B.Sc. (ME) / 6th Semester **Date:** 15th May 2023 (Morning)

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)
ORGANISATION OF ISLAMIC COOPERATION (OIC)
DEPARTMENT OF MECHANICAL AND PRODUCTION ENGINEERING

Semester Final Examination **Summer Semester:** 2021 – 2022
Course Number: ME 4611 **Full Marks:** 150
Course Title: Fluid Machinery **Time:** 3 Hours

There are **6 (Six)** questions. Answer **all** the questions. Marks of each question and corresponding COs/POs are written inside the square brackets. The symbols have their usual meanings. Assume any missing data if necessary.

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1. **(a)** Write brief notes on the following components of a Pelton turbine: **[12]** [CO1] [PO1]
   (i) Manifold
   (ii) Deflector
   (iii) Auxiliary nozzle
   (iv) Brake jet

   (b) Draw an indicator diagram of a single-acting reciprocating pump considering acceleration and friction. What would be the change in the indicator diagram if an air vessel is attached to **[9]** [CO1] [PO1]
   (i) the suction side only,
   (ii) the delivery side only, and
   (iii) to both the suction and delivery sides.

2. **(a)** Write brief notes on **[15]** [CO2] [PO2]
   (i) Circulatory flow in the inter-vane passage
   (ii) Minimum speed of a centrifugal pump
   (iii) Shutoff head of a centrifugal pump

   (b) Derive Euler's equation for a centrifugal pump and explain the physical significance of each term in the equation. **[14]** [CO2] [PO2]

3. **(a)** A Francis turbine has a runner of 60 cm diameter, and the breadth at the inlet is 6 cm. The inner diameter is 45 cm, and the breadth at the outlet is 8 cm. The vanes occupy 5% of the peripheral area. The guide vane angle at the inlet is 22°, and the blade angles at the inlet and outlet are 80° and 25°, respectively. The head on the turbine is 60 m, and the hydraulic efficiency is 90%. Assuming a mechanical efficiency of 95%, calculate the power delivered by the turbine. **[13]** [CO3] [PO4]

   (b) A Kaplan turbine develops 4.0 MW of power under a net head of 6.0 m. A vacuum gauge connected to the entrance of the draft tube indicates a reading of 5.0 m suction pressure head. The elbow-type draft tube of the turbine has an inlet diameter of 3.2 m and an outlet area of 25 m^2. The draft-tube efficiency is 75%, and the draft head is 2.0 m. Calculate (i) the overall efficiency of the turbine, (ii) the head lost in the draft tube, and (iii) the power lost into the tailrace. **[12]** [CO3] [PO4]

4. (a) A double overhung impulse turbine installation is to develop 15 MW at 260 RPM under a net head of 350 m. **[13]** [CO3] [PO4]
(i) Determine the specific speed and wheel pitch diameter when one jet is used in each turbine.
(ii) What would these values be when instead of two turbines, a single wheel with a single jet is used, and a single wheel with four jets is used? Assume speed ratio = 0.46.
(iii) Taking the overall efficiency as 0.90 in all cases, calculate the discharge and jet diameter in all three cases referred to above.
Assume C_v = 0.98 in all the cases.

(b) Following are the details of a 1:5 scale model of a large pump: **[12]**

Power supplied = 10 kW; Head developed = 6 m; Speed = 1000 rpm; Efficiency = 0.8 [CO3] [PO4]

(i) Estimate the prototype speed, the power required, and discharge by considering the prototype head as 36 m and assuming the efficiency remains the same as that of the model.
(ii) What would be the prototype's efficiency by the step-up formulas of Moody and Anderson?

5. **(a)** A centrifugal pump is required to discharge 600 L/s of water and develop a head of 15 m when the impeller rotates at 750 RPM. The manometric efficiency is 0.80. The loss of head in the pump due to fluid resistance can be assumed to be $0.027*V^2$, where V = velocity with which the water leaves the impeller. Water enters the impeller without shock and whirls; the flow velocity is 3.2 m/s. Determine the **[13]** [CO4] [PO3]
(i) impeller diameter,
(ii) blade angle at the outlet, and
(iii) outlet area.

(b) The table below gives the head-discharge-efficiency characteristics of a centrifugal pump. Two pumps of the above type are connected in parallel to a system. The system characteristics are given in Row 4 of the table. *Calculate the operating point when* (i) only one pump is working and (ii) when two pumps connected in parallel are working. *Calculate the brake power required in both the cases mentioned above.* **[12]** [CO4] [PO3]

Head, H (m)	22	22	21	19	17	15	12	9	6	3
Discharge, Q (L/s) of one pump	0	20	40	60	70	80	92	100	110	120
Efficiency (%)	0	33	57	76	80	81	79	74	62	30
System (H-Q) characteristics. (H_{sys} in m)	12.0	12.4	13.3	14.6	15.4	16.3	17.5	18.4	19.6	20.8

6. **(a)** A single-acting reciprocal pump lifts a liquid of specific weight 9.0 kN/m^3 from a pressurized storage reservoir to an overhead container. The free surface in the supply reservoir is at an elevation of 3.5 m above the center of the pump. The ambient pressure over the liquid surface in the supply reservoir is 27 kN/m^2 (Vacuum). The other relevant data relating to the pump are as follows: **[13]** [CO4] [PO3]

Length of suction pipe = 6.0 m	*Length of stroke = 50 cm*
Diameter of suction pipe = 10 cm	*Diameter of cylinder = 20 cm*
Minimum pressure anywhere in the system from cavitation considerations = 27 kPa (abs)	*Atmospheric pressure = 99 kN/m^2 (abs)*

Calculate the maximum permissible speed.

(b) Following are the details of a single-acting, single-cylinder reciprocating pump. **[12]** [CO4] [PO3]

Length of stroke = 50 cm	Suction lift = 3.25 m
Diameter of cylinder = 12.5 cm	Delivery lift = 12.0 m
Length of suction pipe = 5.2 m	Atmospheric pressure head = 10.3 m of water (abs)
Diameter of suction pipe = 10.0 cm	Darcy–Weisbach friction factor f = 0.02

Assuming the safe minimum pressure head is 2.5 m, *calculate the maximum permissible speed of the pump.* If an air vessel is fixed very close to the cylinder in the delivery pipe, *calculate the power required to pump water*. Assume the frictional head in the delivery pipe is 0.15 m, and the velocity heads in the pipes can be neglected. The efficiency of the pump can be assumed as 90%.