Given:
Air at 10°C and 80 kPa enters the diffuser of a jet engine steadily with a velocity of 200 m/s. The inlet area of the diffuser is $0.4\ m^2$. The air leaves the diffuse with a velocity that is very small compared with the inlet velocity.

$T_1 := 10\ °C$ $P_1 := 80\ kPa$ $V_1 := 200\ \frac{m}{s}$ $A_1 := 0.4\ m^2$

Required:
Determine the mass flow rate of air and the temperature of the air leaving the diffuser.

Solution:
The mass flow rate is given by

$$m' = \rho \cdot A \cdot V$$

Assuming air behaves as an ideal gas, the density of air may be found by

$$P \cdot V = m \cdot R \cdot T \quad \text{or} \quad \nu = \frac{V}{m} \quad \text{or} \quad \rho = \frac{1}{\nu}$$

$$\nu = \frac{R \cdot T}{P} \qquad \rho = \frac{P}{R \cdot T}$$

Going to Table A-1 @ air shows

$$R := 0.287\ \frac{kJ}{kg\ K}$$

The density is then given by

$$\rho_1 := \frac{P_1}{R \cdot T_1} = 0.9844\ \frac{kg}{m^3}$$

The mass flow rate is then given by

$$\boxed{m' := \rho_1 \cdot A_1 \cdot V_1 = 78.76\ \frac{kg}{s}}$$

<u>1st Law</u> for an adiabatic, rigid, steady flow device

$$\frac{d}{d\ t} E_{sys} = \Sigma E'_{in} - \Sigma E'_{out}$$

$$0 = \Sigma E'_{in} - \Sigma E'_{out}$$

$$0 = m'_{in} \cdot \left(h_{in} + \frac{V_{in}^2}{2} \right) - m'_{out} \cdot \left(h_{out} + \frac{V_{out}^2}{2} \right)$$ assuming there is no change in potential energy

Rearranging yields

$$h_{out} = h_{in} + \frac{V_{in}^2 - V_{out}^2}{2}$$ knowing $m'_{in} = m'_{out}$

Since it is known that V_{out} is much less than V_{in}

$$h_{out} = h_{in} + \frac{V_{in}^2}{2}$$

Solution (cont.):

Going to Table A-17 @ $T := T_1 = 283.2\ \mathrm{K}$ shows interpolation is needed.

$$T_a := 280\ \mathrm{K} \qquad T_b := 285\ \mathrm{K}$$

$$h_a := 280.13\ \frac{\mathrm{kJ}}{\mathrm{kg}} \qquad h_b := 285.14\ \frac{\mathrm{kJ}}{\mathrm{kg}}$$

$$h_1 := \frac{T_1 - T_a}{T_b - T_a} \cdot \left(h_b - h_a\right) + h_a = 283.3\ \frac{\mathrm{kJ}}{\mathrm{kg}}$$

The enthalpy at the outlet is then given by

$$h_2 := h_1 + \frac{V_1^{\ 2}}{2} = 303.3\ \frac{\mathrm{kJ}}{\mathrm{kg}}$$

Going to Table A-17 @ $h := h_2 = 303.3\ \frac{\mathrm{kJ}}{\mathrm{kg}}$ shows interpolation is needed.

$$h_a := 300.19\ \frac{\mathrm{kJ}}{\mathrm{kg}} \qquad h_b := 305.22\ \frac{\mathrm{kJ}}{\mathrm{kg}}$$

$$T_a := 300\ \mathrm{K} \qquad T_b := 305\ \mathrm{K}$$

$$\boxed{T_2 := \frac{h_2 - h_a}{h_b - h_a} \cdot \left(T_b - T_a\right) + T_a = 303.1\ \mathrm{K}} \qquad \boxed{T_2 = 29.9\ {}^{\circ}\mathrm{C}}$$