KIBABII UNIVERSITY

UNIVERSITY EXAMINATIONS
2022/2023 ACADEMIC YEAR

THIRD YEAR SECOND SEMESTER
MAIN EXAMINATIONS

FOR THE DEGREE OF BACHELOR OF SCIENCE IN RENEWABLE ENERGY AND BIO FUELS TECHNOLOGY

COURSE CODE: REN 323

COURSE TITLE: Wind Energy 1

DURATION: **2 HOURS**

DATE:17/04/2023 **TIME: 2:00-4:00PM**

INSTRUCTIONS TO CANDIDATES

- Answer **QUESTION ONE** (Compulsory) and any other **TWO** (2) Question.
- Indicate **answered questions** on the front cover.
- Start every question on a new page and make sure question's number is written on each page.

This paper consists of **4** printed pages. Please Turn Over

KIBU observes ZERO tolerance to examination cheating

Question One

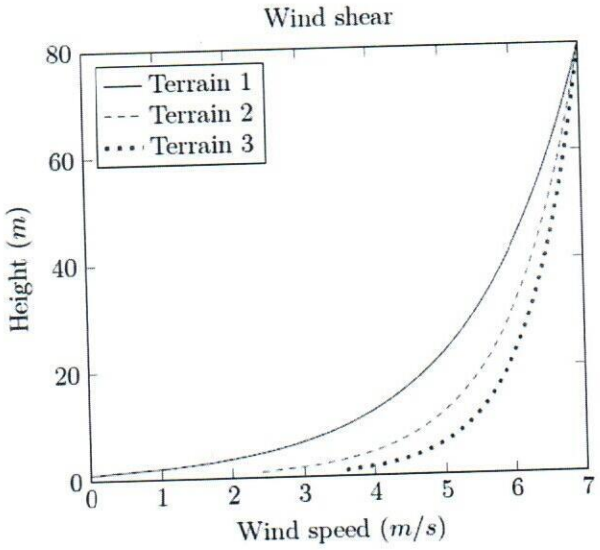
(a)

i. Define roughness length, z_0 **[1 Marks]**

ii How does z_o affect the wind shear, and how could this be estimated for a given site? **[1 Marks]**

iii. Identify which roughness length the terrains below correspond to: **[4 Marks]**

$Z_0 = 1$, 0.1, or 0.01. Justify your choices.



iii. Explain in detail how energy from the sun is responsible for the flow of air masses in the atmosphere **[4 Marks]**

(b) Wind is a highly variable phenomenon, in time and in space. Explain the following variability.

i. Seasonal **[2 Marks]**

ii. Diurnal **[2 Marks]**

iii. Daily **[2 Marks]**

(c) Some of the best sites for wind farm development are found offshore. Explain why this is so. **[4 Marks]**

(d) Based on average speed data only, estimate the annual energy production from a horizontal axis wind turbine with a 12 m diameter operating in a wind regime with an average wind speed of 8 m/s. Assume that the wind turbine is operating under standard atmospheric conditions ($\rho = 1.225$ kg/m^3). Assume a turbine efficiency of 0.4. **[5 Marks]**

(e) With the aid of a diagram, illustrate the phenomenon of over-speeding of a cup anemometer. Relate the response time of a cup anemometer to an increase in wind speed to the distance constant and state a sensible value of this distance constant in order to reduce over-speeding to an acceptable level. **[5 marks]**

Question Two

(a) Estimate the annual wind speed at 80m height if an annual mean of 5.5m/s is measured at 10m height on a site characterized by flat grassland. Make clear what law you have applied and any other assumptions you have made. Indicate very roughly how accurate you might expect your estimate to be. **[10 marks]**

On a different site, offshore, the annual wind speed at a height of 100m has been estimated to be 10m/s ±0.5m/s. A wind farm of 20 identical turbines is installed on this site with average array losses of 10% and average availability of 90%. The turbine characteristics are given in the table below.

Hub height	100m
$V_{cut\text{-}in}$	4m/s
V_{rated}	12m/s
$V_{cut\text{-}out}$	25m/s
P_{ated}	5MW

(b) For simplicity assume each turbine averages 2.5MW when the winds are between cut-in and rated (not accounting for array losses). Calculate the expected annual energy yield from the wind farm, and the uncertainty associated with this calculation. **[10 marks]**

Question Three

For this question refer to Figure Question Three at the end of the question paper

(a) Four sensors have been shown on the Met Mast. For each sensor, state its purpose, name any two types of similar sensors **[15 Marks]**

(b) Describe how the data collection system on the mast is powered and also how the information is relayed to a remote location. **[5 Marks]**

Question Four

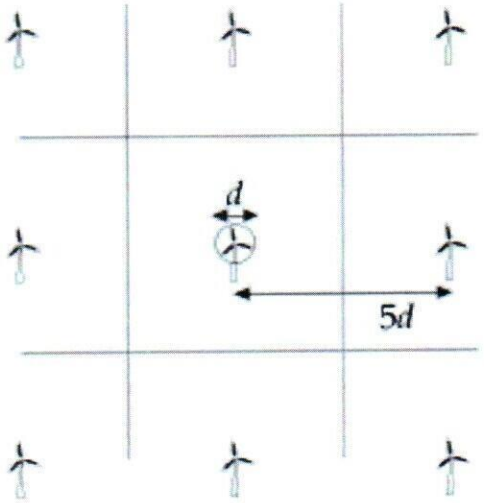
Describe in detail the wind resource in Kenya **[20 Marks]**

Question Five

(a) Consider a wind farm with a layout as shown in Figure 1, in which d corresponds to the diameter of the wind mill. The power per area P generated is expressed by equation **[15 Marks]**

$$P = \frac{\pi}{100} C \frac{1}{2} \rho v^3$$

where ρ is the density of the air (=1.3 kgm^{-3}), C is the conversion efficiency of the windmill, and v is the averaged wind speed. Give the derivation of this equation.



(b) With the aid of a sketch, explain the use of a wind rose **[5 Marks]**

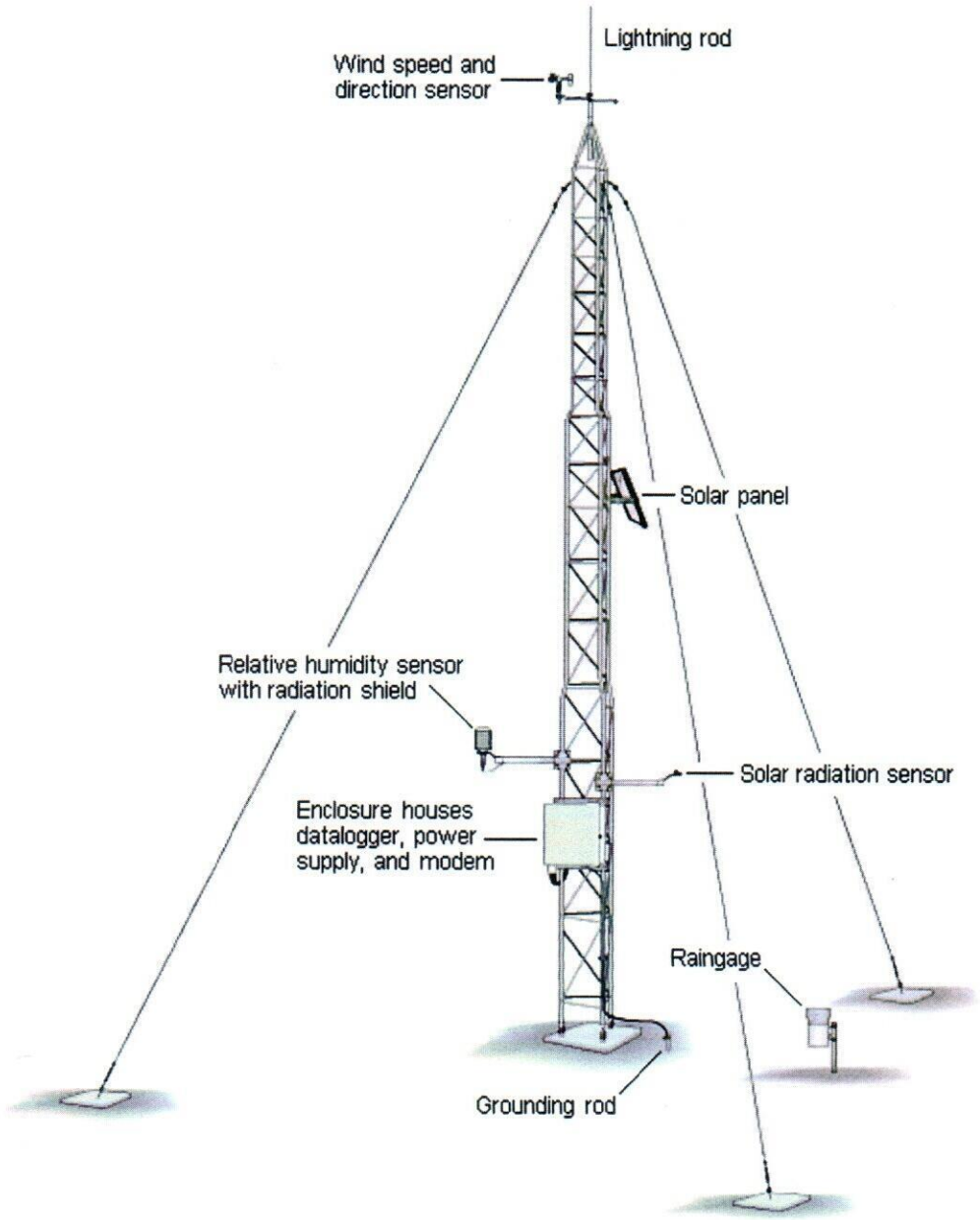


Figure Question Three