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| 1. Using the values of density for water in Saturated Water Table (Table A.3 on page 725), calculate the volumetric thermal expansion coefficient at 300 K from its definition and compare to the tabulated value in the table. |  |

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| 1. Consider a large vertical plate with a uniform surface temperature of 130◦C suspended in quiescent   (not moving) air at 25◦C and atmospheric pressure.   1. (a)  At what location on the plate measured from the lower edge will the boundary layer become turbulent? 2. (b)  Determine the average heat transfer coefficient. 3. (c)  Determine the average heat flux leaving the plate. |  |

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| 3. The 4 m by 4 m horizontal roof of an uninsulated aluminum melting furnace is comprised of a 0.08 m thick fired clay brick covered by a 5 mm thick steel (AISI 1010) plate. The refractory surface exposed to the furnace gases is maintained at 1700 K during operation, while the outer surface of the steel is exposed to the air and walls of a larger room at 25◦C. The emissivity of the steel is ε = 0.3.   1. (a)  What is the rate of heat loss from the roof? 2. (b)  If a 20 mm thick layer of alumina-silica insulation (k = 0.125 W/m-K) is placed between the fired clay brick and the steel, what is the new rate of heat loss from the roof? What is the temperature at the inner surface of the insulation? 3. (c)  One of the process engineers claims that the temperature at the inner surface of the insulation found in part (b) is too high for safe, long-term operation. What thickness of fired clay brick would reduce this temperature to 1350 K? |  |

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| 4. A building window pane that is 1.2 m high and 0.8 m wide is separated from the ambient air by a storm window of the same height and width. The air space between the two windows is 0.06 m thick. If the building and storm window are at 20 and −10◦C, respectively, what is the rate of heat loss by free convection across the air space? |  |

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| 5. Calculate the critical heat flux on a large horizontal surface for the following fluids at 1 atm: mercury, methanol, and refrigerant R-134a. Compare these results to the critical heat flux for water at 1 atm. |  |

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| 6. Advances in very large scale integration (VLSI) of electronic devices on a chip are often restricted by the ability to cool the chip. For mainframe computers, an array of several hundred chips, each of area 25 mm2, may be mounted on a ceramic substrate. A method for cooling the array is by immersion in a low boiling point fluid such as refrigerant R-134a. At 1 atm and 247 K, properties of the saturated liquid are μ = 1.46×10−4 N-s/m2, cp = 1551 J/kg-K, and Pr = 3.2. Assuming values of Cs,f = 0.004 and n = 1.7, estimate the power dissipated by a single chip if it is operating at 50% of the critical heat flux. What is the corresponding value of the chip surface temperature? |  |