Given: $kJ := 1000J$

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.

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

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

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

Going to Table A-1 @ air shows

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

The density is then given by

$$\rho_1 := \frac{P_1}{R \cdot T_1} = 0.984\,\frac{kg}{m^3}$$

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

$$\frac{d}{dt}E_{sys} = \Sigma E'_{in} - \Sigma E'_{out}$$

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

$$0 = m'_{in} \cdot \left(h_{in} + \frac{V_{in}^{\ 2}}{2} \right) - m'_{out} \cdot \left(h_{out} + \frac{V_{out}^{\ 2}}{2} \right)$$ 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 $V_{out} << V_{in}$

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

Solution (cont.):

Going to Table A-17 @ $T_1 = 283.15K$ shows interpolation is needed.

$$T_a := 280K \qquad T_b := 285K$$

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

$$h_1 := \frac{T_1 - T_a}{T_b - T_a}\cdot\left(h_b - h_a\right) + h_a = 283.286\cdot\frac{kJ}{kg}$$

The enthalpy at the outlet is then given by

$$h_2 := h_1 + \frac{V_1^{\ 2}}{2} = 303.286\cdot\frac{kJ}{kg}$$

Going to Table A-17 @ $h_1 = 283.286\frac{kJ}{kg}$ shows interpolation is needed.

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

$$T_a := 300K \qquad T_b := 305K$$

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