(University of Choice)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

UNIVERSITY EXAMINATIONS 2021/2022 ACADEMIC YEAR

THIRD YEAR SECOND SEMESTER MAIN EXAMINATIONS

FOR THE DEGREE OF BACHELOR OF SCIENCE IN PHYSICS

COURSE CODE: SPH 355

COURSE TITLE: WIND ENERGY SYSTEMS

DATE: FRIDAY 29TH APRIL, 2022 **TIME:** 12:00 PM – 2:00 PM

INSTRUCTIONS TO CANDIDATES

Answer QUESTION ONE and any TWO QUESTIONS .
Symbols used bear the usual meanings.

YOU MAY USE THE FOLLOWING CONSTANTS

Density of air = 1.225 kg/m^3

MMUST observes ZERO tolerance to examination cheating

QUESTION ONE (30 marks)

a) Define the following terms as used in wind turbine systems
   i. Solidity
   ii. Tip speed ratio (2 marks)
b) Discuss social, economic and environmental impact of wind energy (3 marks)
c) Distinguish between a wind turbine and a wind mill (1 mark)
d) A rotor diameter of two bladed HAWT is 6.5m. At its rated wind speed of 10 m/s, the power output of the turbine is 15 kW.
   i. Find the efficiency of the turbine at this wind speed (2 marks)
   ii. Calculate the tip speed ratio if the blades are rotating at 230 rpm (2 marks)
e) Show that the air speed through actuator disc (turbine) is the average of the upstream and downstream wind speed (3 marks)
f) By differentiating the expression for power coefficient $C_P = 4a(1-a)^2$., with respect to a (axial induction factor or axial interference factor), show that the maximum value of C_P is 16/27 when $a = 1/3$. (3 marks)
g) Enumerate any three benefits of offshore wind farms compared with onshore wind farms. (3 marks)
h) Discuss losses associated with small wind turbines (3 marks)
i) Sketch wind aerodynamics for stationary airfoil and airfoil in motion. Indicate all the forces acting on the airfoil. (4 marks)
j) In terms of yaw operations, explain the design considerations for two rotor blade design and three rotor blade design. (2 marks)
k) Explain any two advantages of VAWTs (2 marks)

QUESTION TWO (20 MARKS)

a) A wind turbine with a rotor diameter of 56 m is rated at 1 MW at a hub height wind speed of 12 m/s. It has a cut-in speed of 3.5 m/s and a cut-out speed of 24 m/s. Assume that this machine is located at a site where the mean wind speed is 10 m/s and that a Rayleigh wind speed distribution can be used. Calculate the following:
   (i) The number of hours per year that the wind is below the cut-in speed. (4 marks)
   (ii) The number of hours per year that the machine will be shut down due to wind speeds above the cut-out velocity. (4 marks)
b) Using well labelled diagrams describe the power curve parameters (5 marks)
c) Discuss the various models employed in describing wind flow. (4 marks)
d) Explain the various sources of uncertainties that impede accurate assessment of wind flow. (3 marks)

QUESTION THREE (20 MARKS)

a) Show that the power content of a cylindrical column of air is proportional to the square of its diameter D and cube of its speed V. (4 marks)
b) Explain the advantages and disadvantages of three-bladed rotor over two bladed rotor (3 marks)

c) Discuss three planning constraints that make it difficult to install a wind urbine in any farm. (3 marks)

d) Describe stages of development before a wind turbine/ farm can be approved and built. (10 marks)

QUESTION FOUR (20 MARKS)

a) Using suitable illustrations, discuss how mechanical wind mills are used in water pumping (5marks)

b) Deduce the relation between performance coefficient, torque coefficient and tip speed ratio for a system of turbines. (4 marks)

c) Discuss the design principle of horizontal axis wind turbines (HAWTs) and vertical axis wind turbines (VAWTs) (4 marks)

d) A 35 m diameter three bladed wind turbine produces 720 kW at a wind speed of 12 m/s. Find:

i. The rotational speed (rpm) of the rotor at a tip speed ratio of 4 (2 marks)

ii. What is the tip speed in m/s (1 mark)

iii. If the generator turns at 1700 rpm. What gear ratio is needed to match the rotor speed to the generator speed? (2 marks)

iv. The efficiency of the wind turbine system (including blades, transmission, shafts and generator) under these conditions? Assume Betz limit Cp = 16/27 (2 marks)

QUESTION FIVE (20 marks)

a) State policy options available for wind turbines (4 marks)

b) State any three factors that have accelerated the wind power technology development. (3marks)

c) Explain two sets of factors in which the amount of wind energy available at any locations depends on. (2 marks)

d) Give the similarities and differences between Rayleigh and Weibull distribution (3 marks)

e) Analysis of time series data for a given site has yielded an average velocity of 5 m/s. It is determined that a Rayleigh wind speed distribution gives a good fit to the wind data.

i. Based on a Rayleigh wind speed distribution, estimate the number of hours that the wind speed will be between 9.0 and 10.0 m/s during the year. (4 marks)

ii. Using a Rayleigh wind speed distribution, estimate the number of hours per year that the wind speed is equal to or above 15 m/s. (4 marks)