

39.12 A 1200ft^3 room is filled with atmospheric air at 95°F . The room air is cooled to 70°F under constant pressure. How much work is done on the air in the room?

- A. 2Btu
- B. 150Btu
- C. 520Btu
- D. 1330Btu

For a **Closed System** with **No Change in Kinetic or Potential Energy**, work can be expressed for a constant pressure process as such:

$$w = P\Delta v = P(v_1 - v_2)$$

Assuming air behaves as an ideal gas, rearrange the ideal gas law and substitute for specific volume.

$$PV = mRT \rightarrow Pv = RT \rightarrow v = \frac{RT}{P}$$

$$w = P \left(\frac{RT_1}{P_1} - \frac{RT_2}{P_2} \right)$$

Since the process is constant pressure, $P_2 = P_1 = P$.

$$w = R(T_1 - T_2)$$

Substitute and solve.

$$w = \frac{\left(53.35 \frac{\text{ft}\cdot\text{lb}_f}{\text{lb}_m\cdot\text{R}} \right) (95^\circ\text{F} - 75^\circ\text{F}) \left(\frac{^\circ\text{R}}{^\circ\text{F}} \right)}{778 \frac{\text{ft}\cdot\text{lb}_f}{\text{Btu}}} = 1.71 \frac{\text{Btu}}{\text{lb}_m}$$

This is the work per unit mass. Since the answer choices are total work [Btu], multiply by the total mass in the room. Use the ideal gas law and either state. State 1 is arbitrarily chosen here.

$$m = \frac{PV}{RT} = \frac{\left(14.7 \frac{\text{lb}_f}{\text{in}^2} \right) \left(\frac{144\text{in}^2}{\text{ft}^2} \right) (1200\text{ft}^3)}{\left(53.35 \frac{\text{ft}\cdot\text{lb}_f}{\text{lb}_f\cdot\text{R}} \right) [(95 + 460)^\circ\text{R}]} = 85.8\text{lb}_m$$

Calculate the work.

$$W = mw = (85.8\text{lb}_m) \left(1.71 \frac{\text{Btu}}{\text{lb}_m} \right) = 146.7\text{Btu}$$

Answer B

39.13 Steam with a quality of 90% expands isentropically from 350psia to 120psia. What is the change in enthalpy?

- A. $40 \frac{Btu}{lb}$
- B. $80 \frac{Btu}{lb}$
- C. $90 \frac{Btu}{lb}$
- D. $120 \frac{Btu}{lb}$

Look up the **Properties of Saturated Water and Steam** in the Reference Handbook organized by pressure and find 350psia. Call this State 1. From the table, $h_f = 409.8 \frac{Btu}{lb}$ and $h_{fg} = 794.62 \frac{Btu}{lb}$. Calculate the enthalpy at State 1:

$$h_1 = h_f + \chi h_{fg} = 409.8 \frac{Btu}{lb} + (0.9) \left(794.62 \frac{Btu}{lb} \right) = 1125 \frac{Btu}{lb}$$

Also gather entropy values from the same line in the table, $s_f = 0.6059 \frac{Btu}{lb_m \cdot ^\circ F}$ and $s_{fg} = 0.8914 \frac{Btu}{lb_m \cdot ^\circ F}$. Calculate the entropy at State 1:

$$s_1 = s_f + \chi s_{fg} = 0.6059 \frac{Btu}{lb_m \cdot ^\circ F} + (0.9) \left(0.8914 \frac{Btu}{lb_m \cdot ^\circ F} \right) = 1.408 \frac{Btu}{lb_m \cdot ^\circ F}$$

Since the expansion from State 1 to State 2 is isentropic:

$$s_2 = s_1 = 1.408 \frac{Btu}{lb_m \cdot ^\circ F}$$

Gather entropy values from the table for State 2, which has a pressure of $P_2 = 120psia$. $s_f = 0.4919 \frac{Btu}{lb_m \cdot ^\circ F}$ and $s_{fg} = 1.0965 \frac{Btu}{lb_m \cdot ^\circ F}$. Find the quality at State 2 (after the isentropic expansion):

$$\chi = \frac{s_2 - s_f}{s_{fg}} = \frac{\left(1.408 \frac{Btu}{lb_m \cdot ^\circ F} \right) - \left(0.4919 \frac{Btu}{lb_m \cdot ^\circ F} \right)}{\left(1.0965 \frac{Btu}{lb_m \cdot ^\circ F} \right)} = 0.835$$

Gather enthalpy values from the table for State 2. $h_f = 312.55 \frac{Btu}{lb}$ and $h_{fg} = 878.2 \frac{Btu}{lb}$. Calculate the enthalpy at State 2:

$$h_2 = h_f + \chi h_{fg} = 312.55 \frac{Btu}{lb} + (0.835) \left(878.2 \frac{Btu}{lb} \right) = 1046 \frac{Btu}{lb}$$

Finally, calculate the change in enthalpy from State 1 to State 2:

$$\Delta h = h_1 - h_2 = 1125 \frac{Btu}{lb} - 1046 \frac{Btu}{lb} = 79 \frac{Btu}{lb}$$

Answer B