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(University of Choice)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

UNIVERSITY EXAMINATIONS 2021/2022 ACADEMIC YEAR

FOR THE DEGREE OF BACHELOR OF SCIENCE IN ENGINEERING

COURSE CODE: RET 242

COURSE TITLE: WIND AND WAVE ENERGY

DATE: 26-04-2022 **TIME: 08:00-10:00**

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) Tip speed ratio
   (ii) Wind farm (1 marks)

b) A rotor diameter of two bladed HAWT is 6.1m. At its rated wind speed of 13 m/s, the power output of the turbine is 16 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 220 rpm (2 marks)

c) Show that the air speed through actuator disc (turbine) is the average of the upstream and downstream wind speed (3 marks)

d) 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)

e) Enumerate any three benefits of offshore wind farms compared with onshore wind farms. (3 marks)

f) Discuss losses associated with small wind turbines (3 marks)

g) Sketch wind aerodynamics for stationary airfoil and airfoil in motion. Indicate all the forces acting on the airfoil. (4 marks)

h) In terms of yaw operations, explain the design considerations for two rotor blade design and three rotor blade design. (2 marks)

i) Explain any two advantages of VAWTs (2 marks)

j) Discuss any two appositive effects of wave power (2 marks)

k) Discuss social, economic and environmental impact of wind energy (3 marks)

l) Distinguish between a wind turbine and a wind mill (1 mark)

QUESTION TWO (20 MARKS)

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

b) (i)Estimate the annual production of a 12 m diameter horizontal axis wind turbine operating at standard atmospheric conditions (ρ = 1.225 kg/m3) in a 8 m/s average windspeed regime. You are to assume that the site wind speed probability density is given by the Rayleigh density distribution. (3marks)

   (ii)From an analysis of wind speed data (hourly interval average, taken over a one year period), the Weibull parameters are determined to be $c = 6$ m/s and $k = 1.8$. Determine the average velocity at this site? (2 marks)

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

d) A 28 m diameter three bladed wind turbine produces 320 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 1680 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 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 turbine in any farm. (3 marks)
d) Discuss the stages of development of wind turbine/ farm can be approved and built. (10 marks)

QUESTION FOUR (20 MARKS)

a) Deduce the relation between the frequency and wavelength of deep- water surface waves. Also derive the expression for phase velocity of the wave (5 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)
e) Discuss policy options associated with wind energy systems (2 marks)
f) Give the similarities and differences between Rayleigh and Weibull distribution (1 mark)