

Time spent on problems:

Problem 1:

Problem 2:

Problem 3:

Problem 4:

Problem 5:

Problem 6:

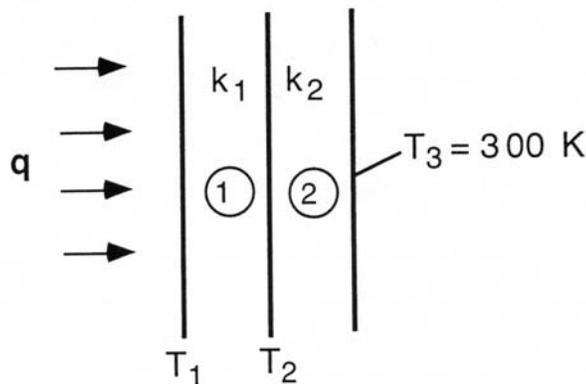
Problem 7:

16.050 Thermal Energy

Problem Set #8 – Fall 2002

Do all problems. Please use a separate sheet of paper for each problem.

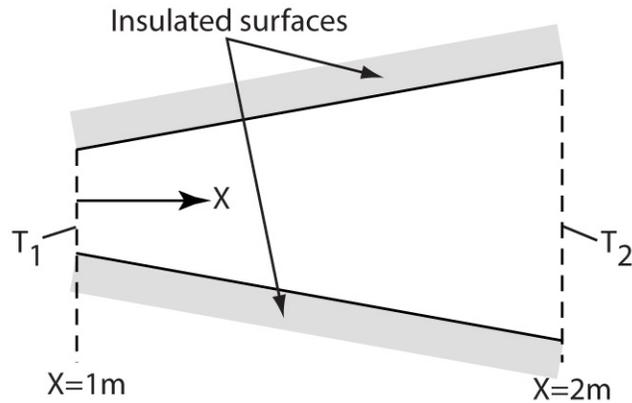
1. Determine the adiabatic flame temperature when liquid octane (C_8H_{18}) at $25^\circ C$ is burned with 300% theoretical air at $25^\circ C$ in a steady flow process at 1 bar. Neglect dissociation. Use the bottom table on p. 17 of the supplemental handout to account for variation of c_p with temperature. (i.e. use $\Delta \bar{h} = \int_{T=25C}^{T_{ad}} \bar{c}_p(\tau) d\tau$)
2. A composite wall is made of two plane slabs of different conductivity. The wall is shown in the figure below. Both slabs are 0.1 m thick. Substance 1 has a thermal conductivity of 100 W/mK and substance 2 has a thermal conductivity of 10 W/mK . The heat flux at the left hand side of slab 1 is given as 10^4 W/m^2 . The temperature T_3 at the right hand side of slab 2 is given as 300 K . All conditions occur in steady-state.



Composite Wall, $L_1 = L_2 = 0.1 \text{ m}$, $q = 10^4 \text{ W/m}^2$

- (a) What is the temperature, T_1 ?
 - (b) What is the temperature T_2 ?
3. Steady-state heat transfer occurs in a conical section. The cone has a circular cross section. The small end has a radius of 0.1 m and the large end a radius of 0.2 m. The length of the conical section is 1 meter. The thermal conductivity is constant and equal to k .

The temperature of the small end is T_1 and that of the large end is T_2 , which is lower than T_1 . The sides of the cone are insulated, so that there is no heat transfer out of the sides of the conical section.



If the heat transfer can be considered to be one-dimensional:

- (a) Derive the **simplified** equation for the overall rate of heat transfer (the total rate over the cross section) in the conical section.
 - (b) Derive the equation for the heat flux (rate of heat transfer per unit area) in the conical section.
 - (c) Derive the equation for the temperature distribution as a function of x .
 - (d) What is the temperature variation (as a function of x)?
 - (e) What is the overall rate of heat transfer (as a function of x)?
 - (f) What is the heat flux variation (as a function of x)?
4. Incropera and DeWitt, Fundamentals of Heat and Mass Transfer, 4th Ed. Problem 3.23, pp. 138.
 5. Incropera and DeWitt, Problem 3.104, pp. 153.
 6. The MIT micro-engine, made out of silicon using micro-fabrication technology, consists of a compressor disk and a turbine disk in a back-to-back arrangement as shown below. In order to prevent the rotor from melting, it must be kept below a temperature of $T = 1000\text{ K}$. This can be achieved by extracting 25 W of heat. A proposed cooling scheme is to use the compressor rotor blades as heat fins to cool the rotor disk from the compressor side. A heat transfer analysis was conducted and the heat transfer per compressor blade is given by

$$\dot{Q} = \sqrt{APhk} \tanh\left(\sqrt{\frac{Ph}{Ak}}L\right) \cdot (T - T_\infty) \quad [W/\text{blade}].$$

The compressor blade cross-sectional area A is $3\text{e-}7\text{ m}^2$, the blade perimeter P is 6 mm and the blade span L is 400 mm . The average gas path temperature in the compressor T_∞ is 600 K . Silicon has a thermal conductivity k of 60 W/mK . You can assume an air density of 3.5 kg/m^3 and a specific heat of $c_p = 1\text{ KJ/kgK}$. The average velocity through the compressor is 250 m/s and the average skin friction coefficient c_f is 0.008 .

How many compressor blades do you need to make sure that the rotor does not melt?