Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

(A constituent unit of MAHE, Manipal)

I SEMESTER M.TECH (TSES) END SEMESTER EXAMINATIONS, NOVEMBER 2018

SUBJECT: SOLAR THERMAL ENERGY SYSTEMS [MME 5143]

REVISED CREDIT SYSTEM

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ALL** the questions.
- Missing data may be suitably assumed.
- Use of Heat and mass transfer data book is permitted

1A. Derive an expression to find the time taken by flat plate solar water heater to reach the mean plate temperature corresponding to fluid inlet temperature. **05**

1B. A cylindrical hot water storage tank, 1.7 m in diameter and 2.1 m height (made from Carbon steel, AISI 1010) is 6 mm thick which is well insulated by glass fibre (poured) having 200 mm thickness. The initial temperature of water in tank is 50°C at 0700 h. Find the water temperature at 0900 h with respect to following energy interactions.

Time	7-8 am	8-9 am
Energy input from solar collectors (kJ/h)	15000	20000
Connected load (kJ/h)	10000	15000
Ambient temperature (°C)	20	22

05

2A. With a neat sketch explain the working, advantages and disadvantages of evacuated tube based solar water heater. By mentioning the overall heat loss coefficient expression, give reason for not including tube side loss in it. **05**

2B. Calculate the time taken for water at 40°C to boil in a solar box cooker with the following specifications and operating conditions:

Efficiency factor = 0.85
Aperture area = 0.36 m^2
Ambient temperature = 15°C
Overall loss coefficient = 6 W/m^2K
Heat capacity of water = 16.76 kJ/K
Transmissivity-absorptivity product = 0.70
Radiation level on aperture area = 600 W/m^2
Radiation due to reflection = 2/3 of direct incident level

If initial water temperature is 50°C and the boiling time required is 3 h, find the **05**

average solar radiation level.

3A. Derive an expression for collector efficiency factor in case of a conventional solar air heater. **05**

3B. Calculate the monthly average hourly global and diffuse radiation during the month of April on a horizontal surface at New Delhi (28°35' N). Time is 0900 h to 1000 h (LAT). The average number of sunshine hours per day is 8.6. Take a = 0.25, b = 0.57.
The constants in monthly average hourly global radiation are defined as:
$a = 0.409 + 0.5016\ sin(\omega_s - 60°)$ and $b = 0.6609 - 0.4767\ sin(\omega_s - 60°)$
Monthly average daily diffused radiation is: $\frac{H_d}{H_g} = 1.411 - 1.696\left(\frac{H_g}{H_o}\right)$ **05**

4A. With a neat sketch explain the working of compound parabolic collector. Also derive an expression for collector efficiency factor. **05**

4B. For a flat plate solar water heater having the following specifications and operating conditions, calculate collector efficiency factor, heat removal factor, mean plate temperature, instantaneous efficiency and H-W-B constants.

Heat loss coefficient	=	6.9 W/m^{2}K	Plate thickness	=	0.40 mm
Tube size	=	Φ 13.5 x 15 mm	Tube spacing	=	120 mm
Tube side coefficient	=	320 W/m^{2}K	Plate material	=	Copper
Incident radiation	=	500 W/m^2	Fluid flow rate	=	0.35 kg/s
Water inlet temperature	=	60°C	Plate area	=	1 m^2
Ambient temperature	=	40°C			

Transmissivity-absorptivity product = 0.80. Neglect wall resistance **05**

5A. A solar air heater (with longitudinal fins attached to the bottom side of the absorber plate) having following specifications.

Absorber plate size	=	1 m x 2 m	Air flow rate	=	200 kg/h
Solar irradiance	=	950 W/m^2	Air inlet temperature	=	50°C
Top loss coefficient	=	6.2 W/m^{2}K	Ambient temperature	=	20°C
Bottom loss coefficient	=	0.8 W/m^{2}K	Blower efficiency	=	80 %
Fin pitch	=	25 mm	Fin height	=	13 mm
Fin thickness	=	3 mm	Fin effectiveness	=	0.98

Spacing between plate and bottom plate = 15 mm
Transmissivity-absorptivity product = 0.85
Average of plate and bottom plate temperature = 60°C

Effective heat transfer coefficient, he = $h_{fp}\left(1 + \frac{2L_f\varphi_f h_{ff}}{W h_{fp}}\right) + \frac{h_r h_{fb}}{h_r + h_{fb}}$

Coefficient of friction, f' = 0.06006 $Re^{-0.2352}$

Find collector heat removal factor, H-W-B constants and thermo-hydraulic efficiency. **05**

5B. A cylindrical parabolic collector having aperture of 1.25 m and a length of 3.657 m. The receiver (Carbon steel- 0.5%C) and glass cover sizes are Φ 38.1 mm x 41.35 mm and, Φ 56 mm x 63 mm respectively. Other specifications and working conditions are:

Overall heat loss coefficient	=	13 W/m^{2}K
Reflectivity of concentrator	=	0.85
Glass cover transmissivity	=	0.85
Receiver absorptivity	=	0.95
Intercept factor	=	0.95
Beam radiation	=	705 W/m^2
Ambient temperature	=	32°C
Wind speed	=	5.3 m/s
Fluid inlet temperature	=	140°C
Twist ratio of twisted tape	=	2
Mass flow rate of thermic fluid (engine oil)	=	0.0986 kg/s

Calculate the percentage rise in useful heat gain due to twisted tape.

For twisted tape, $Nu = 5.172\{1 + 0.005484[Pr(Re/X)^{1.78}]^{0.7}\}^{0.5}$ **05**