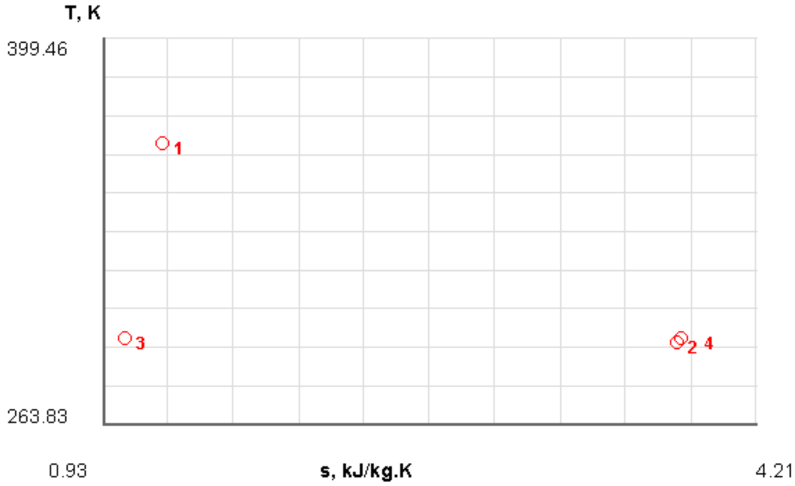
5-3-1 [OHU] A 40 kg aluminum block at 90°C is dropped into an insulated tank that contains 0.5 m^3 of liquid water at 20°C. Determine the equilibrium temperature.

SOLUTION



Given:

$$c_1 = 0.9\ \frac{\text{kJ}}{\text{kg}\cdot\text{K}};$$

$$c_2 = 4.184\ \frac{\text{kJ}}{\text{kg}\cdot\text{K}};$$

State-1 (given T_1, m_1)

State-2 (given T_2, v_2):

$$m_2 = \frac{\cancel{V}}{v} = \frac{0.5}{0.001} = 500\ \text{kg};$$

The energy balance on the system can be expressed as

$$E_{\text{in}} - E_{\text{out}} = \Delta E_{\text{system}};$$

$$\Rightarrow 0 = \Delta U;$$

The total internal energy if the system can be expressed as

$$\Delta U_{\text{system}} = \Delta U_{\text{Al}} + \Delta U_{\text{water}};$$

$$\Rightarrow 0 = \left[m_1 c_1 (T_3 - T_1)\right]_{\text{Al}} + \left[m_2 c_2 (T_3 - T_2)\right]_{\text{water}};$$

$$\Rightarrow 0 = \left[(40)(0.9)(T_3 - 90)\right] + \left[(500)(4.184)(T_3 - 20)\right];$$

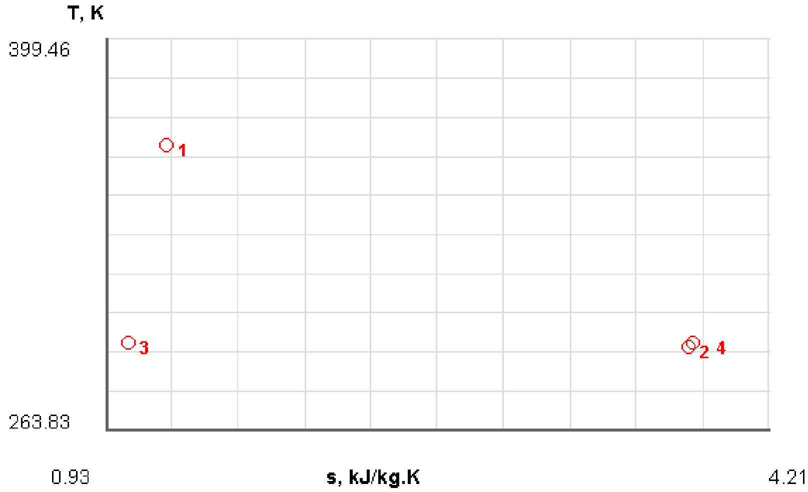
$$\Rightarrow T_3 = 21.18^{\circ}\text{C}$$

TEST Solution:

Launch the SL/SL non-uniform non-mixing closed process system TESTcalc to verify the solution. The TEST-code for this problem can be found in the TEST-Pro site at www.thermofluids.net

5-3-2 [OHC] In the problem described above, determine the entropy generated during the process.

SOLUTION



Given:

$$c_1 = 0.9 \ \frac{\text{kJ}}{\text{kg}\cdot\text{K}};$$

$$c_2 = 4.184 \ \frac{\text{kJ}}{\text{kg}\cdot\text{K}};$$

State-1 (given T_1, m_1)

State-2 (given T_2, v_2):

$$m_2 = \frac{\mathcal{V}}{v} = \frac{0.5}{0.001} = 500 \text{ kg};$$

The energy balance on the system can be expressed as

$$E_{\text{in}} - E_{\text{out}} = \Delta E_{\text{system}};$$

$$\Rightarrow 0 = \Delta U;$$

The total internal energy if the system can be expressed as

$$\Delta U_{\text{system}} = \Delta U_{\text{Al}} + \Delta U_{\text{water}};$$

$$\Rightarrow 0 = \left[m_1 c_1 \left(T_3 - T_1\right)\right]_{\text{Al}} + \left[m_2 c_2 \left(T_3 - T_2\right)\right]_{\text{water}};$$

$$\Rightarrow 0 = \left[(40)(0.9)(T_3 - 90)\right] + \left[(500)(4.184)(T_3 - 20)\right];$$

$$\Rightarrow T_3 = 21.18^{\circ}\text{C};$$

The entropy balance can be expressed as

$$S_{\text{gen,univ}} = \Delta S - \frac{\cancel{Q}^{0}}{\cancel{T_B}};$$

$$\Rightarrow S_{\text{gen,univ}} = m_1 c_1 \ln\frac{T_3}{T_1} + m_2 c_2 \ln\frac{T_3}{T_2};$$

$$\Rightarrow S_{\text{gen,univ}} = (40)(0.9)\ln\frac{(294.18)}{(363)} + (500)(4.184)\ln\frac{(294.18)}{(293)};$$

$$\Rightarrow S_{\text{gen,univ}} = -7.56 + 8.404;$$

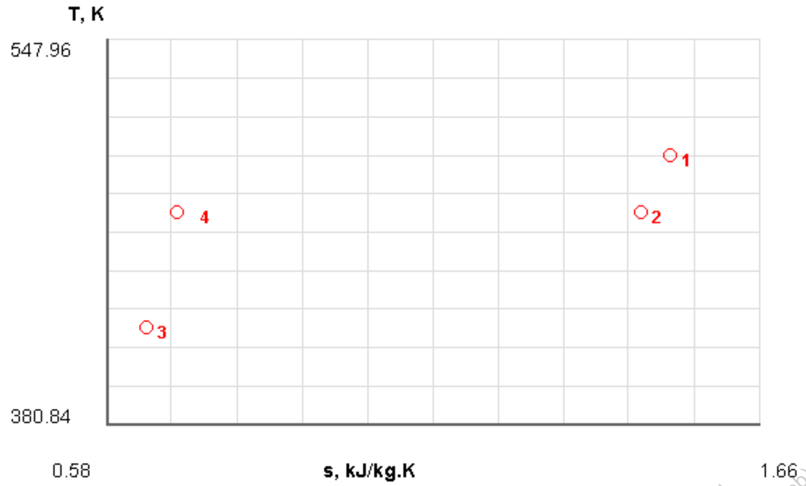
$$\Rightarrow S_{\text{gen,univ}} = 0.848\ \frac{\text{kJ}}{\text{K}}$$

TEST Solution:

Launch the SL/SL non-uniform non-mixing closed process system TESTcalc to verify the solution. The TEST-code for this problem can be found in the TEST-Pro site at www.thermofluids.net

5-3-3 [OHV] A 25 kg aluminum block initially at 225°C is brought into contact with a 25 kg block of iron at 150°C in an insulating enclosure. Determine (a) the equilibrium temperature, (b) and the total entropy change for this process.

SOLUTION



Given:

$$c_1 = 0.9\ \frac{\text{kJ}}{\text{kg}\cdot\text{K}};$$

$$c_2 = 0.45\ \frac{\text{kJ}}{\text{kg}\cdot\text{K}};$$

State-1 (given T_1, m_1)

State-2 (given T_2, m_2)

The energy balance on the system can be expressed as

$$E_{\text{in}} - E_{\text{out}} = \Delta E_{\text{system}};$$

$$\Rightarrow 0 = \Delta U;$$

(a) The total internal energy if the system can be expressed as

$$\Delta U_{\text{system}} = \Delta U_{\text{Al}} + \Delta U_{\text{Fe}};$$

$$\Rightarrow 0 = \left[m_1 c_1 \left(T_3 - T_1\right)\right]_{\text{Al}} + \left[m_2 c_2 \left(T_3 - T_2\right)\right]_{\text{Fe}};$$

$$\Rightarrow 0 = \left[(25)(0.9)(T_3 - 225)\right] + \left[(25)(0.45)(T_3 - 150)\right];$$

$$\Rightarrow T_3 = 200^{\circ}\text{C}$$

(b) The entropy balance can be expressed as

$$S_{\text{gen,univ}} = \Delta S - \cancel{\frac{Q}{T_B}}^{\,0};$$

$$\Rightarrow S_{\text{gen,univ}} = m_1 c_1 \ln\frac{T_3}{T_1} + m_2 c_2 \ln\frac{T_3}{T_2};$$

$$\Rightarrow S_{\text{gen,univ}} = (25)(0.9)\ln\frac{(473)}{(498)} + (25)(0.45)\ln\frac{(473)}{(423)};$$

$$\Rightarrow S_{\text{gen,univ}} = -1.15 + 1.256;$$

$$\Rightarrow S_{\text{gen,univ}} = 0.097\ \frac{\text{kJ}}{\text{K}}$$

TEST Solution:

Launch the SL/SL non-uniform non-mixing closed process system TESTcalc to verify the solution. The TEST-code for this problem can be found in the TEST-Pro site at www.thermofluids.net

5-3-4 [OHQ] A half kg bar of iron, initially at 782°C, is removed from an oven and quenched by immersing it in a closed tank containing 10 kg of water initially at 21°C. Heat transfer from the tank can be neglected. Determine (a) the equilibrium temperature, (b) and the total entropy change for this process.

SOLUTION

Given:

$$c_1 = 0.45 \ \frac{\text{kJ}}{\text{kg} \cdot \text{K}};$$

$$c_2 = 4.184 \ \frac{\text{kJ}}{\text{kg} \cdot \text{K}};$$

State-1 (given T_1, m_1)

State-2 (given T_2, m_2)

The energy balance on the system can be expressed as

$$E_{\text{in}} - E_{\text{out}} = \Delta E_{\text{system}};$$
$$\Rightarrow 0 = \Delta U;$$

(a) The total internal energy if the system can be expressed as

$$\Delta U_{\text{system}} = \Delta U_{\text{Fe}} + \Delta U_{\text{water}};$$
$$\Rightarrow 0 = \left[m_1 c_1 \left(T_3 - T_1\right)\right]_{\text{Fe}} + \left[m_2 c_2 \left(T_3 - T_2\right)\right]_{\text{water}};$$
$$\Rightarrow 0 = \left[(0.5)(0.45)(T_3 - 782)\right] + \left[(10)(4.184)(T_3 - 21)\right];$$
$$\Rightarrow T_3 = 25.07^{\circ}\text{C}$$

(b) The entropy balance can be expressed as

$$S_{\text{gen,univ}} = \Delta S - \cancel{\frac{Q}{T_B}}^{0};$$

$$\Rightarrow S_{\text{gen,univ}} = m_1 c_1 \ln\frac{T_3}{T_1} + m_2 c_2 \ln\frac{T_3}{T_2};$$

$$\Rightarrow S_{\text{gen,univ}} = (0.5)(0.45)\ln\frac{(298.07)}{(1055)} + (10)(4.184)\ln\frac{(298.07)}{(294)};$$

$$\Rightarrow S_{\text{gen,univ}} = -0.284 + 0.575;$$

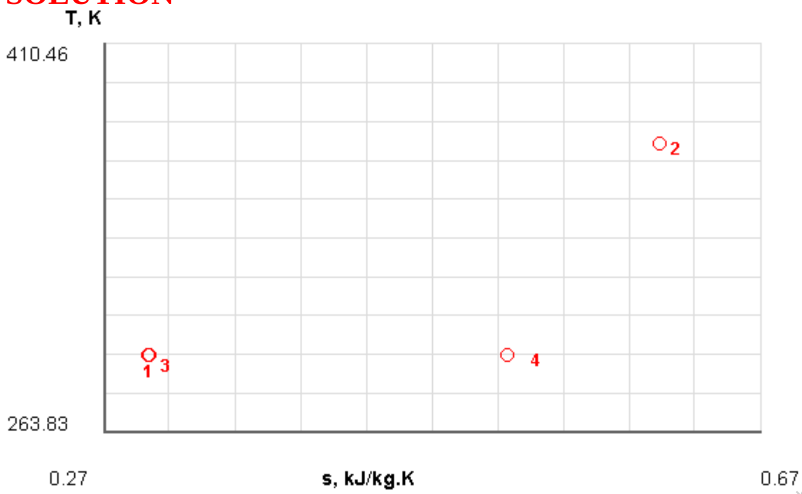
$$\Rightarrow S_{\text{gen,univ}} = 0.291\ \frac{\text{kJ}}{\text{K}}$$

TEST Solution:

Launch the PC/SL non-uniform non-mixing closed process system TESTcalc to verify the solution. The TEST-code for this problem can be found in the TEST-Pro site at www.thermofluids.net

5-3-5 [OHY] A 15 kg block of copper at 100°C is dropped into an insulated tank that contains 1 m^3 of liquid water at 20°C. Determine (a) the equilibrium temperature (b) the entropy generated in this process.

SOLUTION



Given:

$$c_1 = 0.386 \ \frac{\text{kJ}}{\text{kg}\cdot\text{K}};$$

$$c_2 = 4.184 \ \frac{\text{kJ}}{\text{kg}\cdot\text{K}};$$

State-1 (given T_1, m_1)

State-2 (given T_2, v_2):

$$m_2 = \frac{\cancel{V}}{v} = \frac{1}{0.001} = 1000 \text{ kg};$$

The energy balance on the system can be expressed as

$$E_{\text{in}} - E_{\text{out}} = \Delta E_{\text{system}};$$

$$\Rightarrow 0 = \Delta U;$$

(a) The total internal energy if the system can be expressed as

$$\Delta U_{\text{system}} = \Delta U_{\text{Cu}} + \Delta U_{\text{water}};$$

$$\Rightarrow 0 = \left[m_1 c_1 (T_3 - T_1)\right]_{\text{Cu}} + \left[m_2 c_2 (T_3 - T_2)\right]_{\text{water}};$$

$$\Rightarrow 0 = \left[(15)(0.386)(T_3 - 100)\right] + \left[(1000)(4.184)(T_3 - 20)\right];$$

$$\Rightarrow T_3 = 20.11^{\circ}\text{C}$$

(b) The entropy balance can be expressed as

$$S_{\text{gen,univ}} = \Delta S - \frac{\cancel{Q}^{\,0}}{\cancel{T_B}};$$

$$\Rightarrow S_{\text{gen,univ}} = m_1 c_1 \ln\frac{T_3}{T_1} + m_2 c_2 \ln\frac{T_3}{T_2};$$

$$\Rightarrow S_{\text{gen,univ}} = (1000)(4.184)\ln\frac{(293.11)}{(293)} + (15)(0.386)\ln\frac{(293.11)}{(373)};$$

$$\Rightarrow S_{\text{gen,univ}} = 1.570 - 1.396;$$

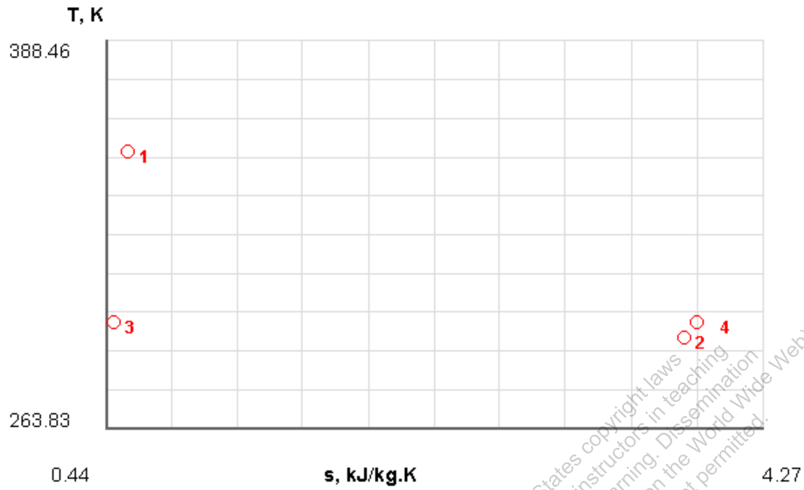
$$\Rightarrow S_{\text{gen,univ}} = 0.174\ \frac{\text{kJ}}{\text{K}}$$

TEST Solution:

Launch the PC/SL non-uniform non-mixing closed process system TESTcalc to verify the solution. The TEST-code for this problem can be found in the TEST-Pro site at www.thermofluids.net

5-3-6 [OHF] An unknown mass of iron at 80°C is dropped into an insulated tank that contains 0.1 m^3 of liquid water at 20°C. Meanwhile, a paddle wheel driven by a 200 W motor is used to stir the water. When equilibrium is reached after 20 min, the final temperature is 25 °C. Determine (a) the mass of the iron block. (b) ***What-if scenario:*** How would the answer in part (a) change if the iron block was at 150 °C at the time of dropping.

SOLUTION



Given:

$$c_1 = 0.45 \ \frac{\text{kJ}}{\text{kg}\cdot\text{K}};$$

$$c_2 = 4.184 \ \frac{\text{kJ}}{\text{kg}\cdot\text{K}};$$

State-1 (given T_1)

State-2 (given T_2, v_2):

$$m_2 = \frac{\cancel{V}}{v} = \frac{0.1}{0.001} = 100 \text{ kg};$$

The energy balance on the system can be expressed as

$$E_{\text{in}} - E_{\text{out}} = \Delta E_{\text{system}};$$

$$\Rightarrow 0 = \Delta U;$$

(a) $$\cancel{Q}^0 = \left[m_1 c_1 (T_3 - T_1)\right]_{\text{Fe}} + \left[m_2 c_2 (T_3 - T_2)\right]_{\text{water}} + W_{\text{ext}};$$

$$\Rightarrow 240 = \left[m_1 (0.45)(25-80)\right] + \left[(100)(4.184)(25-20)\right];$$

$$\Rightarrow m_1 = 74.74 \text{ kg}$$

TEST Solution and What-if Scenario:

Launch the SL/SL non-uniform non-mixing closed process system TESTcalc to verify the solution and conduct the what-if study. The TEST-code for this problem can be found in the TEST-Pro site at www.thermofluids.net.