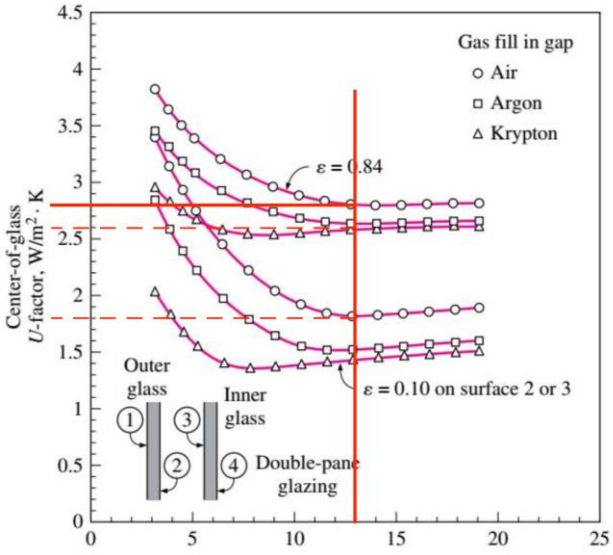
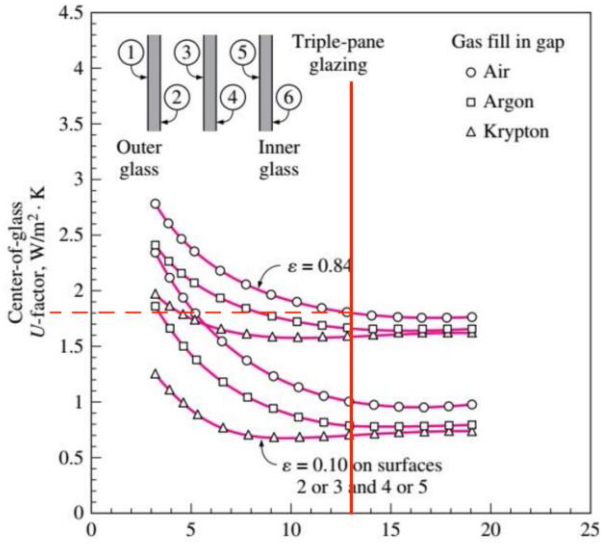
Task1.

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 thickness to be 13 mm)





	BENCHMARK	1	2	3
GAP	13mm	13mm	13mm	13mm
ε	0,84	**0,84**	**0,10**	0,84
N° PANE	2	2	2	**3**
GAS	AIR	**KRYPTON**	AIR	AIR
U_{FACTOR}	2,8 W/m²K	2,6 W/m²K	1,8 W/m²K	1,8 W/m²K
%	100%	93%	64%	64%

1. from the graph it is possible to see that by comparing the benchmark with the
first case where the gas (krypton) has been changed, the UFACTOR value decreases by 7%, thus improving the thermal transmittance of the window.
2. in the second comparison, using a low emissivity coating, the UFACTOR value
decreases by 36%, greatly improving the thermal transmittance compared to the benchmark.
3. in the last comparison, adding an extra pane, the UFACTOR value, still decreases
by 36%, proving a great improvement in the thermal efficiency of the window.

Task 2
Consider the house that we analysed 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 aluminium?

PIACENZA
LAT: 44,92 N
LONG: 9,73 E
ELEV :138
T_{SUMMER}: 24°
T_{WINTER}: 20°
HEATING DB 99%: - 4,8

COOLING DB/MCWB 1%: 31,9
$\Delta T_{cooling}$ = 31,9 − 24 = 7,9 ℃
$\Delta T_{heating}$= 20 − (−4,8) = 24,8 ℃
EAST SIDE OF THE BUILDING
45° LATITUDE
No internal shading – AIC = 1
DR = 11,9

Wood Frame Section

WINDOW 1

A_{W1east}= 14,4 m^2

EAST
FIXED
WOOD FRAME

Heating:

$U_{w1east=}$ 2,84 W/m^2 K

$HF_{w1east=} U_{W1east} * \Delta T_{cooling}$ = 2.84 *24.8 = 70.44

$Q_{w1east}= HF_{W1east} * A_{W1east}$ = 70.44 * 14.4 = 1014.2 W

Cooling

Part for Heat transfer

$CF_{W1east} = U_{W1east} *(\Delta T_{cooling} – 0.46 * DR)$ = 2,84 (7,9 − 0,46 · 11,9) = 6,9 W/m^2

Part for Irradiation part

E_D = 559

E_d= 188

East window of a detached house - FFS = 0.31

SHGC= 0.54

$PXI_{W1east} = E_D + E_d$ = 559 + 188 = 747

CF_{W1east} = PXI*SHGC*IAC*FF_s= 747*0.54*1*0.31=125.1

$CF_{fenestration1east}$= U_{w1east}*($\Delta T_{cooling}$ – 0.46 * DR) +PXI *SHGC *IAC * FF_s = 6.9 +125.1 =132 W/m^2

$\dot{Q}_{w1east}$ = $CF_{fenestration1east}$ * A_{W1east} = 132*14.4 = 1900.8 W

WINDOW 2

A_{W2west}= 14,4 m^2

WEST
FIXED
WOOD FRAME

Heating:

$U_{W2west=}$ 2,84 W/m^2 K

$HF_{W2west=}$ U_{W2west} * $\Delta T_{cooling}$ = 2.84 *24.8 = 70.44

Q_{W2west}= HF_{W2west} * A_{W2west} = 70.44 * 14.4 = 1014.2 W

Cooling

Part for Heat transfer

CF_{W2west} = U_{W2west} *($\Delta T_{cooling}$ – 0.46 * DR) = 2,84 (7,9 − 0,46 · 11,9) = 6,9 W/m^2

E_D = 559

E_d= 188

West window of a detached house - FFS = 0.31

SHGC= 0.54

PXI_{W2west} = E_D + E_d = 559 + 188 = 747

CF_{W2west} = PXI*SHGC*IAC*FF_s=747*0.54*1*0.56=225.9

$CF_{fenestration2west} = U_{w2west}*(\Delta T_{cooling} - 0.46 * DR) + PXI * SHGC * IAC * FF_s = 6.9+225.9=232.8\ W/m^2$

$\dot{Q}_{W2west} = CF_{fenestration2west} * A_{W2west} = 232.8 * 14.4 = 3352.32\ W$

WINDOW 3

$A_{W3south} = 3.6\ m^2$

SOUTH
FIXED
WOOD FRAME

Heating:

$U_{W3south} = 2{,}84\ W/m^2\ K$

$HF_{W3south} = U_{W3south} * \Delta T_{cooling} = 2.84 * 24.8 = 70.44\ W/m^2$

$Q_{W3south} = HF_{W3south} * A_{W3south} = 70.44 * 3.6 = 253.6\ W$

Cooling

Heat transfer part

$CF_{W3south} = U_{W3south}*(\Delta T_{cooling} - 0.46 * DR) = 2{,}84\ (7{,}9 - 0{,}46 \cdot 11{,}9) = 6{,}9\ W/m^2$

Part for Irradiation part

$E_D = 348$

$E_d = 209$

South window of a detached house - FFS = 0.31

SHGC= 0.54

$PXI_{W3south} = E_D + E_d = 348 + 209 = 557$

$CF_{W3south} = PXI*SHGC*IAC*FF_s = 557*0.54*1*0.47=141.4$

$CF_{fenestration3south} = U_{w3south}*(\Delta T_{cooling} - 0.46 * DR) + PXI * SHGC * IAC * FF_s = 6.9 +141.4=148.3\ W/m^2$

$\dot{Q}_{W3south} = CF_{fenestration3south} * A_{W3south} = 148.3*3.6 = 533.88$ W

WINDOW 4

$A_{W4south} = 3.6$ m^2

SOUTH
OPERABLE
WOOD FRAME

Heating:

$U_{W4south} = 2{,}87$ W/m^2 K

$HF_{W4south} = U_{W4south} * \Delta T_{cooling} = 2.87 *24.8 = 71.17$ W/ m^2

$Q_{W4south} = HF_{W4south} * A_{W4south} = 71.17 * 3.6 = 256.2$ W

Cooling

Heat transfer part

$CF_{W4south} = U_{W4south} *(\Delta T_{cooling} - 0.46 * DR) = 2{,}87\ (7{,}9 - 0{,}46 \cdot 11{,}9) = 6{,}96$ W/m^2

Part for Irradiation part

$E_D = 348$

$E_d = 209$

South window of a detached house - FFS = 0.47

SHGC= 0.46

$PXI_{W4south} = E_D + E_d = 348 + 209 = 557$

$CF_{W4south} = PXI*SHGC*IAC*FF_s = 557*0.46*1*0.47=120.4$

$CF_{fenestration4south} = U_{w3south} *(\Delta T_{cooling} - 0.46 * DR) + PXI *SHGC *IAC * FF_s = 6.9 +120.4=127.3$ W/m^2

$\dot{Q}_{W4south} = CF_{fenestration4south} * A_{W4south} = 127.3*3.6 = 458.28$ W

$\dot{Q}_{\text{Total windows Cooling wood frame}}$ = 1900,.8 + 3352.32 + 533.88 + 458.28 = 6245.3 W

$\dot{Q}_{\text{Total windows Heating wood frame}}$ = 1014.2+1014.2+253.6+256.2=2538.2 W

Aluminium Frame Section

Window 1

A_{W1east}= 14,4 m^2

EAST
FIXED
Aluminium FRAME

Heating:

$U_{w1east=}$ 3.61 W/m^2 K

$HF_{w1east=} U_{W1east} * \Delta T_{cooling}$ = 3.61 *24.8 = 89.52 W/m^2

$Q_{w1east}= HF_{W1east} * A_{W1east}$ = 89.52 * 14.4 = 1289.1 W

Cooling

Part for Heat transfer

$CF_{W1east} = U_{W1east} *(\Delta T_{cooling} – 0.46 * DR)$ = 3.61* (7,9 − 0,46 · 11,9) = 8.7 W/m^2

Part for Irradiation part

E_D = 559

E_d= 188

East window of a detached house - FFS = 0.31

SHGC= 0.56

$PXI_{W1east} = E_D + E_d$ = 559 + 188 = 747

CF_{W1east} = PXI*SHGC*IAC*FF_s= 747*0.56*1*0.31=129.6

$CF_{fenestration1east}= U_{w1east}*(\Delta T_{cooling} – 0.46 * DR) +PXI *SHGC *IAC * FF_s = 8.7 +129.6 =138.3\ W/m^2$

$\dot{Q}_{w1east} = CF_{fenestration1east} * A_{W1east} = 138.3*14.4 = 1991.5\ W$

WINDOW 2

$A_{W2west}= 14{,}4\ m^2$

WEST
FIXED
Aluminium FRAME

Heating:

$U_{W2west=} 3.61\ W/m^2\ K$

$HF_{W2west=} U_{W2west} * \Delta T_{cooling} = 3.61 *24.8 = 70.44$

$Q_{W2west}= HF_{W2west} * A_{W2west} = 89.52 * 14.4 = 1289.1\ W$

Cooling

Part for Heat transfer

$CF_{W2west} = U_{W2west} *(\Delta T_{cooling} – 0.46 * DR) = 3.61\ (7{,}9 - 0{,}46 \cdot 11{,}9) = 8.7\ W/m^2$

$E_D = 559$

$E_d= 188$

West window of a detached house - FFS = 0.56

SHGC= 0.56

$PXI_{W2west} = E_D + E_d = 559 + 188 = 747$

$CF_{W2west} = PXI*SHGC*IAC*FF_s=747*0.56*1*0.56=234.26$

$CF_{fenestration2west}= U_{w2west}*(\Delta T_{cooling} – 0.46 * DR) +PXI *SHGC *IAC * FF_s = 8.7+234.26=242.96\ W/m^2$

$\dot{Q}_{W2west} = CF_{fenestration2west} * A_{W2west} = 242.96 * 14.4 = 3498.6$ W

WINDOW 3

$A_{W3south} = 3.6$ m^2

SOUTH
FIXED
ALUMINIUM FRAME

Heating:

$U_{W3south=} 3.61$ W/m^2 K

$HF_{W3south=} U_{W3south} * \Delta T_{cooling} = 3.61 * 24.8 = 89.52$ W/ m^2

$Q_{W3south} = HF_{W3south} * A_{W3south} = 89.52 * 3.6 = 322.2$ W

Cooling

Heat transfer part

$CF_{W3south} = U_{W3south} *(\Delta T_{cooling} - 0.46 * DR) = 3.61\ (7{,}9 - 0{,}46 \cdot 11{,}9) = 8.7$ W/m^2

Part for Irradiation part

$E_D = 348$

$E_d = 209$

South window of a detached house - FFS = 0.47

SHGC= 0.56

$PXI_{W3south} = E_D + E_d = 348 + 209 = 557$

$CF_{W3south} = PXI*SHGC*IAC*FF_s = 557*0.56*1*0.47=146.6$

$CF_{fenestration3south} = U_{w3south} *(\Delta T_{cooling} - 0.46 * DR) + PXI *SHGC *IAC * FF_s = 8.7 +146.6=155.3$ W/m^2

$\dot{Q}_{W3south} = CF_{fenestration3south} * A_{W3south} = 155.3*3.6 = 559.08$ W

WINDOW 4

$A_{W4south}$= 3.6 m^2

SOUTH
OPERABLE
ALUMINIUM FRAME

Heating:

$U_{W4south=}$ 4.62 $W/m^2 K$

$HF_{W4south=} U_{W4south} * \Delta T_{cooling} = 4.62 * 24.8 = 114.57 W/ m^2$

$Q_{W4south} = HF_{W4south} * A_{W4south} = 114.57 * 3.6 = 412.4 W$

Cooling

Heat transfer part

$CF_{W4south} = U_{W4south} *(\Delta T_{cooling} – 0.46 * DR) = 4.62 (7,9 - 0,46 \cdot 11,9) = 11.2 W/m^2$

Part for Irradiation part

$E_D = 348$

$E_d = 209$

South window of a detached house - FFS = 0.47

SHGC= 0.55

$PXI_{W4south} = E_D + E_d = 348 + 209 = 557$

$CF_{W4south} = PXI*SHGC*IAC*FF_s = 557*0.55*1*0.47=143.95$

$CF_{fenestration4south} = U_{w3south} *(\Delta T_{cooling} – 0.46 * DR) + PXI *SHGC *IAC * FF_s = 11.2 +143.98=155.18 W/m^2$

$\dot{Q}_{W4south} = CF_{fenestration4south} * A_{W4south} = 155.18*3.6 = 558.65 W$

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$\dot{Q}_{\text{Total windows Cooling Aluminium frame}} = 1991.5 + 3498.6 + 559.08 + 558.65 = 6607.8\ W$

$\dot{Q}_{\text{Total windows Heating Aluminium frame}} = 1289.1 + 1289.1 + 322.2 + 412.4 = 3312.8\ W$

Conclusion

$\dot{Q}_{\text{Total windows Cooling Aluminium frame}}$ **(6607 W)** $> \dot{Q}_{\text{Total windows Cooling wood frame}}$ **(6245.3 W)**

$\dot{Q}_{\text{Total windows Heating Aluminium frame}}$ **(3312.8 W)** $> \dot{Q}_{\text{Total windows Heating wood frame}}$ **(2538.2 W)**

Based on the results wood is a better material to use for the frames than aluminium since it has better resistance in cooling and heating aspects