Andrea Foppiani / Week 2 assignment

① – SUMMARY

CONVECTION IS A PHENOMENON THAT INVOLVES HEAT TRANSFER WHEN A FLUID (LIKE AIR) MEETS A SOLID SURFACE WITH A HIGHER TEMPERATURE (LIKE A WALL).

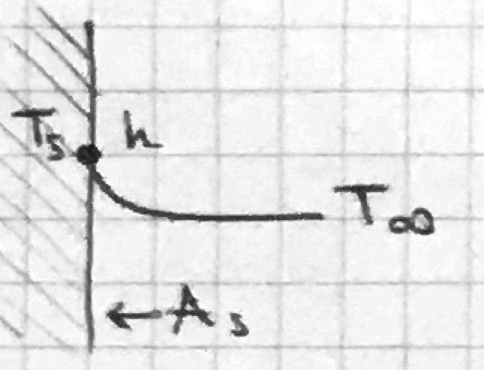
STUDYING HEAT TRANSFER THROUGH WALLS AND WINDOWS, WE REALIZE THAT CONVECTION ALWAYS HAPPENS ALONG THE EXTERNAL AND INTERNAL SURFACE, COMBINED WITH CONDUCTION THROUGH THE SOLID MATERIAL.

CONVECTION CAN BE

1) NATURAL: when naturally a temperature increase in proximity to a certain vertical surface, causes a reduction in the air density, generating a movement: hot air goes up, cold air goes down.

2) FORCED: when the effect of convection is intensified by an external mean, like wind.

CONVECTIVE HEAT TRANSFER CAN BE CALCULATED THROUGH NEWTON'S LAW OF COOLING:



$$\dot{Q}_{conv} = h \cdot A_s \cdot (T_s - T_\infty) = \frac{T_s - T_\infty}{R_{conv}} \rightarrow (W)$$

where:

$$\left[R_{conv} = \frac{1}{hA_s}\right] \rightarrow (°C/W)$$

h = convection heat transfer coefficient → [higher in forced convection]

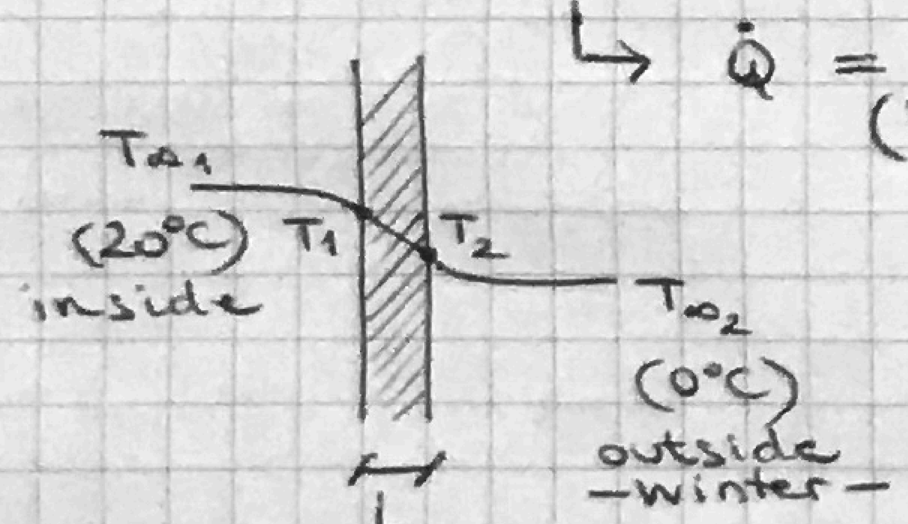
A_s = area of the surface involved in the heat transfer (in our case: window/wall)

T_s = temp. of the surface

T_∞ = temp. of the air far away from the surf.

$\boxed{\text{HEAT LOSS}}$ THROUGH A SINGLE PANE GLASS

$$\hookrightarrow \dot{Q} = \frac{T_{\infty 1} - T_{\infty 2}}{(R_{conv_1} + R_{glass} + R_{conv_2})} \rightarrow \text{resistances in a series}$$



CONVECTION (air–glass)
↳ CONDUCTION (through glass)
↳ CONVECTION (glass–air)

$$R_{conv_1} = \frac{1}{h_1 A}$$

$$R_{glass} = \frac{L}{KA}$$

$$R_{conv_2} = \frac{1}{h_2 A}$$

IF WE USE THE NUMBERS AND CALCULATE THESE 3 RESISTANCES, WHAT COMES OUT IS THAT R_{GLASS} IS ALWAYS MUCH LOWER THAN THE OTHER TWO

THROUGH THIS COMPARISON, WE CAN UNDERSTAND THAT INCREASING THE GLASS THICKNESS (L) DOESN'T AFFECT IMPORTANTLY THE TOTAL R

② – EXPLAIN THE MISTAKES:

I did one mistake in calculating T_1 in example B

$$R_{TOT} = 0{,}1127 \ \frac{°C}{W} \ ✓$$

$$\dot{Q} = 266{,}1934 \ W \ ✓$$

$$\dot{Q} = \frac{T_\infty - T_1}{R_{conv_1}} \rightarrow \dot{Q} \cdot R_{conv_1} = T_\infty - T_1$$

(no mistakes until here)

here I divided instead of doing a subtraction

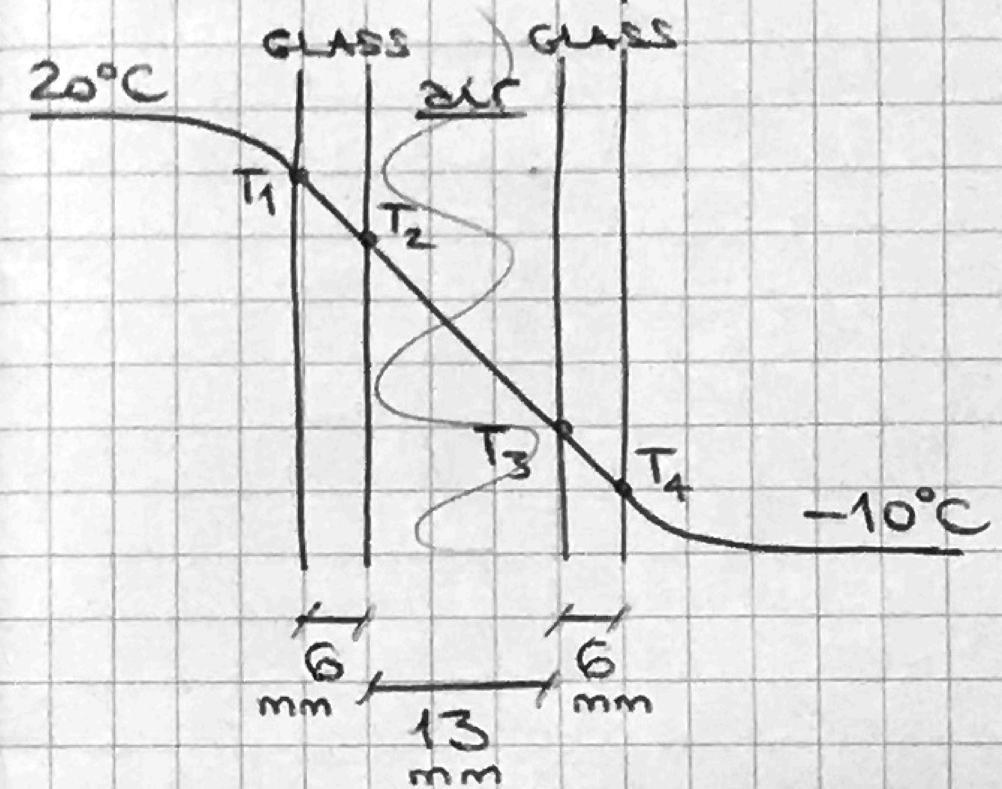
CORRECTION

$$T_1 = T_\infty - \dot{Q} \cdot R_{conv_1}$$

$$T_1 = 20°C - (266{,}1934 \cdot 0{,}0833)°C = -2{,}1739 °C$$

③ – PROBLEM:

Double pane window



$A = 0{,}8 \cdot 1{,}5 \ m^2 = 1{,}2 \ m^2$

$K_{GLASS} = 0{,}78 \ \frac{W}{m \cdot °C}$

K_{AIR} (stagnant) $= 0{,}026 \ \frac{W}{m \cdot °C}$

$h_1 = 10 \ \frac{W}{m^2 \cdot °C}$

$h_2 = 40 \ \frac{W}{m^2 \cdot °C}$

$$R_{TOT} = \Bigg(\underbrace{\frac{1}{10 \cdot 1{,}2}}_{R_{conv_1} = 0{,}0833} + \underbrace{\frac{0{,}006}{0{,}78 \cdot 1{,}2}}_{R_{glass_1} = 0{,}0064} + \underbrace{\frac{0{,}013}{0{,}026 \cdot 1{,}2}}_{R_{air} = 0{,}4167} + \underbrace{\frac{0{,}006}{0{,}78 \cdot 1{,}2}}_{R_{glass_2} = 0{,}0064} + \underbrace{\frac{1}{40 \cdot 1{,}2}}_{R_{conv_2} = 0{,}0208}\Bigg) \frac{°C}{W} = 0{,}5336 \ °C/W$$

$$\dot{Q} = \frac{20°C + 10°C}{0{,}5336} \ W = 56{,}22 \ W$$

$$T_1 = T_{\infty_1} - \dot{Q} \cdot R_{conv_1} = 20°C - (56{,}22 \cdot 0{,}0833)°C = 15{,}32°C$$

THE AIR LAYER IMPROVES THE RESISTANCE OF THE WINDOW TO HEAT TRANSFER, IN THIS CASE EVEN MORE THAN WHAT WE CALCULATED IN CLASS → ($R_{TOT} = 0{,}4332 \frac{°C}{W}$, $\dot{Q} = 69{,}25 W$, $T_1 = 14°C$)

THIS AIR-GAP'S THICKNESS IS IDEAL BECAUSE IT'S THE MOST EFFICIENT IN LOWERING HEAT TRANSFER, MAINTAINING THE TEMPERATURE OF THE INNER SURFACE OF THE GLASS (T_1) AS CLOSE AS POSSIBLE TO THE 20°C OF THE INTERIOR (comfort).