KENYATTA UNIVERSITY

EXAMINATION FOR THE DEGREE OF BACHELOR OF SCIENCE IN RENEWABLE ENERGY TECHNOLOGY

SET 817: WIND AND HYDROPOWER TECHNOLOGIES

2ND SEMESTER 2021/2022 **TIME: 3 HOURS**

INSTRUCTIONS:

Answer question ONE (compulsory) and any other TWO questions.

Question ONE carries 30 Marks. Other questions carry 20 Marks each.

Take:

Standard roughness coefficient $\alpha = 0.20$
Density of air $= 1.225\ kgm^{-3}$

QUESTION ONE

a. Write an expression for the Weibull probability density function (PDF) and explain its functions. (3 marks)

b. A hydroelectric power plants can be classified based on the type of load the plant has to supply, i.e. base load plants, peak load plants and pumped storage plants for peak loads. Discuss these three types and where applicable use diagrams. (6 marks)

c. The driving force for creation of winds, primarily in the difference between the equator and the poles, has been attributed to the uneven heating of the earth surface. In view of this:
i. Explain the difference between air and wind (2 marks)
ii. Why wind energy is called indirect solar energy (1 mark)

d. Discuss the different ways in which hydropower plants can be used. What are the limitations to its use in Kenya, and how can these limitations be overcome? (2 marks)

e. Various factors would have affected the current wind parks in Kenya (for instance at Ngong hills) if proper wind park planning with respect to wind park layout had not been considered. Describe four (4) factors or criteria to be considered when planning a wind farm lay out. (4 marks)

(g) Discuss two factors that should be considered before putting up a hydropower plant in a locality. (4 marks)

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f. Calculate the amount of wind energy consumed by five 80W light bulbs left accidentally on overnight for a period of 10 hours. How much does this cost, if the electricity cost is Ksh 15 per Kilowatt hour. (2 marks)

g. State three hydropower plants in Kenya and corresponding annual power output (in megawatts). (2 marks)

(f) Write an expression for the Rayleigh probability density function in terms of the average wind speed. Hence or otherwise, show that the average power in the wind, assuming Rayleigh statistics is given by

$$\bar{P} = \frac{6}{\pi}.\frac{1}{2}\rho A v^{-3}$$ (The symbols carry their usual meaning). (3 marks)

QUESTION TWO

(a) Discuss the factors that currently prevent hydropower plants from contributing a greater percentage of primary energy consumption (6 marks)

(b) In the future, according to the literature 80% of carbon emissions will come from the developing world. Discuss all the factors developing countries need to take into account when confronted with such problem. (6 marks)

(c) Discuss the status of hydropower sources in Kenya, its advantages, disadvantages, and projected growth? (5 marks)

(d) Hydropower power is reliable, renewable base load electric source able to provide a steady flow of power regardless of external conditions. Outline three hydropower plants in Kenya (3 marks)

QUESTION THREE

(a) Sketch, under the same axes, a typical graph showing the performance curves for a multi-bladed, four bladed, three bladed and two bladed wind machines. Comment on the shape of the graphs (5 marks)

(b) (i) With the aid of a sketch diagram of an aerofoil, explain the following terminologies; *lift force, drag force, angle of attack* and *quarter chord length.* (6 marks)

(ii) In the four-digit NACA specification for airfoils, explain the meaning of NACA2415. (3 marks)

(c) (i) Explain two factors that determine the output from a hydropower plant. (2 marks)

(ii) A researcher in KU has developed a wind turbine with a cut in wind speed of 4 m/s and a cut out speed of 25 m/s. If the turbine is installed at a site with Weibull shape factor of 2.6 and a scale factor of 8 m/s, for how many hours in a day will the turbine generate power? Also estimate the probability for the wind velocity to exceed 25 m/s at this site.

(4 marks)

QUESTION FOUR

(a) Distinguish between a horizontal axis wind turbine (HAWT) and a vertical axis wind turbine (VAWT). Discuss **two** advantages and **two** disadvantages of each (4 marks)

(b) Compare tidal range, tidal stream and wave power giving both merits and demerits.

(6 marks)

(c) The cut-in velocity of a 25 m diameter wind turbine is 1.5 m/s, the rated velocity is 7 m/s and the cut-out velocity 20 m/s. (Assuming a combined efficiency of 80%). The turbine is placed in a location with the following wind velocity frequency:

Speed range (m/s)	Percentage of time (%)
0 to 1.5	20
1.5 to 3	14
3 to 5	12
5 to 8	28
8 to 15	12
15 to 22	10
22 o 28	4

i. What is the total annual energy(kWh) that can be produced by turbine (5 marks)

ii. If the rated velocity of the turbine is extended to 13m/s what would be the production in a year? (5 marks)

QUESTION FIVE

(a) Discuss at least 5 environmental impacts of a hydroelectric power plant.

(5 marks)

(b) With the aid of a sketch diagram discuss the components of a wind electric/energy conversion system including the control system. (5 marks)

(c) Discus the possible barriers to ocean thermal conversion system. (3 marks)

(d) Discuss the characteristics, advantages and disadvantages of a

(i) Savonius Rotor (2 marks)

(ii) Darrius Rotor (2 marks)

(e) Calculate the tip speed ratio and the torque coefficient of a wind turbine, given that the rotor diameter = 10 m, power coefficient =0.35, average wind speed =10 m/s and rotor revolution =130 rev/minute. (3 marks)