KENYATTA UNIVERSITY

EXAMINATION FOR THE DEGREE OF MASTER OF SCIENCE IN RENEWABLE ENERGY TECHNOLOGY

SET 814: SOLAR ENERGY

2ND SEMESTER 2021/2022 **TIME: 3 HOURS**

INSTRUCTIONS: Answer Question ONE and any other TWO Questions
Question ONE carries 30 marks and all the others carry 20 marks each

Useful expressions

Collector efficiency; $\eta = F_R(\tau\alpha) - F_R U_L \frac{(T_i - T_a)}{G_t}$

Solar thermal energy demand; $L = V \times \rho \times c(T_o - T_i)$

Collector Area; => $A_c = \frac{L \times F_{solar}}{\eta_{solar} \times I_{av}}$

Resistance of 1 mm^2 cable = 0.02 Ω/m

Planck's constant, $h = 6.626 \times 10^{-34}$

Energy of an electron, $eV = 1.602 \times 10^{-19}$

Speed of light, $C = 2.998 \times 10^8$ m/s

Question 1 (Compulsory - 30 Marks)

[a] With an ordinary flat plate solar collector in mind and with the help of thermal resistances, R and/or heat loss coefficients h, illustrate the overall heat loss, U_l, phenomena/network from top and bottom of the absorber. *(4 Marks)*

[b] The band gaps of Germanium, Titanium, Silicon, and Hematite are 0.5 eV, 3.0 eV, 1.1 eV and 2.5 eV, respectively. Considering a blue light (450 nm - 495 nm), which semiconductor would only absorb this light and transmit the rest of the visible range? *(1 Mark)*

[c] Explain concentration ratio as applied to concentrated solar power systems *(2 Marks)*

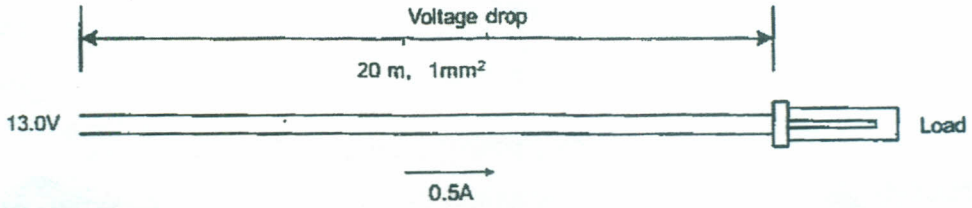
[d] Explain five (5) types of solar cells *(5 marks)*

[e] Discuss the advantages and disadvantages of air solar heating systems as compared to water-based systems. *(3 Marks)*

[f] Explain the main functions of a charge controller *(2 Marks)*

[g] Using a simple sketch and based on crystalline silicon technology, name the various parts of a solar PV module *(3 Marks)*

[h] Consider a DC wiring diagram shown in the figure below. Determine the voltage at the load, V_{load} under those conditions. *(2 Marks)*



[i] Convective heat transfer mechanism is very significant in solar thermal systems. Briefly discuss this mechanism using terminologies such as Rayleigh, Reynolds and Nusselt numbers. *(5 Marks)*

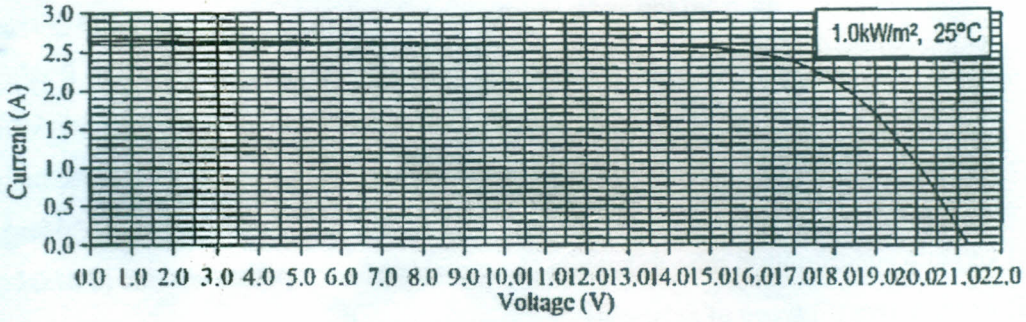
[j] A certain battery has the following specifications, 9 V, 150 Ah, C100. Determine the total ampere-hour rating, voltage and stored energy when four (4) such batteries are connected;

- In series
- In parallel *(3 marks)*

Question 2 (20 Marks)

[a] Discuss the concept of food drying in solar dryers and further, with the aid of a neat sketch discuss the working principle of an active mixed-mode solar dryer. *(12 Marks)*

[b] The following graph shows the I-V curve of a 36-cell module at 1.0 kW/m², 25 °C. Its Isc = 2.65 A, Voc = 21.20 V, Vmp = 16.70 V, Imp = 2.42 A,



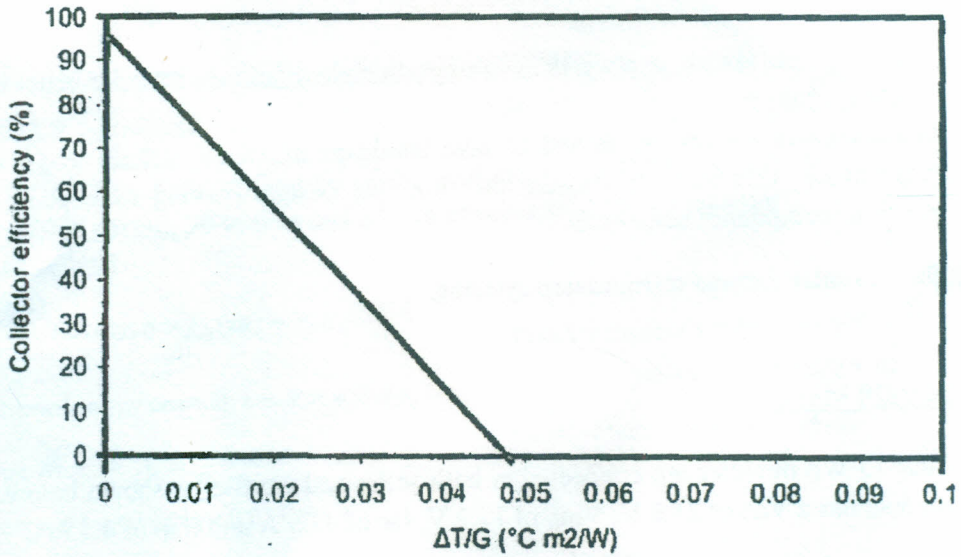
i. Discuss the I-V characteristics of this module and further, if the temperature coefficient for the Voc is -0.10176 V/°C, calculate the Voc at 55 °C. *(4 Marks)*

ii. On the same module, what is the temperature coefficient for the Voc in percentage (% /°C)? *(2 Marks)*

iii. If this module is connected to a 12 V battery (100 Ah C20) and the Irradiance is 0.7 kW/m², how much would be the output power? *(2 Marks)*

Question 3 (20 Marks)

[a] The figure below shows an efficiency plot of a certain collector.



i. If the collector has an absorbance-transmitance term, ($\tau\alpha$) equal to 0.88, what is the heat removal factor of the collector? *(2 marks)*

ii. What is the overall heat loss coefficient, U_L of the collector? *(3 marks)*

iii. If the inlet temperature is constant at 55 °C and the irradiance is 800 W.m^{-2}, what is the overall instantaneous efficiency at an ambient temperature of 24 °C? *(5 marks)*

[b] Consider the following data obtained from a certain customer;

S/N	Accessory	Rating (W)	Quantity	Hours of use (h)	Given parameters	
1	TV	80	1	4	Insolation	5.4 kWh/m²
2	Radio	18	1	6	Battery efficiency	80%
3	Light 1	20	1	5	Inverter efficiency	95%
4	Light 2	13	1	4	Recommended DOD	20%
5	Light 3	9	3	2	PV mismatch losses	20%
6	Pump	500	1	0.5	System voltage	24 V

iii. Determine the overall energy demand and the peak load for this customer

(3 Marks)

iv. Based on the proposed system voltage, advice the owner on the right number and capacities of the PV array, charge controller, inverter and battery bank to purchase. *(7 Marks)*

Question 4 (20 Marks)

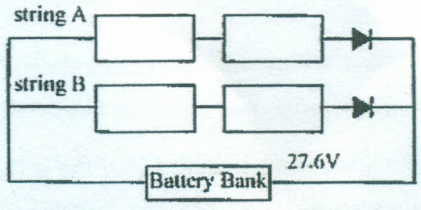
[a] Using a simple sketch, explain the working principle of an indirect solar water heating system *(7 marks)*

[b] Three semiconductors, A, B and C have bandgaps of 18 eV, 1.2 eV and 0.65 eV, respectively. Use them to explain the principle design/working concept of multi-junction (compound) solar cells *(8 marks)*

[c] Discuss solar thermal refrigeration systems. *(5 Marks)*

Question 5 (20 Marks)

[a] Four 75 Wp modules are connected in both series and parallel as shown below. Each module has a Voc of 21.6 V, Vmp of 17.2 V, Isc of 4.65 A and Imp of 4.35 A,



i. Determine the fill factor (FF) of the modules *(2 marks)*

ii. If the charging current for one module at 1 kW/m^2 is 4.4 A, determine the overall output power of the array when the irradiance is 0.8 kW/m^2. *(6 marks)*

[b] Discuss both low and high temperature solar thermal technologies used for power generation *(12 marks)*