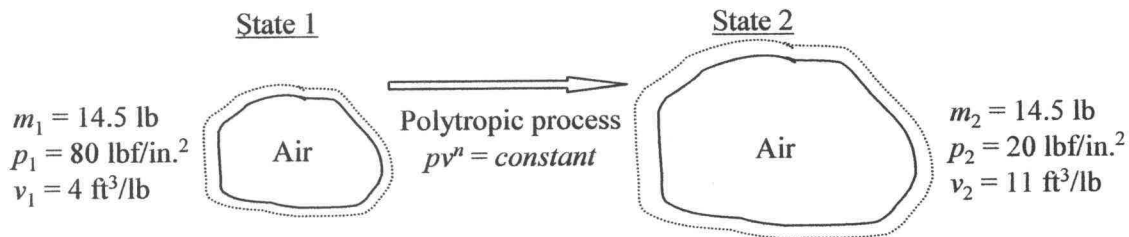


## PROBLEM 2.30

**KNOWN:** Air undergoes a polytropic process between two specified states.

**FIND:** Determine the work.

**SCHEMATIC AND GIVEN DATA:**



**ENGINEERING MODEL:**

1. The air is a closed system.
2. The system undergoes a polytropic process.

**ANALYSIS:**

The pressure-volume relationship for a polytropic process is

$$pV^n = \text{constant}$$

or

$$pv^n = \text{constant}$$

Thus

$$p_1 v_1^n = p_2 v_2^n$$

Solving for  $n$  yields

$$n = \frac{\ln\left(\frac{p_1}{p_2}\right)}{\ln\left(\frac{v_2}{v_1}\right)} = \frac{\ln\left(\frac{80 \frac{\text{lbf}}{\text{in.}^2}}{20 \frac{\text{lbf}}{\text{in.}^2}}\right)}{\ln\left(\frac{11 \frac{\text{ft}^3}{\text{lb}}}{4 \frac{\text{ft}^3}{\text{lb}}}\right)} = 1.37$$

To solve for work

$$W = \int_{V_1}^{V_2} p dV = m \int_{v_1}^{v_2} p dv = m \int_{v_1}^{v_2} \frac{(\text{constant}) dv}{v^n}$$

$$W = m \frac{(\text{constant}) v_2^{1-n} - (\text{constant}) v_1^{1-n}}{1-n} = m \frac{(p_2 v_2^n) v_2^{1-n} - (p_1 v_1^n) v_1^{1-n}}{1-n} = m \frac{p_2 v_2 - p_1 v_1}{1-n}$$

$$W = (14.5 \text{ lb}) \frac{\left(20 \frac{\text{lbf}}{\text{in.}^2}\right) \left(11 \frac{\text{ft}^3}{\text{lb}}\right) - \left(80 \frac{\text{lbf}}{\text{in.}^2}\right) \left(4 \frac{\text{ft}^3}{\text{lb}}\right)}{1-1.37} \left| \frac{144 \text{ in.}^2}{1 \text{ ft}^2} \right| \left| \frac{1 \text{ Btu}}{778 \text{ ft} \cdot \text{lbf}} \right| = \underline{\underline{725.4 \text{ Btu}}}$$

The positive sign for work denotes energy transfer out of the system.