Question # 79002

A domestic freezer has an internal capacity of 1m x 10.5m x 0.5m. The temperature inside is maintained at -5°C in ambient temperature of up to 35°C. Calculate the maximum rate of heat transfer to the freezer if the wall and door consists of:

5mm plastic. K = 1W/mK

15mm insulation K = 0.05W/mK

2mm steel. K = 40W/mK

and the convective heat transfer coefficient is 8W/m²K on both sides of the freezer

Answer:

The maximum rate of the heat transfer Q to the freezer is given by:

$$Q = UA(T_{out} - T_{in}), \tag{1}$$

where

$$U = \left(\frac{1}{h_{in}} + \frac{t_1}{K_1} + \frac{t_2}{K_2} + \frac{t_3}{K_3} + \frac{1}{h_{out}}\right)^{-1}, \tag{2}$$

is the overall heat transfer coefficient,

$h_{in} = h_{out}$ = 8 W/m²K – the convective heat transfer coefficients at the inner and outer surfaces,

t_1 = 0.005 m, t_2 = 0.015 m, t_3 = 0.02 m – the thickness of the plastic, the insulation and the steel layers, respectively,

K_1 = 1 W/mK, K_2 = 0.05 W/mK, K_3 = 40 W/mK – the thermal conductivity coefficient of the plastic, the insulation and the steel, redpectively.

$$A = 2(ab + bc + ac), \tag{3}$$

the area of the freezer walls,

a = 1 m, b = 10.5 m, c = 0.5 m – the dimensions of the freezer,

T_{in} = -5°C, T_{out} = 35°C – the temperature inside and outside the freezer, respectively.

Substitute into (3), (2) and (1):

$$A = 2(1 \cdot 10.5 + 10.5 \cdot 0.5 + 1 \cdot 0.5) = 32.5 \text{ m}^2,$$

$$U = \left(\frac{1}{8} + \frac{0.005}{1} + \frac{0.015}{0.05} + \frac{0.002}{40} + \frac{1}{8}\right)^{-1} = 1.802 \text{ W/m}^2\text{K},$$

$$Q = 1.802 \cdot 32.5 \cdot (35 + 5) = 2342 \text{ W}.$$