KIBABII UNIVERSITY

UNIVERSITY EXAMINATIONS
2021/2022 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 I**

DURATION: **2 HOURS**

DATE: 30/08/2022 **TIME: 2:00PM-4:00PM**

INSTRUCTIONS TO CANDIDATES

- Answer **QUESTION ONE** (Compulsory) and any other TWO (2) Questions.
- 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.

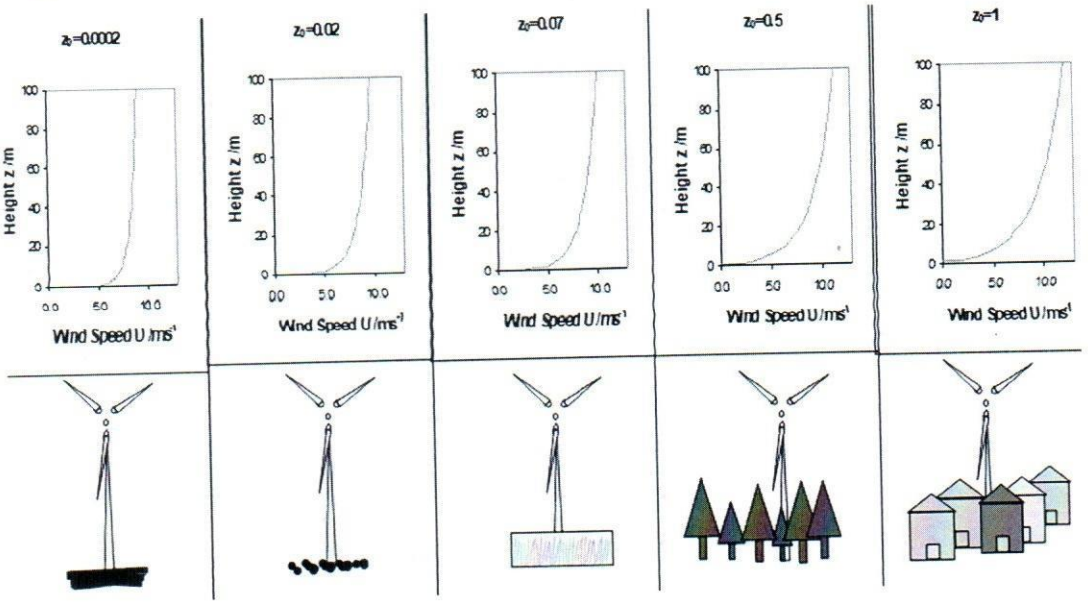
This paper consists of **4** printed pages. Please Turn Over

Question One

(a) Describe why turbine efficiency never reach the Betz Limit. Assume that mechanical losses are negligible. **[5 marks]**

(b) A wind farm development company is only able to measure the wind speed at a height of 20m above ground level. They measure a mean value of 6.6m/s. The site is in a field with long grass and it is decided to take a value for the surface roughness length of z_o of 0.07 to use in the calculation. There are two types of wind turbine under consideration. The first has a hub height of 30m and the other of 45m. Estimate the mean wind speed at these two heights using the log law. **[6 marks]**

(c) The attached picture shows the variation of wind speed with height for different ground roughness. Describe the change in the shape of the graph as the ground roughness increases. **[6 marks]**



(d) A particular turbine can extract 40% of the power available in the wind. The efficiency of converting mechanical shaft power to electrical power is 90%. Estimate the rotor diameter of a horizontal axis wind turbine required, at a wind speed of 10m/s, to provide an electrical power output of: **[6 marks]**

i) 200Watts

ii) 10kW

iii) 600kW

(e) (i) What are the advantages of using a cup anemometer for wind speed measurements? **[3 marks]**

(ii) What are the alternative instruments that can be used? **[4 marks]**

Question Two

(a) Outline the key requirements to be considered during the site selection process for a wind farm project **[15 Marks]**

(b) State and describe the functions of the main components of a commercial horizontal axis wind turbine **[5 Marks]**

Question Three

(a) What is the van de Hoven spectrum? Draw a schematic representation of this spectrum labeling key features including their associated time-scales and use this diagram to explain why wind speed is often averaged over the period of 10 minutes to an hour for purpose of wind resource assessment **[8 marks]**

(b) With the aid of a sketch, define the drag and lift coefficients for an aerofoil; what directions do they act in? **[6 marks]**

(c) A particular form of the log law for wind shear in the lower atmospheric boundary layer can be written as:

$$U_{(Z)} = \frac{U^*}{k}[Ln(z/z_0]$$

Describe carefully all the terms which appear in this equation and the conditions under which it applies **[6 marks]**

Question Four

(a) Sketch a typical power curve of Horizontal axis wind turbine indicating on the graph the cut-in, rated, and cut-out wind speeds **[10 marks]**

(b) Explain the reasons why the cut-in and cut-out wind speeds are imposed **[10 marks]**

Question Five

In the following table, the total energy conversion efficiency of two wind turbines is provided. Assume an air density of 1,25 kg/m^3.

(a) Calculate the power curve for each turbine and fill in the results in the table. **[12 Marks]**

(b) What can you say about the turbines based on just looking at their power curves? *(Hint: rated power output, rated wind speed, cut-in wind speed, type of power regulation)* **[4 Marks]**

(c) How much will be the reduction in greenhouse gas emissions if each of the wind turbines replaces an existing diesel engine (see the engine parameters below) for one full year of operation. Consider that each turbine has a capacity factor of 0.30 per year. **[4 Marks]**

	Turbine 1	**Turbine 2**		
Rotor Diameter (m)	79	67		

Wind Speed (m/s)	Efficiency (%) Turbine 1	Efficiency (%) Turbine 2	Power Output Turbine 1 (kW)	Power Output Turbine 2 (kW)
1	0.00	0.00		
2	0.00	0.00		
3	5.23	0.00		
4	19.31	9.29		
5	32.76	29.33		
6	38.41	36.01		
7	40.66	38.42		
8	41.03	39.38		
9	43.10	40.78		
10	42.72	40.72		
11	37.14	39.23		
12	30.64	36.84		
13	24.10	33.83		
14	19.30	27.08		
15	15.69	22.02		
16	12.93	18.15		
17	10.78	15.13		
18	9.08	12.74		
19	7.72	10.83		
20	6.62	9.29		

Diesel engine specifications:
CO2 emission factor (kg/GJ) = 77,4
CH4 emission factor (kg/GJ) = 0,003
N2O emission factor (kg/GJ) = 0,002
Fuel energy conversion efficiency = 30%