NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

School of Mechanical & Aerospace Engineering
MA3010 – Thermodynamics & Heat Transfer
AY2021 – Continual Assessment 2 (Solution guide)

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 1115 am.

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1. An ideal gas mixture contains $\boldsymbol{m_a}$ kg of gas $\boldsymbol{A}$ and $\boldsymbol{m_b}$ kg of gas $\boldsymbol{B}$. What is the mole fraction $\boldsymbol{y_A}$ of gas $\boldsymbol{A}$ in the mixture? (10 marks)

$$N_A = \frac{m_A}{M_A}, \qquad N_B = \frac{m_B}{M_B}$$

$$y_A = \frac{N_A}{N_A + N_B}$$

2. A tank is filled with atmospheric air at $\boldsymbol{T}$°C, $\boldsymbol{P}$ kPa and $\boldsymbol{\phi}$% relative humidity. If the mass of water vapour in the tank is $\boldsymbol{m_v}$ kg, what is the mass of the dry air $\boldsymbol{m_a}$? (10 marks)

$$\omega = \frac{0.622\phi P_g}{P - \phi P_g}, P_g = P_{sat\ @\ T}$$

$$m_a = \frac{m_v}{\omega}$$

3. Warm moist air at 1 atm, $\boldsymbol{T_1}$°C and $\boldsymbol{\phi_1}$% relative humidity is cooled to $\boldsymbol{T_2}$°C at a rate of $\boldsymbol{\dot{m}_a}$ kg dry air per second. What is the rate of condensate removal $\boldsymbol{\dot{m}_v}$? (10 marks)

obtain from psychrometric chart: ω_1 @ T_1 and ϕ_1

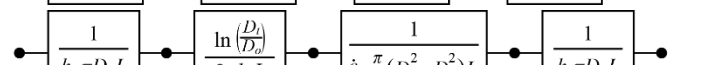
obtain from psychrometric chart: ω_2 @ T_2 and $\phi = 100\%$

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

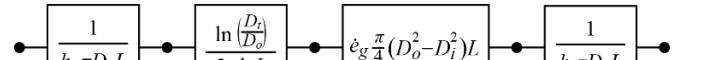
4. Water flows inside a cylindrical titanium pipe ($k = k_p$) of length L in which the internal and external diameters are D_i and D_o, respectively. A large current is conducted through the pipe, causing $\dot{e}g$ heat to be generated in the pipe wall. The pipe is covered by a layer of material ($k = k_r$) and the resultant outer diameter is D_t. The heat transfer coefficients for water in the pipe and air surrounding the pipe are h_i and h_o, respectively. Which of the following diagrams represent the thermal circuit for calculating steady-state heat conduction for the pipe heater from water to air? (10 marks)

a)

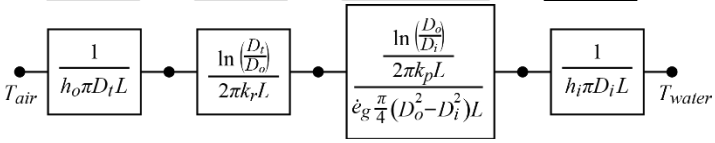
b)

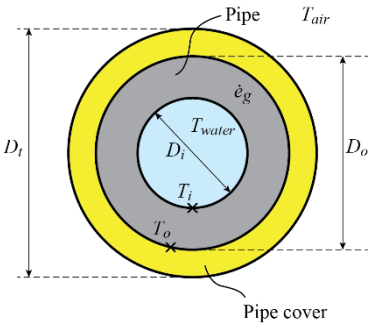


c)



d)





e) None of the options.

No thermal circuit exists for heat generation in material.

5. $\boldsymbol{I}$ A of current is passed through a $\boldsymbol{t}$ cm thick, $\boldsymbol{L}$ m long circular pipe with an internal diameter of $\boldsymbol{d_i}$ cm. If the electrical resistance of the pipe is $\boldsymbol{R}$ Ω, what is the volumetric heat generation rate ($\boldsymbol{\dot{e}_g}$) for the pipe? (10 marks)

$$V = \frac{\pi(d_o^2 - d_i^2)L}{4}, d_o = d_i + 2t$$

$$\dot{E}_g = I^2 R$$

$$\dot{e}_{gen} = \dot{E}_g / V$$

LONG QUESTION (50 marks)

6. A composite cylindrical wall is composed of two materials of conductivity $\boldsymbol{k_A}$ and $\boldsymbol{k_B}$, which are separated by a very thin, electric resistance heater for which the interfacial contact resistances are negligible. Liquid is pumped through the tube at a temperature of $\boldsymbol{T_i}$ and provides a convective heat transfer coefficient of $\boldsymbol{h_i}$ at the inner surface of the composite. The outer surface is exposed to ambient air, which is at $\boldsymbol{T_\infty}$ and provides a convective heat transfer coefficient of $\boldsymbol{h_o}$. Under steady-state conditions, a uniform heat flux $\boldsymbol{\dot{q}_h}$ of 50 W/m^2 is dissipated by the heater which is maintained at a heater temperature of $\boldsymbol{T_h}$.

A) Draw the equivalent thermal circuit and label the temperature points clearly.

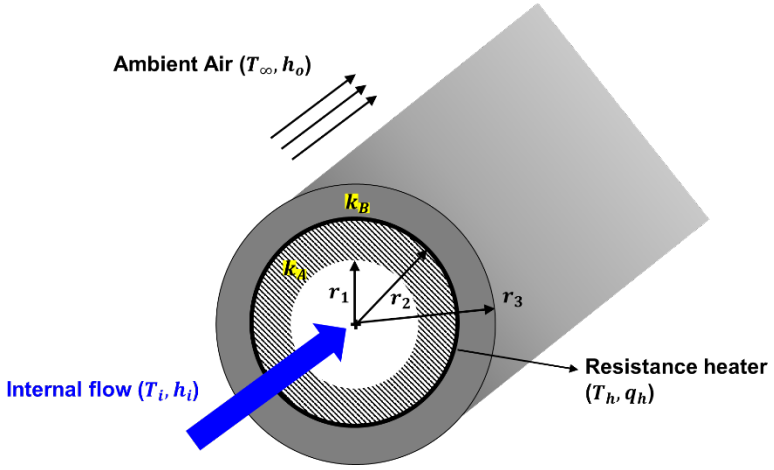
B) Determine the temperature $\boldsymbol{T_i}$ based on the following parameters:

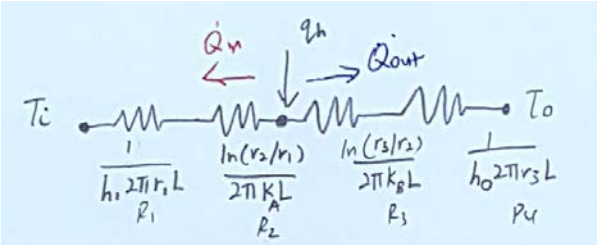
k_A
k_B

r_1
r_2
r_3

h_i
h_o

T_∞
T_h





Considering a 1 m long section (L = 1),

$$R_1 = \frac{1}{h_i \times 2\pi r_1 L}$$

$$R_2 = \frac{\ln(r_2/r_1)}{2\pi k_A L}$$

$$R_3 = \frac{\ln(r_3/r_2)}{2\pi k_B L}$$

$$R_4 = \frac{1}{h_o \times 2\pi r_3 L}$$

Energy balance:

$$\dot{Q}_H = \dot{Q}_{in} + \dot{Q}_{out}$$

$$\dot{q}_H(2\pi r_2 L) = \frac{T_H - T_i}{R_1 + R_2} + \frac{T_H - T_\infty}{R_3 + R_4}$$