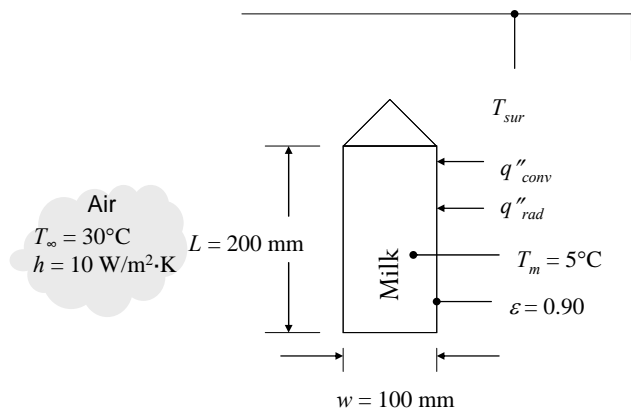


PROBLEM 1.47

KNOWN: Dimensions of a milk carton. Temperatures of milk carton and surrounding air. Convection heat transfer coefficient and surface emissivity.

FIND: Heat transferred to milk carton for durations of 10, 60, and 300 s.

SCHEMATIC:



ASSUMPTIONS: (1) Negligible heat transfer from bottom surface of milk carton and from top surface since it is not in contact with cold milk, (2) Radiation is to large surroundings at the air temperature.

ANALYSIS: The area of the four sides is $A = 4L \times w = 4(0.2 \text{ m} \times 0.1 \text{ m}) = 0.08 \text{ m}^2$. Thus,

$$\begin{aligned} q &= (q_{\text{conv}} + q_{\text{rad}}) = hA(T_{\infty} - T_s) + \epsilon\sigma A(T_{\text{sur}}^4 - T_s^4) \\ &= 10 \text{ W/m}^2 \cdot \text{K} \times 0.08 \text{ m}^2 (30^\circ\text{C} - 5^\circ\text{C}) + 0.90 \times 5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4 \times 0.08 \text{ m}^2 \left((303 \text{ K})^4 - (278 \text{ K})^4 \right) \\ &= 20.0 \text{ W} + 10.0 \text{ W} = 30.0 \text{ W} \end{aligned}$$

For a duration of 10 s,

$$Q = q\Delta t = 30.0 \text{ W} \times 10 \text{ s} = 300 \text{ J}$$

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Similarly, $Q = 1800 \text{ J}$ and 9000 J for durations of 60 and 300 s, respectively.

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COMMENTS: (1) The predicted heat transfer rates do not account for the fact that the milk temperature increases with time. If the increase in milk temperature were accounted for, the values of Q would be less than calculated. (2) If the coefficient of performance of the refrigerator is 2, $\text{COP} = Q/W = 2$, then the required work input to re-cool the milk after leaving it in the kitchen for 300 s is 4500 J. At an electricity price of \$0.18/kW·h, this would cost about \$0.0002, which is insignificant. Preventing bacterial growth is a more important reason to return the milk to the refrigerator promptly. (3) The analysis neglects condensation that might occur on the outside of the milk carton. Condensation would increase the rate of heat transfer to the milk significantly, increasing the importance of returning the milk to the refrigerator promptly.