(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 WITH APPROPRIATE TECHNOLOGY

COURSE CODE: SPH 353

COURSE TITLE: PHOTOVOLTAIC SYSTEMS AND DESIGN

DATE: TUESDAY 26TH APRIL, 2022 **TIME:** 12:00 PM – 2:00 PM

INSTRUCTIONS TO CANDIDATES

TIME: 2 Hours

Answer question ONE and any TWO of the remaining.
Symbols used bear the usual meaning.

MMUST observes ZERO tolerance to examination cheating

Useful constants
Speed of light, $c = 3 \times 10^8\, m/s$
$\varepsilon_0 = 8.83 \times 10^{-12} C^2/Nm^2$
$electron\ charge = 1.6 \times 10^{-19} C$
$electron\ mass = 9.11 \times 10^{-31} kg$
$h = 6.626 \times 10^{-34} Js$
$Boltzmann\ constant = 1.38 \times 10^{-23}\, J/mol.K$
Avogadros no. $6.02 \times 10^{23} mol^{-1}$

QUESTION ONE (30 MARKS)

a) Determine the value of saturation current for silicon at 40^{0}C. ($E_g = 1.11eV$) (3 marks)

b) Calculate the fill factor for a solar cell which has the following parameters: $V_{oc} = 0.2V; I_{SC} = 5.5mA, V_{max} = 0.125V, I_{max} = 3mA$ (3 marks)

c) Calculate the power output from a solar cell under standard test conditions ($I(t) = 1000\, w/m^2\ and\ T_c = 25^0 C$), when, $\eta = 16\%$, $FF = 0.782$ aperture area $A = 4.02 \times 10^{-4} m^2$ (3 marks)

d) Calculate the packing factor of a PV module (36 solar cells) of area 0.605 m^2, each pseudo-solar cell having an area of 0.015 m^2. (2 marks)

e) Calculate the efficiency of a PV module at an intensity of 400 W m^{-2}, given: $FF = 0.8$; $I_{SC} = 3.2A, V_{OC} = 16V, I_L = 1A, V_L = 14V$ and area of module $1m^2$ (3 marks)

f) What is the importance of MPPT in an SPV system? Explain various strategies used for the operation of an MPPT. (3 marks)

g) Describe the working principles of Lithium ion batteries (3 marks)

h) Calculate the carbon dioxide emissions per year from a solar panel in a lifetime of 30 years, when the total embodied energy required for manufacturing the system is 1060 kWhm^{-2}. (3 marks)

i) If ksh20,000 compounds to ksh28,240 in 4 years of a given solar system, what will be the rate of return? (3 marks)

j) State four possible scenarios in which solar modules can be integrated into building facades (4 marks)

QUESTION TWO (20 MARKS)

2a) Illustrate the equivalent circuit of a solar cell describing the necessary components (6marks)

2b Calculate the maximum power and cell efficiency of the cell at an intensity of 200 Wm^{-2}, given $V_{OC} = 0.24V$, $I_{SC} = 9mA$, $V_{max} = 0.14V$, and $I_{max} = 6mA$, $A_c = 4cm^2$. (6marks)

2c) Discuss the four main limits to solar cell efficiency (8 marks)

QUESTION THREE (20 MARKS)

3a) Draw a circuit diagram for a two way and intermediate switching circuit and explain how it works (6 marks)

3b) Discuss the electro-chemical action of a lead acid accumulator (6marks)

3c) Installation of a ksh50,00,000 energy management system in an industry is expected to result in a 25% reduction in electricity use and a 40% saving in process heating costs. This translates to net yearly savings of ksh600,000 and ksh750,000 respectively. If the energy management system has an expected useful life of 20 years, determine the internal rate of return on the investment. Salvage value need not be considered in the analysis. (8marks)

QUESTION FOUR (20 MARKS)

4a) Discuss the silicon thin film fabrication technology with well labelled diagrams
(i) Czochralski (ii) Float Zone (iii) Ribbon silicon (15 marks)

4b) Show the structure of a high efficiency monocrystalline solar cell indicating all the components (5 marks)

QUESTION FIVE (20 MARKS)

5a) Calculate the daily load for domestic use and how many PV panels are required in the array. The household has the following appliances used for 5hour daily; 10W lights in 4 rooms, one 80W TV, 40W Laptop, 20W Ceiling Fan, 60W Refrigerator used throughout with compressor on 50% of the time, Four security lights 10W used for 10hours daily assume a 5.2 peak sun hours daily (8marks)

5b) The table below shows appliances available in a home

Appliance	Power rating (W)	Usage (Hrs)
Sewing Machine	80	2
14" color Television	80	3
Laptop Computer	80	4
Radio	30	3
Three Lighting Bulbs	10	6

Assuming system loss of 10% and Inverter loss of 15% for a 12V system

(i) Design a system for this solar home

(ii) Sizing for the number of modules, storage batteries assuming 100Ah Battery with 50% depth of discharge and 3 storage days, assume 80W module with $I_p = 4.7A$, $V_{oc} = 21.8V$, and $I_{sc} = 5.4A$

(iii) Inverter sizing (12 marks)