ta3220 - Fluid Flow, Heat and Mass Transfer
Unsteady conduction problems, part 1

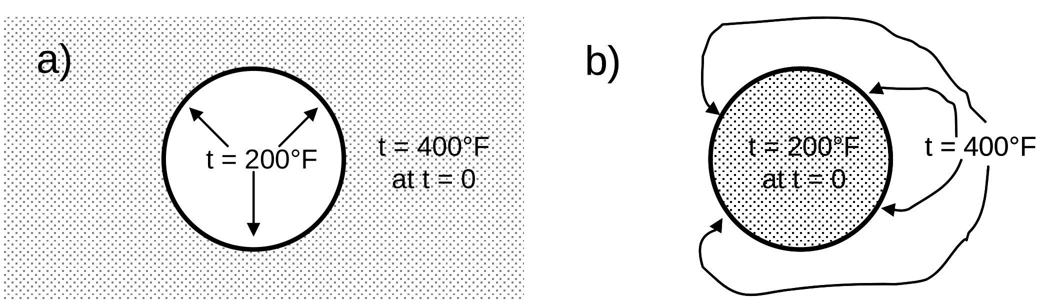
1. In a steamflood, a thin zone of area 10,000 m^2 is rapidly filled with pressurized steam. Thereafter its temperature can be considered constant at 300°F. Above it is a permeability barrier, and the rock above, initially at 150°F, starts to heat from conduction. This rock has properties k=0.99 J/(m s K), ρ = 2320 kg/m^3, $\hat{C}_p$ = 761 J/(kg K).

   a) Use Eq. 12.1-10 in BSL to estimate the total rate of heat loss to the rock above as a function of time since steam injection began. Express time in days.
   b) Integrate the expression in part (a) to determine the total cumulative heat loss to the overlying rock as a function of time.
   Be careful to use consistent time units in this problem!

2. Two large (i.e., infinite), rectangular blocks of lead, one with temperature 300°F and the other at 100°F, are brought into contact at t=0. What is the temperature of the cooler block (in °F) 5 cm from the contact after 1 minute? Do not bother to convert from °F to °K for this problem.

   properties of lead
   k = 0.346 W/(cm °C) $\hat{C}_p$= 0.031 cal/(g °C) ρ = 11.34 g/cm^3

3. During drilling into geothermal formations it is important to keep drilling fluid circulating in order to prevent the hot formation from heating the drilling fluid excessively.
   a) Suppose that during drilling circulation within the fluid keeps the fluid at a uniform temperature of 200°F right up to the rock surface and that the surrounding formation is at 400°F. Use the correlations of Carslaw and Jaegar to estimate the rate of heat transfer from the formation into the fluid, in units W/m of well depth, after 2 days. The well has radius 4 1/2 in. Assume the rock properties of problem 1 apply here.
   b) Now suppose the circulation stops. Suppose the formation has a temperature of 400°F at the outer radius of the well and that the fluid heats as a solid. (In other words, assume the yield stress of the drilling fluid prevents free convection.) Assume there is only fluid in the well. How long would it take the fluid at the center of the hole to heat to 350°F? Assume the following properties for the fluid:
      ρ = 983 kg/m^3 $\hat{C}_p$ = 4181 J/(kg K) k = 0.658 W/(m K)



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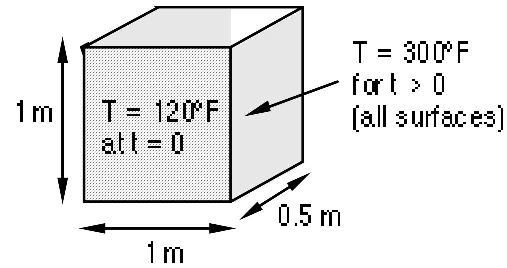
Unsteady conduction problems, part 2 (extending 1D solutions)

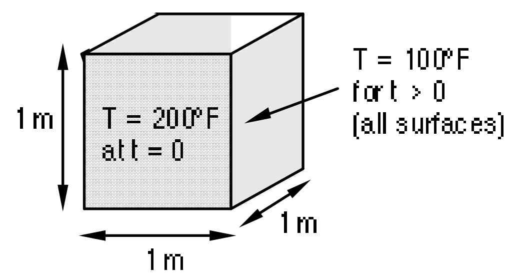
1. A fractured reservoir consists of matrix blocks of dimensions 1 m x 1 m x 0.5 m. An operator begins to flood the fracture system with steam, and she estimates that at time t = 0 the surfaces of the blocks near the injection well are raised instantaneously from the initial, uniform temperature of 120°F to 300°F. The matrix blocks have properties listed below. What would be the temperature of the center of a block after 6 hr? Ignore any flow in the blocks; assume each heats as a solid. Do not bother to convert temperatures to °K.



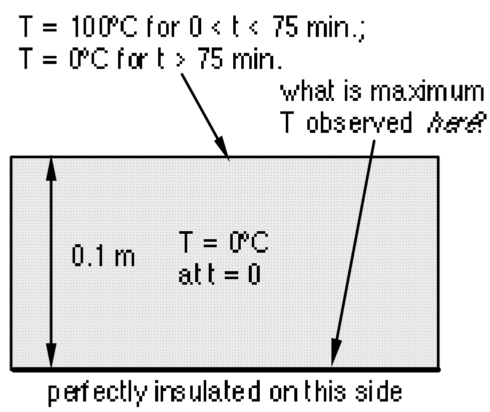
rock properties

ρ = 2270 kg/m^3 k = 2.61 J/(m s K) $\hat{C}_p$ = 1000 J/(kg K)

2. A different fractured reservoir consists of cubic matrix blocks 1 m on a side. The rock is initially at 200°F. Upon injection of cold water from the surface at t=0, however, cold water fills the fractures and the temperature of the surfaces of the rock is immediately reduced to 100°F. At what time will the temperature in the middle of the blocks reach 120°F? The matrix blocks have properties listed in problem 1. Ignore any flow in the blocks; assume each heats as a solid. Do not bother to convert temperatures to °K.



3. A long, wide concrete slab, 0.1 m thick, is initially at a uniform temperature of 0°C. One side of the slab is insulated; the other side is suddenly raised in temperature to 100°C for 75 min; then that surface is suddenly returned to 0°C. Estimate the temperature at the insulated side at several times, and from these results estimate the maximum temperature observed at the insulated side of the slab.



Properties of the slab

ρ = 3010 kg/m^3 $\hat{C}_p$ = 880 J/(kg K) k = 1.21 W/(m °K)