Task 1:

Using the diagrams given in the presentation 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 ? (keep the gap thickenss to be 13 mm)

Answer

To calculate the U − value of a window,

$$U_{window} = \frac{U_{center}A_{center} + U_{edge}A_{edge} + U_{fram}A_{fram}}{A_{window}},$$

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

$$\frac{1}{U_{double-pane\ (center\ region)}} \approx \frac{1}{h_i} + \frac{1}{h_{space}} + \frac{1}{h_0},\ h_{space} = h_{rad,\ space} + h_{conv,\ space}$$

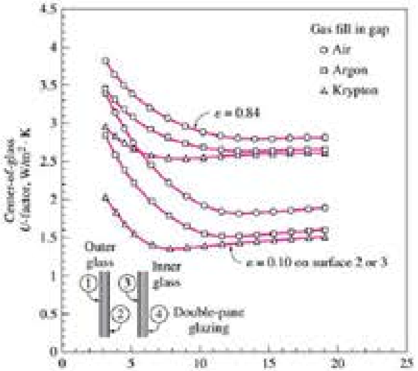
The U_{center}, i.e. the h_{space} changes by changing the gas that fills the gap.

From the diagram in the right side, we can see that:

When the gap thickenss is 13 mm,

By changing the gas that fills the gap from air to argon, the U-value of the center of the glass decreases from 2.8 $\frac{W}{m^2K}$ to 2.65 $\frac{W}{m^2K}$, which means the U-value decreases about 5.36%;

By changing the gas that fills the gap from air to krypton, the U-value of the center of the glass decrease from 2.8 $\frac{W}{m^2K}$ to 2.6 $\frac{W}{m^2K}$, which means the U-value decreases abouth 7.14%.

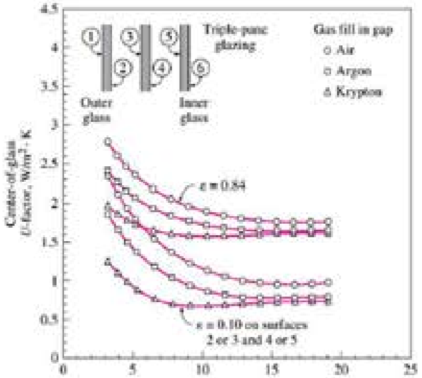


The U_{center}, i.e. the h_{space} changes by adding an extra pane.

From the diagram in the right side, we can see that:

When the gap thickenss is 13 mm, and the gas that fills the gap is air,

By adding an extra pane, the U-value of the center of the glass decreases from 2.8 $\frac{W}{m^2K}$ to 1.8 $\frac{W}{m^2K}$, which means the U-value decreases about 35.71%.



Another way to change the U_{center}, is to coat the glass surfaces with a film that has a low emissivity.

From the diagram in the right we can see that:

When the gap thickenss is 13 mm, and the gas fills the gap is air,

By coating the glass surfaces with a film that has the emissivity of 0.1, the U-value of the center of the glass decreases from 2.8 $\frac{W}{m^2K}$ to 1.8 $\frac{W}{m^2K}$, which means the U-value decreases about 35.71%.

Task 2:

Consider the house that we analysed in the alst 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 aluminium ?

(The questions *exempli gratia*:

1. The net area of walls (excluding doors and windows) of a building located in Piacenza is 105.8 m², the calculated U value is 0.438 W/m²K for the winter and 0.435 W/m²K for the summer. Find the corresponding heating and cooling load.
2. A fixed heat absorbing double layer glass (with a wooden frame) window at the east side of a building located in Piacenza has a surface of 14.4 m². In case there are no internal and external shading factors. Calculate the heating and cooling load of the corresponding to that window.)

PIACENZA, Italy

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)
1	-6.2	-4.8	-11.6	1.4	3.1	-8.8	1.8	1.8	8.8	5.6	7.7	6.2	2.1	250

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)
8	11.9	33.1	22.7	31.9	22.4	30.3	21.8	24.6	30.2	23.7	29.2	22.9	28.3	2.4	90

Answer:

First of all, define the cooling design temperature $T_{cooling}$ = 24 °C, and heating design temperature $T_{heating}$ = 20 °C. thus

$\Delta T_{cooling}$ = 31.9 °C − 24 °C = 7.9 °C = 7.9K

$\Delta T_{heating}$ = 20°C − (−4.8°C) = 24.8 °C = 24.8K

From the table above, DR = 11.9 °C = 11.9K

Table 10 Peak Irradiance, W/m²

[illegible]	[illegible]

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

$q_{window_{west}} = A \times CF_{window_{west}}$

$A = 14.4m^2,$

$CF_{window_{west}(Heat\ Transfer\ Part)} = U_{window_{west}}(\Delta T_{cooling} - 0.46\,DR)$

∵The window has a fixed heat absorbing double layer glass with a wooden frame,

$\therefore U_{window_{west}} = 2.84 \frac{W}{m^2K}$

i.e., $CF_{window_{west}(Heat\ Transfer\ Part)} = 2.84 \frac{W}{m^2K} \times (7.9\,K - 0.46 \times 11.9\,K) = 6.89 \frac{W}{m^2}$

$PXI_{window_{west}} = E_D + E_d = 559 + 188 = 747$

SHGC = 0.54

No internal shading, so IAC = 1

Table 13 Fenestration Solar Load Factors FF$_s$

Exposure	Single Family Detached	Multifamily
North	0.44	0.27
Northeast	0.21	0.43
East	0.31	0.56
Southeast	0.37	0.54
South	0.47	0.53
Southwest	0.58	0.61
West	0.56	0.65
Northwest	0.46	0.57
Horizontal	0.58	0.73

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$FF_s = 0.56$

$CF_{window_{west}(Irradiation\ Part)} = PXI \times SHGC \times IAC \times FF_s$

$q_{window_{west}} = A \times CF_{window_{west}} = A \times (CF_{window_{west}(Heat\ Trasnfer\ Part)} + CF_{window_{west}(Irradiation\ Part)})$

$\approx 14.4\ m^2 \times (6.89 + 747 \times 0.54 \times 1 \times 0.56) \frac{W}{m^2} \approx 3352.07\ W$

Calculating the heating load of the fixed window on the west:

$q_{window_{west}} = A \times HF_{window_{west}} = A \times U_{window_{west}} \Delta T_{heating}$

$= 14.4\ m^2 \times 2.84 \frac{W}{m^2K} \times 24.8K \approx 1014.22\ W$

When the frame were to be aluminium, $U_{window_{west}} = 3.61 \frac{W}{m^2K}$, $HSGC = 0.56$

$CF'_{window_{west}(Heat\ Trasnfer\ Part)} = U'_{window_{west}} (\Delta T_{cooling} - 0.46\ DR)$

$= 3.61 \frac{W}{m^2K} \times (7.9\ K - 0.46 \times 11.9\ K) \approx 8.76 \frac{W}{m^2}$

Cooling load $q'_{window_{west}} = A \times CF'_{window_{west}}$

$= A \times (CF'_{window_{west}(Heat\ Trasnfer\ Part)} + CF'_{window_{west}(Irradiation\ Part)})$

$\approx 14.4\ m^2 \times (8.76 + 747 \times 0.56 \times 1 \times 0.56) \frac{W}{m^2} \approx 3499.48\ W$

Heating load $q'_{window_{west}} = A \times HF'_{window_{west}} = A \times U'_{window_{west}} \Delta T_{heating}$

$= 14.4\ m^2 \times 3.61 \frac{W}{m^2K} \times 24.8\ K \approx 1289.20\ W$

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

$q_{window_{south}} = A \times CF_{window_{south}}$

$A = 3.6\ m^2$,

$CF_{window_{south}(Heat\ Trasnfer\ Part)} = U_{window_{south}} (\Delta T_{cooling} - 0.46\ DR)$

$\because$ *The window has a fixed heat absorbing double layer glass with a wooden frame,*

$\therefore U_{window_{south}} = 2.84 \frac{W}{m^2K}$

i.e., $CF_{window_{south}(Heat\ Trasnfer\ Part)} = 2.84 \frac{W}{m^2K} \times (7.9\ K - 0.46 \times 11.9\ K) \approx 6.89 \frac{W}{m^2}$

$PXI_{window_{south}} = E_D + E_d = 348 + 209 = 557$

$SHGC = 0.54$

No internal shading, so IAC =1

$FF_s = 0.47$

$CF_{window_{south}(Irradiation\ Part)} = PXI \times SHGC \times IAC \times FF_s$

$q_{window_{south}} = A \times CF_{window_{south}} = A \times (CF_{window_{south}(Heat\ Trasnfer\ Part)} + CF_{window_{south}(Irradiation\ Part)})$

$\approx 3.6\ m^2 \times (6.89 + 557 \times 0.54 \times 1 \times 0.47) \frac{W}{m^2} \approx 553.72\ W$

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

$q_{window_{south}} = A \times HF_{window_{south}} = A \times U_{window_{south}} \Delta T_{heating}$

$= 3.6\ m^2 \times 2.84 \frac{W}{m^2K} \times 24.8K \approx 253.56\ W$

When the frame were to be aluminium, $U_{window_{south}} = 3.61 \frac{W}{m^2K}$, $HSGC = 0.56$

$CF'_{window_{south}(Heat\ Trasnfer\ Part)} = U'_{window_{south}} (\Delta T_{cooling} - 0.46\ DR)$

$= 3.61 \frac{W}{m^2K} \times (7.9\ K - 0.46 \times 11.9\ K) \approx 8.76 \frac{W}{m^2}$

Cooling load $q'_{window_{south}} = A \times CF'_{window_{south}}$

$= A \times (CF'_{window_{south}(Heat\ Trasnfer\ Part)} + CF'_{window_{south}(Irradiation\ Part)})$

$\approx 3.6\ m^2 \times (8.76 + 557 \times 0.56 \times 1 \times 0.47) \frac{W}{m^2} \approx 559.30\ W$

Heating load $q'_{window_{south}} = A \times HF'_{window_{south}} = A \times U'_{window_{south}} \Delta T_{heating}$

$= 3.6\ m^2 \times 3.61 \frac{W}{m^2K} \times 24.8\ K \approx 322.30\ W$

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

$q_{window_{south}} = A \times CF_{window_{south}}$

$A = 3.6\ m^2$,

$CF_{window_{south}(Heat\ Trasnfer\ Part)} = U_{window_{south}} (\Delta T_{cooling} - 0.46\ DR)$

$\because$ *The window has an operable heat absorbing double layer glass with a wooden frame,*

$\therefore U_{window_{south}} = 2.87 \frac{W}{m^2K}$

i.e., $CF_{window_{south}(Heat\ Trasnfer\ Part)} = 2.87 \frac{W}{m^2K} \times (7.9\ K - 0.46 \times 11.9\ K) \approx 6.96 \frac{W}{m^2}$

$PXI_{window_{south}} = E_D + E_d = 348 + 209 = 557$

$SHGC = 0.46$

No internal shading, so IAC =1

$FF_s = 0.47$

$CF_{window_{south}(Irradiation\ Part)} = PXI \times SHGC \times IAC \times FF_s$

$q_{window_{south}} = A \times CF_{window_{south}} = A \times (CF_{window_{south}(Heat\ Trasnfer\ Part)} + CF_{window_{south}(Irradiation\ Part)})$

$\approx 3.6\ m^2 \times (6.96 + 557 \times 0.46 \times 1 \times 0.47) \frac{W}{m^2} \approx 458.58\ W$

Calculating the heating load of the operable window on the south:

$q_{window_{south}} = A \times HF_{window_{south}} = A \times U_{window_{south}} \Delta T_{heating}$

$= 3.6\ m^2 \times 2.87 \frac{W}{m^2K} \times 24.8K \approx 256.23\ W$

When the frame were to be aluminium, $U_{window_{south}} = 4.62 \frac{W}{m^2K}$, $HSGC = 0.55$

$CF'_{window_{south}(Heat\ Trasnfer\ Part)} = U'_{window_{south}} (\Delta T_{cooling} - 0.46\ DR)$

$= 4.62 \frac{W}{m^2K} \times (7.9\ K - 0.46 \times 11.9\ K) \approx 11.21 \frac{W}{m^2}$

Cooling load $q'_{window_{south}} = A \times CF'_{window_{south}}$

$= A \times (CF'_{window_{south}(Heat\ Trasnfer\ Part)} + CF'_{window_{south}(Irradiation\ Part)})$

$\approx 3.6\ m^2 \times (11.21 + 557 \times 0.55 \times 1 \times 0.47) \frac{W}{m^2} \approx 558.70\ W$

Heating load $q'_{window_{south}} = A \times HF'_{window_{south}} = A \times U'_{window_{south}} \Delta T_{heating}$

$= 3.6\ m^2 \times 4.62 \frac{W}{m^2K} \times 24.8\ K \approx 412.47\ W$

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