VIT
Vellore Institute of Technology

Final Assessment Test – November 2019

Course: MEE2030 - Energy Systems Analysis and Design
Slot: F1+TF1
Class NBR(s): 3909
Max. Marks: 100
Time: Three Hours

KEEPING MOBILE PHONE/SMART WATCH, EVEN IN 'OFF' POSITION, IS EXAM MALPRACTICE

Answer any FIVE Questions
(5 X 20 = 100 Marks)

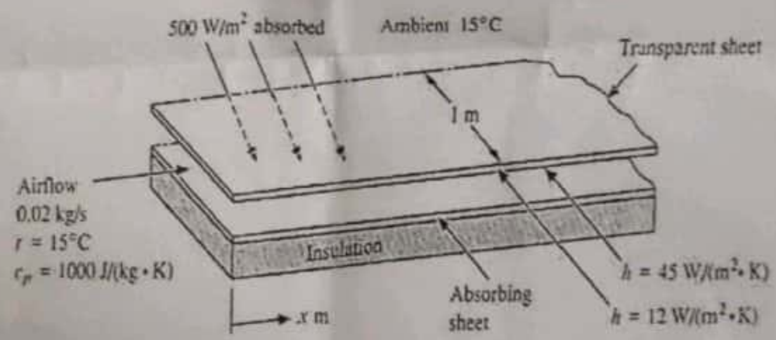
1. a) Explain various steps involved in evaluating and planning an engineering undertaking with a flow diagram. [5]

   b) The temperature T of a small copper sphere cooling in air is measured as a function of time (t) to yield the following data: [15]

t (s)	0.2	0.6	1.0	1.8	2.0	3.0	5.0	6.0	8.0
T (°C)	146.0	129.5	114.8	90.3	85.1	63.0	34.6	25.6	14.1

   An exponential decrease in temperature is expected from lumped mass modelling. Obtain a best fit to represent these data.

2. A solar air heater consists of a flat air duct composed on one side of an absorbing sheet backed by insulation and on the other side by a transparent sheet, as shown in the figure. The absorbing sheet absorbs 500 W/m^2 and delivers all this heat to the air being heated, which loses some to the atmosphere through the transparent sheet. The convection heat-transfer coefficient from the transparent sheet to the ambient air is 12 W/(m^2.K) and from the air being heated to the transparent sheet is 45 W/(m^2.K). The air enters with a temperature that is the same as the ambient 15°C, and the flow rate of air is 0.02 kg/s per meter width. Develop the equation for the temperature of the heated air t as a function of length along the collector x assuming no conduction in the sheet in the direction of flow.

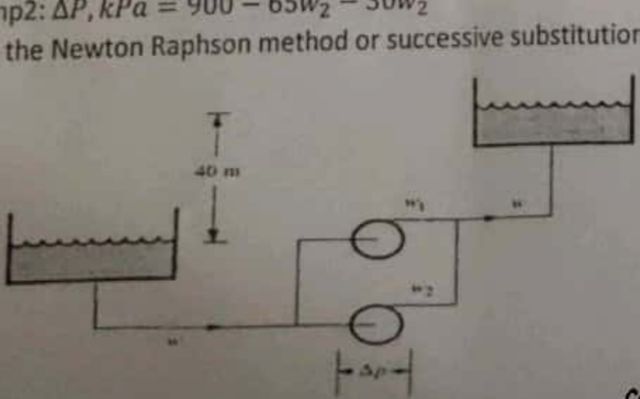


3. A water pumping system consists of two parallel pumps drawing water from a lower reservoir and delivering it to another that is 40 m higher, as shown in the figure. In addition to overcoming the pressure difference due to elevation, the friction in the pipe is 7.2w^2 kPa, where w is the combine flow tare in kg/s. the pressure-flow rate characteristics of the pump are

   Pump1: $\Delta P, kPa = 810 - 25w_1 - 3.75w_1^2$

   Pump2: $\Delta P, kPa = 900 - 65w_2 - 30w_2^2$

   Use the Newton Raphson method or successive substitution method to simulate the system.

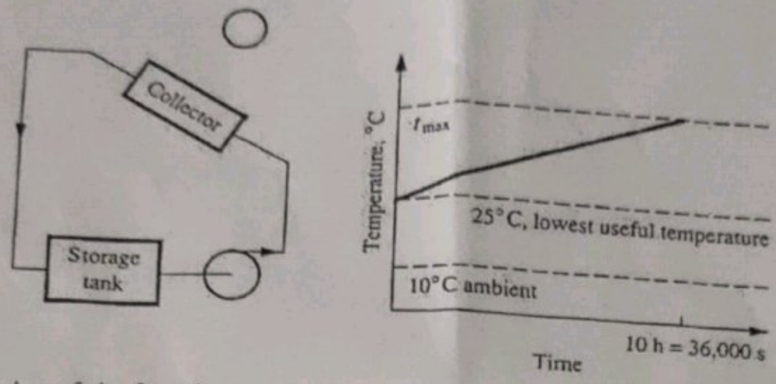


4. A solar collector and storage tank, shown in the figure, is to be optimized to achieve minimum first cost. During the day the temperature of water in the storage vessel is elevated from 25°C (the minimum useful temperature to t_{max}, as shown in the figure. The collector receives 260 W/m² of solar energy, but there is heat loss from the collector to ambient air by convection. The convection coefficient is 2 W/(m²K), and the average temperature difference during the 10-hour day is $(25+t_{max})/2$ minus the ambient temperature of 10°C.

The energy above the minimum useful temperature of 25°C that is to be stored in the vessel during the day is 200,000 kJ. The density of water is 1000 kg/m³, and its specific heat is 4.19 kJ/(kgK). The cost of the solar collector in dollars is 20A, where A is the area in square meters, and the cost of the storage vessel in dollars is 101.5 V, where V is the volume in cubic meters.

a) Using A and V as the variables, set up the objective function and constraint to optimize the first cost. [10]

b) Optimize by the Lagrange multipliers method. [10]



5. a) The minimum value of the function [10]

$$y = \frac{72x_1}{x_2} + \frac{360}{x_1x_3} + x_1x_2 + 2x_3$$

is to be sought using the method of steepest descent. If the starting point is $x_1 = 5$, $x_2 = 6$, $x_3 = 8$ and x_1 is to be changed by 1.0, what is the location of the next point.

b) The minimum value of the function [10]

$$y = 3x_1^2 + x_2^2$$

subject to $x_1x_2 - 8 = 0$

has to be solved by the hemstitching method. Perform one cycle of calculation starting with $x_2 = 1.7$ and $\Delta x_2 = 0.05$.

6. The optimization of a combined gas- and steam turbine plant has resulted in the following linear objective function and three linear constraints. Use the simplex algorithm to determine the optimum value of q_1 and q_2.

Objective function:

$$q = q_1 + q_2$$

Constraints:

$$q_1 + 1.2q_2 \geq 28\text{MW}$$
$$q_1 + 0.4q_2 \geq 19\text{MW}$$
$$q_1 + 1.7q_2 \geq 32\text{MW}$$

7. a) Derive the Clapeyron equation. Use that and the following properties to predict the change in saturation pressure between 50 and 51°C. [15]

Temp °C	v_f m³/kg	v_g m³/kg	h_f kJ/kg	h_g kJ/kg
50	0.0010121	12.05	209.26	2592.2
51	0.0010126	11.5	213.44	2593.9

b) What does the term retrofit mean in the steam-turbine power plant? Considering the complete power plant as a system, discuss any three challenges one could anticipate while performing retrofit. [5]

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