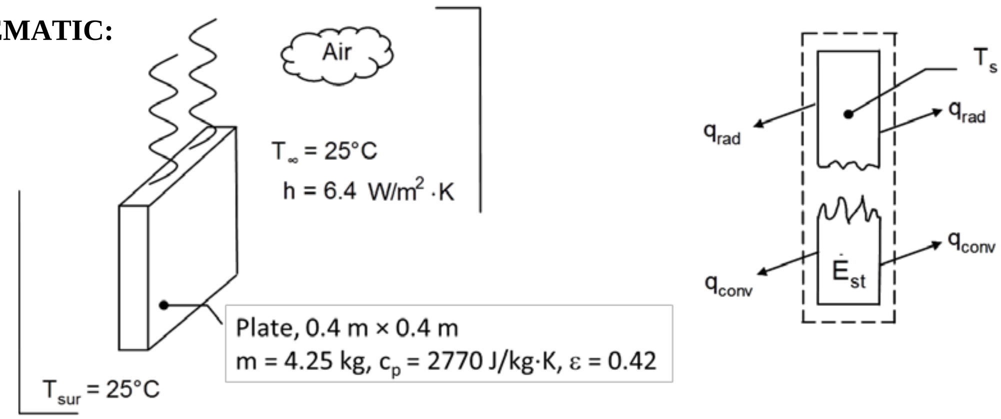
PROBLEM 1.54

KNOWN: Hot plate suspended in a room, plate temperature, room temperature and surroundings temperature, convection coefficient and plate emissivity, mass and specific heat of the plate.

FIND: (a) The time rate of change of the plate temperature, and (b) Heat loss by convection and heat loss by radiation.

SCHEMATIC:



ASSUMPTIONS: (1) Plate is isothermal and at uniform temperature, (2) Large surroundings, (3) Negligible heat loss through suspension wires.

ANALYSIS: For a control volume about the plate, the conservation of energy requirement is

$$\dot{E}_{in} - \dot{E}_{out} = \dot{E}_{st} \qquad (1)$$

where $$\dot{E}_{st} = mc_p \frac{dT}{dt} \qquad (2)$$

and $$\dot{E}_{in} - \dot{E}_{out} = \varepsilon A\sigma(T_{sur}^4 - T_s^4) + hA(T_\infty - T_s) \qquad (3)$$

Combining Eqs. (1) through (3) yields $\frac{dT}{dt} = \frac{A[\varepsilon\sigma(T_{sur}^4 - T_s^4) + h(T_\infty - T_s)]}{mc_p}$

Noting that $T_{sur} = 25^oC + 273\ K = 298\ K$ and $T_s = 225^oC + 273\ K = 498\ K$,

$$\frac{dT}{dt} = \frac{2\times0.4\ m\times0.4\ m\left[0.42\times5.67\times10^{-8}\frac{W}{m^2\cdot K^4}\times(298^4 - 498^4)\ K^4 + 6.4\frac{W}{m^2\cdot K}\times(25^oC - 225^oC)\right]}{4.25\ kg\times2770\ \frac{J}{kg\cdot K}}$$

$= -0.0695$ K/s <

The heat gain by radiation is the first term in the numerator of the preceding expression and is

$q_{rad} = -409$ W (a loss of 409 W) <

The heat gain by convection is the second term in the preceding expression and is

$q_{conv} = -410$ W (a loss of 410 W) <

COMMENTS: (1) Note the importance of using kelvins when working with radiation heat transfer. (2) The temperature difference in Newton's law of cooling may be expressed in either kelvins or degrees Celsius. (3) Radiation and convection losses are of the same magnitude. This is typical of many natural convection systems involving gases such as air.