43.20 An office floor has dimensions of $120ft \times 200ft$ with $12ft$ ceiling height. There is one window with dimensions $4ft$ wide by $6ft$ high for every $8ft$ of external wall. The inside and outside design temperatures are $70°F$ and $10°F$, respectively. The overall heat transfer coefficients for the walls and windows are $0.2\frac{Btu}{hr \cdot ft^2 \cdot °F}$ and $0.7\frac{Btu}{hr \cdot ft^2 \cdot °F}$, respectively. The floors above and below are heated. Ignoring infiltration, ventilation, and internal equipment loads, what is the heating load for the space?

A. $120,000\frac{Btu}{hr}$

B. $130,000\frac{Btu}{hr}$

C. $140,000\frac{Btu}{hr}$

D. $150,000\frac{Btu}{hr}$

The problem statement calls for ignoring infiltration and ventilation, as well as the internal loads, and to assume the roof and floors above and below are heated. Therefore, the only heat loss to be considered is the heat escaping through walls and windows.

The overall coefficients of heat transfer for the walls and windows are both given, and the ΔT is also known. Calculate the total window area:

Along the long sides:

$$\frac{200ft}{8ft} = 25windows \times 2$$

Along the short sides:

$$\frac{120ft}{8ft} = 15windows \times 2$$

In total:

$$50 + 30 = 80windows$$

Window Area:

$$A_{windows} = (80)(4ft)(6ft) = 1920ft^2$$

The Wall Area must exclude the windows. Write an expression for the wall area based on perimeter times height minus window area:

$$A_{walls} = PH - A_{windows} = [(2)(200ft) + (2)(120ft)](12ft) - 1920ft^2 = 5760ft^2$$

Find the total heat loss through the windows:

$$\dot{Q}_{windows} = U_{windows}A_{windows}\Delta T$$

$$\dot{Q}_{windows} = \left(0.7\frac{Btu}{hr \cdot ft^2 \cdot {}^\circ F}\right)\left(1920ft^2\right)\left(70^\circ F - 10^\circ F\right) = 80,640\frac{Btu}{hr}$$

Find the total heat loss through walls:

$$\dot{Q}_{walls} = U_{walls}A_{walls}\Delta T$$

$$\dot{Q}_{walls} = \left(0.2\frac{Btu}{hr \cdot ft^2 \cdot {}^\circ F}\right)\left(5760ft^2\right)\left(70^\circ F - 10^\circ F\right) = 69,120\frac{Btu}{hr}$$

Find the total heat loss:

$$\dot{Q}_{total} = \dot{Q}_{windows} + \dot{Q}_{walls} = 80,640\frac{Btu}{hr} + 69,120\frac{Btu}{hr} = 149,760\frac{Btu}{hr}$$

Answer D

43.21 A building in Chicago has a design heat loss of $300,000\frac{Btu}{hr}$. The heating season is 250 days long and there are 6000 heating degree days per season. The outside design temperature is $-10^\circ F$. The inside design temperature is initially $70^\circ F$. The heating system burns natural gas which costs $0.75 per therm on average. The total system efficiency is 80%. If the heating setpoint is reduced to $68^\circ F$, what will the annual savings be?

A. $270

B. $420

C. $6,000

D. $8,000

Determine the average ΔT using the heating degree days and and the length of the heating season:

$$\Delta T_{avg,65} = \frac{6000 degree \cdot days}{250 days} = 24^\circ F$$

It is implied (unless otherwise stated) that the indoor reference temperature for heating degree days is 65°F. Since the initial design temperature is 70°F, the average ΔT is actually +5°F higher.

$$\Delta T_{avg,70} = 29^\circ F$$

Use the design ΔT and the design heat loss to calculate the product of the overall coefficient of heat transfer and the area for this building. Looking at the units, think of this product as the rate of heat transfer per unit change in temperature, e.g. the rate at which heat must be added to compensate for one degree of temperature reduction for this particular building.

$$\dot{Q} = UA\Delta T$$