MCL142: Major Test
Sem 2, 2015-2016

Duration: 2 hrs. 15 min. **Full Marks: 52**

Instructions

Answer all parts of a question at the same place. Mention question number with part numbers such as 2(b) in your solution. Write legibly without too many strikethroughs. Penalty through negative marking will be imposed, if you fail to do so.

1. Consider two **long**, slender rods of the same diameter but different materials. One end of each rod is attached to a base surface maintained at 100°C, while the surfaces of the rods are exposed to ambient air at 20°C. By traversing the length of each rod with a thermocouple, it was observed that the temperatures of the rods were equal at the positions $x_a = 0.15\,\text{m}$ and $x_b = 0.075\,\text{m}$, where x is measured from the base surface. If the thermal conductivity of the rod A is known to be $k_a = 70\,\text{W/m}\cdot\text{K}$, determine the value of k_B for rod B.

[7 Marks]

2. A stainless steel ($k = 14.4\,\text{W/m}\cdot\text{K}$) tube used to transport a chilled pharmaceutical has an inner diameter of 36 mm and a wall thickness of 2 mm. The pharmaceutical and ambient air are at temperatures of 6°C and 23°C, respectively, while the corresponding inner aand outer convection coefficients are $400\,\text{W/m}^2\cdot\text{K}$ and $6\,\text{W/m}^2\cdot\text{K}$, respectively.

   (a) What is the heat gain per unit tube length?

   (b) What is the heat gain per unit length if a layer of calcium silicate insulation with a thickness of 10 mm and thermal conductivity of $0.050\,\text{W/m}\cdot\text{K}$ is applied to the tube?

[6+6=12 Marks]

3. Consider a liquid metal ($Pr \ll 1$), with free stream conditions u_∞ and T_∞, in parallel flow over an isothermal flat plate at temperature T_s. Assume that $u = u_\infty$ throughout the thermal boundary layer.

   (a) Write the boundary layer energy equation in its simplest form. Provide appropriate initial ($x = 0$) and boundary conditions to this equation.

   (b) Obtain the boundary layer temperature field $T(x, y)$ analytically by solving the problem in part (b). Further, obtain an expression for the local Nusselt number Nu_x.

   Consult your handout(s), if necessary.

[4+8=12 Marks]

4. For approximate calculations, the sun may be considered a black body, emitting radiation with a maximum intensity at $\lambda = 0.5\,\mu\text{m}$. With this information, estimate **(a)** the surface temperature of the sun, and **(b)** the emitted heat flux at the sun's surface. Take $\sigma = 5.670367 \times 10^{-8}\text{W}\cdot\text{m}^{-2}\cdot\text{K}^{-4}$. Consult your handout if necessary.

[6 Marks]

5. A heat exchanger is used to heat cold water at 15°C entering a a rate of 2 kg/s by hot air at 85°C entering at a rate of 3 kg/s. The heat exchanger is not insulated and is losing heat at a rate of 25 kJ/s. If the exit temperature of hot air is 20°C, calculate the exit temperature of cold water. Consult thermodynamic tables if necessary.

[5 Marks]

6. A piston-cylinder device contains 5 kg of saturated water vapor at 3 MPa. Now, heat is rejected from the cylinder at constant pressure until the water vapor completely condenses so that the cylinder contains saturated liquid at 3 MPa at the end of process. Calculate the enthalpy and entropy change of the system.

[4 Marks]

7. A heat engine draws heat from a source with finite thermal capacity C (units: J/K) initially at temperature t_1. generates work and transfers heat to a sink with thermal capacity C, initially at temperature t_2. Calculate the theoretical maximum work that can be obtained from the heat engine.

[6 Marks]