43.8 A single family house is maintained at $70°F$ in the winter when the outside design temperature is $10°F$. The roof area is $2000ft^2$ and the R-value is R-32. The wall area is $2500ft^2$ and the R-value is R-15. There are (12) $3ft \times 4ft$ double pane glass windows with R-value R-3. Infiltration and ventilation account for $100cfm$ of air exchange. What is the design heat load?

A. $6500\frac{Btu}{hr}$

B. $10,000\frac{Btu}{hr}$

C. $17,000\frac{Btu}{hr}$

D. $23,000\frac{Btu}{hr}$

To calculate the heat gain through interior surfaces, use the equation from the reference handbook: $\dot{Q} = UA\Delta T$.

Recall from Heat Transfer that the overall coefficient of heat transfer, U, is the reciprocal of the total resistance, R.

$$U = \frac{1}{R_T}$$

It is implied that the R-values given are the resistances for the roof, walls, and windows, respectively.

Calculate the heat gain through the roof:

$$\dot{Q}_{roof} = \frac{\left(2000ft^2\right)\left(70°F - 10°F\right)}{\left(32\frac{hrft^2°F}{Btu}\right)} = 3750\frac{Btu}{hr}$$

Calculate the heat gain through the walls:

$$\dot{Q}_{walls} = \frac{\left(2500ft^2\right)\left(70°F - 10°F\right)}{\left(15\frac{hrft^2°F}{Btu}\right)} = 10,000\frac{Btu}{hr}$$

Calculate the heat gain through the windows:

$$\dot{Q}_{windows} = \frac{\left[\left(12ft\right)\left(12ft\right)\right]\left(70°F - 10°F\right)}{\left(3\frac{hrft^2°F}{Btu}\right)} = 2880\frac{Btu}{hr}$$

Determine the heat gain due to infiltration and ventilation using the sensible heating rule of thumb:

$$\dot{Q}_{oa} = 1.08cfm\Delta T = 1.08\left(100\right)\left(70 - 10\right) = 6480\frac{Btu}{hr}$$

Find the sum of the heat gain through the surfaces and the heat gain due to outside air:

$$\dot{Q}_{total} = \dot{Q}_{roof} + \dot{Q}_{walls} + \dot{Q}_{windows} + \dot{Q}_{oa}$$

$$\dot{Q}_{total} = 3750\frac{Btu}{hr} + 10,000\frac{Btu}{hr} + 2880\frac{Btu}{hr} + 6480\frac{Btu}{hr} = 23,110\frac{Btu}{hr}$$

Answer D

43.9 In an effort to allow for increased ceiling heights, a design engineer specifies a 3:1 aspect ratio for a duct that delivers $500cfm$. The velocity is to be kept under $400fpm$. What is the dimension of the long side of the duct?

A. $13in$

B. $14in$

C. $23in$

D. $24in$

Solve for the minimum area required to keep the velocity under the maximum:

$$Q = VA$$

$$A = \frac{Q}{V} = \frac{500\frac{ft^3}{min}}{400\frac{ft}{min}} = 1.25ft^2\left(\frac{12in}{1ft}\right)^2 = 180in^2$$

Let the short side of the duct have length x and the long side have a length of $3x$ to achieve a 3:1 aspect ratio. Write an expression for the area and solve for the length of the short side, x.

$$3x^2 = 180in^2$$

$$x = 7.74in$$

The duct dimensions must be integers. Since $7 < 7.74 < 8$, the short side may be $7in$ or $8in$ in length. Generate several possible sets of dimensions for consideration:

$$7 \times 23 \rightarrow A = 161in^2 < 180in^2\ (insufficient)$$

$$7 \times 24 \rightarrow A = 168in^2 < 180in^2\ (insufficient)$$

$$8 \times 23 \rightarrow (not\,3:1\,ratio)$$

$$8 \times 24 \rightarrow A = 192in^2 > 180in^2,\ 3:1\,ratio\ OK,\ V < 400fpm$$

The long side is $24in$.
Answer D