

School of Mechanical & Aerospace Engineering
MA3010 – Thermodynamics & Heat Transfer
AY21S1 – Continual Assessment 2

Instructions:

- Please read the questions carefully before answering them.
- There is no need to print this question sheet. Please write your workings and answers neatly on blank or foolscap paper.
- All workings and answers are to be scanned and uploaded before **11:14:59 am**.

- Hot desert air at 1 atm, 38°C, and 20% relative humidity is cooled and humidified with a water spray to 25°C. If the air flow rate is 2.5 kg dry air/s, determine the rate of water spray.

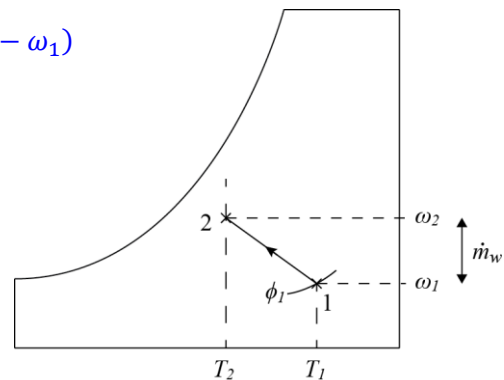
(10 marks)

Obtain ω_1 and ω_2 from psychrometric chart; this is an evaporative process which occurs at constant wet-bulb temperature and intersects with T_2 .

Mass balance for water:

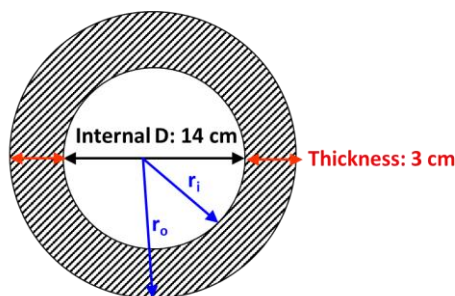
$$\dot{m}_w = \dot{m}_a(\omega_2 - \omega_1)$$

Psychrometric chart:



2. A current of 8 A is passed through a 3 cm thick, 1.5 m long circular pipe with an internal diameter of 14 cm. If the electrical resistance of the pipe is $2\ \Omega$, what is the volumetric heat generation rate ($\dot{e}_q$) for the pipe?

(10 marks)



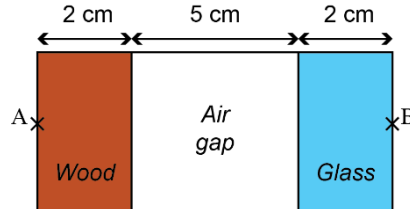
$$\text{Pipe volume} = \pi(r_o^2 - r_i^2)L$$

$$\text{Power generated} = I^2 R$$

$$\dot{e}_{gen} = Power/volume$$

3. A 1 m² by 2 cm thick wooden panel ($k = 0.2 \text{ W/m}\cdot\text{K}$) is used to cover up 1 m² by 2 cm thick glass window ($k = 1.0 \text{ W/m}\cdot\text{K}$), leaving a 5 cm air gap between the panel and the glass. The convection heat transfer coefficient in the air gap is $2 \text{ W/m}^2\cdot\text{K}$. If the temperatures at point A and B are 30°C and 10°C respectively, what is the heat transfer rate through the window?

(15 marks)



$$R_{total} = R_{wood} + R_{air,wood} + R_{air,glass} + R_{glass}$$

$$= \frac{L_{wood}}{K_{wood} A} + \frac{1}{h A} + \frac{1}{h A} + \frac{L_{glass}}{K_{glass} A}$$

$$\dot{Q} = \frac{\Delta T}{R_{total}}$$

4. A steel ball ($k = 43.0 \text{ W/m}\cdot\text{K}$, $\rho = 8000 \text{ kg/m}^3$, $c_p = 0.49 \text{ kJ/kg}\cdot\text{K}$) of radius 6 cm initially at 27°C is placed into an oven of 800°C . The oven is maintained at the constant temperature of 800°C and the convective heat transfer coefficient in the oven is $120 \text{ W/m}^2\cdot\text{K}$. Determine the instantaneous heat transfer at $t = 200 \text{ second}$.

(10 marks)

$$b = \frac{h}{\rho C L_c}$$

$$\frac{T(t) - T_\infty}{T_i - T_\infty} = e^{-bt}$$

$$\text{Instantaneous } Q = hA(T_{t=200s} - T_\infty)$$

5. A cube of length 5 mm ($k = 1.5 \text{ W/m}\cdot\text{K}$) is heated and left to cool in air with a heat transfer coefficient of $15 \text{ W/m}^2\cdot\text{K}$. If 2 surfaces of the cube are insulated, calculate the Biot number.

(10 marks)

$$L_c = \frac{V}{A}$$

$$Bi = \frac{hL_c}{k}$$

6. Moist air at 1 atm, 35°C , and 70% relative humidity is cooled to 20°C . Assuming that the condensate is also removed at 20°C , calculate the heat removal rate when the flow rate of the moist air is 1.2 kg dry air/s.

(15 marks)

Obtain ω_1 , h_1 , ω_2 and h_2 from psychrometric chart; state 2 is at 100% relative humidity and T_2 .

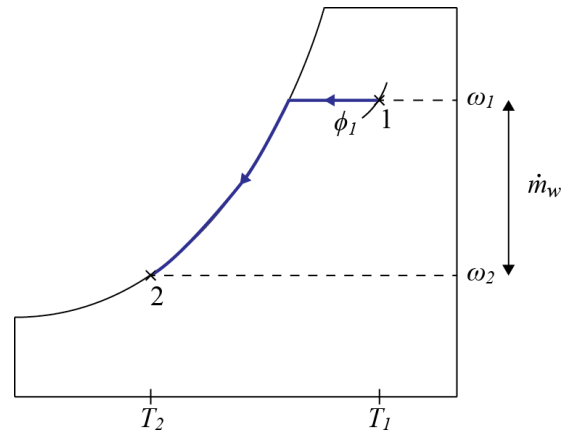
Mass balance (rate of condensate removed):

$$\dot{m}_w = \dot{m}_a(\omega_1 - \omega_2)$$

Energy balance (h_f = saturated liquid water enthalpy at T_2):

$$\dot{m}_a h_1 = \dot{m}_a h_2 + \dot{m}_w h_f + \dot{Q}_{out}$$

$$\dot{Q}_{out} = \dot{m}_a(h_1 - h_2) - \dot{m}_w h_f$$



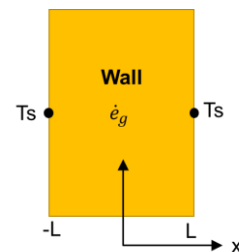
7. Heat is internally generated in a wall ($k = 0.750 \text{ W/m}\cdot\text{K}$) of thickness 20 cm at a rate of $\dot{e}_g = 700 \text{ W/m}^3$. The surface temperature on both sides of the wall are maintained at the same temperature (T_s) with equal convective heat losses on both sides. Assuming 1D heat conduction, sketch the temperature profile within the wall, and determine the value of T_s if the maximum internal temperature is 50°C . Hint: the temperature distribution of the wall along its thickness is $T = -\frac{\dot{e}_g}{2k}x^2 + T_s + \frac{\dot{e}_g}{2k}L^2$, where the origin is at the channel centre.

(15 marks)

Thickness = $2L$

$$T = -\frac{\dot{e}_g}{2k}x^2 + T_s + \frac{\dot{e}_g}{2k}L^2$$

$$T_{max} = T_s + \frac{\dot{e}_g}{2k}L^2 \text{ at } x = 0$$



8. A ski jacket made of multiple layers of synthetic fabric has a total thermal resistance of 0.3 K/W . Assuming inner surface temperature of the jacket is 28°C and the surface area is 1.25 m^2 , determine the temperature at the outer jacket when the outdoor temperature is 0°C and the heat transfer coefficient at the outer surface is $25 \text{ W/m}^2\cdot\text{K}$.

(15 marks)

$$R_{total} = R_{ski \text{ jacket}} + R_{conv, outside}$$

$$\dot{Q} = \frac{\Delta T}{R_{total}}$$

$$\frac{T_0 - T_{\infty,0}}{R_{conv}} = \dot{Q}$$

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