KISII UNIVERSITY

UNIVERSITY EXAMINATIONS

FOURTH YEAR EXAMINATION FOR THE AWARD OF THE DEGREE OF BACHELOR OF SCIENCE IN RENEWABLE ENERGY FIRST SEMESTER 2022/2023 [SEPTEMBER-DECEMBER, 2022]

PHRE 411: WIND ENERGY II

STREAM: Y4S1   **TIME: 2 HOURS**

DAY: THURSDAY, 12:00 – 2:00 PM   **DATE: 22/12/2022**

INSTRUCTIONS

1. *Do not write anything on this question paper.*
2. *Answer Question ONE and any other TWO Questions.*

QUESTION ONE [30 MARKS]

a. If you wish to closely examine wind data from selected stations, state five attributes about the data that you should determine.   [5marks]

b. Briefly discuss the following terms as used in the data validation process; data screening and data verification.   [2marks]

c. Estimate the annual energy production (AEP) for a wind turbine with a rotor diameter of 60 m in a region with 450 W/m^2. Assume the CF is 0.40.   [3marks]

d. State three reasons why rotor speed must be controlled.   [3marks]

e. The speed control requirement of the rotor has five separate regions. In brief, discuss the regions.   [5marks]

f. What is the difference between cut-in and cut-out wind speed in wind turbine technology?   [2marks]

g. What do you understand by the word 'rated speed?'   [1mark]

h. Why are wind turbines on tall towers?   [1mark]

i. What are the two differences between drag and lift devices?   [2marks]

j. Besides being nondepletable, name any other three advantages of wind power.   [3 marks]

k. Show how to determine the tip speed ratio of a wind turbine and state its importance. [2 marks]

QUESTION TWO [20 MARKS]

In an experiment to find how wind picks from one height to another, the following data was collected.

Height (m)	Hourly wind speeds (m/s)					
	12:00	**1:00**	**2:00**	**3:00**	**4:00**	**5:00**
20	4.0	5.0	7.0	12.0	3.0	6.0
60	3.5	4.6	6.4	11.7	2.7	5.5

Using the information above and applying the appropriate method;

a. Calculate the wind power density per unit area for the site at the 20m hub height. (Assume an air density of 1.225kg/m³). [4 marks]
b. The turbulence intensity at the 20m hub height. [5 marks]
c. The wind shear exponent of the site [4 marks]
d. Surface roughness parameter. [4 marks]
e. The Average wind speed at a height of 100m above the ground. [3 marks]

QUESTION THREE [20 MARKS]

a. Discuss the 6 main components of a windmill. [6 marks]
b. The turbine blade operates on a two-principle design. State and explain the designs stating which of the two is well suited for electricity generation and why. [6 marks]
c. With the help of well-labelled diagrams, discuss the following schemes as used in wind power systems for maximum energy capture; [8 marks]
    i. Constant TSR schemes.
    ii. Peak-Power-Tracking scheme.

QUESTION FOUR [20 MARKS]

a. Using the stream tube control set-up below, show that the Betz limit (C_{Max}) is ≈ 0.5926. [12 marks]

U1

U2

U3

U4

1   2 3   4
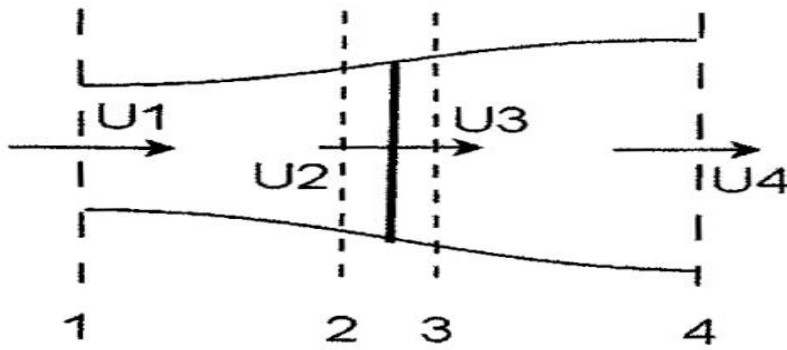
b. Name three main aerodynamic effects that reduce the efficiency (C_P) of real wind turbines. [3marks]

c. Name any three factors that determine the efficiency of a wind power conversion machine. [3marks]

d. state any two assumptions made while determining the Betz limit. [2marks]

QUESTION FIVE [20 MARKS]

a. State three reasons why the armature voltage E_A is not equal to the output voltage V_ϕ in a synchronous machine. [3 marks]

b. State three quantities that must be determined to describe the generator model [3marks]

c. A 200KV, 480V, 50HZ, Y-connected synchronous generator with a rated field current of 5A was tested and the following data was obtained;

   i. $V_{T,OC} = 540V$ at the rated I_F

   ii. $V_{L,SC} = 300A$ at the rated I_F

When a DC voltage of 10V was applied to two of the terminals, a current of 25A was measured. Find the generator's model at the rated conditions. (i.e., the armature resistance and the approximate synchronous reactance) [8marks]

d. With the aid of a diagram, discuss the Doubly Fed Induction Generator (WECS) with Reduced Capacity Power. [6marks]