JARAMOGI OGINGA ODINGA UNIVERSITY OF SCIENCE AND TECHNOLOGY

SCHOOL OF ENGINEERING AND TECHNOLOGY

UNIVERSITY EXAMIMATION FOR THE DEGREE IN SCIENCE IN RENEWABLE ENERGY TECHNOLOGY AND MANAGEMENT

3RD YEAR 2ND SEMESTER 2023/2024 ACADEMIC YEAR

CENTRE: MAIN CAMPUS

COURSE CODE: TEB 1308

COURSE TITLE: SOLAR THERMAL ENERGY TECHNOLOGY

EXAM VENUE: **STREAM: BSc. REN ENGY TEC & MGT**

DATE: /04/2024 **EXAM SESSION:**

DURATION: 2 HOURS

Instructions

1. **Answer question 1 (Compulsory) and ANY other two questions**
2. **Candidates are advised not to write on question paper**
3. **Candidates must hand in their answer booklets to the invigilator while in the examination room.**

<u>Question One (Compulsory)</u>

a) Enumerate **THREE** applications of sun path diagrams. **(3 Marks).**

b) Discuss the working principle of a Campbell-Stokes sunshine recorder. **(4 Marks)**

c) Discuss and give an example of the two types of solar collectors that are available in the market **(3 Marks).**

d) Using well labelled diagrams discuss three types of absorber plates that can be used to manufacture flat plate collector (FPC) **(3 Marks)**

e) State three reasons why most developers prefer flat plate collectors than evacuated tube collectors. **(3 Marks)**

d) A solar collector with an area (A =11 m^2) is used for air heating and it operates under the following conditions:

• Cold air temperature at the collector inlet T_{in} = 30°C

• Hot air temperature at the collector outlet T_{out} = 72°C

• Effective optical efficiency of the collector η_{opt} = 0.76

• Effective overall heat loss coefficient of the collector $U_{c,e}$ = 3.6 W/m2K

• Ambient air temperature T_a = 23°C

• Solar radiation flux incident on the tilted collector surface I_c = 778 W/m2

• Isobaric specific heat of the air cp = 1050 J/(kg K)

Calculate

(i) The rate of useful heat output of the collector **(2 Marks)**

(ii) The air mass flow rate in the collector. **(2 Marks)**

(iii) The collector efficiency. **(2 Marks)**

e) Outline four reasons why it is important to install sun tracking concentrating collectors **(4 Marks).**

f) Outline three design guidelines that should be followed to ensure that passive solar heating is effective in a building **(3 Marks)**

<u>QUESTION TWO</u>

a) Using the following data calculate the overall loss coefficient of a flat plate collector **(10 Marks)**

Size of the absorber plate 2.15m×1.15m

Spacing between absorber plate and 1st glass cover 5cm

Spacing between absorber plate and 1st and 2nd glass cover 5cm

Glass cover emissivity 0.85

Plate emissivity 0.90

Mean plate temperature 75ºC

Ambient temperature 20ºC

Collector tilt 30º

Wind speed 3m/s

Back insulation thickness 8cm

Side insulation thickness 4cm

Thermal conductivity of insulation 0.035W/m-K

Stefan-Boltzmann constant $5.67\times10^{-8}W/m^2\text{-}K^4$

b) With the help of an illustration discuss any five angles that define the position of the sun relative to the solar collector plane. **(10 Marks).**

<u>QUESTION THREE</u>

a) Using illustrations discuss the four various configurations of absorbers used for compound parabolic concentrators **(4 Marks).**

b) Discuss three types of solar collectors that Energy regulatory commission has endorsed for the Kenyan market **(6 Marks)**

c) Outline any five key important points you have to consider when designing a tube and sheet absorber for evacuated solar collectors. **(5 Marks)**

d) Calculate the monthly average hourly radiation falling on a flat plate collector facing due south (ɣ=0º) with a slope of 15º given the following data **(5 Marks).**

Location: Bondo (13º00' N)

Month: October

Time: 1100-1200h

Ig =: 2408Kj/m2/h

Id =: 1073Kj/m2/h

Ground reflectivity =0.2

<u>QUESTION FOUR</u>

a) Using a well labeled diagram discuss five components found on a flat plate collector. **(8 Marks)**

b) An evacuated glass tube solar collector (ETC) array (refer to Figure 4b) comprising 80 solar modules, each with an absorber surface area A of 0.19 m^2, operates under the following conditions:

• Intensity of solar radiation Ic incident on the collector surface is 760 W/m^2

• Collector fluid (water) inlet temperature Tin = 48°C

• Total mass flow rate of water m = 0.169 kg/s

• Ambient air temperature Ta = 32°C

• Collector effective optical efficiency ηopt = 0.77

• Collector effective overall heat loss coefficient Uc,e = 1.6 W/m^2K

• Isobaric specific heat of water cp = 4187 J/kg K

Calculate the following **(8 Marks)**

1. The collector useful heat output Q_c,
2. The collector fluid outlet temperature T_{out},
3. The absorber stagnation temperature $T_{stag,}$
4. The collector efficiency.

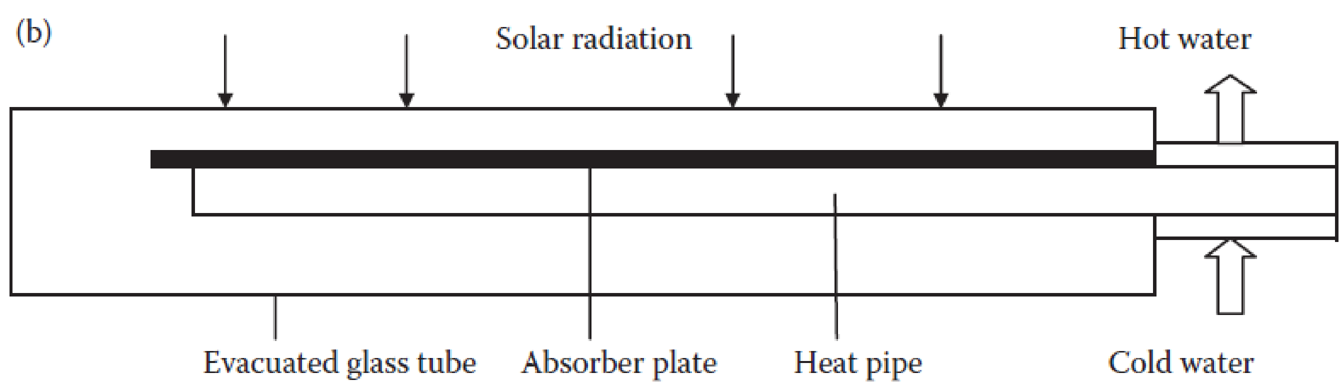

Figure 4b: Evacuated glass tube collector (ETC). HTF, heat transfer fluid.

c) Outline two properties of selective surfaces which are considered major for their applications in manufacturing solar collectors **(4 Marks)**

QUESTION FIVE

a) Discuss five applications of solar thermal technology **(10 Marks)**

b) A point-focus concentrating solar collector comprising a heliostat field and central receiver and a steam turbine–generator unit (as shown in Figure below) operates under the following conditions:

• Power plant electric power output Pel = 150 MWe

• Single heliostat surface area Ah = 150 m^2

• Beam solar radiation flux incident on the heliostat Ib,N = 840 W/m^2

• Heliostat–receiver concentration ratio C = 480

• Efficiency of the solar collector system including heliostat field and central receiver, $\eta_c = 0.74$

• Thermal efficiency of the power plant cycle $\eta_{th} = 0.40$

• Efficiency of the electric generator $\eta_g = 0.976$

• HTF in the absorber/receiver: molten salt (sodium potassium nitrates)

• HTF temperature rises in the absorber/receiver from 295°C to 565°C, that is, $\Delta Tf = 270$ K

• HTF specific heat cp = 1.03 kJ/(kg K)

Calculate the following parameters **(10 Marks)**

(i) The overall (electrical) efficiency of the power plant

(ii) The rate of useful heat output of the central receiver/absorber,

(iii) The total reflecting surface area of the heliostat field,

(iv) The number of heliostats and absorber surface area in the central receiver

(iv) The HTF mass flow rate.

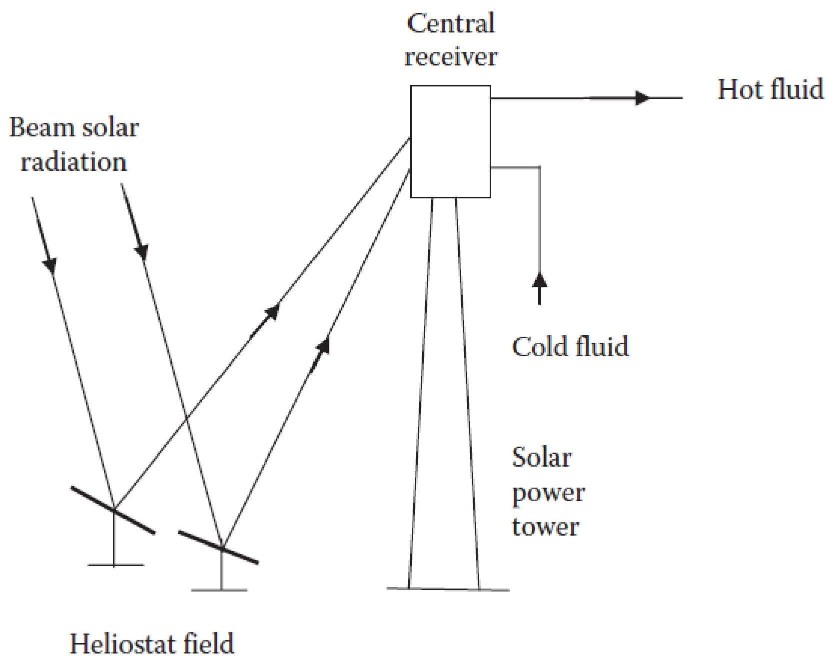

Figure 5b point focus solar concentrator