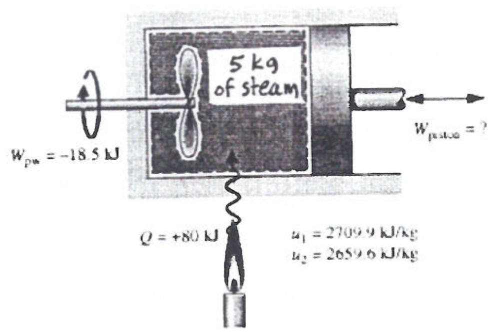
PROBLEM 2.56

KNOWN: Five kg of steam undergo an expansion in a piston-cylinder assembly from state 1 to state 2. During the process there is a known heat transfer to the steam and a known work transfer of energy to the steam by a paddle wheel. The change in specific internal energy of the steam is also known.

FIND: Determine the amount of energy transfer by work from the steam to the piston during the process.

SCHEMATIC & GIVEN DATA:



ENGR. MODEL: 1. The steam is the closed system. 2. There is no change in the kinetic or potential energy from state 1 to state 2.

ANALYSIS: The net work can be determined from an energy balance. That is, with assumption 2

$$\Delta KE^{0} + \Delta PE^{0} + \Delta U = Q - W$$

or

$$W = Q - \Delta U$$

The net work is the sum of the work associated with the paddle wheel W_{pw} and the work done on the piston W_{piston}:

$$W = W_{pw} + W_{piston}$$

From the given information $W_{pw} = -18.5\ kJ$, where the minus sign is required because the paddle wheel transfers energy to the system. Collecting results

$$W_{pw} + W_{piston} = Q - \Delta U$$

or

$$W_{piston} = Q - \Delta U - W_{pw}$$

$$= Q - m(u_2 - u_1) - W_{pw}$$

$$= 80\ kJ - 5\ kg\ (2659.6 - 2709.9)\frac{kJ}{kg} - (-18.5\ kJ)$$

$$= +350\ kJ \leftarrow W_{piston}$$

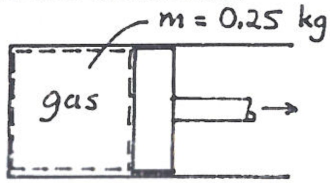
where the positive sign indicates that energy is transferred from the steam to the piston as the steam expands during the process.

PROBLEM 2.63

KNOWN: A gas of known mass expands in a piston-cylinder from a specified initial state to a known final pressure. The pressure-volume for the process is given. Also, the specific internal energy change is known.

FIND: Determine the heat transfer for the process.

SCHEMATIC & GIVEN DATA:



$p_1 = 8$ bar, $V_1 = 0.02$ m^3
$p_2 = 2$ bar
$pV^{1.2} = \text{constant}$
$\Delta u = -55$ kJ/kg

ENGR. MODEL: (1) The gas is a closed system. (2) Kinetic and potential energy effects are negligible. (3) The process is described by $pV^{1.2} = \text{constant}$. (4) Volume change is the only work mode.

ANALYSIS: The heat transfer can be found using an energy balance. First, find the work using Eq. 2.17, as follows:

$$W = \int_{V_1}^{V_2} p\,dV = \int_{V_1}^{V_2} \frac{\text{const.}}{V^{1.2}}\,dV$$

Integrating and simplifying (see Example 2.1 for details),

$$W = \frac{p_2V_2 - p_1V_1}{(1-1.2)}$$

The volume at the final state is $V_2 = (p_1/p_2)^{1/1.2} V_1 = 0.0635$ m^3. Thus

$$W = \frac{(2\text{ bar})(0.0635\text{ m}^3) - (8)(0.02)}{(1-1.2)} \left|\frac{10^5\text{ N/m}^2}{1\text{ bar}}\right| \left|\frac{1\text{ kJ}}{10^3\text{ N}\cdot\text{m}}\right|$$

$$= 16.5\text{ kJ}$$

Now, to get the heat transfer, begin with the energy balance

$$\Delta KE^{\,0} + \Delta PE^{\,0} + \Delta U = Q - W$$

Solving for Q and noting that $\Delta U = m\Delta u$

$$Q = m\Delta u + W$$

$$= (0.25\text{ kg})(-55\text{ kJ/kg}) + (16.5\text{ kJ})$$

① $= 2.75$ kJ ← Q

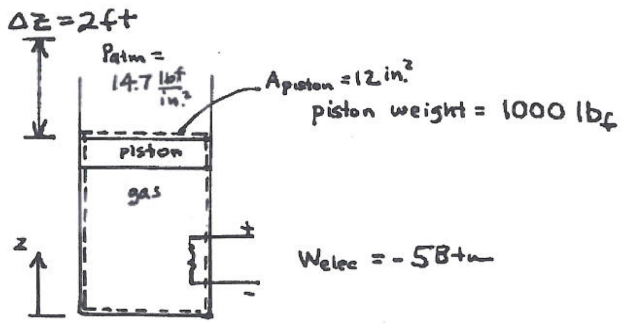
1. The heat transfer is positive, denoting energy transfer by heat to the gas as it expands.

PROBLEM 2.70

KNOWN: An electrical resistor transfers energy to a gas contained in a vertical piston-cylinder assembly.

FIND: Determine the change in internal energy of the gas

SCHEMATIC & GIVEN DATA:



ENGR. MODEL: 1. The system is the piston *plus* the gas. 2. For the piston, $\Delta U = 0$, $\Delta KE = 0$. For the gas, $\Delta PE = 0$, $\Delta KE = 0$. 3. For the system, $Q = 0$. 4. Friction between piston and cylinder can be ignored. (5) The mass of the electrical resistor is negligible. So $\Delta U = 0$ for the resistor.

ANALYSIS: An energy balance for the system reads

$$\cancel{\Delta KE}^{0} + [(\Delta PE)_{piston} + \cancel{(\Delta PE)_{gas}}^{0}] + [\cancel{(\Delta U)_{piston}}^{0} + (\Delta U)_{gas} + \cancel{(\Delta U)_{resistor}}^{0}] = \cancel{Q}^{0} - W$$

or

$$(\Delta PE)_{piston} + (\Delta U)_{gas} = -W$$

For the piston

$$(\Delta PE)_{piston} = mg(z_2 - z_1)$$

For the system consisting of freely-moving piston (assumption 4) and gas, the net work is the sum of the electrical work and the work done at the top of the piston in displacing the surrounding atmosphere:

$$W = W_{elect} + \int_{z_1}^{z_2} (P_{atm} A_{piston})dz \Rightarrow W = W_{elect} + (P_{atm} A_{piston})(z_2 - z_1)$$

Collecting results

$$mg(z_2 - z_1) + (\Delta U)_{gas} = -[W_{elect} + (P_{atm} A_{piston})(z_2 - z_1)]$$

Thus

$$(\Delta U)_{gas} = -W_{elec} - P_{atm} A_{piston}(z_2 - z_1) - mg(z_2 - z_1)$$

$$= -(-5\ Btu) - (14.7\ \tfrac{lbf}{in^2})(12\ in^2)(2\ ft)\left|\frac{1\ Btu}{778\ ft\cdot lbf}\right| - (1000\ lbf)(2\ ft)\left|\frac{1\ Btu}{778\ ft\cdot lbf}\right|$$

$$= 1.98\ Btu \longleftarrow \Delta U$$