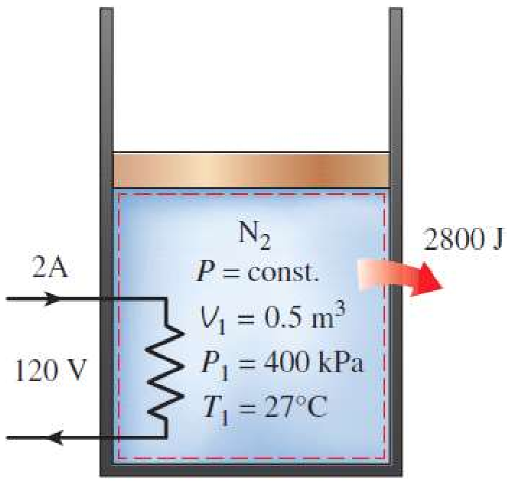
Given: $kJ := 1000J$

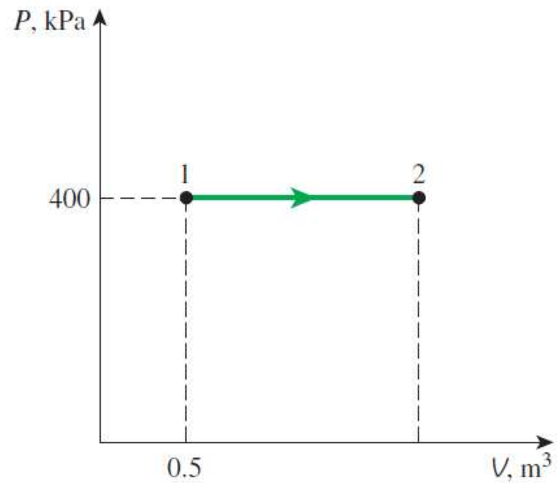
A piston cylinder device initially contains 0.5 m^3 of nitrogen gas at 400 kPa and 27°C. An electric heater with the device used 2 A of current from a 120 V source for 5 minutes. As the nitrogen expands, a heat lost of 2800 J occurs during the process.

$V_1 := 0.5m^3$ $\quad I_s := 2A$ $\quad Q_{loss} := 2800J$

$P_1 := 400kPa$ $\quad V_s := 120V$

$T_1 := 27\,°C$ $\quad \Delta t := 5min$





Required:

Determine the final temperature.

Solution:

Starting with the first law

$$\Delta E_{sys} = \Sigma E_{in} - \Sigma E_{out}$$

Assuming no changes in kinectic and potential energy, the first law becomes

$$\Delta U = W_h - Q_{loss} - W_b$$

Rearranging shows

$$\Delta U + W_b = W_h - Q_{loss}$$

$$\Delta H = W_h - Q_{loss}$$

$$m \cdot (h_2 - h_1) = W_h - Q_{loss}$$

Assuming that the c_p value remains constant over the temperature range of this process the first law is

$$m \cdot c_p \cdot (T_2 - T_1) = W_h - Q_{loss}$$

Solution (cont.):

Rearranging to solve for the final temperature yields

$$T_2 = \frac{W_h - Q_{loss}}{m \cdot c_p} + T_1$$

The work done by the heater is simply the product of the current, voltage, and time which is

$$W_h := V_s \cdot I_s \cdot \Delta t = 72 \cdot kJ$$

Assuming the nitrogen behaves as an ideal gas, the mass in the cylinder may be found by using the ideal gas law. Going to Table A-2(a) @ nitrogen,

$$R := 0.2968 \frac{kJ}{kg \cdot K} \qquad c_p := 1.039 \frac{kJ}{kg \cdot K}$$

The mass is then found by

$$PV = m \cdot R \cdot T \qquad \text{or} \qquad m := \frac{P_1 \cdot V_1}{R \cdot T_1} = 2.245\,kg$$

The final temperature is then

$$\boxed{T_2 := \frac{W_h - Q_{loss}}{m \cdot c_p} + T_1 = 329.8\,K} \qquad \boxed{T_2 = 56.7 \cdot °C}$$