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(*University of Choice*)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

MAIN CAMPUS

UNIVERSITY EXAMINATIONS

2021/2022 ACADEMIC YEAR

SECOND YEAR SECOND SEMESTER EXAMINATIONS

FOR THE DEGREE

OF

BACHELOR OF SCIENCE IN RENEWABLE ENERGY TECHNOLOGY

COURSE CODE: RET 232

COURSE TITLE: FLUID MACHINERY

DATE: 29-04-2022 **TIME: 08:00-10:00**

INSTRUCTIONS TO CANDIDATES

1. This paper consists of **FOUR** questions
2. Answer Question **ONE (Compulsory)** and any other **TWO** Questions
3. All symbols have their usual meaning
4. Candidates are not allowed to share calculators in the examination

TIME: 2 Hours

MMUST observes ZERO tolerance to examination cheating

This Paper Consists of 3 Printed Pages. Please Turn Over

QUESTION ONE [30 marks]

1)

a) Using a typical layout of a hydroelectric station, **succinctly** explain the terms gross head, friction losses and net head. **(5 marks)**

b) Starting with Bernoulli's principle, then to the kinetic energy of a water jet for a plant with Head H and flow Q, show that the power of water jet with a density of ρ is given by $P_w = \rho.g.Q.H$. **(4 marks)**

c) With an aid of a simple flow chart, distinguish the terms hydraulic, mechanical and overall efficiencies **(4 marks).**

d) Select the appropriate turbines for the following plant scenarios and your basis for selection

i. A plant with a head of 200 m and flow of 5 m^3/s **(1 mark).**

ii. A plant with a head of 10 meters and flow of 25 m^3/s **(1 mark).**

iii. A plant with a head of 100 meters and flow of 2 m^3/s **(1 mark).**

e) Describe the classification of hydraulic turbines according to the type of energy at the inlet and give an example turbine for each **(5 marks)**

f) A turbine is to operate under a head of 45 m at 200 r.p.m. The discharge is 9 cumecs (cubic meter per second). If the efficiency is 90%, determine:

i. Specific speed of the machine **(3 marks).**

ii. Type of turbine **(1 mark).**

Specific Speed RPM	Types of Turbine	Specific Speed RPM	Types of Turbine
8.5 to 30	Pelton wheel with single jet	51 to 255	Francis
30 to 51	Pelton wheel with 2 or more jets	255 to 860	Kaplan/ Propeller

g) Show that the **Euler Turbine Equation** for power delivered to the turbine is given as $P = \dot{m}(V_{w1}u_1 - V_{w2}u_2)$ where V_{w1}, V_{w2}, u_1, u_2 are the tangential component of absolute velocity of fluid at inlet, tangential component of absolute velocity of fluid at outlet, tangential velocity of turbine at inlet, tangential velocity of turbine at outlet, respectively. **(5 marks)**

QUESTION TWO [20 marks]

2)

a) A single jet Pelton wheel is working under a gross head of **300 m**. The water is supplied through penstock of diameter 1 m and length 3 km from a reservoir to the Pelton wheel. The coefficient of friction for the penstock is given as **0.008**. The jet of water of diameter 150 mm strikes the buckets of the wheel and gets deflected through an angle of 160°. The coefficient of velocity at inlet is 0.97. The relative velocity of water at the outlet is reduced by 15% due to friction between the inside surface of the bucket and water. If the velocity of the buckets is 0.45 times the jet velocity at the inlet and mechanical efficiency as 85% . The average speed of water in the penstock is 2.5 m/s.

i) Using a well labelled velocity triangle at inlet and outlet, map out the velocities along the tangential and radial directions **(4 marks).**

Calculate the following:

ii) Net head available at turbine inlet **(2 marks)**
iii) Jet area and hence the actual water power at the turbine inlet in **kW (3 marks)**
iv) The power given to the runner in **kW (5 marks).**
v) Shaft Power in **kW (1 mark).**
vi) Hydraulic efficiency **(1 mark).**

b) A hydropower plant with a design flow of 2.5 cumecs and head of 300 m has a Pelton wheel whose operating curve shown in **Figure 1**. Calculate the following

i. Installed capacity in **kW** if the generator and transformer efficiency are (0.96 and 0.98) respectively **(1.5 marks).**
ii. Minimum plant capacity in **kW (2.5 marks)**

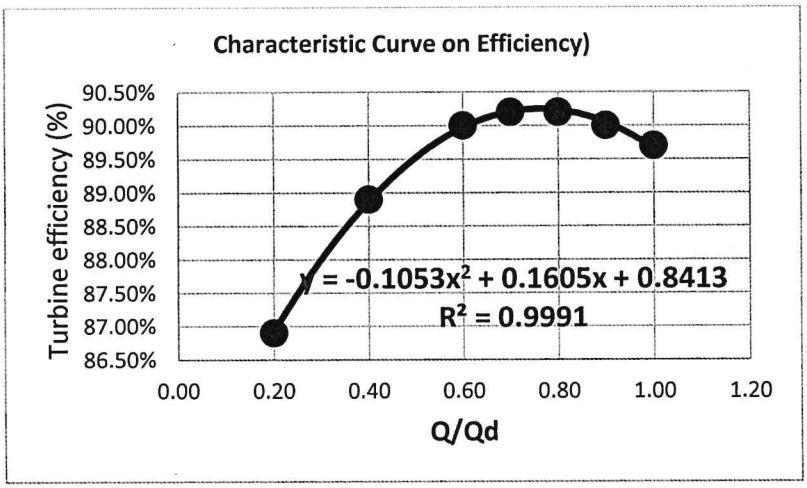

Figure 1 Operating curve for a Pelton Wheel

QUESTION THREE **[20 marks]**

3)

a) Francis is a mixed flow type turbine where water enters the turbine runner in the radial direction at inlet and exits in the axial direction at the runner outlet. Using this concept:

i. Draw a well labelled velocity triangle at inlet and outlet, map out the velocities along the tangential, axial and radial directions **(3 marks).**
ii. Based on direction of flow principle, explain why the whirl velocity at the exit is zero **(2 mark)**

b) A Francis turbine with an overall efficiency of 75% is required to produce 6648 kW power. It is working under a head of 92.8 m. The peripheral velocity is $\mathbf{0.26}\sqrt{2gH}$ and the radial velocity of flow at the inlet is $\mathbf{0.96}\sqrt{2gH}$. The wheel runs at 150 RPM and the hydraulic losses in the turbine are 22% of the available energy. Assuming radial discharge, determine:

i. Whirl velocity at inlet **(3 marks)**
ii. Guide blade angle, α_1 **(2 marks)**
iii. Wheel vane angle at inlet, β_1 **(2 marks)**

c) **Briefly** explain the turbine parts of the Francis Turbine **(4 marks)**

d) A plant with a gross head of 20 m operates on Kaplan turbine with the following specifications. Calculate:

Kaplan Turbine Technical Data			
Runner outer diameter	3.5 m	Hub diameter	1.75m
Guide blade angle , α_1	35	Overall efficiency	84%
Speed, RPM	66	Flow velocity at entry, v_{f1}	9.9 m/s

i. Installed capacity of the plant in **kW (2 mark)**

ii. Hydraulic efficiency **(2 marks)**

QUESTION FOUR [20 marks]

4)

a) Using a well-labeled diagram, describe the working principle of a reciprocating pump **(6 marks)**

b) A double acting reciprocating pump operating at 45 RPM has a discharge rate of 1.95 m3 per minute. The pump's stroke is 450 mm and diameter of piston 250 mm. The delivery and suction head are 25 and 8 m respectively. Calculate

i. Slip of the pump **(2 marks)**

ii. Power required to run the pump **(2 marks)**

c) Describe the design of a centrifugal pump **(6 marks)**

d) A centrifugal pump has a velocity triangle shown below. It operates at a discharge of 0.15 m3/s at a speed of 1450 RPM against a head of 20 m. The impeller diameter is 0.25 m and outlet width of 0.05m. Given a manometric efficiency of 75%, determine the vane angle at the outer periphery of the impeller **(4 marks)**