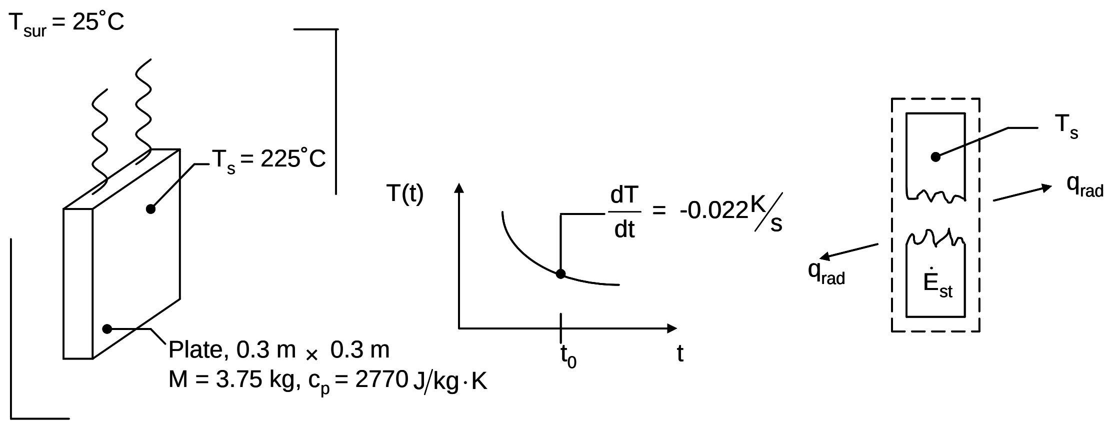
PROBLEM 1.32

KNOWN: Hot plate suspended in vacuum and surroundings temperature. Mass, specific heat, area and time rate of change of plate temperature.

FIND: (a) The emissivity of the plate, and (b) The rate at which radiation is emitted from the plate.

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 $\dot{E}_{st} = Mc_p \dfrac{dT}{dt}$ (2)

and for large surroundings $\dot{E}_{in} - \dot{E}_{out} = A\varepsilon\sigma(T_{sur}^4 - T_s^4)$ (3)

Combining Eqns. (1) through (3) yields

$$\varepsilon = \frac{Mc_p}{A\sigma}\frac{\frac{dT}{dt}}{(T_{sur}^4 - T_s^4)}$$

Noting that T_{sur} = 25˚C + 273 K = 298 K and T_s = 225˚C + 273 K = 498 K, we find

$$\varepsilon = \frac{3.75\text{ kg} \times 2770\dfrac{\text{J}}{\text{kg}\cdot\text{K}} \times (-0.022\dfrac{\text{K}}{\text{s}})}{2 \times 0.3\text{ m} \times 0.3\text{ m} \times 5.67 \times 10^{-8}\dfrac{\text{W}}{\text{m}^2\cdot\text{K}^4}(498^4 - 298^4)\text{ K}^4} = 0.42 \qquad <$$

The rate at which radiation is emitted from the plate is

$$q_{rad,e} = \varepsilon A\sigma T_s^4 = 0.42 \times 2 \times 0.3\text{ m} \times 0.3\text{ m} \times 5.67 \times 10^{-8}\frac{\text{W}}{\text{m}^2\cdot\text{K}^4} \times (498\text{ K})^4 = 264\text{ W} \qquad <$$

COMMENTS: Note the importance of using kelvins when working with radiation heat transfer.