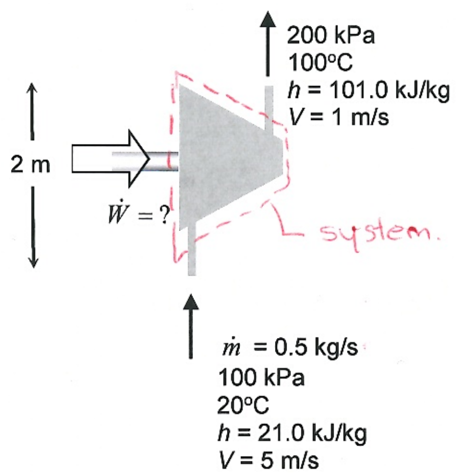
Example

0.5 kg/s of air flows steadily through a compressor. The air enters and exits the compressor at the states shown in the figure. If the compression is **adiabatic** (buzza buzza buzz) calculate the power input to the compressor.



CoE → Steady state

$$\frac{d}{dt}(\cancel{E_{sys}})^{0} = \cancel{\dot{Q}_{IN}}^{0\ \text{ADIABATIC}} + \dot{W}_{IN} + \sum_{IN} \dot{m}\left(h + \frac{V^2}{2} + gz\right) - \sum_{OUT} \dot{m}\left(h + \frac{V^2}{2} + gz\right)$$

Set to 0.

$$0 = \dot{W}_{IN} + \dot{m}\left(h_1 + \frac{V_1^2}{2} + g\cancel{z_1}\right) - \dot{m}\left(h_2 + \frac{V_2^2}{2} + gz_2\right)$$

$$\dot{W}_{IN} = \dot{m}\left(h_2 - h_1 + \frac{V_2^2 - V_1^2}{2} + g(z_2 - \cancel{z_1}^{0})\right)$$

$$= 0.5\frac{kg}{s}\left[(101.0 - 21.0)\frac{kJ}{kg} + \frac{1^2 - 5^2}{2}\frac{m^2}{s^2}\left\langle\frac{J/kg}{m^2/s^2}\right\rangle\left\langle\frac{kJ}{1000\,J}\right\rangle + 9.81\frac{m}{s^2}\cdot[2\,m]\left\langle\frac{J/kg}{m^2/s^2}\right\rangle\left\langle\frac{kJ}{1000\,J}\right\rangle\right]$$

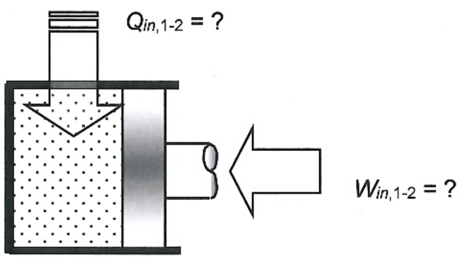
$$= \left(0.5\frac{kg}{s}\right)\left(80\frac{kJ}{kg} \underbrace{- 0.012\frac{kJ}{kg} + 0.0197\frac{kJ}{kg}}_{\text{Notice these are orders of magnitude smaller.}}\right)$$

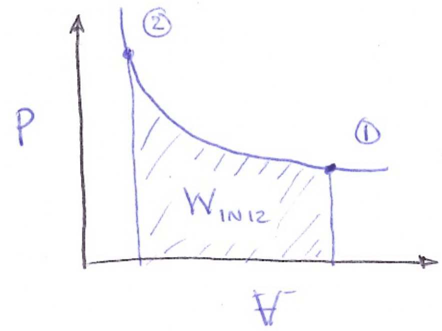
$$= \boxed{40.0\ kW}$$

Example

0.3 kg of air is contained in a piston-cylinder assembly. Initially, the air is at 200 kPa and 20°C with a volume of $\forall_1$ = 0.126 m³. The air is then compressed in a process for which $p\forall^2$= constant until the pressure is 500 kPa.

a) Sketch the p-$\forall$ diagram and calculate the work (in kJ) into the piston cylinder.
b) If the change in *specific* internal energy during the process is 121.0 kJ/kg, calculate the heat transfer (in kJ) into the piston cylinder during the process.





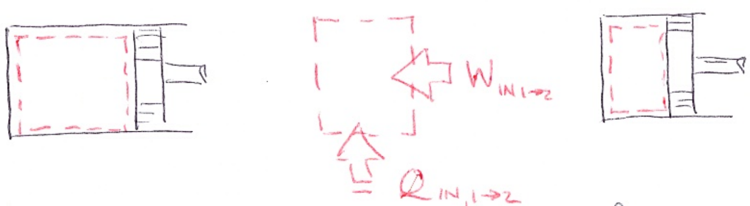
(a) $$W_{IN\,12} = -\int_1^2 p\,d\forall = -\int_1^2 \frac{CONST}{\forall^2}\,d\forall$$

$$= -CONST\int_1^2 \frac{1}{\forall^2}\,d\forall = -CONST\left[-\forall^{-1}\right]_1^2 = CONST\left[\frac{1}{\forall_2} - \frac{1}{\forall_1}\right]$$

$$= P_1\forall_1^2\left[\frac{1}{\forall_2} - \frac{1}{\forall_1}\right] = P_1\forall_1\left[\frac{\forall_1}{\forall_2} - 1\right] = P_1\forall_1\left[\left(\frac{P_2}{P_1}\right)^{1/2} - 1\right]$$

$$= (200\text{ kPa})(0.126\text{ m}^3)\left[\left(\frac{500}{200}\right)^{1/2} - 1\right] = \boxed{14.6\text{ kJ}}$$

(b)



Cons. of energy, closed system, finite time

$$E_2 - E_1 = Q_{IN,1\to2} + W_{IN,1\to2}$$

Only internal energy is important:

$$U_2 - U_1 = Q_{IN,1\to2} + W_{IN,1\to2}$$

$$m(u_2 - u_1) = Q_{IN,1\to2} + W_{IN\,1\to2}$$

$$Q_{IN,1\to2} = m(u_2-u_1) - W_{IN\,1\to2} = (0.3\text{kg})(121.0\tfrac{\text{kJ}}{\text{kg}}) - 14.6\text{kJ} = \boxed{21.8\text{ kJ}}$$