1.5) Two jets of air, each having the same mass flow rate, are thoroughly mixed and then discharged into a large chamber. One jet has a temperature of 120°C and a velocity of 100 m/s, whereas the other has a temperature of −50°C and a velocity of 300 m/s. Assuming that the process is steady and adiabatic, find the temperature of the air in the large chamber.

Solution:

A schematic diagram of the configuration is shown in Fig. 1.

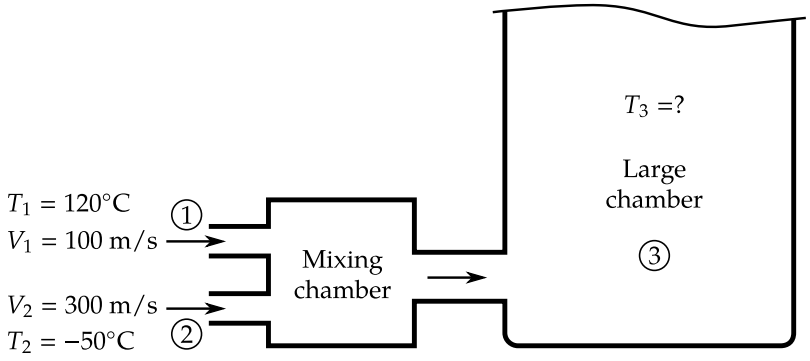

Fig. 1: Schematic diagram for problem description

Given: $T_1 = 120°\text{C} = 393\,\text{K}$, $V_1 = 100\,\text{m/s}$, $T_2 = -50°\text{C} = 223\,\text{K}$, $V_2 = 300\,\text{m/s}$.
The mass flow rate is same through the two inlets, therefore,

$$\dot{m}_1 = \dot{m}_2 = \dot{m}$$

$$\dot{m}_3 = \dot{m}_1 + \dot{m}_2 = 2\,\dot{m}$$

Applying the conservation of energy equation (without heat and work),

$$\left(\dot{m}_1\, c_p\, T_1 + \dot{m}_1 \frac{V_1^2}{2}\right) + \left(\dot{m}_2\, c_p\, T_2 + \dot{m}_2 \frac{V_2^2}{2}\right) = \left(\dot{m}_3\, c_p\, T_3 + \dot{m}_3 \frac{V_3^2}{2}\right)$$

$$\left(\dot{m}\, c_p\, T_1 + \dot{m} \frac{V_1^2}{2}\right) + \left(\dot{m}\, c_p\, T_2 + \dot{m} \frac{V_2^2}{2}\right) = \left(2\,\dot{m}\, c_p\, T_3 + 2\,\dot{m} \frac{V_3^2}{2}\right)$$

$$\left(c_p\, T_1 + \frac{V_1^2}{2}\right) + \left(c_p\, T_2 + \frac{V_2^2}{2}\right) = \left(2\, c_p\, T_3 + 2\frac{V_3^2}{2}\right)$$

$$T_3 = \frac{c_p\, T_1 + \frac{V_1^2}{2} + c_p\, T_2 + \frac{V_2^2}{2} - V_3^2}{2\, c_p}$$

Assuming $c_p = 1005\,\text{J/kg-K}$ for air and the velocity in the large chamber to be effectively zero,

$$T_3 = \frac{1005 \times 393 + \frac{100^2}{2} + 1005 \times 223 + \frac{300^2}{2} - 0}{2 \times 1005}$$

$$\boxed{T_3 = 332.87562\,\text{K} = 59.87562°\text{C}}$$