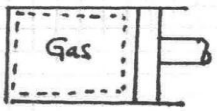
PROBLEM 2.60

KNOWN: A gas contained in a piston-cylinder assembly undergoes two processes, A and B, between the same end states. State data are provided.

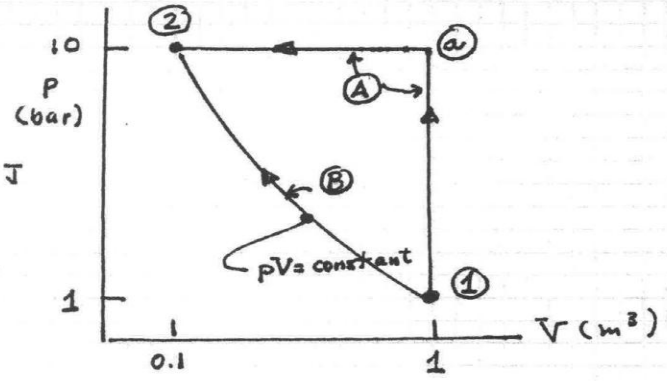
FIND: For each process, sketch it on p-V coordinates and evaluate the work and heat transfer, each in kJ.

SCHEMATIC & GIVEN DATA:



$P_1 = 1$ bar, $V_1 = 1\ m^3$, $U_1 = 400$ kJ

$P_2 = 10$ bar, $V_2 = 0.1\ m^3$, $U_2 = 450$ kJ



ENGINEERING MODEL:

1. The gas is the closed system.
2. Volume change is the only work mode.
3. Kinetic and potential energy effects are ignored.

ANALYSIS: Reducing an energy balance for the gas: $\Delta U + \cancel{\Delta KE} + \cancel{\Delta PE} = Q - W$

$$\Rightarrow \quad Q = \Delta U + W = (450 - 400)\,kJ + W$$

$$\Rightarrow \quad Q = 50\,kJ + W \qquad (1)$$

Eq. (1) applies to each of the processes, A and B.

Evaluating work from Eq. 2.17, $W = \int_1^2 p\,dV$.

Process A:

$$W_A = \cancel{W_{1a}}^{0} + W_{a2} = P_2[V_2 - V_1]$$

$$= \left(10 \times 10^5 \frac{N}{m^2}\right)(0.1 - 1)\,m^3 \left| \frac{1\,kJ}{10^3\,N \cdot m} \right| = -900\,kJ \leftarrow$$

Then, with Eq. (1)

$$Q_A = 50\,kJ + (-900\,kJ) = -850\,kJ \leftarrow$$

Process B:

$$W_B = \int_1^2 p\,dV = \int_1^2 \frac{C}{V}\,dV = C \ln \frac{V_2}{V_1} = P_1 V_1 \ln \frac{V_2}{V_1}$$

$$= \left(10^5 \frac{N}{m^2}\right)(1\,m^3) \ln\left[\frac{0.1}{1.0}\right] \left| \frac{1\,kJ}{10^3\,N \cdot m} \right| = -230.3\,kJ \leftarrow$$

Then, with Eq. (1)

$$Q_B = 50\,kJ + (-230.3\,kJ) = -180.3\,kJ \leftarrow$$