# MACHAKOS UNIVERSITY

**University Examinations for 2024/2025 Academic Year**

**SCHOOL OF ENGINEERING AND TECHNOLOGY**
**DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING**

**FIFTH YEAR FIRST SEMESTER EXAMINATION FOR DEGREE IN BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING**

**EEE 501 RENEWABLE ENERGY TECHNOLOGIES**

**DATE: 20TH JANUARY 2025** **TIME: 11.00 AM - 1.00 PM**

**INSTRUCTIONS:**

- *This paper consists of Five Questions*
- *Question* ***One is Compulsory***
- *Attempt Any other Two Questions*

*Some Useful Constants*

- Plank's Constant: $h = 6.63x10^{-34}Js$
- Speed of Light in a Vacuum : $c = 3.0x10^{8}m/s$
- Stefan Boltzmann's Constant : $\sigma = \frac{5.67x10^{-8}W}{m^2}/k^4$
- Gravitational Acceleration : $g = 9.81N/Kg$
- Kinematic viscosity of water at $20℃$ is $10^{-6}\mathrm{m/s}$

**QUESTION ONE *(COMPULSORY)* (30 MARKS)**

a) Define Renewable Energy Integration (REI) and Point of Common Coupling (PCC) (2 marks)

b) Discuss the Four Factors that have led to increased Renewable Energy Integration (REI) (4marks)

c) Discuss Challenges facing Renewable Energy Integration (REI) (7marks)

d) A short circuit fault of capacity 100MVA occurs for a solar PV system rated 500MW. A constant load unit of 50KW is assumed. For a utility grid three phase voltage of 66KV,

explain whether the grid is well suited for Renewable Energy Integration from Frist Principles

(4marks)

e) For case d) above, asses the level of Renewable Energy Penetration from Frist Principles (3marks)

f) Using a diagram Only, explain the fact that "Renewable Energy Integration (REI) provides a virtual storage" (3marks)

g) Giving time scale and examples, discuss the *Grid-Side Benefits* of Electrical Energy Storage (EES) in Renewable Energy Integration (REI) (7marks)

**QUESTION TWO (20 MARKS)**

a) State and explain the Plank's Radiation Law (PRL). Hence or otherwise, evaluate the constants C1 and C2 involved (6marks)

b) From the Law Stated in a) above, prove the Wien Displacement Law (WDL). All the derivation and integration must be shown (8marks)

c) State and explain Stefan Boltzmann Equation (SBE). Hence or otherwise, show that the Thermal Resistance of Black Bodies is strongly dependent on temperature (6marks)

**QUESTION THREE (20 MARKS)**

a) Beginning from the Weibull Function, derive the Rayleigh Probability Distribution for Wind Speeds in Wind Power Modelling (6marks)

b) Show that for the Rayleigh Distribution of Wind Speed (6marks)

i) $\Phi_{u>u'} = exp\left[-\frac{\pi}{4}\left(\frac{u'}{u}\right)^2\right]$ (2 marks)

ii) $\left(\overline{u^3}\right)^{1/3} = 1.24\overline{u}$ (1.5 marks)

iii) $P_O \cong A\rho(\overline{u})^3$ (1 mark)

iv) $\Phi_{u(max)}$ occurs at $u = \left(\frac{2}{\pi}\right)^{1/2} \overline{u}$. Determine $\Phi_{u(max)}$ (1.5 marks)

c) If the average wind speed at the site is *7 m/s* and the wind speed displays a *Rayleigh Distribution*, determine the average output power of the turbine using any Two Approaches. Assume the turbine cut-off wind speed to be 20 m/s (8marks)

**QUESTION FOUR (20 MARKS)**

a) From first principles, show that the power extracted by any wind turbine is proportional to the cube of the wind speed and the efficiency factor. Hence or otherwise, estimate the radius of the rotor in m that will enable 100 kW to be generated by the turbine at a wind speed of 12 m/s and at the optimal tip speed ratio. Consider the air density to be $1.225\ kg/m^3$ (4marks)

b) Show that the power coefficient for any wind turbine can be expressed in the form of a dual equation (11marks)

$$C_P = ax(1 + ay + a^2) = z\lambda$$

Hence define a and z and state the values of $x, y\ and\ z$

c) A three-bladed horizontal axis turbine is being considered for electricity generation at a site. The variation of the coefficient of performance, $C_p$ of this turbine with the tip speed ratio,$\lambda$, is given by

$$C_p = 46.6 \times 10^{-3}\,\lambda^2 - 6 \times 10^{-3}\,\lambda^3$$

Determine the maximum energy conversion efficiency (5marks)

**QUESTION FIVE (20 MARKS)**

a) Define the following terms as used in Renewable Energy Economics:

i) LCOE (3marks)

ii) IRR (2marks)

b) A solar power company invests in a 1 MWp PV system at a sunny location, where the system output is expected to be 6 MWh/day on the average for the whole year. The company will minimize the system degradation to less than 0.15%/year by aggressive maintenance and repairs. The company expects that the system will be down for 7 days/year for maintenance or repair. The total initial costs of the system are expected to be $2.5 M and the average annual maintenance/repair costs are expected to be 3% of the initial costs. The company plans to invest 30% equity and finance 70% of the capital costs as debt at 6%/year. The company expects to get feed-in tariff of $0.22/kWh for 20 years. Determine for the system:

i) LCOE

ii) IRR (15marks)