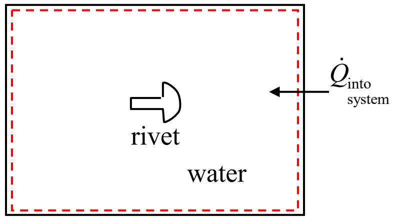
A steel rivet of mass 2 lb_m, initially at 1000 °F, is placed in a large tank containing 5 ft^3 of liquid water initially at 70 °F. Eventually, the rivet and water cool back to 70 °F as a result of heat transfer to the surroundings. Taking the rivet and water as the system, determine the heat transfer, in Btu, to the surroundings. The specific heat for steel is 0.11 Btu/(lb_m·°R).

SOLUTION:

Apply the 1st Law to the rivet/water system.



$$\Delta E_{\text{system}} = Q_{\substack{\text{into}\\\text{system}}} + W_{\substack{\text{on}\\\text{system}}} \tag{1}$$

Assuming that the tank is rigid, $W_{\text{on system}} = 0$. Furthermore, the change in the total energy of the system will be due solely to changes in the internal energy, *i.e.* $\Delta E_{\text{system}} = \Delta U_{\text{system}}$ where:

$$\begin{aligned}\Delta U_{\text{system}} &= \Delta U_{\text{rivet}} + \Delta U_{\text{water}} \\ &= m_{\text{rivet}} c_{\text{rivet}} \left(T_{f,\text{rivet}} - T_{i,\text{rivet}}\right) + m_{\text{water}} c_{\text{water}} \left(T_{f,\text{water}} - T_{i,\text{water}}\right)\end{aligned} \tag{2}$$

Substitute Eqn. (2) into Eqn. (1) and simplify.

$$Q_{\substack{\text{into}\\\text{system}}} = m_{\text{rivet}} c_{\text{rivet}} \left(T_{f,\text{rivet}} - T_{i,\text{rivet}}\right) + m_{\text{water}} c_{\text{water}} \left(T_{f,\text{water}} - T_{i,\text{water}}\right) \tag{3}$$

Since the final water temperature is the same as the initial water temperature, *i.e.* $T_{f,\text{water}} = T_{i,\text{water}}$, the change in the water internal energy will be zero. Hence,

$$Q_{\substack{\text{into}\\\text{system}}} = m_{\text{rivet}} c_{\text{rivet}} \left(T_{f,\text{rivet}} - T_{i,\text{rivet}}\right) \tag{4}$$

Using the given parameters.

$T_{f,\text{rivet}}$ = 70 °F

$T_{i,\text{rivet}}$ = 1000 °F

c_{rivet} = 0.11 Btu/(lb$_m$·°R)

m_{rivet} = 2 lb$_m$

⇒ $\boxed{Q_{\text{into system}} = -205\text{ Btu}}$ (205 Btu leave the system)