MACHAKOS UNIVERSITY

University Examinations 2020/2021 Academic Year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

THIRD YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (APPLIED PHYSICS AND TECHNOLOGY)

SPH 352: SOLAR ENERGY TECHNOLOGY

DATE: 9/8/2021 **TIME: 2.00-4.00 PM**

INSTRUCTIONS:

- The paper consists of **two** sections.
- Section **A** is **compulsory** (30 marks).
- Answer any **two** questions from section **B** (each 20 marks).

CONSTANTS

- Take: Specific heat capacity of water = $4200 Jkg^{-1}K^{-1}$
- Density of water = $1000\ kgm^{-3}$
- Stefan's constant = $5.7 \times 10^{-8}\ Wm^{-2}K^{-4}$

SECTION A

QUESTION ONE (30 MARKS)

a) i Distinguish between radiant flux density and spectral radiant flux density.(2 marks)

ii Determine the radiant flux density (RFD) emitted by black body at a temperature of 3000K in the wavelength range 0.7 μm to 1.2 μm. (4 marks)

b) Define the photovoltaic effect (1 mark)

c) Calculate the longest wavelength of light capable of forming an electron-hole pair in silicon (3 marks)

d) State three similarities of a PV cell and a battery (3 marks)

e) Define the two main functions of a charge controller (4 marks)

f) Distinguish between conductors, insulators and semiconductors in terms of energy gap (3 marks)

g) Explain the **three** main regions of the solar spectrum. For each region, indicate the percentage amount of irradiance. (3 marks)

h) Explain the factors that affect the amount of solar radiation reaching the earth (3 marks)

i) Describe any **Two** instruments used in measurement of solar radiation, for each of the instrument, explain the principle of operation. (4 marks)

QUESTION TWO (20 MARKS)

a) Discuss qualitatively the following high temperature solar collectors:

i. Parabolic trough designs

ii. Power tower designs

iii. Dish designs

iv. Fresnel Reflectors (8 marks)

b) A monochromatic red laser beam emitting 1×10^{-3}W at a wavelength of 638 nm is incident on a silicon solar cell. Calculate;

i. the number of photons per second incident on the cell (6 marks)

ii. the maximum possible efficiency of conversion of this laser beam to electricity (3 marks)

c) For solar collector analysis with a cover of transmittance, τ and of absorbance, α show that the absorbance-transmittance product is given by:

$$<\alpha\tau>=\sum_{n=0}^{n=\infty}[(1-\alpha)\rho]^{n}$$ where ρ refers to the quantity of reflection on the cover plate of the diffuse radiation. (3 marks)

QUESTION THREE (20 MARKS)

a) i With the aid of a diagram, discuss **four** main components of a flat plate collector. (6 marks)

ii Give three advantages and three disadvantages of concentrating collectors over the flat plate collectors. (6 marks)

b) Explain **five** broad categories of energy storage. What factors do optimum energy systems depend on? (5 marks)

c) A flat plate collector having an area $1.8m^2$, loss resistance $0.15\ m^2KW^{-1}$, plate transfer efficiency of 0.85, transmittance 0.9 and absorbance, 0.9. The collector is exposed to an irradiance of $600\ Wm^{-2}$. Given that water enters at 40^0C and the ambient temperature is 25^oC, calculate the flow rate needed to produce a temperature rise of 4^oC (3 marks)

QUESTION FOUR (20 MARKS)

a) Discuss the extent to which solar thermal energy has been harnessed in Kenya. What are the advantages and limitations of harnessing the resource? (6 marks)

b) The monthly insolation, H_o, at the top of the atmosphere is given by

$$H_o = 1.04x10^3\left[\left\langle 1 + 0.033\cos\left(\frac{360n}{365}\right)\right\rangle \cos\phi\cos\delta\sin\omega + \frac{2\pi\omega_s}{360}\sin\phi\sin\delta\right]$$

{The symbols carry their usual meaning}

i. Define the latitude, ϕ, the declination, δ, the hour angle, ω. (3 marks)

ii. Determine the value of H_o over a horizontal surface for June 22 at latitude 10^oN (4 marks)

c) A rectangular black bag 1.0 m x 1.0 m x 0.1 m with walls 5mm thick is filled with 100 liters of water and exposed to an irradiance $G = 800\ W/m^2$. The bag is supported by a thin non-conductive grid well above the ground. The ambient temperature is 25^oC. Given that the resistance to heat losses from the bag $R_L = 0.015\ KW^{-1}$ and the absorbance $\alpha = 0.8$, estimate the maximum average temperature of the water and the time taken to reach that temperature. State any assumption(s) made. (7 marks)

QUESTION FIVE (20 MARKS)

a) Explain the following regions of the solar spectrum

i. Solar short wave

ii. Environmental long wave

For each region, write the wavelength ranges (3 marks)

b) An electric lamp has a filament at a temperature of 1727°C. If the filament is regarded as a black body, calculate

i. The wavelength of radiation emitted with highest intensity (3 marks)

ii. The power of the lamp if the filament is a wire of diameter 1.0×10^{-4}m and length 200 mm. (3 marks)

c) A 50 bed single storey hotel located near the equator in Kenya proposes to install a solar water heating system. As an energy consultant, explain to the management all the different requirements and processes that they will need to consider. (7 marks)

d) A family of five persons requires 200 liters of hot water at 50 °C per day in a location which has an average radiation intensity of 8 kWh m^{-2}. If the temperature of the supply water to the bottom of the storage tank is 25 °C and the collector efficiency is 40%, determine the required collector area. (4 marks)