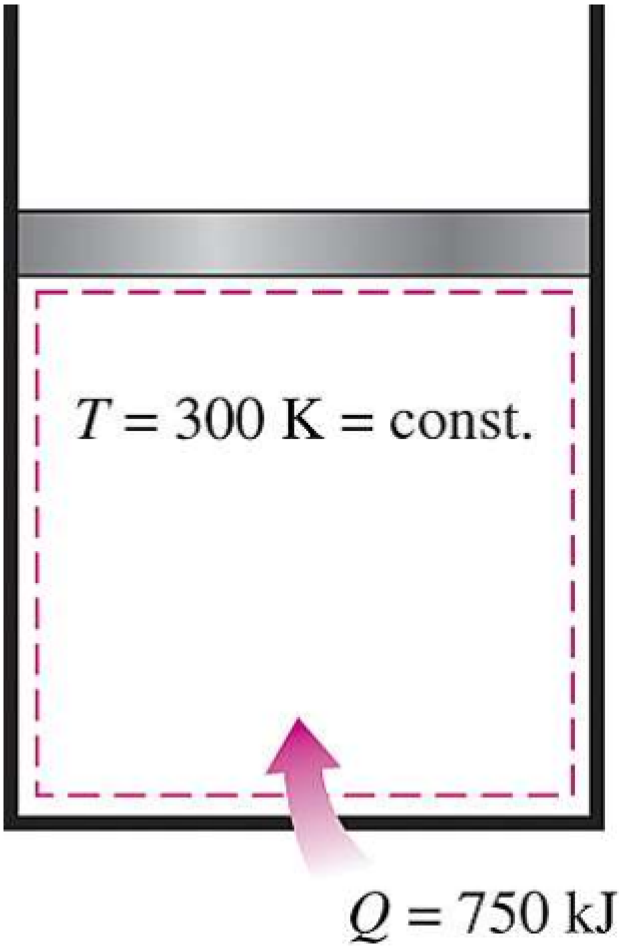
EX_7

EX 7.1

A piston–cylinder device contains a liquid–vapor mixture of water at $300\ K$. During a constant-pressure process, $750\ kJ$ of heat is transferred to the water. As a result, part of the liquid in the cylinder vaporizes. Determine the entropy change of the water during this process.

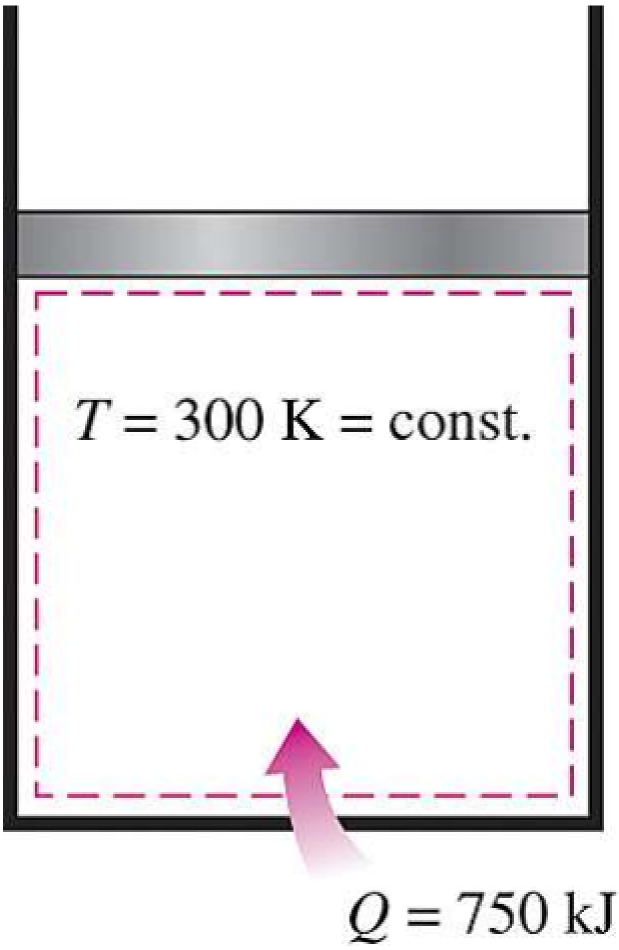


$$\Delta S_{sys} = \frac{Q}{T} = \frac{750}{300} = 2.5kJ/K$$

EX 7.2

A heat source at 800 K loses 2000 kJ of heat to a sink at (a) 500 K and (b) 750 K.

Determine which heat transfer process is more irreversible.



(a)

$$\Delta S_{source} = \frac{-Q}{T} = \frac{-2000}{800} = -2.5kJ/K$$

$$\Delta S_{sink} = \frac{Q}{T} = \frac{2000}{500} = 4kJ/K$$

$$\Delta S = \Delta S_{source} + \Delta S_{sink} = 1.5kJ/K$$

(b)

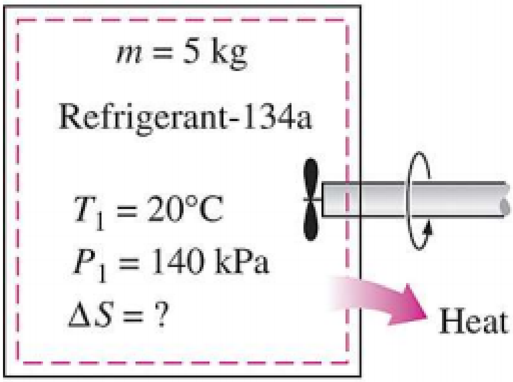
$$\Delta S_{source} = \frac{-Q}{T} = \frac{-2000}{800} = -2.5kJ/K$$

$$\Delta S_{sink} = \frac{Q}{T} = \frac{2000}{750} = 2.67kJ/K$$

$$\Delta S = \Delta S_{source} + \Delta S_{sink} = 0.17kJ/K$$

EX 7.3

A rigid tank contains $5\ kg$ of refrigerant-134a initially at $20^{\circ}C$ and $140\ kPa$. The refrigerant is now cooled while being stirred until its pressure drops to $100\ kPa$. Determine the entropy change of the refrigerant during this process.



according to the pressure table on the Table A-13 on p.919, got the data of the superheated refrigerant-134a

$$s_1 = 1.0625\ kJ/kg \cdot K$$

$$v_1 = 0.16544\ m^3/kg$$

$$v_f = 0.0007258\ m^3/kg$$

$$v_g = 0.19255\ m^3/kg$$

$$v_2 = x \cdot v_g + (1 - x)v_f$$

$$x = 0.8587$$

$$s_f = 0.07182\ kJ/kg \cdot K$$

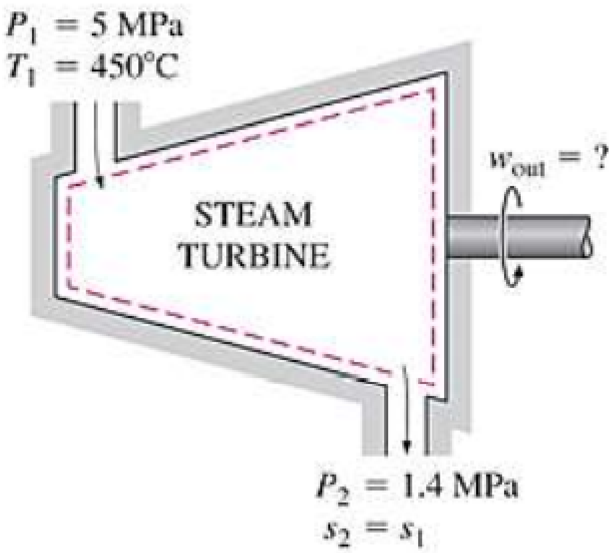
$$s_g = 0.95191\ kJ/kg \cdot K$$

$$s_2 = x \cdot s_g + (1 - x) \cdot s_f = 0.8276\ kJ/kg \cdot K$$

$$\Delta S = m \cdot (s_2 - s_1) = -1.1745 kJ/K$$

EX 7.4

Steam enters an adiabatic turbine at $5\ MPa$ and $450^\circ C$ and leaves at a pressure of $1.4\ MPa$. Determine the work output of the turbine per unit mass of steam if the process is reversible.



from the Table A-6 on p. 910, we can get the information of superheated water

$$h_1 = 3317.2kJ/kg$$

$$s_1 = 6.8210kJ/kg \cdot K$$

from the Table A-6 on p. 909, we can get the information of superheated water

$$s_1 = s_2$$

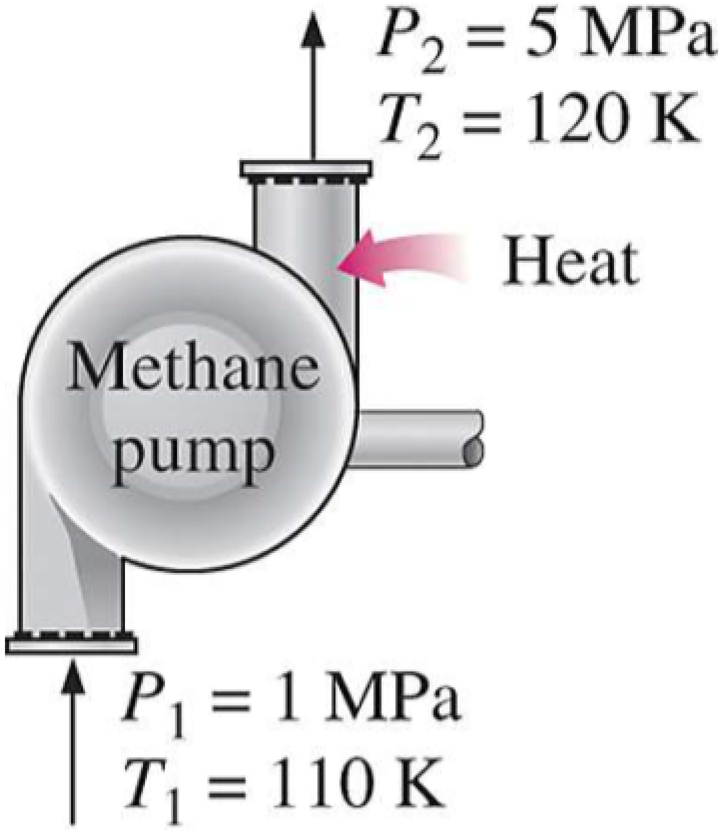
$$h_2 = 2967.4kJ/kg$$

$$w_{out} = h_1 - h_2 = 349.8kJ/kg$$

EX 7.5

Liquid methane is commonly used in various cryogenic applications. The critical temperature of methane is $191\ K$(or $-82°C$), and thus methane must be maintained below $191\ K$ to keep it in liquid phase. The properties of liquid methane at various temperatures and pressures are given in Table 7-1.

Determine the entropy change of liquid methane as it undergoes a process from $110\ K$ and $1\ MPa$ (a) using tabulated properties and (b) approximating liquid methane as an incompressible in the latter case



(a)

from the Table 7-1 on p. 350, we can get the data of the compressed liquid water

$$s_1 = 4.875kJ/kg \cdot K$$

$$s_2 = 5.145kJ/kg \cdot K$$

$$\Delta s = s_2 - s_1 = 0.270kJ/kg \cdot K$$

(b)

$$c_{p1} = 3.471 kJ/kg \cdot K$$

$$c_{p2} = 3.486 kJ/kg \cdot K$$

$$c_{avg} = \frac{c_{p1} + c_{p2}}{2} = 3.479 kJ/kg \cdot K$$

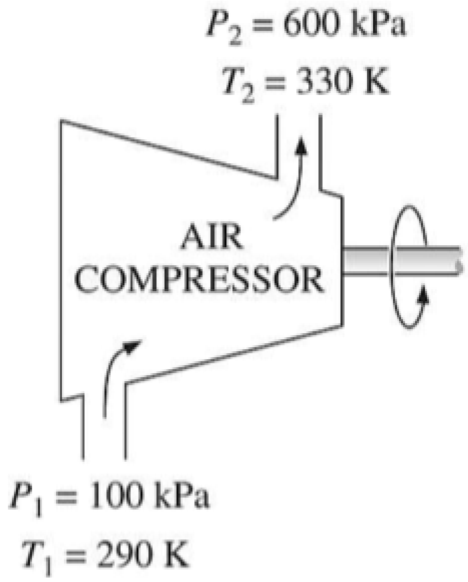
$$\Delta s = c_{avg} \ln(\frac{T_2}{T_1}) = 0.303 kJ/kg \cdot K$$

$$error = \frac{|\Delta s_2 - \Delta s_1|}{\Delta s_1} = 12.22\%$$

EX 7.6

Air is compressed from an initial state of $100\ kPa$ and $17^{\circ}C$ to a final state of $600\ kPa$ and $57^{\circ}C$.

Determine the entropy change of air during this compression process by using (a) property values from the air table and (b) average specific heats.



(a)

$$\Delta s = s_2 - s_1 = s_2^0 - s_1^0 - R \ln \frac{P_2}{P_1}$$

$$= 1.79783 kJ/kg \cdot K - 1.66802 kJ/kg \cdot K - 0.2870 \times \ln \frac{600}{100}$$

$$= -0.3844 kJ/kg \cdot K$$

(b)

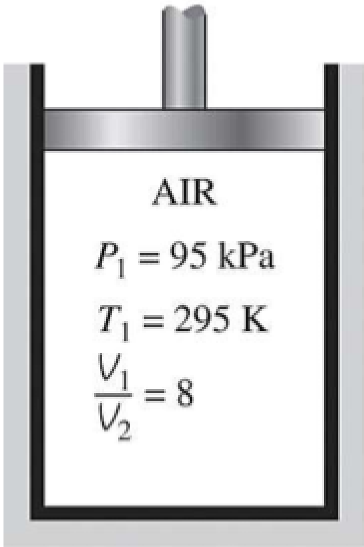
$$\Delta s = s_2 - s_1 = c_{p,avg} \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}$$

$$= 1.0056 \times \ln \frac{330}{290} - 0.2870 \times \ln \frac{600}{100}$$

$$= -0.3843 kJ/kg \cdot K$$

EX 7.7

Air is compressed in as car engine from $22^{\circ}C$ and $95\ kPa$ in a reversible and adiabatic manner. If the compression ratio V_1/V_2 of this engine is 8, determine the final temperature of the air.



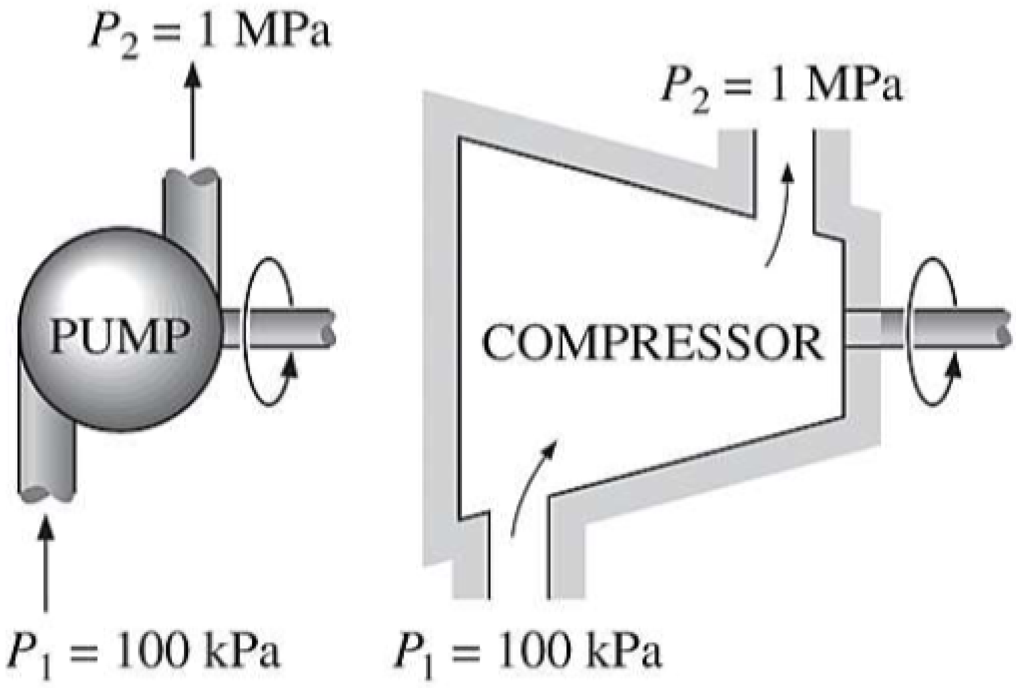
$$\frac{V_1}{V_2} = \frac{v_{r1}}{v_{r2}}$$

$$v_{r2} = \left(\frac{V_2}{V_1}\right) v_{r1} = \frac{1}{8} \times 647.9 = 80.9875$$

where the temperature is $662.75\ K$

EX 7.8

Determine the compressor work input required to compress steam isentropically from 100 kPa to 1 MPa, assuming that the steam exists as (a) saturated liquid and (b) saturated vapor at the inlet state.



(*a*) Compressing a liquid

(*b*) Compressing a vapor

(a)

from the table A-5, got the data of the specific volume of the saturated water

$$w = \int v_f \mathrm{d}P = 0.001043 \times (1000 - 100)$$

$$= 0.94kJ/kg$$

(b)

since the specific volume of the vapor would change hugely during compressing

$$w = h_2 - h_1$$

$$s_1 = 7.3589$$

$$h_1 = 2675.0kJ/kg$$

$$s_2 = s_1$$

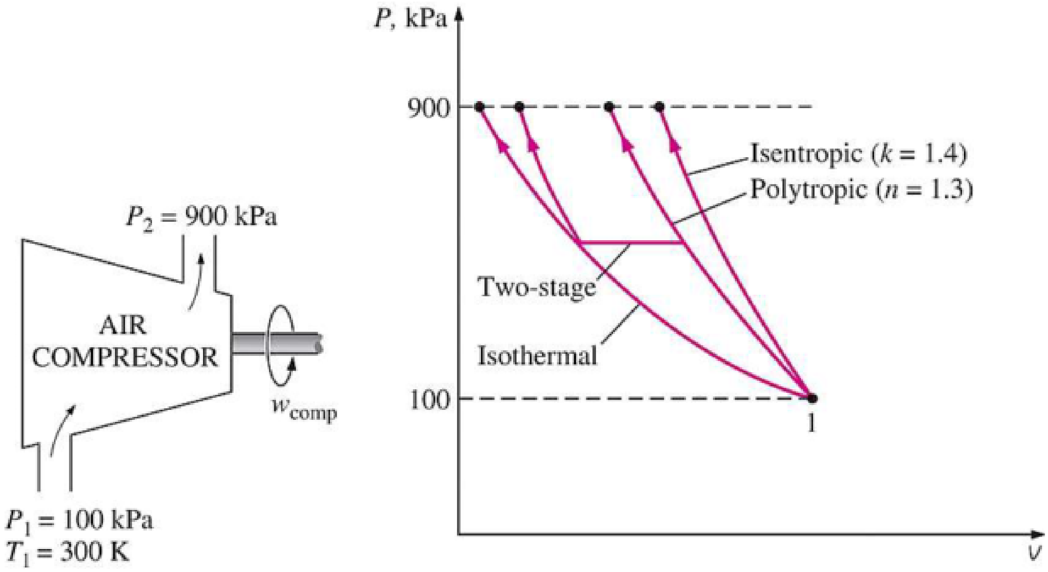
$$h_2 = 3194.5kJ/kg$$

$$w = 519.5kJ/kg$$

EX 7.9

Air is compressed steadily by a reversible compressor from an inlet state of 100 kPa and 300 K to an exit pressure of 900 kPa.

Determine the compressor work per unit mass for (a) isentropic compression with k =1.4, (b) polytropic compression with n =1.3, (c) isothermal compression, and (d) ideal two-stage compression with intercooling with a polytropic exponent of 1.3.



(a) and (b)

$$W_1 = \frac{kRT_1}{k-1}\left[\left(\frac{P_2}{P_1}\right)^{(k-1)/k} - 1\right]$$

$$= 263.21kJ/kg$$

$$W_2 = \frac{nRT_1}{n-1}\left[\left(\frac{P_2}{P_1}\right)^{(n-1)/n} - 1\right]$$

$$= 246.4kJ/kg$$

(c)

$$W_3 = RT\ln\frac{P_2}{P_1}$$

$$= 189.18kJ/kg$$

(d)

$$P_x = \sqrt{P_1P_2} = 300kPa$$

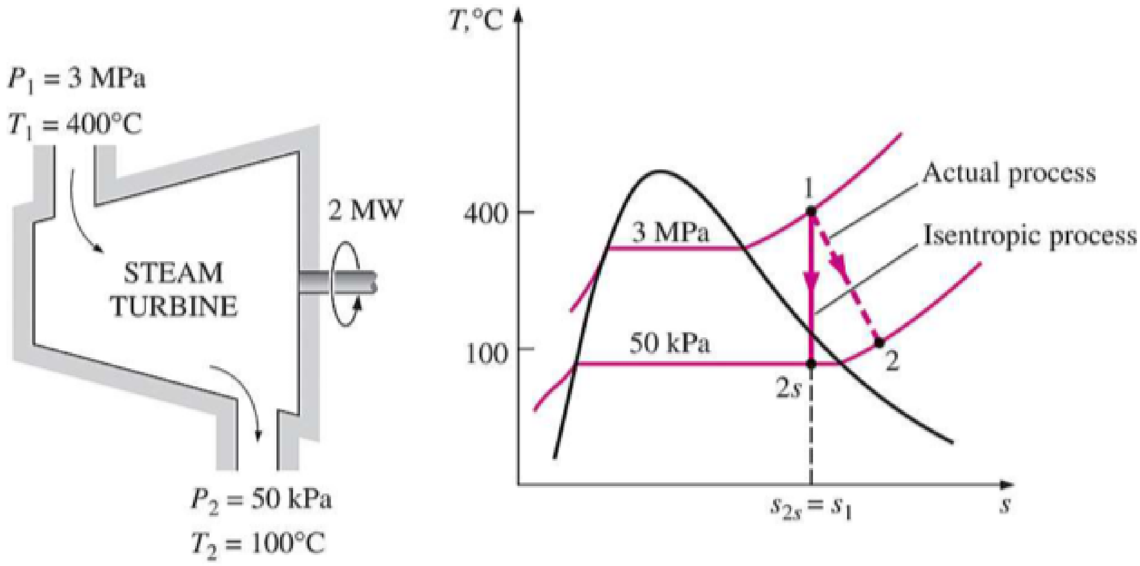
$$W_4 = 2\frac{nRT_1}{n-1}\left[\left(\frac{P_x}{P_1}\right)^{(n-1)/n} - 1\right]$$

$$= 215.3kJ/kg$$

EX 7.10

Steam enters an adiabatic turbine steadily at 3 MPa and 400°C and leaves at 50 kPa and 100°C. If the power output of the turbine is 2 MW.

Determine (a) the isentropic efficiency of the turbine and (b) the mass flow rate of the steam flowing through the turbine.



(a)

$$h_1 = 3231.7kJ/kg$$

$$s_1 = 6.9235kJ/kg$$

$$h_{2s} = 2407.85kJ/kg$$

$$h_{2a} = 2682.4kJ/kg$$

$$\eta = \frac{h_1 - h_{2a}}{h_1 - h_{2s}} = 66.8\%$$

(b)

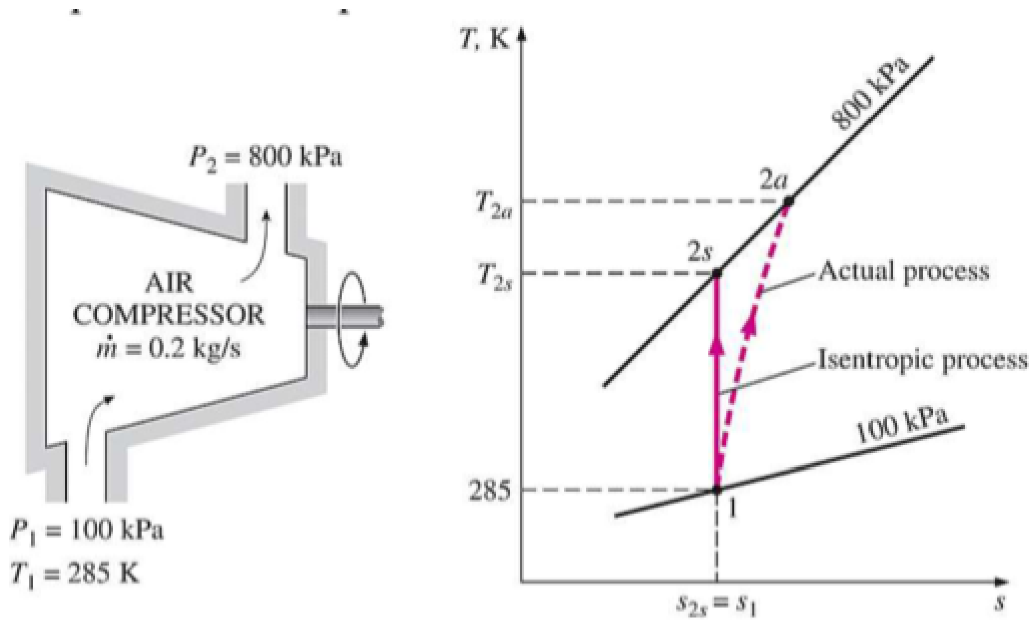
$$\dot{W} = \dot{m}(h_1 - h_{2a})$$

$$\dot{m} = 3.64kg/s$$

EX 7.11

Air is compressed by an adiabatic compressor from $100\ kPa$ and $12°C$ to a pressure of $800\ kPa$ at a steady rate of $0.2\ kg/s$.

If the isentropic efficiency of the compressor is 80 percent, determine (a) the exit temperature of air and (b) the required power input to the compressor.



(a)

$$h_1 = 285.14kJ/kg$$

$$P_{r1} = 1.1584$$

$$\frac{P_{r1}}{P_{r2}} = \frac{P_1}{P_2}$$

$$P_{r2} = 9.2672$$

$$h_{2s} = 517.05kJ/kg$$

$$\eta = \frac{h_{2s} - h_1}{h_{2a} - h_1} = 0.8$$

$$h_{2a} = 575.03kJ/kg \longrightarrow T_{2a} = 569.5K$$

(b)

$$\dot{W} = \dot{m}(h_{2a} - h_1) = 58.0kW$$