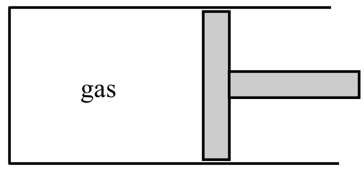
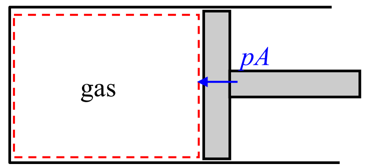
Four kilograms of a certain gas is contained within a piston-cylinder assembly. The gas undergoes a polytropic process where: $pV^{1.5}$=constant. The initial pressure is 3 bars (abs), the initial volume is 0.1 m^3, and the final volume is 0.2 m^3. The change in the specific internal energy of the gas in the process is Δu = -4.5 kJ/kg. There are no significant changes in the kinetic or potential energies of the gas. What is the net heat transfer for the process?



SOLUTION:
Apply the First Law to the system of gas as shown in the figure below,



$$\Delta E_{sys} = Q_{\substack{\text{added}\\ \text{to sys}}} + W_{\text{on sys}}, \tag{1}$$

where,

$$W_{on\ sys} = \int_{V=V_1}^{V=V_2} -p dV = \int_{V=V_1}^{V=V_2} -(cV^{-1.5}) dV = 2c\left(V^{-0.5}\right)_{V_1}^{V_2} = 2\underbrace{p_1 V_1^{1.5}}_{=c}\left(V_2^{-0.5} - V_1^{-0.5}\right), \tag{2}$$

and,

$$\Delta E_{sys} = m_{sys}\Delta e_{sys} = m_{sys}\Delta u_{sys}. \quad \text{(The kinetic and potential energy changes are negligible.)} \tag{2}$$

Re-arranging Eq. (1) and substituting Eqs. (2) and (3) gives,

$$\boxed{Q_{\substack{added\\ to\ sys}} = m_{sys}\Delta u_{sys} - 2p_1 V_1^{1.5}\left(V_2^{-0.5} - V_1^{-0.5}\right)}. \tag{3}$$

Using the given values:

m_{sys} = 4 kg
Δu_{sys} = -4500 J/kg
p_1 = $3*10^5$ Pa
V_1 = 0.1 m^3
V_2 = 0.2 m^3
$\Rightarrow$ $\boxed{Q_{added} = -0.426 \text{ kJ}}$ (heat is leaving the system)