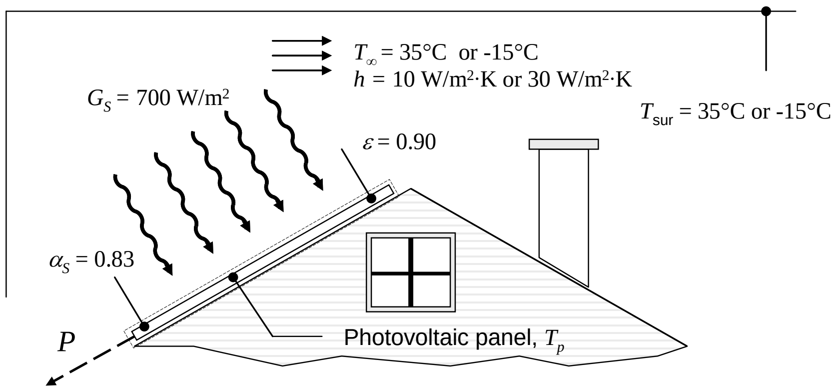
PROBLEM 1.52

KNOWN: Dimensions, emissivity, and solar absorptivity of solar photovoltaic panel. Solar irradiation, air and surroundings temperature, and convection coefficient. Expression for conversion efficiency.

FIND: Electrical power output on (a) a still summer day, and (b) a breezy winter day.

SCHEMATIC:



ASSUMPTIONS: (1) Steady-state conditions, (2) Lower surface of solar panel is insulated, (3) Radiation from the environment can be treated as radiation from large surroundings, with $\alpha = \varepsilon$.

ANALYSIS: Recognize that there is conversion from thermal to electrical energy, therefore there is a negative generation term equal to the electrical power. Performing an energy balance on the solar panel gives

$$\dot{E}_{\text{in}} - \dot{E}_{\text{out}} + \dot{E}_g = 0$$

$$q_{\text{rad}} - q_{\text{conv}} - P = 0$$

$$\left[\alpha_S G_S - \varepsilon\sigma(T_s^4 - T_{\text{sur}}^4)\right]A - hA(T_s - T_\infty) - \eta\alpha_S G_S A = 0$$

Dividing by A, and substituting the expression for η as a function of T_p yields

$$\left[\alpha_S G_S - \varepsilon\sigma(T_p^4 - T_{\text{sur}}^4)\right] - h(T_p - T_\infty) - (0.553 - 0.001T_p)\alpha_S G_S = 0$$

(a) Substituting the parameter values for a summer day:

$$0.83\times 700\ \text{W/m}^2 - 0.90\times 5.67\times 10^{-8}\ \text{W/m}^2\cdot\text{K}^4(T_p^4 - (308\ \text{K})^4) - 10\ \text{W/m}^2\cdot\text{K}(T_p - 308\ \text{K})$$

$$-(0.553 - 0.001T_p)\times 0.83\times 700\ \text{W/m}^2 = 0$$

$$3799\ \text{W/m}^2 - 5.1\times 10^{-8}\ \text{W/m}^2\cdot\text{K}^4 T_p^4 - 9.42\ \text{W/m}^2\cdot\text{K}\ T_p = 0$$

Solving this equation for T_p using IHT or other software results in T_p = 335 K. The electrical power can then be found from

$$P = \eta\alpha_S G_S A = (0.553 - 0.001T_p)\alpha_S G_S A$$

$$= (0.553 - 0.001\ \text{K}^{-1}\times 335\ \text{K})\times 0.83\times 700\ \text{W/m}^2\times 8\ \text{m}^2 = 1010\ \text{W}$$ <

(b) Repeating the calculation for the winter conditions yields T_p = 270 K, P = 1310 W. <

COMMENTS: (1) The conversion efficiency for most photovoltaic materials is higher at lower temperatures. Therefore, for the same solar irradiation, more electrical power is generated in winter conditions. (2) The total solar energy generated would generally be less in the winter due to lower irradiation values and a shorter day.