(*University of Choice*)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY

(MMUST)

MAIN CAMPUS

UNIVERSITY EXAMINATIONS

2021/2022 ACADEMIC YEAR

THIRD YEAR SECOND SEMESTER EXAMINATIONS

FOR THE DEGREE

OF

BACHELOR OF SCIENCE IN RENEWABLE ENERGY TECHNOLOGY

COURSE CODE: RET 342

COURSE TITLE: SOLAR AND OTEC ENERGY

DATE: 29-04-2022 **TIME: 08:00-10:00**

INSTRUCTIONS TO CANDIDATES

1. This paper consists of **FOUR** questions
2. Answer Question **ONE (Compulsory)** and any other **TWO** Questions
3. All symbols have their usual meaning
4. Candidates are not allowed to share calculators in the examination

TIME: 2 Hours

MMUST observes ZERO tolerance to examination cheating

This Paper Consists of 3 Printed Pages. Please Turn Over

QUESTION ONE [30 marks]

1)

a) Using a simple sketch, distinguish the terms diffuse, beam and total radiation **(3 marks).**

b) Briefly describe the two basic types of solar radiation measurement instruments **(2 marks).**

c) The equation relating the angle of incidence, $\boldsymbol{\theta}$ of beam radiation on a surface to other angles is given below and only valid when the sun hour angle is between sunrise and sunset:

$$Cos\theta = sin\delta sin\phi cos\beta - sin\delta cos\phi sin\beta cos\gamma + cos\delta cos\phi cos\beta cos\omega + cos\delta sin\phi sin\beta cos\gamma cos\omega + cos\delta sin\beta sin\gamma sin\omega$$

For a horizontal surface,

i. Show that the angle of incidence of beam radiation is zenith angle and illustrate how it relates with other angles **(2 marks).**

ii. Derive the solar hour angle at sunset **(2 marks)**

d) A surface collector located in Kenya **(Lat: 1.30 N, Long: 35.4 E)** at 10:00 (solar time) on February 26 2022 is tilted 35^0 from the horizontal and pointed 25^o west of south.

i. Calculate the angle of incidence of beam radiation **(4 marks)**

ii. Sketch the plate showing all the angles **(1 mark)**

e) You are required to install a flat plate collector for the above location **(Lat: 1.30N, Long: 35.4 E)** whose time zone is **UTC+3.** Assuming it is a horizontal surface and given the equations below, Calculate for **4th March 2022**:

$$E = (9.87\sin 2B - 7.53\cos B - 1.5\sin B)min \ , B = (n-81).\frac{360}{365}$$

$$\bar{G}_{day} = 433\ [w_{ss}sin\phi sin\delta + cos\phi cos\delta sinw_{ss}]$$

i. The earth's declination angle **(2 marks)**

ii. Number of daylight hours N **(3 marks).**

iii. Time compensation Tc **(3 marks)**

iv. Sunrise and sunset hours in local and solar time **(5 marks).**

v. Average daily solar irradiance (W/m2) given that **(2 marks)**

vi. Average daily irradiation (kWh/m2) **(1 mark)**

QUESTION TWO [20 marks]

2)

a) A flat plate collector will be installed for hot water production in a house for a design outlet temperature of 65°C and a design total irradiance on the collector of 935 W/m^2 . Your research on solar collectors for solar thermal applications yielded the following information:

Parameters	Value
Average transmission of glass τ_G	0.90
Absorption coefficient collector α_A	0.95
U-value front	5 W/(m^{2}K)
U-value back	0.5 W/(m^{2}K)
Collector efficiency F	0.945

Nominal mass flow rate	0.25 m^3/h
Specific cost per m^2	180 $/$m^2$

Assumption: Collector considered perfectly insulated (adiabatic) at the sides and the ambient temperature equal 20°C. The fluid inlet temperature to the collector can be assumed to be 25°C For both collectors determine at the design time:

i. Find the useful energy per time on the water **(3 marks).**
ii. The collector area required to achieve the design outlet temperature of 65°C **(3 marks).**
iii. Find the cost of the plate **(1 mark)**

b) State a disadvantage of water as a working fluid for flat collectors in the polar and temperate regions of the world and provide a potential remedies that can be adopted to alleviate such a problem **(3 marks).**

c) Using a horizontal flow chart, explain the process of Thermal Generation process starting from sun's radiation to electrical energy generation (national grid). **(4 marks)**

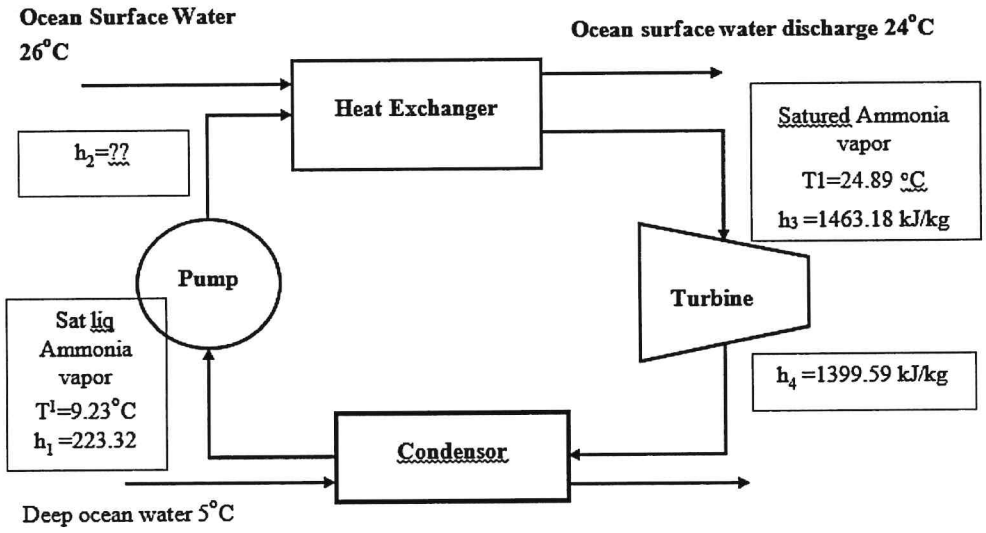
d) With the aid of a well-labelled diagram, explain the architecture (components) and working principle of a solar tower power plant **(6 marks)**

QUESTION THREE [20 marks]

3)

a) With an aid of a well-labelled diagram, distinguish the two types of OTEC energy technologies according to cycle **(6 marks)**

b) A closed-cycle OTEC power plant operating on an ideal ranking cycle has the following specifications. The working fluid has a mass flow rate of 10 kg/s.



Calculate the following:

i. Power output of the turbine **(2 marks).**
ii. Enthalpy of fluid leaving the pump given pump rating is 500 Watts **(2 marks).**
iii. The plant efficiency **(2 marks)**

c) Using temperature profile, explain why OTEC technology is viable in the tropical zone unlike the Polar Regions **(3 marks).**
d) Give two benefits of an OTEC power plant in an aquatic environment **(2 marks).**
e) Outline the environmental impacts of OTEC power plants **(3 marks).**

QUESTION FOUR **[20 marks]**

4)

a) With examples, explain the two categories of costs of solar process systems **(4 marks).**
b) Describe three limitations of the solar energy **(6 marks)**
c) A solar company plans to install a **solar thermal energy system** for a **CAPEX of** $27,500. The system is connected to the grid with a net metering plan (i.e., the homeowner pays for the difference in the electricity used and that produced by the system). The system produced 20000 kWhe in the first year. If the effective tariff is $0.15/kWh, find the payback period for the system. Assume equipment depreciation factor of 0.25%, O&M costs at 2% of CAPEX, 5% tariff increment **(5 marks)**
d) With an aid of a well-labeled diagram, briefly describe the operating principle of a solar pond power plant **(5 marks).**