KIBABII UNIVERSITY

UNIVERSITY EXAMINATIONS
2021/2022 ACADEMIC YEAR

THIRD YEAR FIRST SEMESTER
MAINS EXAMINATIONS

FOR THE DEGREE OF BACHELOR OF SCIENCE IN RENEWABLE ENERGY AND BIO FUELS TECHNOLOGY

COURSE CODE: REN 311

COURSE TITLE: **Solar Energy 1**

DURATION: **2 HOURS**

DATE: 25/05/2022 **TIME: 2:00PM-4:00PM**

INSTRUCTIONS TO CANDIDATES

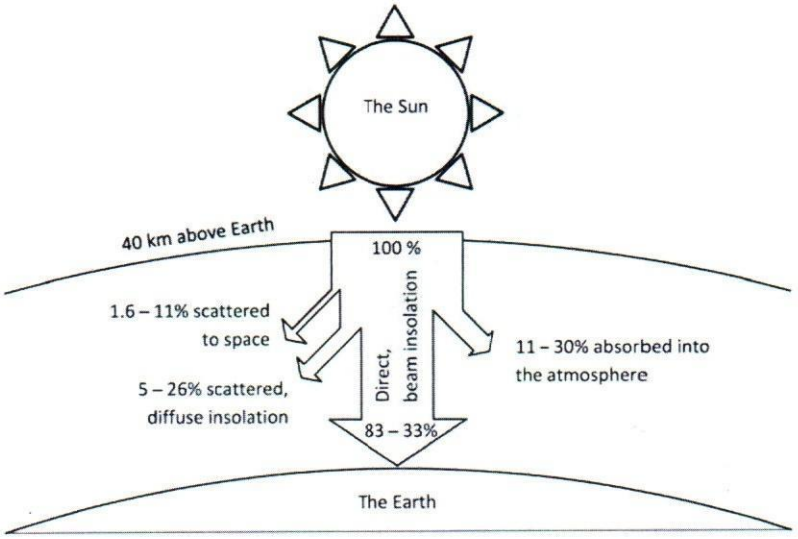
- Answer **QUESTION ONE** (Compulsory) and any other **ONE** (1) Question.
- Indicate **answered questions** on the front cover.
- Start every question on a new page and make sure question's number is written on each page.

This paper consists of **4** printed pages. Please Turn Over

KIBU observes ZERO tolerance to examination cheating

Question One

The figure below shows the dispersion of solar irradiance through the atmosphere as it travels from the sun to the Earth



(a) **(i)** State the process in the sun that is responsible for the energy dispersed **[1/2 mark]**

(ii) Define solar constant and state its value **[2 marks]**

(iii) What is the final energy received at the surface of the Earth? **[1/2 mark]**

(b) Knowing that the radius of the Sun is 6.96×10^{8}m and the distance between the Sun and the Earth is roughly 1.5×10^{11}m, and assuming that the Sun is a perfect sphere, calculate the temperature in K at the Sun's surface. Assume that the irradiance arriving to the Earth is the value for AM0: 1350W/m^2 **[5 marks]**

(c) The position of the sun in the sky varies continuously. How does this affect the collection of solar energy? **[2 marks]**

(d) Solar energy reaches the earth's surface as *short-wave radiation*, is absorbed by the earth and objects on the earth that heat up, and then it is *re-radiated as long-wave radiation*. Obtaining useful power from solar energy is based on the principle of capturing the short-wave radiation and preventing it from radiating away into the atmosphere. For storage of this trapped heat, a liquid or solid with a high thermal mass is used. In a water heating system this will be the fluid that runs through the collector. Illustrate this in a clearly and neatly labelled sketch of flat plate solar water heater that includes storage tank. **[5 marks]**

(e) With the help of a sketch, explain the working principle of Ocean Thermal Energy Conversion System. **[5 marks]**

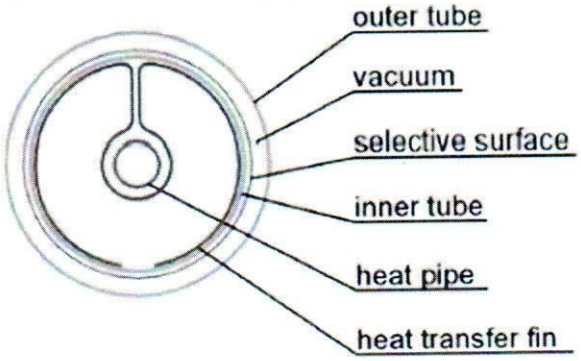
(f) With the help of a sketch, explain the working principle of Concentrating Solar Power System. **[5 marks]**

(g) Explain, with examples, how "solar thermal technologies" can be used to create wealth in rural areas of developing countries. **[5 marks]**

Question Two

(a) The design of solar thermal collectors is based on heat transfer principles. *Explain* the three principles of heat transfer as they relate to a flat plate solar collector. **[7 Marks]**

(b) The figure below shows a cross section through an evacuated tube solar collector. Answer the following questions:



(i) Describe the construction and the function of the heat pipe **[3 Marks]**

(ii) What is the purpose of the vacuum in this device? **[1 Mark]**

(c) During the cold season, the inside of an average house is maintained at 20 °C, while the outside temperature is 0 °C. Assuming that the only mechanism of heat transfer is conduction, the walls are 10 cm thick and the heat conductivity of the walls is 0.5W/km.

(i) Calculate the heat flux (flow) from the room to the surroundings in w/m^2. **[2 Marks]**

(ii) It is decided that, to reduce the heat loss through the walls, the material should be changed to an insulator material. The new overall conductivity will be 0.1W/km, and the thickness of the wall is maintained. Calculate the reduction of the heat flux throughout the walls in % compared to the initial case. **[4 Marks]**

(c) What are the thermal applications of solar energy? **[3 Marks]**

Question Three

A hotel wants to cover their water heating demand by solar energy. The hotel needs 1500 L/day of warm water every day and the water is to be heated from 10 to 60°C. The specific heat capacity of water is 4.18J/gK. Assume an irradiance of $1000W/m^2$ for 3 equivalent sun hours and an efficiency of 70% for the installation.

(a) **[7Marks]**

How much energy does the system need to produce per day to meet the warm water demand? Give your answer in kWh/day.

(b) If the hotel has $30m^2$ available for this application, what is the maximum percentage of the warm water demand that can be covered by solar energy? **[3 Marks]**

(c) What are the main advantages of a solar tower power plant? Note that more than one correct answer is possible. **[4 Marks]**

(d) **(i)** Explain the working principle of the two main types of solar cookers **[3 Marks]**

(ii) State the advantages and limitations of a typical solar cooker. **[3 Marks]**

Question Four

A solar collector of $1.5m^2$ is installed on the rooftop of a house. Assuming that the radiative energy arriving from the sun is $1000W/m^2$, the collector reflects 10% of the energy arriving on its surface. Also, the collector is not perfectly insulated, and losses occur. The collector has a heat transfer coefficient h of $2W/m^2K$. The side areas of the collector are assumed to be negligible. The ambient temperature is 20 °C and the collector is assumed to be at a temperature of 50 °C. Consider that this temperature is constant throughout the whole collector. The collector is assumed to behave like a black body.

(a) What is the power output of the collector in W? **(12 Marks)**

(b) What percentage of the total losses is caused by radiation? **(2 Marks)**

(c) What is the most important heat transfer mechanism in domestic solar water heating systems? **(4 Marks)**

(d) What does it mean when the water heating system is in an open loop? **(2Marks)**

Question Five

(a) State and explain the factors that you would consider in choosing an energy system **5 marks**

(b) Compare and contrast Ocean Thermal Energy Conversion Technology (OTEC) and Concentrating Solar Power (CSP) for electricity generation. Pay special attention to: **10 marks**

- Resource availability
- Conversion technology
- Maturity of technology

(c) Between the two technologies discussed above, which one would you recommend first for Kenya. Give reasons **5 marks**