**Given:** $kJ := 1000J$

Steam enters an adiabatic turbine at 5 MPa and 450°C and leaves at a pressure of 1.2 MPa.

**Required:**

Determine the work output of the turbine per unit mass of steam if the process is reversible.

**Solution:**

The inlet pressure and temperature are defined as

$$P_{in} := 5MPa \qquad T_{in} := 450\,°C = 723.15\,K$$

The outlet pressure is defined as

$$P_{out} := 1.2MPa$$

<u>1st Law</u> (for steady state, adiabatic device with no ΔKE and ΔPE)

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

$$0 = m' \cdot h_{in} - m' \cdot h_{out} - W'_{out}$$

Solving for the specific work out shows

$$w_{out} = h_{in} - h_{out}$$

Going to Table A-5 @ $P_{in} = 5000 \cdot kPa$ shows

$$T_{sat} := 263.94\,°C$$

Since $T_{in} > T_{sat}$ the state is superheated. Going to Table A-6 @ $P_{in} = 5 \cdot MPa$ & $T_{in} = 450 \cdot °C$ shows

$$h_{in} := 3317.2\,\frac{kJ}{kg} \qquad s_{in} := 6.8210\,\frac{kJ}{kg \cdot K}$$

Since the process is adiabatic and reversible, it is isentropic. Thus $\Delta s = 0$ and

$$s_{out} := s_{in} = 6.821 \cdot \frac{kJ}{kg \cdot K}$$

Going to Table A-5 @ $P_{out} = 1200 \cdot kPa$ shows

$$s_g := 6.5217\,\frac{kJ}{kg \cdot K}$$

**Solution (contd.):**

Since $s_{out} > s_g$ the state is superheated. Gong to Table A-6 @ $P_{out} = 1.2 \cdot \text{MPa}$ & $s_{out} = 6.821 \cdot \frac{\text{kJ}}{\text{kg} \cdot \text{K}}$ shows that interpolation is needed. This is shown below.

$$s_a := 6.5909 \frac{\text{kJ}}{\text{kg} \cdot \text{K}} \qquad s_b := 6.8313 \frac{\text{kJ}}{\text{kg} \cdot \text{K}}$$

$$h_a := 2816.1 \frac{\text{kJ}}{\text{kg}} \qquad h_b := 2935.6 \frac{\text{kJ}}{\text{kg}}$$

$$h_{out} := \frac{s_{out} - s_a}{s_b - s_a} \cdot \left(h_b - h_a\right) + h_a = 2930.5 \cdot \frac{\text{kJ}}{\text{kg}}$$

The specific work out of the device is then

$$\boxed{w_{out} := h_{in} - h_{out} = 386.72 \cdot \frac{\text{kJ}}{\text{kg}}}$$