CHG 3314
Midterm Exam

May 26, 2003

Duration: 90 min
Open book exam
Do any 2 problems; the exam will be marked out of 20
State clearly all assumptions

Good Luck!!!

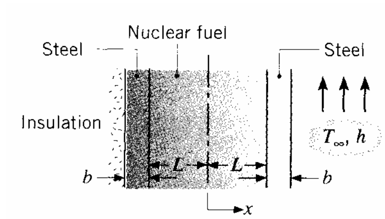
(10) **Problem 1**

A thin-wall spherical stainless steel vessel has a diameter of 50 cm and contains reactants, which maintain the vessel surface at 90°C. The tank is located in a laboratory where the air is maintained at 20°C and the steady state heat losses from the vessel are 1000 W. What is the outside heat transfer coefficient (h_o)?

To decrease heat losses and to prevent workers from being burnt by accidental contact with the vessel, it is proposed to insulate the vessel. The chosen insulation has thermal conductivity of 0.25 W/m K. How thick should the layer of insulation be if the threshold for skin burn on a nonmetallic surface is 50°C? Also calculate the rate of heat loss from the insulated vessel. The outside heat transfer coefficient between the spherical vessel and the air depends on the diameter of the vessel, $h_o = BD^{-1}$, where B is a constant and D is the outer diameter (in meters) of the insulated vessel.

(10) **Problem 2**

A nuclear fuel element of thickness $2L$ is covered with steel cladding of thickness b. Heat generated within the nuclear fuel as a result of uniform volumetric rate of heat generation Q_o''' (W/m^3), is removed by a fluid at T_∞, which adjoins one surface and is characterized by a convection coefficient h. The other surface is perfectly insulated, and the fuel and steel have thermal conductivities of k_f and k_s, respectively.

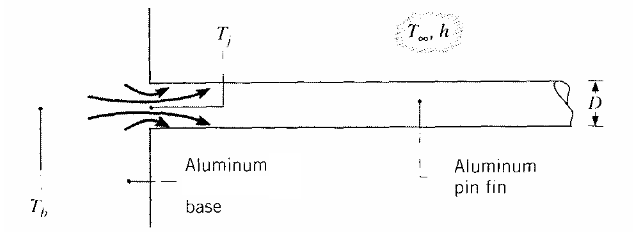


i) Obtain an equation for the temperature distribution $T(x)$ in the nuclear fuel. Express your results in terms of Q_o''', L, b, k_f, k_s, T_∞, h.

ii) Sketch the temperature distribution $T(x)$ for the entire system.

(10) **Problem 3**

In derivation of the equation governing temperature distribution along a pin fin we assumed that whenever fins are attached to the base material, the temperature of the fin at the base (at $x = 0$) is equal to the temperature of the base material to which the fin is attached. What in fact happens is that, if the temperature of the base material exceeds the fluid temperature, attachment of a fin depresses the junction temperature T_j below the original temperature of the base, and heat flow from the base material to the fin is two-dimensional.



Consider conditions for which a 5 cm long aluminum pin fin of diameter D = 4 mm is attached to an aluminum base (k = 240 W/m K), whose temperature far from the junction is maintained at T_b = 100°C. Fin convection conditions correspond to h = 40 W/m^2 K and T_∞ = 25°C.

i) Assuming that $T_j = T_b$, calculate the rate of heat dissipation by the fin.
ii) Allowing for the two-dimensional heat flow between the base and the fin calculate the actual T_j and hence recalculate the rate of heat dissipation by the fin.

Appendix

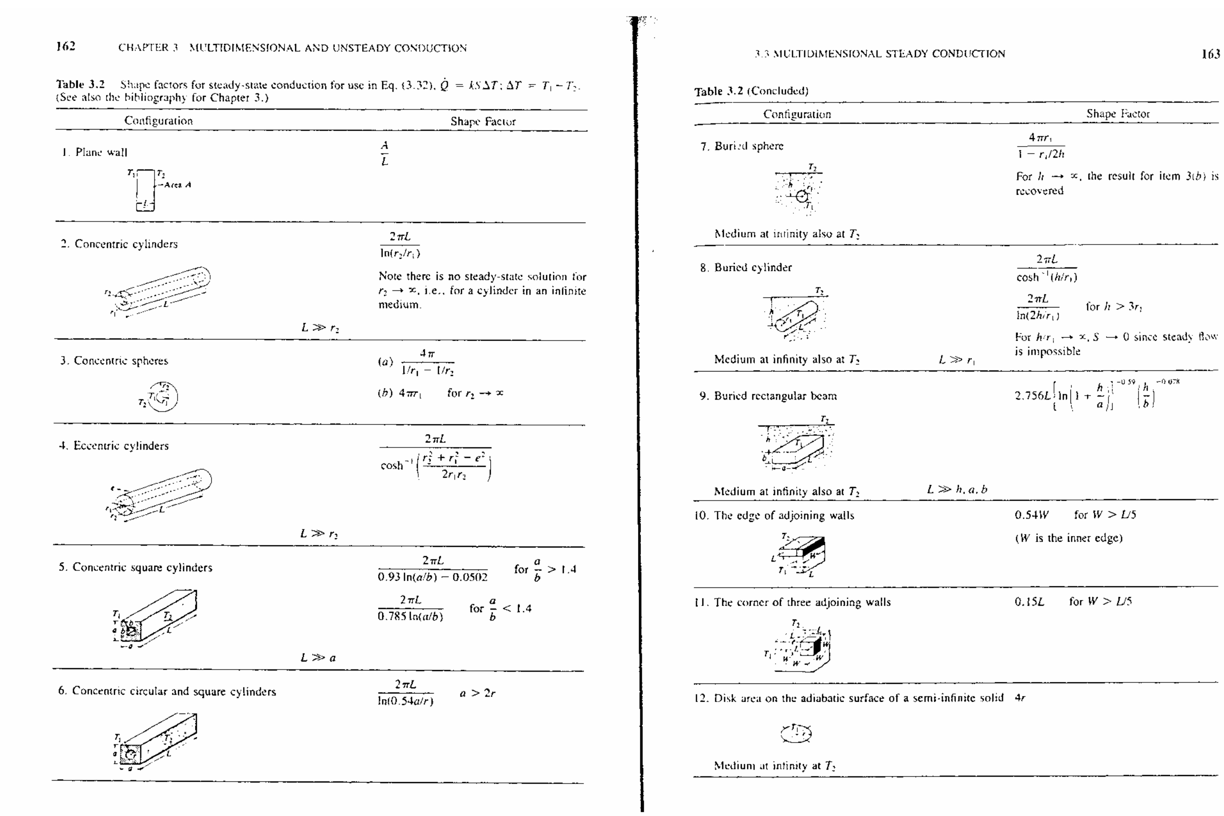


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Table 3.2 Shape factors for steady-state conduction for use in Eq. (3.32), $\dot{Q} = kS\Delta T$; $\Delta T = T_1 - T_2$. (See also the bibliography for Chapter 3.)

Configuration		Shape Factor
1. Plane wall		$\frac{A}{L}$
2. Concentric cylinders	$L \gg r_2$	$\frac{2\pi L}{\ln(r_2/r_1)}$ Note there is no steady-state solution for $r_2 \to \infty$, i.e., for a cylinder in an infinite medium.
3. Concentric spheres		(a) $\frac{4\pi}{1/r_1 - 1/r_2}$ (b) $4\pi r_1$ for $r_2 \to \infty$
4. Eccentric cylinders	$L \gg r_2$	$\frac{2\pi L}{\cosh^{-1}\left(\frac{r_2^2 + r_1^2 - e^2}{2r_1 r_2}\right)}$
5. Concentric square cylinders	$L \gg a$	$\frac{2\pi L}{0.93\ln(a/b) - 0.0502}$ for $\frac{a}{b} > 1.4$; $\frac{2\pi L}{0.785\ln(a/b)}$ for $\frac{a}{b} < 1.4$
6. Concentric circular and square cylinders		$\frac{2\pi L}{\ln(0.54a/r)}$ $a > 2r$

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Table 3.2 (Concluded)

Configuration		Shape Factor
7. Buried sphere. Medium at infinity also at T_2		$\frac{4\pi r_1}{1 - r_1/2h}$ For $h \to \infty$, the result for item 3(b) is recovered
8. Buried cylinder. Medium at infinity also at T_2	$L \gg r_1$	$\frac{2\pi L}{\cosh^{-1}(h/r_1)}$; $\frac{2\pi L}{\ln(2h/r_1)}$ for $h > 3r_1$. For $h/r_1 \to \infty$, $S \to 0$ since steady flow is impossible
9. Buried rectangular beam. Medium at infinity also at T_2	$L \gg h, a, b$	$2.756L\left[\ln\left(1 + \frac{h}{a}\right)\right]^{-0.59}\left(\frac{h}{b}\right)^{-0.078}$
10. The edge of adjoining walls		$0.54W$ for $W > L/5$ (W is the inner edge)
11. The corner of three adjoining walls		$0.15L$ for $W > L/5$
12. Disk area on the adiabatic surface of a semi-infinite solid. Medium at infinity at T_2		$4r$