

CHUKA



UNIVERSITY

UNIVERSITY EXAMINATIONS

**FIFTH YEAR EXAMINATION FOR THE AWARD OF DEGREE OF BACHELOR OF
SCIENCE IN ELECTRICAL ENGINEERING**

EENG 566: ALTERNATIVE ENERGY**STREAMS:****TIME: 2 HOURS****DAY/DATE: THURSDAY 13/04/2023****2.30 P.M. – 4.30 P.M.****INSTRUCTIONS**

- This paper consist four questions
- Attempt Question one and any other two.

QUESTION ONE (30 MARKS)

- a). Discuss the photovoltaic effect. (3 marks)
- b). Explain the significance of the bandgap energy in relation to the photovoltaic effect. (3 marks)
- c). i). For a silicon based solar cell, determine the minimum frequency a photon must have to be able to create an electron-hole-pair. (3 marks)
- ii). calculate the corresponding maximum wavelength for (c). i). above. (3 marks)
- d). i). With various expressions, distinguish between Spectral Irradiance, Insolation, and Radiation (4 marks)
- ii). A photovoltaic module that has an area of 0.3 m^2 receives a light whose spectral irradiance is $1000(\text{W}/\text{m}^2 \mu\text{m})$ limited over the wavelength from λ 0.60 to $0.7 \mu\text{m}$. Calculate the insolation received and the radiation after one day. (4 marks)
- e). Give an expression of air mass ratio and explain its significance to the photovoltaic effect. (4 marks)
- f). A PV module is made up of 36 identical cells, each having a parallel resistance of 6 ohms and a reverse saturation current of $I_0 = 5 \times 10^{-10} \text{ A}$. On average, the module provides 4A for 7 hours

each day. The module is connected without a blocking diode to a battery with voltage 12.7V.

(6 marks)

- i. Estimate the ampere-hours that will be discharged from the battery over a 12-hour night and the energy in watt-hours that will be lost due to this discharge.
- ii. If a blocking diode is added, how much energy will be dissipated through the diode during the daytime assuming the on-state voltage of the diode is 0.6V?

QUESTION TWO (20 MARKS)

a). Explain with a block diagram why a power processing system is normally needed as an interface in a PV generating system. (6 marks)

b). A PV module made from crystalline silicon has an open-circuit voltage of 21.5V and a maximum power of 120W at STC. The module has a NOCT of 45°C. Estimate for this module under insolation $G = 1000\text{K/m}^2$ and ambient temperature of 30°C. (9 marks)

- i. the cell temperature
- ii. the open-circuit voltage
- iii. the maximum power output

c). Explain the significance of blocking diodes in PV modules and arrays. (5 marks)

QUESTION THREE (20 MARKS)

a). Draw a block diagram of grid-connected a PV system and explain the function of each block. (6 marks)

b). A permanent magnet DC motor has an armature resistance of 1 ohm. When it is spinning at its rated speed of 52.4 rad/s, the back EMF is 10V and the armature current is 2A. Determine;

(8 marks)

- i. The motor applied voltage
 - ii. The motor back EMF constant
 - iii. The electrical input and mechanical output powers
 - iv. The steady-state torque.
- c). A 200-Ah, 12V battery with an open-circuit voltage of 12.4V at its current SoC is charged at a C/5 rate with a charging voltage of 13.5V. Determine: (6 marks)

- i. The internal resistance of the battery.

- ii. The percentage of the battery input power dissipated as heat in the internal resistance of the battery
- iii. The percentage of the battery input power dissipated as heat in the internal resistance of the battery if the battery is charged at a $C/20$ rate.

QUESTION FOUR (20 MARKS)

- a). Discuss four factors that affect the efficiency of a solar cell. (4 marks)

 - b). A solar cell has a reverse saturation current of $I_0 = 10^{-10} \text{ A}$ and a short-circuit current of 5A at full insolation and room temperature. Given that its ideality factor is unity, determine its;
 - i. Open-circuit voltage at full insolation (3 marks)
 - ii. The percentage change in the open-circuit voltage if the insolation is reduced by 50%. (3 marks)
 - iii. Comment on the results of b). ii. Above. (2 marks)
 - c). With a neat structure, discuss the operation of a generic PV cell (8 marks)
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