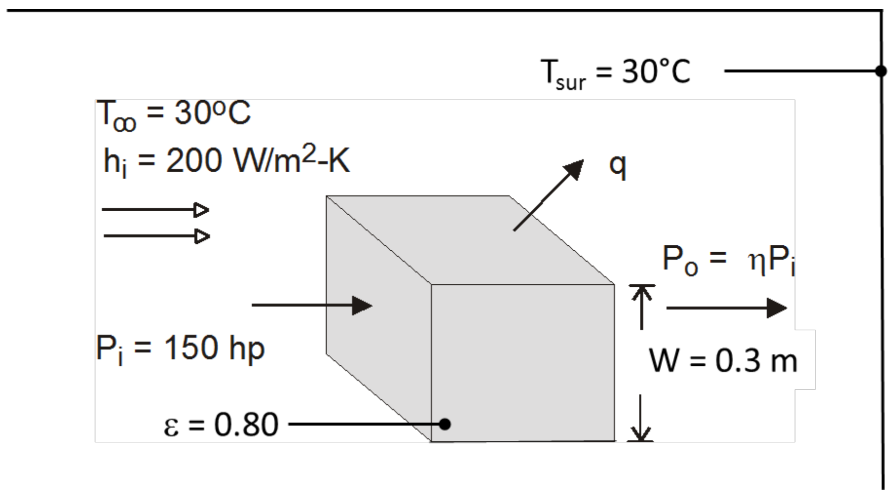
PROBLEM 1.36

KNOWN: Width, input power, and efficiency of a transmission. Temperature and convection coefficient for air flow over the casing. Emissivity of casing and temperature of surroundings.

FIND: Surface temperature of casing. Resistances due to convection and radiation.

SCHEMATIC:



ASSUMPTIONS: (1) Steady state, (2) Uniform convection coefficient and surface temperature, (3) Radiation exchange with large surroundings.

ANALYSIS: Heat transfer from the case must balance heat dissipation in the transmission, which may be expressed as $q = P_i - P_o = P_i (1 - \eta)$ = 150 hp × 746 W/hp × 0.07 = 7833 W. Heat transfer from the case is by convection and radiation, in which case

$$q = A_s\left[h\left(T_s - T_\infty\right) + \varepsilon\sigma\left(T_s^4 - T_{sur}^4\right)\right]$$

where $A_s = 6\ W^2$. Hence,

$$7833\,W = 6\left(0.30\,m\right)^2\left[200\,W/m^2\cdot K\left(T_s - 303K\right) + 0.8\times5.67\times10^{-8}\,W/m^2\cdot K^4\left(T_s^4 - 303^4\right)K^4\right]$$

A trial-and-error solution yields

$$T_s \approx 373\,K = 100°C$$ <

The thermal resistances can be found from Eq. 1.11, that is, $R_t = \Delta T/q$. For convection, the relevant temperature difference is $T_s - T_\infty$.

$$R_{t,conv} = \left(T_s - T_\infty\right)/q_{conv} = \left(T_s - T_\infty\right)/\left[hA_s\left(T_s - T_\infty\right)\right] = 1/hA_s$$

$$R_{t,conv} = 1/\left[6\left(0.30\,m\right)^2 200\,W/m^2\cdot K\right] = 0.00926\ K/W$$ <

For radiation, the relevant temperature difference is $T_s - T_{sur}$ and

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$$R_{t,rad} = (T_s - T_{sur})/q_{rad} = (T_s - T_{sur})/\left[\varepsilon\sigma\left(T_s^4 - T_{sur}^4\right)A_s\right]$$

$$R_{t,rad} = (373 - 303)\,K/\left[0.8 \times 5.67 \times 10^{-8}\ W/m^2 \cdot K^4\left(373^4 - 303^4\right)K^4\,6(0.30\,m)^2\right]$$

$$= 0.262\ K/W$$ <

COMMENTS: (1) For $T_s \approx 373$ K, $q_{conv} \approx 7{,}560$ W and $q_{rad} \approx 270$ W, in which case heat transfer is dominated by convection. This can also be seen by the fact that the resistance to radiation heat transfer is much larger than the resistance to convection heat transfer. (2) If radiation is neglected, the corresponding surface temperature is $T_s = 102.5°C$.