Name:

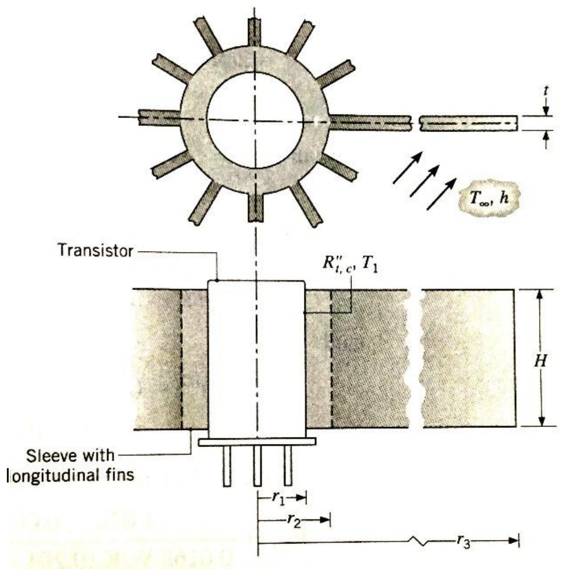
Roll No.:

ME341A: Heat and Mass Transfer

Instructor: Prof. Sameer Khandekar

Time: 120 minutes **Marks: 80**

MID SEMESTER EXAMINATION (22.02.2018)



Q1 (24 marks): A cylindrical shaped small transistor dissipating 2.2 W is to be cooled.

An engineer suggests inserting the transistor in an aluminum sleeve having 12 integrally machined longitudinal fins on its outer surface, as shown in the figure alongside.

The transistor radius and height are r_1 = 2 mm, and H = 6 mm, respectively, while the fins are of length $L = r_3 - r_2$ = 10 mm, and uniform thickness t = 0.7 mm. The thickness of the sleeve base $r_2 - r_1$ = 1 mm. The contact resistance of the sleeve-transistor interface $R_{th,\ t\text{-}c} = 10^{-3}$ m^{2}K/W. Air at T_{amb} = 20°C flows over the fin surface, providing an approximately uniform convection coefficient of h = 25 W/m^{2}K.

(i) Write all assumptions which you plan to invoke to solve this problem (03 marks).

(ii) Draw the equivalent thermal resistance network from the transistor case ($r = r_1$) to the ambient air. Clearly label each resistor. (03 marks)

(iii) Evaluate each of the resistances in the foregoing circuit. (12 marks)

(iv) If the temperature of the transistor case is T_1 = 80°C, will the suggested fin design function satisfactorily; Why/Why not? (03 marks)

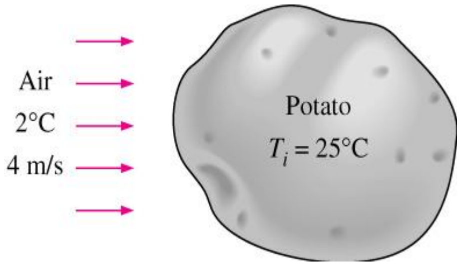
(v) Discuss, giving quantitative arguments, what measures can be specifically taken to improve the design if T_1 cannot exceed 80°C. Justify your answer properly. (03 marks)

Temperature distribution and heat loss for fins of uniform cross section

Case	Tip Condition $(x = L)$	Temperature Distribution θ/θ_b	Fin Heat Transfer Rate q_f
A	Convection heat transfer: $h\theta(L) = -kd\theta/dx\vert_{x=L}$	$\dfrac{\cosh m(L-x) + (h/mk)\sinh m(L-x)}{\cosh mL + (h/mk)\sinh mL}$	$M\dfrac{\sinh mL + (h/mk)\cosh mL}{\cosh mL + (h/mk)\sinh mL}$
B	Adiabatic $d\theta/dx\vert_{x=L} = 0$	$\dfrac{\cosh m(L-x)}{\cosh mL}$	$M \tanh mL$
C	Prescribed temperature: $\theta(L) = \theta_L$	$\dfrac{(\theta_L/\theta_b)\sinh mx + \sinh m(L-x)}{\sinh mL}$	$M\dfrac{(\cosh mL - \theta_L/\theta_b)}{\sinh mL}$
D	Infinite fin $(L \rightarrow \infty)$: $\theta(L) = 0$	e^{-mx}	M

$\theta \equiv T - T_\infty$ $\quad m^2 \equiv hP/kA_c$

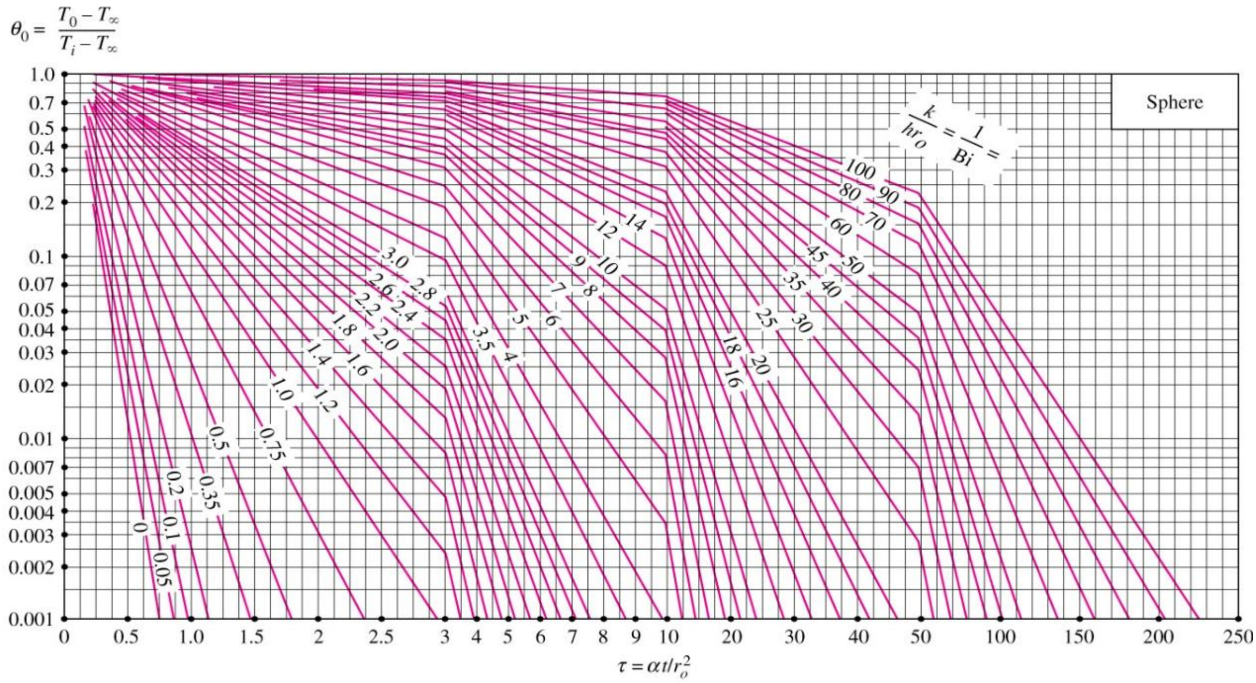
$\theta_b = \theta(0) = T_b - T_\infty$ $\quad M \equiv \sqrt{hPkA_c}\,\theta_b$



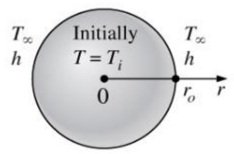
Q2 (16 marks): There are many potato cold storages on G. T. Road, while going to Delhi from Kanpur. In these storages, potatoes that are initially at uniform temperature of 25°C, having average diameter of 6 cm are to be cooled by refrigerated air at 2°C flowing at a velocity of 4 m/s. The average Nusselt Number between the potatoes and the air is experimentally determined to follow the relation Nu = $0.128 \cdot Re^{0.618} \cdot Pr^{0.333}$. (i) Determine how long it will take for the center temperature of the potatoes to drop to 6°C. (ii) Also determine if any part of the potatoes will experience chilling injury during the process.

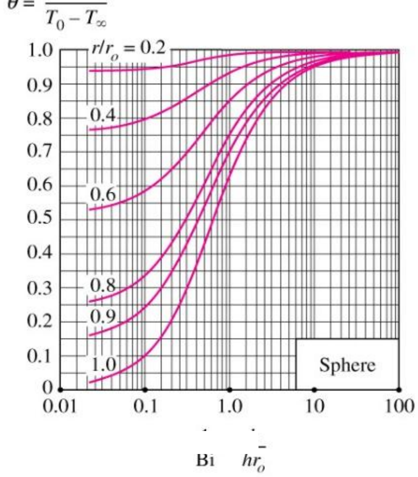
For potatoes, k = 0.5 W/mK and $\alpha = 0.13 \times 10^{-6}$ m^2/s. For air at the average film temperature, use:

ρ (kg/m^3)	*Cp* (kJ/kg.K)	*μ* (Ns/m^2)	*k* (W/mK)	*v* (m^2/s)
1.1614	1.007	184.6×10^{-7}	0.0263	15.89×10^{-6}

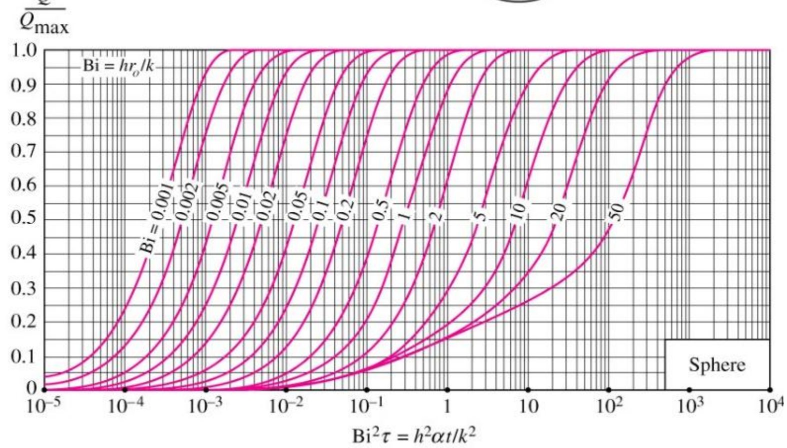


(*a*) Midpoint temperature (from M. P. Heisler, "Temperature Charts for Induction and Constant Temperature Heating," *Trans. ASME 69*, 1947, pp. 227–36. Reprinted by permission of ASME International.)





(*b*) Temperature distribution (from M. P. Heisler, "Temperature Charts for Induction and Constant Temperature Heating," *Trans. ASME 69*, 1947,



(*c*) Heat transfer (from H. Gröber et al.)

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Q3: Write True or False (20 Marks: 1 mark each with 100% negative marking)

1. Longer the fins better is their thermal efficiency.	
2. In 2-D boundary layer flow, pressure varies in normal direction of the wall.	
3. For ideal parallel flow over a flat plate, pressure varies in the flow direction.	
4. If Pr >> 1, velocity BL develops much faster than thermal BL.	
5. Non-dimensional concentration gradient at a wall is the Schmidt Number.	
6. At the leading edge of a flat plate, all specie transfer coefficients are zero.	
7. If the kinematic viscosity of the fluid increases, the BL over a plate thickens.	
8. Even if the pipe wall and fluid are at same temperature, a thermal BL develops.	
9. Convective heat transfer coefficient is fluid property.	
10. Lumped capacity model is applicable for systems with large temperature gradient.	
11. Liquid metals have typically very low Prandtl Number.	
12. For unity Le, velocity and concentration boundary layers are comparable.	
13. By definition, a control volume isolated for analysis must have physical boundaries.	
14. High thermal conductivity of diamond is attributed to its highly regular lattice structure.	
15. One dimensional heat transfer through a cylinder with constant thermal conductivity leads to a linear temperature profile inside it.	
16. A potato is a good thermal storage device because its C_p is low.	
17. 500 W of heat passes through a temperature drop of 50 K. The thermal resistance is 0.1 W/K.	
18. Larger the material thermal diffusivity, greater is its heat absorbing capacity.	
19. At room temperature, the thermal conductivity of glass fiber insulation is more than that of air.	
20. For electrical analogy of heat transfer, the 'EMF' corresponds to the applicable temperature difference.	

Q4: Define/ Draw/Write briefly/ Explain (20 marks: 02 marks each)

Lewis Number	Sherwood number
Ficks law of diffusion	Total derivative of temperature
Laplace equation	Error function
Boundary layer assumptions	Difference between Nu and Bi
$\mu(T)$ for liquids and gases	Fin efficiency