Problem 3

Given: -Air enters an insulated compressor operating at steady state at 0.95 bar, 27°C, and exits at 8.7 bar
- $\Delta KE = \Delta PE = 0$
- Mass flow rate = 4000 kg/hr

Determine: (a) Minimum Theoretical power input and exit temperature
(b) If the exit temperature is 347°C, the power input and the isentropic efficiency

(a) $(\dot{W}_{cv})_{min} = \dot{m}(h_1 - h_{2s})$

Table A-22 @ $T_1 = 300\,K$, $h_1 = 300.19\ kJ/kg$
$s^\circ(T_1) = 1.70203\ kJ/kg \cdot K$

$s_{2s} = s_1$ (0)

$s_{2s} - s_1 = s^\circ(T_{2s}) - s^\circ(T_1) - R\ln\left(\frac{P_2}{P_1}\right)$

$0 = s^\circ(T_{2s}) - 1.70203\ kJ/kg\cdot K - \left(\frac{8.314}{28.97}\right)\ln\left(\frac{8.7\ bar}{0.95\ bar}\right)$

$s^\circ(T_{2s}) = 2.3376\ kJ/kg \cdot K$

Table A-22: Interpolating with $s^\circ(T_{2s}) = 2.3376\ kJ/kg\cdot K$

$$\boxed{T_{2s} = 560.4\ K = 287.4^\circ C}$$

$$\boxed{h_{2s} = 565.59\ kJ/kg}$$

$$(\dot{W}_{cv})_{min} = (4000\ kg/hr)\left(\frac{1\ hr}{3600\ sec}\right)(300.19\ kJ/kg - 565.59\ kJ/kg)$$

$$\boxed{(\dot{W}_{cv})_{min} = -294.9\ kW}$$

(b) $T_2 = 620\ K$ Table A-22, $h_2 = 628.07\ kJ/kg$

$$\dot{W}_{cv} = \dot{m}(h_1 - h_2) = (4000\ kg/hr)\left(\frac{1\ hr}{3600\ sec}\right)(300.19\ kJ/kg - 628.07\ kJ/kg)$$

$$\boxed{\dot{W}_{cv} = -364.3\ kW}$$

$$\eta_c = \frac{294.9\ kW}{364.3\ kW} = 0.809 = \boxed{80.9\%}$$