ME 109 Heat Transfer
Midterm Exam

September 30, 2015
10:10 - 11:00 am

Name: . . . .

SID #: . . . .

Discussion: Tu / Th

Comments

Write solutions on this exam booklet.

Notes: Permitted 2 pages (each 8.5" x 11", both sides).

Calculator permitted.

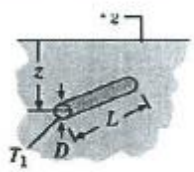
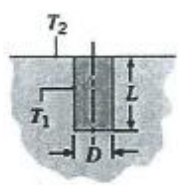
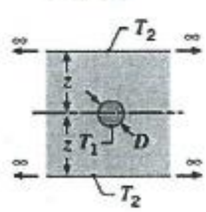
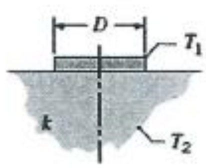
3 questions, equal weight.

Reasonable approximations are fine (no penalty for up to 10% error).

Show your work.

Properties (approximate)	k [W/m-K]	ρ [kg/m^3]	c [J/kg-K]
Stainless Steel	15	8,000	500
Aluminium	200	3,000	1,000
Concrete	1.0	2,000	1,000

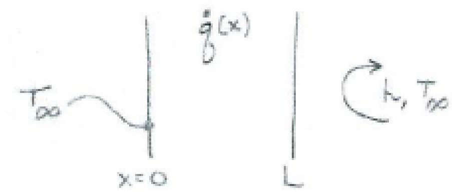
Shape factors $[q = Sk(T_1 - T_2)]$

System	Schematic	Restrictions	Shape Factor
Horizontal isothermal cylinder of length L buried in a semi-infinite medium		$L \gg D$	$\frac{2\pi L}{\cosh^{-1}(2z/D)}$
		$L \gg D$, $z > 3D/2$	$\frac{2\pi L}{\ln(4z/D)}$
Vertical cylinder in a semi-infinite medium		$L \gg D$	$\frac{2\pi L}{\ln(4L/D)}$
Horizontal circular cylinder of length L midway between parallel planes of equal length and infinite width		$z \gg D/2$, $L \gg z$	$\frac{2\pi L}{\ln(8z/\pi D)}$
Disk of diameter D and temperature T_1 on a semi-infinite medium of thermal conductivity k and temperature T_2		None	$2D$

Problem 1. (20 pts)

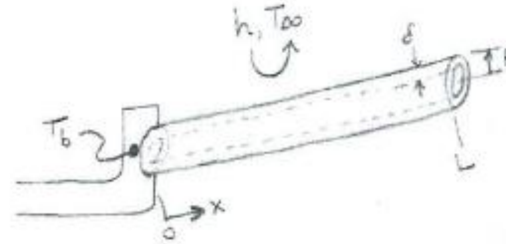
A slab of thickness L experiences non-uniform heat generation $\dot{q}(x) = \gamma \sin(\pi x / L)$, where γ is a constant. The left face is fixed at T_∞, and the right face convects to the same T_∞ through a convection coefficient h.

Obtain an expression for the steady-state temperature profile, $T(x)$.



(Note: This problem has nothing to do with Fourier Series.)

Problem 2. (20 pts)



A frying pan handle is made of thin-walled stainless steel tube (outer radius $R = 20$ mm, wall thickness δ=1.0 mm, total length L=250 mm). The external surface of the tube convects to the surrounding air ($T_\infty = 20$ °C, h=10 W/m^{2}K). Neglect all heat transfer in the interior of the tube. The base of the handle is at T_b=220 °C.

(a) Find the temperature at the location x=100 mm. Give a numerical value, in [° C].

(b) We want to modify the design to reduce the heat loss q through the handle. Consider three options:

i) Reduce L by 10%, while holding R and δ constant; or

ii) Reduce R by 10%, while holding L and δ constant; or

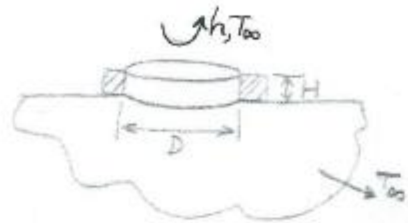
iii) Reduce δ by 10%, while holding L and R constant.

Which option or options will best reduce q? You must justify your answer. (It is *not* necessary to make any additional numerical calculations.)

Hint: The algebra is a bit easier if you notice that $\delta << R$

Problem 3. (20 pts)

A hot aluminum disk (diameter D, height H, with $H<D$) is initially at a uniform temperature of T_i. At time $t=0$, the disk is placed on a concrete floor. We can approximate the floor as semi-infinite medium, with temperature T_∞ far away from the disk. In addition, the top of the disk experiences convection (known h, and same T_∞), and the sides of the disk are well-insulated.



We suspect the transient cooling of this disk may be analyzed using a lumped-capacitance approximation.

Obtain an equation which may be used to determine whether the lumped-capacitance treatment is appropriate. You must be clear about your criteria for lumped vs. not-lumped.