39.11 An outside air handling unit delivers $5000cfm$ of outside air. On a winter day, the outside air is $18°F$ and is heated to $68°F$ using a hot water coil. Hot water is supplied at $165°F$ and returned at $140°F$. What is the required flow rate of hot water?

A. $0.4gpm$

B. $3gpm$

C. $22gpm$

D. $173gpm$

The air undergoes sensible heating. Use the sensible heating rule of thumb:

$$Q_s = 1.08CFM\Delta T_{air}$$

The heat given up by the water can be determined with the sensible heating/cooling rule of thumb for water:

$$Q_w = 500GPM\Delta T_{water}$$

The quantity of heat added to the air is supplied entirely by the hot water, therefore we can equate the two formulas:

$$1.08CFM\Delta T_{air} = 500GPM\Delta T_{water}$$

The GPM of the hot water is the only unknown. Isolate, substitute, and solve:

$$GPM = \frac{1.08CFM\Delta T_{air}}{500\Delta T_{water}} = \frac{1.08\,(5000)\,(68-18)}{500\,(165-140)} = 21.6GPM$$

Note that no units need to be included when using these "rules of thumb" provided *all input values are in the correct units in the first place* i.e. CFM, GPM, and Farenheit.

Answer C

39.12 A $1200 ft^3$ 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. $2 Btu$

B. $150 Btu$

C. $520 Btu$

D. $1330 Btu$

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.

$$w = \frac{\left(53.35\frac{ft \cdot lb_f}{lb_m \cdot R}\right)(95°F - 75°F)\left(\frac{°R}{°F}\right)}{778\frac{ft \cdot lb_f}{Btu}} = 1.71\frac{Btu}{lb_m}$$

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.

$$m = \frac{PV}{RT} = \frac{\left(14.7\frac{lb_f}{in^2}\right)\left(\frac{144 in^2}{ft^2}\right)(1200 ft^3)}{\left(53.35\frac{ft \cdot lb_f}{lb_f \cdot R}\right)[(95 + 460)° R]} = 85.8 lb_m$$

Calculate the work.

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

Answer B