<u>Question 1:</u> Calculate how much (%) is the effect of applying different modifications (changing the gas, adding an extra pane, using a low emissivity coating) on the U value with respect to a benchmark case of double layer with air and no coating ?

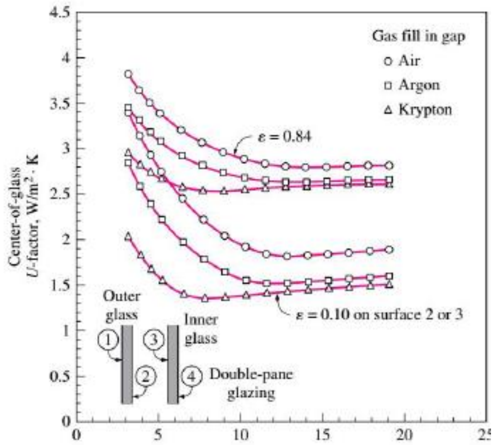
<u>The gap thickness to be 13 mm</u>:

$Uwindow = UcenterAcenter + UedgeAedge + UframeAframe\ /Awindow$

If it is a double − pane window, disregard the thermal resistances of glass layers,

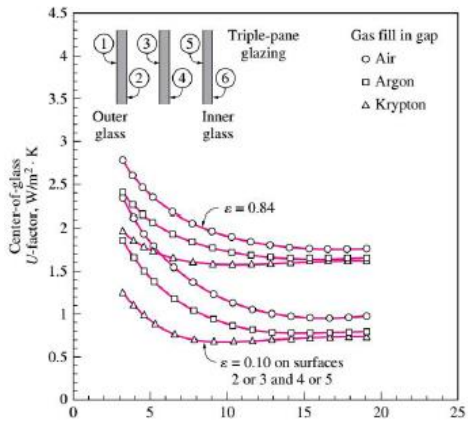
<u>With double pane glazing: (when e = 0.10):</u>

- U factor (krypton) when using Krypton = 1.4 w/m2k
- U factor (Argon) = 1.5 w/m2k when e = 0.84
- U factor of Krypton and Argon = 2.1 w/m2k
- U factor of the air is 2.3 w/m2k



<u>With triple pane glazing: (when e = 0.10):</u>

- U factor (Krypton) = 0.7 w/m2k
- U factor (Argon) = 0.8 w/m2k when e = 0.84
- U factor of Krypton and Argon = 1.6 w/m2k
- U factor of the air is 1.8 w/m2k



Question2: Consider the house that we analyzed in the last two examples, calculate the heating and cooling load of the other windows which are fixed 14.4 m2 on the west, fixed 3.6 m2 on the south and an operable 3.6 m2 on the south (the same window and frame type). How much does the total value change if I change the frame of the window from wooden one to aluminum ?

<u>From the Table we gathered that:</u>

1. Net area of a building located in Piacenza is 105.8 $m2$, and the calculated U value is 0.438 $W\ m2K$ for the winter while in the summer it is 0.435 $W\ m2K$

2. A fixed heat absorbing double later glass with a wooden frame window at the east side of a building located in Piacenza has a surface of 14.4$m2$

3. $\Delta Tcooling$ = 24℃ 4. $\Delta Theating$ = 20℃

<u>Hence:</u>

- $\Delta Tcooling$=31.9℃−24℃=7.9℃=7.9K
- $\Delta Theating$=20℃−(−4.8℃)=24.8℃=24.8K
- From the table we get that DR=11.9℃ = 11.9K

To calculate the cooling load of the fixed window on the West:

- $q_{west\ window}=A\times CF_{westwindow}$
- A=14.4m2 $CF_{westwindow}=U_{westwindow}(\Delta T_{cooling}-0.46DR)$
- $U_{westwindow}=2.84\ Wm2K$
- $CF_{westwindow}=2.84\ _{Wm2K}\times(7.9K-0.46\times11.9\text{K})=6.89_{Wm2K}$
- $PXI_{westwindow}=E_D+E_d=599+188=747$ SHGC=0.54
- No internal shading:
- IAC=1 $FF_s=0.56$ $CF_{westwindow}=PXI\ \times SHGC\ \times IAC\ \times\ FF_S$
- $q_{westwindow}=A\times CF_{westwindow}=A\times(CF_{heat\ transfer}+CF_{irradation})$ $\approx14.4m2\times(6.89+747\times0.54\times1\times0.56)Wm2\approx3352W$

To calculate the heating load of the fixed window on the west

$q_{westwindow}=A\times HF_{westwindow}=A\times U_{westwindow}\Delta T_{heating}=14.4m2\times2.84Wm2K\times24.8K\approx1014.22W$

If the frames were made of aluminum:

- $U_{westwindow}=3.61_{Wm2K}$
- SHGC=0.56 $CF'_{westwindow\ for\ heat\ transfer}=U'_{west\ window}\times(\Delta T_{cooling}-0.46DR)$

$=3.61Wm2K\times(7.9K-0.46\times11.9K)\approx8.76\ Wm2$

- **Cooling load** $q'_{westwindow}=A\times CF'_{westwindow}=$

$A\times(CF'_{westwindow\ for\ heat\ transfer}+CF'_{westwindow\ irradation}\approx14.4m2\times(8.76+747\times0.54\times1\times0.56)$ $Wm2\approx3499.48W$

- **Heating load** $q'_{westwindow}=A\times HF'_{westwindow}=A\times U'_{westwindow}\Delta T_{heating}$

$=14.4m2\times3.61Wm2K\times24.8K\approx1289.2\ W$

Calculating the cooling load of the fixed window on the south:

$q_{west\ window}=A\times CF_{southwindow}$

A=3.6m2 $CF_{southwindow}=U_{southwindow}(\Delta T_{cooling}-0.46DR)$

$U_{southwindow}=2.84\ Wm2K$

$PXIsouthwindow=ED+Ed=348+209=577$

SHGC=0.54

No internal shading so IAC=1 $FFs=0.47$ $CFsouthwindow=PXI\ \times SHGC\ \times IAC\ \times\ FFS$

$qsouthwindow=A\times CFsouthwindow=A\times(CFheat\ transfer+CFirradation)$ $\approx3.6m2\times(6.89+557\times0.54\times1\times0.47)Wm2\approx553.72W$

To calculate the heating load of the fixed window on the south

$qsouthwindow=A\times HFsouthwindow=A\times Usouthwindow\Delta Theating$ $=3.6m2\times2.84Wm2K\times24.8K\approx253.56W$

If the frames were made of aluminum: $Usouthwindow=3.61Wm2K$ and SHGC=0.56 $CF'southwindow\ for\ heat\ transfer=U'south\ window\times(\Delta Tcooling-0.46DR)=3.61Wm2K\times(7.9K-0.46\times11.9K)\approx8.76\ Wm2$

- Cooling load $q'southwindow=A\times CF'southwindow=A\times(CF'southwindow\ for\ heat\ transfer+CF'southwindow\ irradation\approx3.6m2\times(8.76+557\times0.56\times1\times0.47)$ $Wm2\approx559.3W$

- Heating load $q'southwindow=A\times HF'southwindow=A\times U'southwindow\Delta Theating$ $=3.6m2\times 3.61Wm2K\times 24.8K\approx 322.3\ W$

To calculate the cooling load of the operable window on the South:

$qsouth\ window=A\times CFsouthwindow$

A=3.6m2 $CFsouthwindow=Usouthwindow(\Delta Tcooling-0.46DR)$

$PXIsouthwindow=ED+Ed=348+209=577$

SHGC=0.54

No internal shading so IAC=1 $FFs=0.47$ $CFsouthwindow=PXI\ \times SHGC\ \times IAC\ \times\ FFS$

$qsouthwindow=A\times CFsouthwindow=A\times(CFheat\ transfer+CFirradation)$ $\approx 3.6m2\times(6.89+557\times 0.54\times 1\times 0.47)Wm2\approx 553.72W$ A

To calculate the heating load of the fixed window on the south

$q_{southwindow}=A\times HF_{southwindow}=A\times U_{southwindow}\Delta T_{heating}=3.6m_2\times 2.84Wm_2K\times 24.8K\approx 253.56W$

If the frames were made of aluminum: $U_{southwindow}=3.61_{Wm2K}$ and SHGC=0.56

$CF'_{southwindow\ for\ heat\ transfer}=U'_{south\ window}\times(\Delta T_{cooling}-0.46DR)=3.61Wm_2K$ $\times(7.9K-0.46\times 11.9K)\approx 8.76\ Wm_2$

- Cooling load $q'_{southwindow}=A\times CF'_{southwindow}=A\times(CF'_{southwindow\ for\ heat\ transfer}+CF'_{southwindow\ irradiation}\approx 3.6m_2\times(8.76+557\times 0.56\times 1\times 0.47)\ Wm_2\approx 559.3W$
- Heating load $q'_{southwindow}=A\times HF'_{southwindow}=A\times U'_{southwindow}\Delta T_{heating}$ $=3.6m_2\times 3.61Wm_2K\times 24.8K\approx 322.3\ W$

To calculate the cooling load of the operable window on the South:

$q_{south\ window}=A\times CF_{southwindow}$

A=3.6m2 $CF_{southwindow}=U_{southwindow}(\Delta T_{cooling}-0.46DR)$

$Uwestwindow=2.87\ Wm2K$

$CFwestwindow=2.87\ Wm2K\times(7.9K-0.46\times 11.9\text{K})=6.96Wm2K$

$PXIwestwindow=ED+Ed=348+209=557$

SHGC=0.46

No internal shading so IAC=1 $FFs=0.47$ $CFsouthwindow=PXI\ \times SHGC\ \times IAC\ \times\ FFS$

$qsouthwindow=A\times CFsouthwindow=A\times(CFheat\ transfer+CFirradation)$ $\approx 3.6m2\times(6.89+557\times 0.46\times 1\times 0.47)Wm2\approx 458.58W$

To calculate the heating load of the operable window on the south

$qsouthwindow=A\times HFsouthwindow=A\times Usouthwindow\Delta Theating$ $=3.6m2\times 2.87Wm2K\times 24.8K\approx 256.23W$

If the frames were made of aluminum:

- $Uwestwindow=4062Wm2K$ and SHGC=0.55 $CF'westwindow\ for\ heat\ transfer=U'west\ window\times(\Delta Tcooling-0.46DR)=4.62Wm2K$ $\times(7.9K-0.46\times 11.9K)\approx 11.21\ Wm2$

- Cooling load $q'southwindow=A\times CF'southwindow =A\times(CF'southwindow\ for\ heat\ transfer+CF'southwindow\ irradation$ ≈3.6$m2$×(11.21+557×0.55×1×0.47) $Wm2$≈558.7W
- Heating load $q'westwindow=A\times HF'southwindow=A\times U'southwindow\Delta Theating$ =3.6$m2$×4.62$Wm2K$×24.8K≈412.47 W

$Uwestwindow$=2.87 $Wm2K$

$CFwestwindow$=2.87 $Wm2K$×(7.9K−0.46×11.9K) = 6.96$Wm2K$
$PXIwestwindow=ED+Ed$=348+209=557

SHGC=0.46

No internal shading so IAC=1 FFs=0.47 $CFsouthwindow=PXI\ \times SHGC\ \times IAC\ \times\ FFS$

$qsouthwindow=A\times CFsouthwindow=A\times(CFheat\ transfer+CFirradation)$ ≈3.6$m2$×(6.89+557×0.46×1×0.47)$Wm2$≈458.58W

To calculate the heating load of the operable window on the south

$q_{southwindow}=A\times HF_{southwindow}=A\times U_{southwindow}\Delta T_{heating}$ =3.6m_2×2.87Wm_2K×24.8K ≈256.23W

If the frames were made of aluminum:

$U_{westwindow}$=4062$_{Wm2K}$ and SHGC=0.55 $CF'_{westwindow\ for\ heat\ transfer}=U'_{west\ window}\times$ ($\Delta T_{cooling}$−0.46DR) =4.62Wm_2K ×(7.9K−0.46×11.9K)≈11.21 Wm_2

- Cooling load $q'_{southwindow}=A\times CF'_{southwindow}=A\times(CF'_{southwindow\ for\ heat\ transfer}+CF'_{southwindow\ irradation}$ ≈3.6m_2×(11.21+557×0.55×1×0.47) Wm_2≈558.7W
- Heating load $q'_{westwindow}=A\times HF'_{southwindow}=A\times U'_{southwindow}\Delta T_{heating}$ =3.6m_2×4.62Wm_2K×24.8K≈412.47 W

The results show that a window with a wooden frame has a greater resistance in cooling and heating than a window with an aluminum frame.