Week2 Assignment
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1(1) A summary about the convective heat transfer.

Convective heat transfer is movement between various parts of the fluid (liquids or gases), heat transfer process caused by hot and cold fluids. Convection includes both natural convection and forced convection.

1) Natural convection

(Increase in temperature → reduction in density → hot air goes up and cold air goes down.)

2) Forced convection

(wind)

Newton's law of cooling(steady state heat convection), finding how fast air is moving through the wall. The formula is $\dot{Q}_{CONV}=\frac{T_S-T_\infty}{\mathrm{R_{CONV}}}$ (W), and $R_{conv}=\frac{1}{h\cdot A_S}$ (℃/W), h is convection heat transfer coefficient, (forced convection, h is higher; natural convection, h is lower)

Thermal resistance network: convection(air/wall)→conduction(inside wall)→ convection(wall/air), so the formula is $\dot{Q}=\frac{T_{\infty1}-T_{\infty2}}{\mathrm{R_{CONV1}}+R_{WALL}+R_{CONV2}}$ (W), and $R_{tot}=R_{CONV1}+R_{WALL}+R_{CONV2}$ (in series)$=\frac{1}{h_1\cdot A}+\frac{L}{\mathrm{k}\cdot A}+\frac{1}{h_2\cdot A}$(℃/W), A is area of the wall is always the same.

Thick glass is useless, the characteristics of the glass has a small influence on heat loss, changing thickness doesn't affect the heat loss（single pane）. Thickness is only useful against wind force which can break it.

1(2) Explain why increasing the thickness of a single pane glass does not increase the total resistance.

Because the formula for calculating the resistance is $R_{glass}=\frac{L}{k\cdot A}$, where L is the thickness of the glass (the unit is meter), but in reality, the thickness of the glass is converted to the unit of meter, the value is very small. So increasing the thickness of the glass, not enough to significantly affect the resistance of glass. And the total resistance is the resistance of the heat convection and the resistance of the glass, so the thickness of the glass is not enough to significantly affect the total resistance (the effect is small enough to be ignored).

2An explanation about what mistakes I made in the class that resulted in wrong answers.

When I calculate the resistance of the glass, using formula $R_{glass}=\frac{L}{k\cdot A}$, I have an error when converting millimeter (the unit of thickness of the glass -L) into meters. I mistakenly converted into 1mm=0.01m. But in fact, 1mm=0.001m. This is really a very low level error and will cause the final numerical error.

3(1) Heat loss through a double pane window

Consider two 0.8m high and 1.5m wide glass window, shown above with a thermal conductivity of k_{glass}=0.78W/m • ℃, k_{airGap}=0.026 W/m • ℃， the air-gap thickness of 13 mm, glass thickness of 6 mm. Take the convection heat transfer coefficients on the inner and outer surfaces of the window. h_1=10W/m^2 • ℃ and h_2=40W/m^2 • ℃, which includes the effects of radiation. Determine the steady rate of heat transfer through the glass window and the temperature of its inner surface.

Firstly, calculate the total resistance:
A=0.8*1.5=1.2 m^2

$R_{g1} = R_{g2} = \frac{L_g}{k_g \cdot A} = \frac{0.006}{0.78*1.2} = 0.0064$ ℃/W

$R_{airGap} = \frac{L_{airGap}}{k_{airGap} \cdot A} = \frac{0.013}{0.026*1.2} = 0.4167$ ℃/W

$R_{conv1} = \frac{1}{h_1 \cdot A} = \frac{1}{10*1.2} = 0.0833$ ℃/W

$R_{conv2} = \frac{1}{h_2 \cdot A} = \frac{1}{40*1.2} = 0.0208$ ℃/W

$R_{tot} = R_{conv1} + R_{conv2} + 2* R_g + R_{airGap} = 0.0833+0.0208+2*0.0064+0.4167=0.5336$ ℃/W

$\dot{Q} = \frac{\Delta T}{R_{tot}} = \frac{30}{0.5336} = 56.2$ W

$\dot{Q} = \frac{\Delta T}{R_{con1}} = \frac{20-T_1}{0.0833} = 56.2$ W $\rightarrow$ $T_1=15.3$ ℃

3(2) Comment on the results and explain why we have an optimal range for the air-gap's distance.

Because air-gap should be large enough to permit natural convection, but when the air-gap’s distance becomes too large, the natural convection causes air to move too quickly inside the air-gap. So, we have an optimal range for the air-gap’s distance.

Besides, comparing with the result of the example in the class, as the air-gap's distance increases, the resistance of the air-gap increases significantly, resulting in an increase in the value of the total resistance and a decrease in the rate of heat convection. The above results show that the air-gap's distance is only increased by 3 mm, which can have such a large influence on the calculated value.