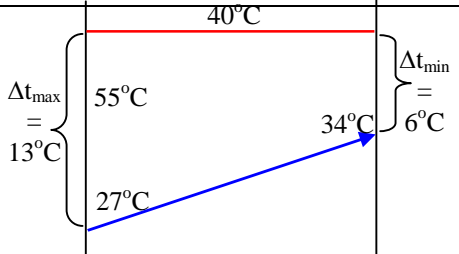


HEAT TRANSFER SOLUTION SEMESTER 2 ACADEMIC YEAR: 2025-2026
Course ID: HEAT230332 Examination date: April 17, 2026 FIE

Question	Solution	Point	Total
1			3.0
	The inner radius of insulation (is the outer of tube): $r = d/2 = 5/2 = 2.5 \text{ cm}$ The critical radius of insulation for asbestos: $r_{cr} = \lambda/h = 0.17/5 = 0.034 \text{ m} = 3.4 \text{ cm}$	0.5	
	The heat loss when covered with the critical radius of insulation: $q_l = \frac{2\pi(t_{w1} - t_{f2})}{\frac{1}{\lambda} \ln \frac{r_{cn}}{r} + \frac{1}{\alpha r_{cn}}} = \frac{2\pi(200 - 25)}{0.17 \ln \frac{3.4}{2.5} + \frac{1}{5 \times 0.34}} = 142.9 \text{ W/m}$	0.5	
	The heat loss when without insulation: $q_l = \alpha(\pi d)(t_i - t_o) = 5 \times \pi \times 0.05(200 - 25) = 137.4 \text{ W/m}$	0.5	
	The insulation thickness by $3.4 - 2.5 = 0.9 \text{ cm}$ will increase the heat loss $(142.9 - 137.4)/137.4 = 4\%$ (or 5.5 W/m)	0.5	
	When replaced asbestos by fiberglass having the thermal conductivity of $0.04 \text{ W/m} \cdot ^\circ\text{C}$, the critical radius of insulation for fiberglass: $r_{cr2} = \lambda_2/h = 0.04/5 = 0.008 \text{ m} = 0.8 \text{ cm}$.	0.5	
	The critical radius of insulation for fiberglass is less than the outer radius of tube, so fiberglass is used to reduce the heat loss.	0.5	
2			3.0
	Properties of air at $t_f = 35^\circ\text{C}$, we have: $\lambda_f = 0.0272 \text{ W/m} \cdot \text{K}$; $\nu_f = 16.35 \times 10^{-6}$; $\text{Pr}_f = 0.7$ And $t_w = 90^\circ\text{C}$, we have: $\text{Pr}_w = 0.69$ We have: $\text{Re}_f = \frac{\omega d}{\nu_f}$; with $\omega = \omega_{\max}$ for through the narrowest gap	0.5	
	With $\omega_{\max} = \frac{s_1}{s_1 - d} \omega = \frac{70}{70 - 34} 4.5 = 8.8 \text{ m/s}$	0.5	
	$\text{Re}_f = \frac{\omega_{\max} d}{\nu_f} = \frac{8.8 \times 34 \times 10^{-3}}{16.35 \times 10^{-6}} = 18196 > 2200 \gg \text{turbulent model}$	0.5	
	For in-line arrangement: $\text{Nu}_f = 0.22 \text{Re}_f^{0.65} \text{Pr}_f^{0.36} \left(\frac{\text{Pr}_f}{\text{Pr}_w} \right)^{0.25} \varepsilon_\psi \varepsilon_i = 0.22 \times 18196^{0.65} \times 0.7^{0.36} \left(\frac{0.7}{0.69} \right)^{0.25} \times 1 \times 1 = 114.1$	0.5	
a)	$\alpha = \frac{\text{Nu}_f \cdot \lambda_f}{d} = \frac{114.1 \times 2.72 \times 10^{-2}}{34 \times 10^{-3}} = 91.3 \text{ [W/m}^2 \cdot \text{K]}$	0.25	
	$\bar{\alpha} = \frac{(0.6 + 0.9 + (n - 2))\alpha}{n} = \frac{(0.6 + 0.9 + 5)91.3}{7} = 84.7 \text{ [W/m}^2 \cdot \text{K]}$	0.25	
b)	The heat transfer rate of the heat exchanger: $Q = q \cdot F = N\pi \cdot d \cdot h \cdot \alpha(t_w - t_f) = 49\pi \times 0.034 \times 1.7 \times 84.7(90 - 35) = 41450 \text{ W} = 41.4 \text{ kW}$	0.5	
3			3.0
	We have: $\frac{F_1}{F_2} = \frac{D_1}{D_2} = \frac{1}{2}$ and $F_1 = \pi D_1 \cdot L = 3.14 \times 0.3 \times 1.6 = 1.51 \text{ m}^2$	0.5	
a)	The radiant heat transfer rate between the two tubes:	1	

	$Q_{12} = \frac{F_1 C_0 \left[\left(\frac{T_1}{100} \right)^4 - \left(\frac{T_2}{100} \right)^4 \right]}{\frac{1}{\varepsilon_1} + \frac{F_1}{F_2} \left(\frac{1}{\varepsilon_2} - 1 \right)}$ $= \frac{1.51 \times 5.67 \left[\left(\frac{950}{100} \right)^4 - \left(\frac{450}{100} \right)^4 \right]}{\frac{1}{0.96} + \frac{1}{2} \left(\frac{1}{0.76} - 1 \right)} = 55105 \text{ W} = 55.1 \text{ W}$		
b)	The radiant heat transfer rate with a shield: $Q_{12c} = Q_{12}/2 = 55105/2 = 27553 \text{ W}$	0.5	
	$Q_{12c} = \frac{F_1 C_0 \left[\left(\frac{T_1}{100} \right)^4 - \left(\frac{T_2}{100} \right)^4 \right]}{\frac{1}{\varepsilon_1} + \frac{F_1}{F_2} \left(\frac{1}{\varepsilon_2} - 1 \right) + \frac{F_1}{F_c} \left(\frac{2}{\varepsilon_c} - 1 \right)} = \frac{1.51 \times 5.67 \left[\left(\frac{950}{100} \right)^4 - \left(\frac{450}{100} \right)^4 \right]}{\frac{1}{0.96} + \frac{1}{2} \left(\frac{1}{0.76} - 1 \right) + \frac{3}{4} \left(\frac{2}{\varepsilon_c} - 1 \right)} = 27553 \text{ W}$	0.5	
	$\Rightarrow \varepsilon_c = 0.77$	0.5	
4			3.0
	The heat of vaporization of water at 40°C is $h_{fg} = 2406 \text{ kJ/kg}$ The specific heat of cold water at the average temperature of $(27+34)/2 = 30.5 \text{ °C}$ is $C_p = 4174 \text{ J/kg} \cdot \text{°C} = 4.174 \text{ kJ/kg} \cdot \text{°C}$	0.5	
	We have: $\Delta t_{\max} = 13 \text{ °C}$ $\Delta t_{\min} = 6 \text{ °C}$ So: $\Delta t_{lm} = \frac{\Delta t_{\max} - \Delta t_{\min}}{\ln \frac{\Delta t_{\max}}{\Delta t_{\min}}} = \frac{13 - 6}{\ln \frac{13}{6}} = 9.1 \text{ °C}$ 	1	
	Then the heat transfer rate in the condenser is determined from: $Q = m_s \times h_{fg} = 0.5 \times 2406 = 1203 \text{ kW}$	0.5	
a)	The surface area of the tubes: $A = \frac{Q}{k \Delta t_{lm}} = \frac{1203 \times 10^3}{2200 \times 9.1} = 60.4 \text{ m}^2$	0.5	
b)	The mass flow rate of the cooling water needed: $m_{cw} = \frac{Q}{C_p (t_{wo} - t_{wi})} = \frac{1203}{4.174(34 - 27)} = 41.2 \text{ °C}$	0.5	

Chú ý: - Theo tình hình thực tế, đa số sinh viên chỉ làm khoảng 2/3 bài thi nên Tổng điểm: 12 điểm. Nếu sinh viên > 10 điểm sẽ được 10 điểm (khả năng ít đạt được).
- Không thể số hay không ghi công thức: - 0,25 điểm
- Sai đơn vị: - 0,25 điểm.