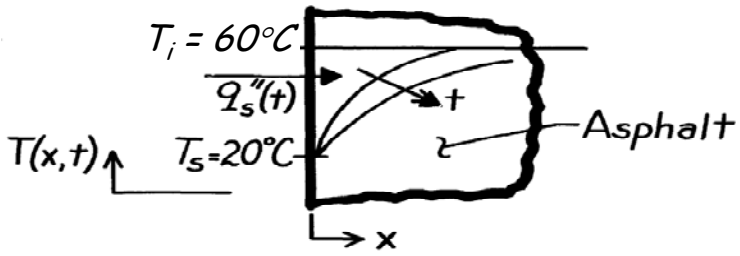
PROBLEM 5.85

KNOWN: Asphalt pavement, initially at 60°C, is suddenly exposed to a rainstorm reducing the surface temperature to 20°C.

FIND: Total amount of energy removed (J/m^2) from the pavement for a 30 minute period.

SCHEMATIC:



ASSUMPTIONS: (1) Asphalt pavement can be treated as a semi-infinite solid, (2) Effect of rainstorm is to suddenly reduce the surface temperature to 20°C and is maintained at that level for the period of interest.

PROPERTIES: *Table A-3*, Asphalt (300K): ρ = 2115 kg/m^3, c = 920 J/kg·K, k = 0.062 W/m·K.

ANALYSIS: This solution corresponds to Case 1, Figure 5.7, and the surface heat flux is given by Eq. 5.61 as

$$q_s''(t) = k(T_s - T_i)/(\pi\alpha\, t)^{1/2} \tag{1}$$

The energy into the pavement over a period of time is the integral of the surface heat flux expressed as

$$Q'' = \int_0^t q_s''(t)\,dt. \tag{2}$$

Note that $q_s''(t)$ is into the solid and, hence, Q represents energy into the solid. Substituting Eq. (1) for $q_s''(t)$ into Eq. (2) and integrating find

$$Q'' = k(T_s - T_i)/(\pi\alpha)^{1/2} \int_0^t t^{-1/2} dt = \frac{k(T_s - T_i)}{(\pi\alpha)^{1/2}} \times 2\, t^{1/2}. \tag{3}$$

Substituting numerical values into Eq. (3) with

$$\alpha = \frac{k}{\rho\, c} = \frac{0.062\ \text{W/m}\cdot\text{K}}{2115\ \text{kg/m}^3 \times 920\ \text{J/kg}\cdot\text{K}} = 3.18\times10^{-8}\ \text{m}^2/\text{s}$$

find that for the 30 minute period,

$$Q'' = \frac{0.062\ \text{W/m}\cdot\text{K}\ (20-60)\,\text{K}}{\left(\pi \times 3.18\times10^{-8}\ \text{m}^2/\text{s}\right)^{1/2}} \times 2\,(30\times60\text{s})^{1/2} = -6.65\times10^5\ \text{J/m}^2. \quad <$$

COMMENTS: Note that the sign for Q'' is negative implying that energy is removed from the solid.