KIBABII UNIVERSITY

UNIVERSITY EXAMINATIONS
2021/2022 ACADEMIC YEAR

FOURTH YEAR FIRST SEMESTER
MAIN EXAMINATIONS

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

COURSE CODE: REN 413

COURSE TITLE: WIND ENERGY II

DURATION: 2 HOURS

DATE: 24/05/2022 **TIME:** 8:00AM-11:00AM

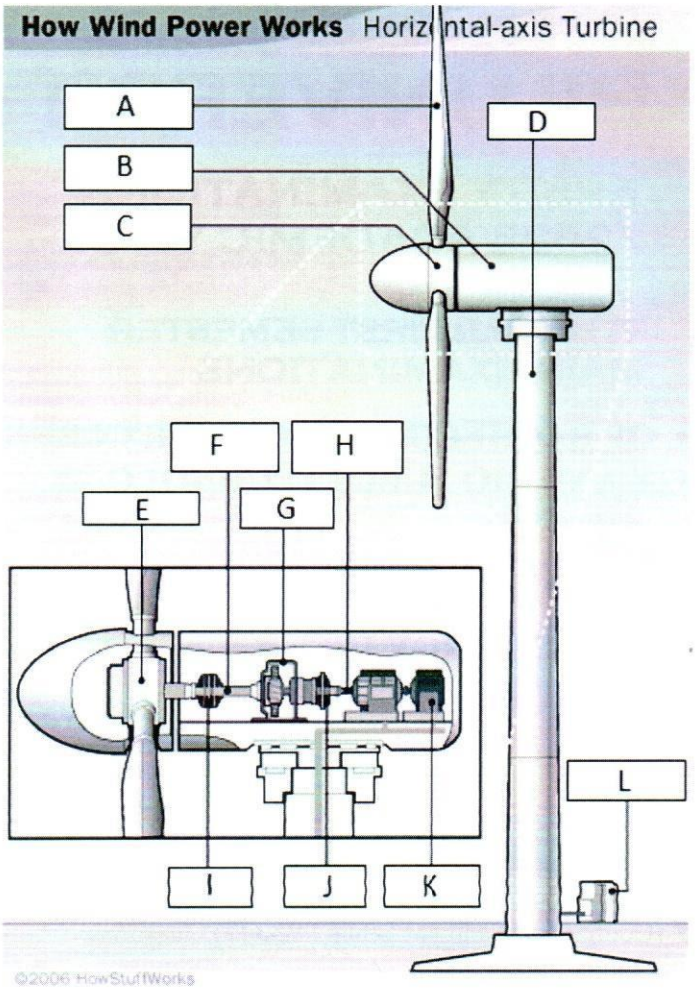
INSTRUCTIONS TO CANDIDATES

- 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 **6** printed pages. Please Turn Over

Question One

(a) Identify the labelled parts of the horizontal axis wind turbine shown below **[6 marks]**



(b) State the purpose of each part identified in (a) **[6 marks]**

(c) The power per area P generated by a wind turbine is expressed by equation **[4 marks]**

$$P = \frac{\pi}{100} C \frac{1}{2} \rho v^3 \qquad \text{(Eq.1)}$$

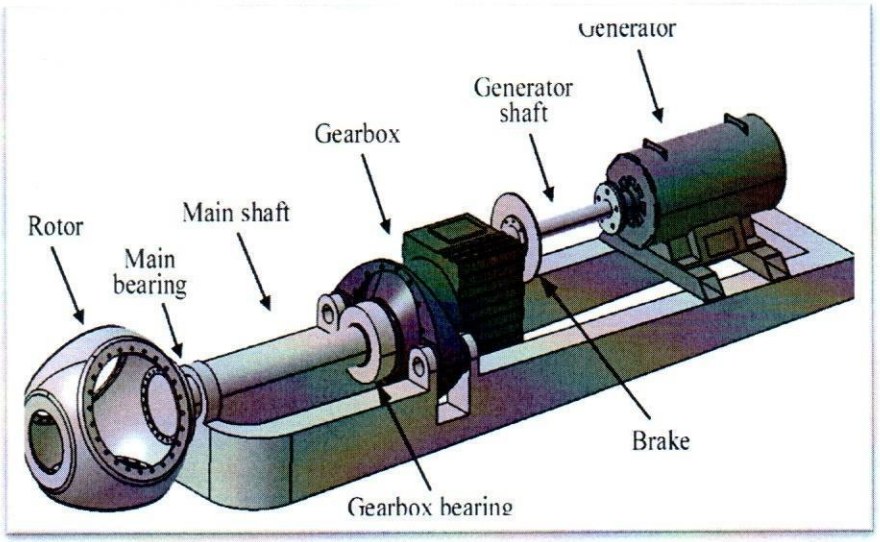
where ρ is the density of the air (=1.3 kgm^{-3}), C is the conversion efficiency of the turbine, and v is the averaged wind speed. Derive this equation.

(d) Describe the options available for construction of part D of the wind turbine **[6 marks]**

(e) During the operation of the wind turbine, control actions are applied to parts A and B due to the variability nature of wind. State the control actions **[2 marks]**

(f) Explain the purposes of the control actions named in (e) **[4 marks]**

[2 marks]



One of the parts in the sketch above sketch is not "accurately" named. Identify it and provide the correct name.

Question Two

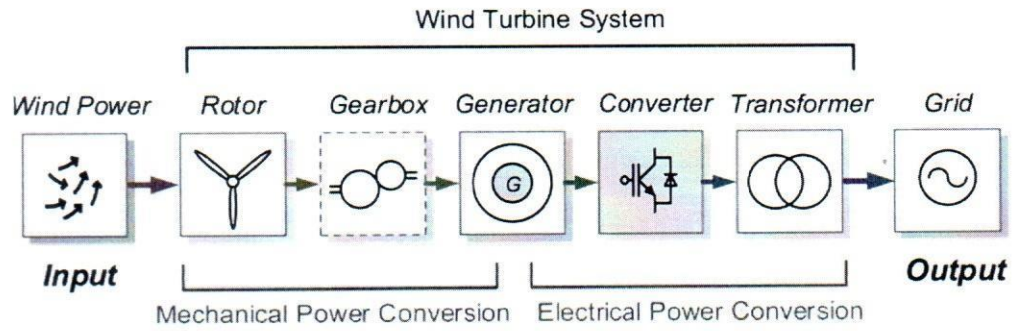


Figure 1: Block diagram of a wind turbine system

Study the figure above carefully and then answer the questions that follow

(a) Explain the purpose of the "wind turbine system" as depicted in the diagram? **[5 marks]**

(b) The "input" to the system is wind and is shown as being multi-directional. Why is this so? **[2 marks]**

(c) What is the "output" of the system as shown in the diagram? **[1 mark]**

(d) Describe in detail what happens in each of the components of "mechanical power conversion", bearing in mind that the wind input is highly variable. **[5 marks]**

(f) The generator is depicted as being part mechanical and part electrical. Why is **[2 marks]**

this so?

(g) Describe in detail what happens in each of the components of "electrical power conversion", bearing in mind that the wind input is highly variable. **[5 marks]**

Question Three

(a) Using the data sheet for Vesta V52-850 kW given at **the end of this question paper** draw the power curve for the turbine. **[12 Marks]**

(b) Show that efficiency of the turbine at a speed of $7ms^{-1}$ is equal to 45.5% **[4 Marks]**

(c) Explain why, in a fixed-speed wind turbine operation at maximum conversion efficiency occurs at a wind speed below the rated wind speed. **[4 Marks]**

Question Four

A 40 m diameter, three bladed wind turbine produces 700 kW at a wind speed (hub height) of 14 m/s. The air density is 1.225 kg/m^3. Find:

(a) The rotational speed (rpm) of the rotor at a tip-speed ratio of 5.0. **[6 Marks]**

(b) The tip-speed (m/s) **[2 Marks]**

(c) Gear ratio needed to match the rotor speed to the generator speed if the generator turns at 1800 rpm. **[6 Marks]**

(d) The efficiency of the wind turbine system (including blades, transmission, shafts, and generator) under these conditions **[6 Marks]**

Question Five

At a certain site a 15 MW wind farm is to be installed. The annual average wind speed is given in Figure 1 below. Figure 2 shows the power curve for the 77m
rotor diameter wind turbine selected for the installation.

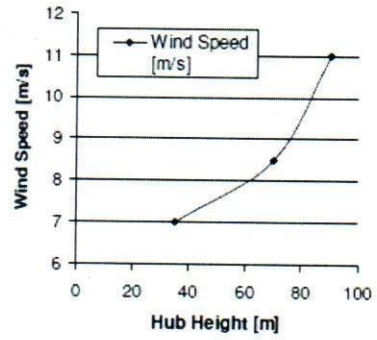


FIGURE 1 Annual average wind

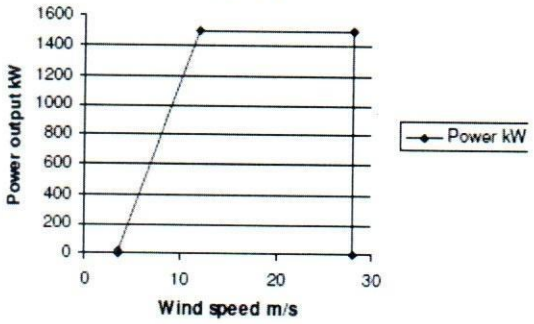


FIGURE 2 Power curve of the selected HAWT

(a) Calculate the size of the wind resource at 80 m height (in kW). **[5 Marks]**

(b) Explain the power curve in Figure 2. **[5 Marks]**

(c) Describe 'Active Pitch' and 'Passive Stall' control mechanisms for power regulation on HAWT **[5 Marks]**

(d) State and explain any Five:

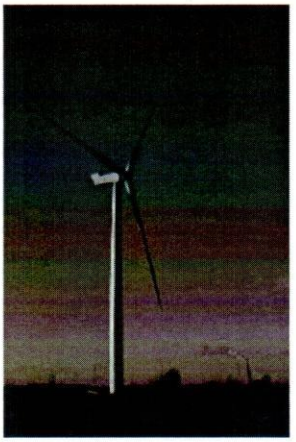
(i) Advantages of wind energy **[2 Marks]**

(ii) Disadvantages of wind energy **[3 Marks]**

(10)

VESTAS V52 850 52.0

Company	VESTAS
Type/Version	V52
Rated power	850,0 kW
Secondary generator	0,0 kW
Rotor diameter	52,0 m
Tower	Tubular
Grid connection	50/60 Hz
Origin country	DK
Blade type	VESTAS
Generator type	One generator
Rpm, rated power	26,0 rpm
Rpm, initial	0,0 rpm
Hub height(s)	49,0; 36,5; 40,0; 44,0; 55,0; 60,0; 65,0; 70,0; 74,0; 86,0 m
Maximum blade width	2,30 m
Blade width for 90% radius	0,40 m
Valid	Yes
Creator	
Created	2000-11-20 11:13
Edited	2000-11-20 11:13



Power curve: Level 0 - calculated - 104.2 dB(A) - 07-2006
Source Manufacturer

Source date	Creator	Created	Edited	Default	Stop windSpeed [m/s]	Air density [kg/m3]	Tip angle [°]	Power control	CT curve type
2006-07-20 00:00		2000-11-16 08:29	2008-11-25 11:31	Yes	25,0	1,225	0,0	Pitch	User defined

Special calculated, guaranteed power curve for standard operation.
For different air densities, different calculated power curves are available at Vestas. Powercurves based on item no: 946506.R8 dated 2004-06-14. Ct curve based on Document no. 946506.R9 2006-07-20. Please contact Vestas for information on latest power curves.

Power curve

Wind speed [m/s]	3,00	4,00	5,00	6,00	7,00	8,00	9,00	10,00	11,00	12,00	13,00	14,00	15,00	16,00	17,00
Power [kW]	0,00	25,50	67,40	125,00	203,00	304,00	425,00	554,00	671,00	759,00	811,00	836,00	846,00	849,00	850,00
Ce	0,000	0,306	0,415	0,445	0,455	0,456	0,448	0,426	0,388	0,338	0,284	0,234	0,193	0,159	0,133

Wind speed [m/s]	19,00	20,00	21,00	22,00	23,00	24,00	25,00
Power [kW]	850,00	850,00	850,00	850,00	850,00	850,00	850,00
Ce	0,095	0,082	0,071	0,061	0,054	0,047	0,042

Ct curve

Wind speed [m/s]	4,00	5,00	6,00	7,00	8,00	9,00	10,00	11,00	12,00	13,00	14,00	15,00	16,00	17,00	18,00	19,00	20,00	21,00	22,00	23,00	24,00	25,00
Ct	0,82	0,82	0,82	0,82	0,82	0,79	0,75	0,68	0,60	0,42	0,32	0,26	0,21	0,17	0,15	0,13	0,11	0,09	0,08	0,07	0,06	0,06

HP curve comparison

Vmean [m/s]	5	6	7	8	9	10
HP value [MWh]	988	1 631	2 300	2 953	3 505	3 994