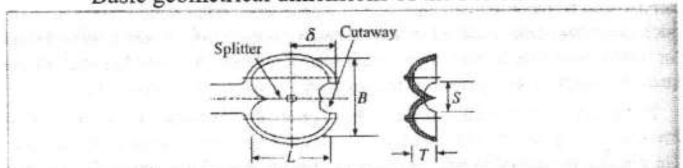
$$(\sigma_c)_{Kaplan} = 0.28 + \left(\frac{1}{7.5}\left(\frac{n_s}{380.78}\right)^3\right)$$

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

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

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

Basic geometrical dimensions of the Pelton bucket



Radial length = L	Axial width = B	Depth of bucket = T	Axial width of cutaway = S	Radial length of cutaway = δ	Inlet bucket angle = β_1	Outlet bucket angle = β_2
L/d	B/d	T/d	S/d	δ/d	β_1	β_2
2.0 to 3.0	3.0 to 5.0	0.8 to 1.2	1.1 to 1.2	0.18 to 0.20	5° to 8°	165° to 170°