PROBLEM 2.34

KNOWN: Air within a piston-cylinder assembly undergoes three processes in series.

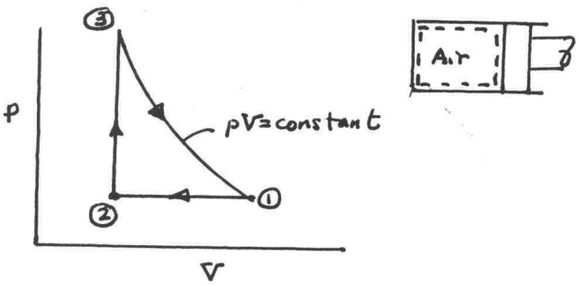
FIND: Sketch the processes in series on p-V coordinates, evaluate volume at state 2, and evaluate the work for each process.

SCHEMATIC & GIVEN DATA

Process 1–2: Compression at constant pressure from $p_1 = 10$ lbf/in^2, $V_1 = 4$ ft^3 to state 2.

Process 2–3: Constant-volume heating to state 3, where $p_3 = 50$ lbf/in^2.

Process 3–1: Expansion to the initial state, during which the pressure-volume relationship is $pV = constant$.



ENGR. MODEL:

1. The air is the closed system. 2. Each of the three processes is specified. 3. Volume change is the only work mode.

ANALYSIS: Since volume change is the work mode, Eq. 2.17 applies.

Process 1-2: $W_{12} = \int_{V_1}^{V_2} p\,dV = p[V_2 - V_1]$. Volume V_2 is needed.

Note that $V_2 = V_3$ and $P_1 V_1 = P_3 V_3 \Rightarrow V_3 = (P_1/P_3)V_1 = \left(\frac{10\ \text{lbf/in}^2}{50\ \text{lbf/in}^2}\right)(4\ \text{ft}^3) = 0.8\ \text{ft}^3$ ←

Thus, $W_{12} = 10\ \frac{\text{lbf}}{\text{in}^2}\left[0.8\ \text{ft}^3 - 4\ \text{ft}^3\right]\left|\frac{144\ \text{in}^2}{1\ \text{ft}^2}\right|\left|\frac{1\ \text{Btu}}{778\ \text{ft}\cdot\text{lbf}}\right| = -5.92\ \text{Btu}$ ←

Process 2-3. The piston does not move (V = constant). Thus, $W_{23} = 0$. ←

Process 3-1. $W_{31} = \int_{V_3}^{V_1} p\,dV = \int_{V_3}^{V_1} \frac{C}{V}\,dV = C \ln\left(\frac{V_1}{V_3}\right) = P_1 V_1 \ln\left(\frac{V_1}{V_3}\right)$

$= \left(10\ \frac{\text{lbf}}{\text{in}^2}\right)(4\ \text{ft}^3)\ln\left(\frac{4\ \text{ft}^3}{0.8\ \text{ft}^3}\right)\left|\frac{144\ \text{in}^2}{1\ \text{ft}^2}\right|\left|\frac{1\ \text{Btu}}{778\ \text{ft}\cdot\text{lbf}}\right|$

$= +11.92\ \text{Btu}$ ←

PROBLEM 2.35

KNOWN: Operating data is provided for a belt sander.

FIND: Evaluate the power transmitted by the belt to the surface and work done in one minute of sanding.

SCHEMATIC & GIVEN DATA:

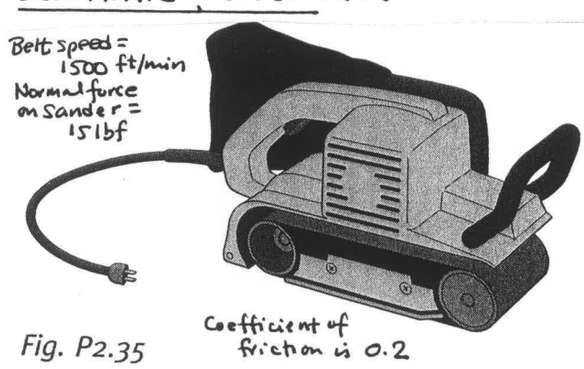


Fig. P2.35

ENGR. MODEL

1. The force exerted by the belt is related to the normal force, F_N, by the coefficient of friction:

$F = (\text{coeff. of friction})\,F_N = 0.2\,F_N$

ANALYSIS: (a) Using Eq. 2.13, the power, $\dot{W}$, transmitted is

$\dot{W} = F \cdot V = 0.2\,F_N\,V$

or

$\dot{W} = 0.2\,(15\ \text{lbf})(1500\ \frac{\text{ft}}{\text{min}})\left|\frac{1\ \text{min}}{60\ \text{s}}\right|\left|\frac{1\ \text{Btu}}{778\ \text{ft}\cdot\text{lbf}}\right|$

$= 0.096\ \text{Btu/s}$ ←

or

$\dot{W} = 0.096\ \frac{\text{Btu}}{\text{s}}\left|\frac{3600\ \text{s}}{\text{h}}\right|\left|\frac{1\ \text{hp}}{2545\ \text{Btu/h}}\right|$

$= 0.136\ \text{hp}$ ←

(b) In one minute of sanding, the work done on the surface is

$W = \left(0.096\ \frac{\text{Btu}}{\text{s}}\right)\left|\frac{60\ \text{s}}{\text{min}}\right|(1\ \text{min})$

$= 5.76\ \text{Btu}$ ←