ta 3220 Practice Problems

Shell balances for heat-transfer problems

[redacted]

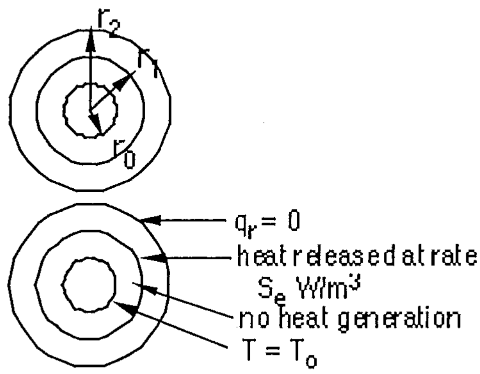
1. Using BSL Example 9.6-1 as a guide, derive expressions similar to BSL Eqs. 9.6-30 and 9.6-31 for heat conduction through multiple *spherical* layers.

2. A 100 m length of 6-inch I.D. steel pipe, with 1-inch-thick walls, has water and steam flowing under pressure through it, so that its internal surface temperature may be taken to be constant and uniform at 300°F. The outside air temperature is 70°F, and the heat-transfer coefficient on the outer pipe wall is h_{outer}= 100 W/(m^2 K). For the steel pipe itself, k = 16.3 W/(m K).

a) What total rate of heat loss can be expected from the pipe?

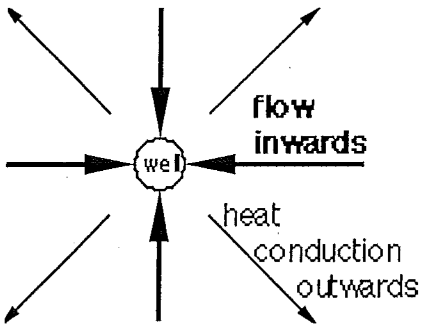
b) What rate of heat loss would be expected if the operator covers the pipe with a 1-inch layer of insulation with k=0.02 W/(m K)? Assume that the value of h_{outer} continues to apply to the outer surface of the insulation.

3. An experimentalist wants to heat fluid in a laboratory injection line by surround-ing the tube with heating tape. "Heating tape" is a cloth tape with small wires running through it; when a voltage is applied, the wires heat up. This sort of tape is wrapped around pipes to warm them. The experimentalist approximates the geometry of his system as shown at right. He assumes that within the electrically conducting (outer) layer ($r_1 \le r \le r_2$) heat is generated at a rate of Se (in units W/m^3). The inner layer ($r_0 \le r \le r_1$) has no heat generation, and the innermost surface can be assumed to be maintained by fluid at temperature T_o. The inner layer has thermal conductivity k^{01} and the outer layer has thermal conductivity k^{12}. Around the heating tape the experimentalist has placed insulation, so that there is no heat flux at the outer surface of this layer.



   a) Use shell balance(s) to derive a formula for T(r) for $r_0 \le r \le r_1$.
   b) Compute the total rate of heat transmitted to the fluid in W/m of tubing.

4. A heater is placed in the wellbore of a production well. Although the heater is primarily intended to heat oil flowing up the pipe, some heat is conducted out into the formation; at steady state, this conductive flux is balanced by convective flux of heated oil flowing toward the wellbore. Assume the oil is incompressible, that only oil is flowing, and that the well's steady rate of oil production (in volume per unit thickness of formation per unit time) is q_o. Assume that the thermal conductivity k of the oil-saturated rock is known. At the surface of the well, $T = T_w$; far from the well, the reservoir temperature is T_o ($T_o < T_w$). Assume both T_w and T_o are known.



Derive a differential equation for temperature T as a function of radial position r at steady state. Assume that all fluid and rock properties are known and are independent of temperature. **You do not need to solve this differential equation.**