Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

A Constituent Institution of Manipal University

I SEMESTER M.TECH. (THERMAL SCIENCES AND ENERGY SYSTEMS)

END SEMESTER EXAMINATIONS, NOV/DEC 2016

SUBJECT: SOLAR THERMAL ENERGY SYSTEMS [MME 5143]

REVISED CREDIT SYSTEM

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ANY FIVE FULL** questions.
- Missing data may be suitably assumed.

1A.	State the assumptions made for thermal analysis of flat plate collectors. Using thermal network for two cover flat plate collector, obtain an expression for overall loss coefficient.	**06**
1B.	Calculate the transmittance, reflectance and absorptance of a single glass cover 2.3 mm thick at an angle of 60 degrees. The extinction coefficient of the glass is 32 m-1.	**04**
2A.	Explain the energy position in India. What are the salient measures taken to bridge the gap between energy demand and supply in India	**05**
2B.	A home located at 33^0 N requires 62 kWh of heat on a winter day to maintain a constant indoor temperature of 20 °C. The average solar radiation in winter is about 6.5 kWh/m^2/day. The hot fluid in the secondary loop is at 60^0C and the cold water going into the storage tank is at 20^0C (a) How much collector surface area does it need for an all-solar heating system that has a 20% efficiency? (b) How large does the storage tank have to be to provide this much energy? c) If molten salt (c_p = 1.560 kJ/kg K, Density = 1680 kg/m^3) is used instead of water for storage, what is the capacity of storage tank needed.	**05**
3A.	Explain the significance of transmittance-absorptance product in the calculation of useful gain solar energy	**02**
3B.	Determine the efficiency of a solar collector and its stagnation temperature with the following design and operating data: • collector area = 3 m^2, • absorber plate thickness = 0.6 mm, • absorber plate thermal conductivity = 385 W/m·K, • absorber plate solar absorptivity = 0.95, • Transmissivity of glass covers = 0.95, • Inner and outer diameter of absorber tubes = 10 mm, 11 mm, • overall heat loss coefficient = 5 W/m^2·K • Tube spacing, w = 0.15 m,	**08**

- bond conductance = 385 W/m·K,
- heat transfer coefficient inside absorber tube = 300 $W/m^2 \cdot K$,
- Ambient temperature = 18^oC,
- Solar insolation = 700 W/m^2,
- water mass flow rate = 0.25 kg/s, and
- Inlet water temperature = 30^oC.

Use the following expressions with usual notations:

$$F' = \frac{1/U_L}{W\left[\frac{1}{U_L\left[D+(W-D)F\right]}\right]+\frac{1}{C_b}+\frac{1}{\pi D_i h_{fi}}}$$

$$F = \tanh(mL)/mL$$

$$F_R = \frac{\dot{m}c_p}{A_c U_L}\left[1-e^{\frac{-U_L A_c F'}{\dot{m}c_p}}\right]$$

4A. What is time constant of a flat plate collector. How it is measured. **03**

4B. Calculate the outlet temperature and efficiency of a single-cover type air heater at a 45° slope when the radiation incident on the collector is 1000 W/m^2. The plate-to-cover spacing is 15 mm and the air channel depth is 10 mm. The collector is 1m wide by 3m long. The absorber plate is selective with an emittance of 0.1 and the effective transmittance-absorptance product is 0.85. The inlet air temperature is 60°C, the ambient air temperature is 12°C, and the mass flow rate of the air is 0.05 kg/s. The wind heat transfer coefficient is 12 W/m^2 ◦C and the sum of the back and edge loss coefficients is 1.5 W/m^2 ◦C which is 20% of overall loss coefficient. The emittances of the surfaces of the inside of the duct, ε_1 and ε_2, are both 0.95. The mean fluid temperature is 70^0C. Stephen-Boltzmann const is 5.67 x 10^{-8} W m^{-2} K^{-4}. The absolute viscosity of air at mean fluid temperature can be taken as 2.04 x 10^{-5} Pa-s. Thermal conductivity of air is 0.0257 W/m K. The following equations may be used with usual notations **07**

$$h_r = \frac{4\sigma \bar{T}^3}{\frac{1}{\varepsilon_1}+\frac{1}{\varepsilon_2}-1}$$

$$F' = \left[1+\frac{U_L}{h+\left[\frac{1}{h}+\frac{1}{h_r}\right]^{-1}}\right]^{-1}$$

$$F'' = \frac{\dot{m}c_p}{A_r U_L F'}\left[1-\exp\left(-\frac{A_r U_L F'}{\dot{m}c_p}\right)\right]$$

5A. Explain the working of PCM based thermal energy storage system. What factors to be considered for the selection of the phase change material. **04**

5B. A cylindrical parabolic concentrator with width 2m and length 8 m has an absorbed radiation per unit area of aperture of 480 W/m^2. The receiver is a cylinder with an emittance of 0.3 and is surrounded by an evacuated glass cylindrical envelope. The absorber has a diameter of 50 mm, and the transparent envelope has an outer diameter of 80 mm with a thickness of 4 mm. The collector is designed to heat a fluid entering the absorber at 150° C at a flow rate of 0.05 kg/s. The fluid has C_p = 3.2 kJ/kg◦C. The heat transfer **06**

coefficient inside the tube is 2800 W/m^2 °C and the overall loss coefficient is 4 W/m^2 °C. The tube is made of stainless steel (k = 16 W/m ^{0}C) with a wall thickness of 4 mm. If the ambient temperature is 12° C, calculate the useful gain and exit fluid temperature. Use the following equations with usual notations

$$F' = \frac{1/U_L}{\frac{1}{U_L} + \frac{D_o}{h_{fi} D_i} + \left(\frac{D_o}{2K} \ln \frac{D_o}{D_i} \right)} \qquad F'' = \frac{\dot{m} c_p}{A_r U_L F' \left[1 - \exp\left(- \frac{A_r U_L F'}{\dot{m} c_p} \right) \right]}$$