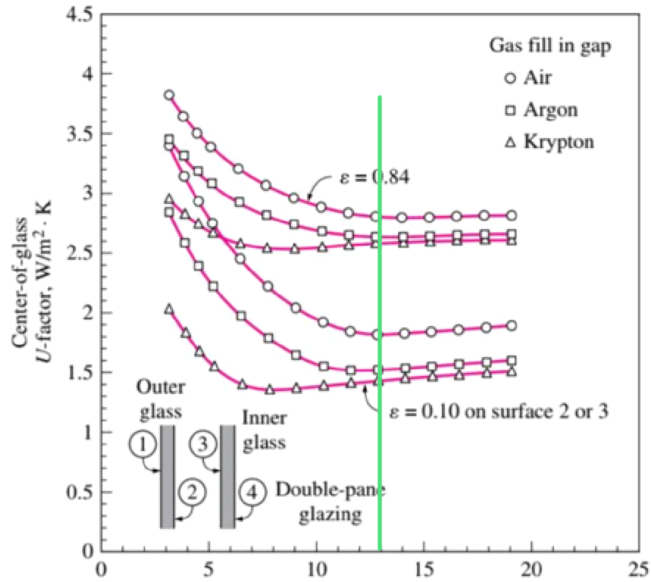
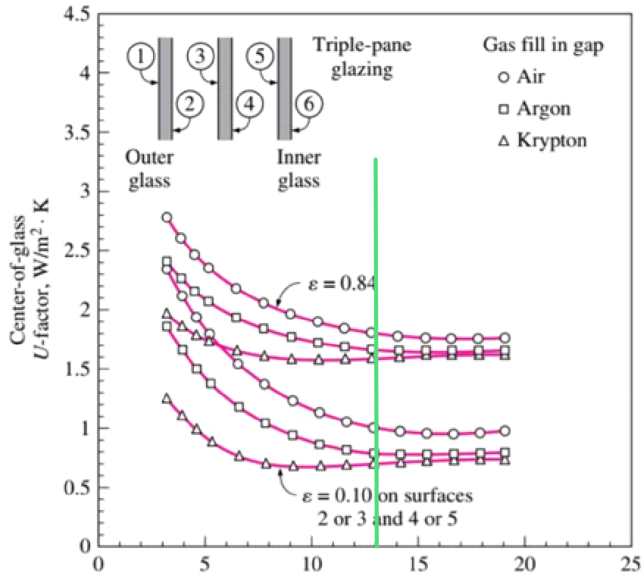
Task 1:

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 thickens to be 13 mm)





<u>With double pane glazing: (when ε=0.10):</u>
The U factor when using Krypton gas is 1.4 $\frac{W}{m^2K}$ while with Argon gas the U factor is 1.5$\frac{W}{m^2}$ → it notable that there is not so much difference, but using air in the gap bwtween the two pane the U factor is increasing 1.8$\frac{W}{m^2}$
<u>when ε=0.84</u> - the U factor of Krypton and Argon gases are almost the same 2.1 $\frac{W}{m^2}$ while the Ufactor of the air is 2.3$\frac{W}{m^2}$

<u>With triple pane glazing: (when ε=0.10):</u>
The U factor when using Krypton gas is 0.7 $\frac{W}{m^2K}$ while with Argon gas the U factor is 0.8$\frac{W}{m^2}$ → it notable that there is not so much difference, but using air in the gap bwtween the three pane the U factor is increasing 1$\frac{W}{m^2}$
<u>when ε=0.84</u> - the U factor of Krypton and Argon gases are almost the same1.6 $\frac{W}{m^2}$ while the Ufactor of the air is 1.8$\frac{W}{m^2}$

- Comparing a double glazed window to a triple glazing window, it notable that the U factor varies significantly changing (by almost half)
- The differences between the emissivity in a double glazed window are also significant and almost triple up. Compared to a window with triple glazing, which values only multiply itself.

Task 2:

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 ?

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.

PIACENZA, Italy WMO#: **160840**

Lat: **44.92N** Long: **9.73E** Elev: **138** StdP: **99.68** Time Zone: **1.00 (EUW)** Period: **89-10** WBAN: **99999**

Annual Heating and Humidification Design Conditions

Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB		
			99.6%			99%			0.4%		1%				
	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD	
(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	(1)

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB		
		0.4%		1%		2%		0.4%		1%		2%				
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD	
(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	(2)

$\Delta T_{cooling} = 31.9 - 24 = 7.9\,°C$

$\Delta T_{heating} = 20 - (-4.8) = 24.8\,°C$

$DR = 11.9\,°C$

The RLF method uses the following to estimate cooling load:

$$q_{opq} = A \times CF_{opq}$$

$$CF_{opq} = U(OF_t \Delta t + OF_b + OF_r DR)$$

where

q_{opq} = opaque surface cooling load, W
A = net surface area, m^2
CF = surface cooling factor, W/m^2
U = construction U-factor, $W/(m^2 \cdot K)$
Δt = cooling design temperature difference, K
OF_t, OF_b, OF_r = opaque-surface cooling factors (see Table 7)
DR = cooling daily range, K

Surface Type	OF_t	OF_b, K	OF_r
Ceiling or wall adjacent to vented attic	0.62	$14.3\alpha_{roof} - 4.5$	–0.19
Ceiling/roof assembly	1	$38.3\alpha_{roof} - 7.0$	–0.36
Wall (wood frame) or door with solar exposure	1	8.2	–0.36
Wall (wood frame) or door (shaded)	1	0	–0.36
Floor over ambient	1	0	–0.06
Floor over crawlspace	0.33	0	–0.28
Slab floor (see Slab Floor section)			

α_{roof} = roof solar absorptance (see Table 8).

$Q_{heating\_wall}$ = 105.8*5.175= 547.558$\frac{W}{m^2}$

$CF_{opq} = U(OF_t \Delta t + OF_b + OF_r DR)$ = 0.438(1*7.9+8.2-0.36*11.9)=5.175$\frac{W}{m^2}$

$Q_{cooling\_wall}$= 105.8*5.139=543.80 $\frac{W}{m^2}$

$CF_{opq} = U(OF_t \Delta t + OF_b + OF_r DR)$ = 0.435(1*7.9+8.2-0.36*11.9)=5.139$\frac{W}{m^2}$

$Q_{load-south}$ =3.6*5.175=18.63$\frac{W}{m^2}$

$CF_{opq} = U(OF_t \Delta t + OF_b + OF_r DR)$ = 0.438(1*7.9+8.2-0.36*11.9)=5.175$\frac{W}{m^2}$

$Q_{load-west}$ = 14.4*5.139=74$\frac{W}{m^2}$

$CF_{opq} = U(OF_t \Delta t + OF_b + OF_r DR)$ = 0.435(1*7.9+8.2-0.36*11.9)=5.139$\frac{W}{m^2}$

The U-factors for various frames are listed in the Table as a function of spacer materials and the glazing unit thicknesses. The U-factor of metal framing and thus the rate of heat transfer through a metal window frame is more than three times that of a wood or vinyl window frame.

Frame material	U-factor, W/m^2 · °C*
Aluminum:	
Single glazing (3 mm)	10.1
Double glazing (18 mm)	10.1
Triple glazing (33 mm)	10.1
Wood or vinyl:	
Single glazing (3 mm)	2.9
Double glazing (18 mm)	2.8
Triple glazing (33 mm)	2.7

$Q_{load\ -south}$ =3.6*524.456=1888.044$\frac{W}{m^2}$

$CF_{opq-wood} = U\left(OF_t\Delta\,t + OF_b + OF_r DR\right)$ = 2.8(1*7.9+8.2-0.36*11.9)=524.456$\frac{W}{m^2}$

$Q_{load-west}$ = 14.4*1891.79=27241.784$\frac{W}{m^2}$

$CF_{opq-aluminium} = U\left(OF_t\Delta\,t + OF_b + OF_r DR\right)$ = 10.1(1*7.9+8.2-0.36*11.9)=1891.79$\frac{W}{m^2}$

Transparent Fenestration Surface

Cooling load associated with non-door fenestration is calculated as follows:

$$q_{fen} = A \times \mathrm{CF}_{fen}$$

$$\mathrm{CF}_{fen} = U(\Delta t - 0.46\mathrm{DR}) + \mathrm{PXI} \times \mathrm{SHGC} \times \mathrm{IAC} \times \mathrm{FF}_s$$

where

q_{fen} = fenestration cooling load, W
A = fenestration area (including frame), m^2
CF$_{fen}$ = surface cooling factor, W/m^2
U = fenestration NFRC *heating* U-factor, W/(m^2·K)
Δt = cooling design temperature difference, K
PXI = peak exterior irradiance, including shading modifications, W/m^2 [see Equations (26) or (27)]
SHGC = fenestration rated or estimated NFRC solar heat gain coefficient
IAC = interior shading attenuation coefficient, Equation (29)
FF$_s$ = fenestration solar load factor, Table 13

					Frame									
					Operable					Fixed				
Glazing Type	Glazing Layers	ID[b]	Property[c,d]	Center of Glazing	Aluminum	Aluminum with Thermal Break	Reinforced Vinyl/Aluminum Clad Wood	Wood/Vinyl	Insulated Fiberglass/Vinyl	Aluminum	Aluminum with Thermal Break	Reinforced Vinyl/Aluminum Clad Wood	Wood/Vinyl	Insulated Fiberglass/Vinyl
Clear	1	1a	U	5.91	7.24	6.12	5.14	5.05	4.61	6.42	6.07	5.55	5.55	5.35
			SHGC	0.86	0.75	0.75	0.64	0.64	0.64	0.78	0.78	0.75	0.75	0.75
	2	5a	U	2.73	4.62	3.42	3.00	2.87	5.83	3.61	3.22	2.86	2.84	2.72
			SHGC	0.76	0.67	0.67	0.57	0.57	0.57	0.69	0.69	0.67	0.67	0.67
	3	29a	U	1.76	3.80	2.60	2.25	2.19	1.91	2.76	2.39	2.05	2.01	1.93
			SHGC	0.68	0.60	0.60	0.51	0.51	0.51	0.62	0.62	0.60	0.60	0.60
Low-e, low-solar	2	25a	U	1.70	3.83	2.68	2.33	2.21	1.89	2.75	2.36	2.03	2.01	1.90
			SHGC	0.41	0.37	0.37	0.31	0.31	0.31	0.38	0.38	0.36	0.36	0.36
	3	40c	U	1.02	3.22	2.07	1.76	1.71	1.45	2.13	1.76	1.44	1.40	1.33
			SHGC	0.27	0.25	0.25	0.21	0.21	0.21	0.25	0.25	0.24	0.24	0.24
Low-e, high-solar	2	17c	U	1.99	4.05	2.89	2.52	2.39	2.07	2.99	2.60	2.26	2.24	2.13
			SHGC	0.70	0.62	0.62	0.52	0.52	0.52	0.64	0.64	0.61	0.61	0.61
	3	32c	U	1.42	3.54	2.36	2.02	1.97	1.70	2.47	2.10	1.77	1.73	1.66
			SHGC	0.62	0.55	0.55	0.46	0.46	0.46	0.56	0.56	0.54	0.54	0.54
Heat-absorbing	1	1c	U	5.91	7.24	6.12	5.14	5.05	4.61	6.42	6.07	5.55	5.55	5.35
			SHGC	0.73	0.64	0.64	0.54	0.54	0.54	0.66	0.66	0.64	0.64	0.64
	2	5c	U	2.73	4.62	3.42	3.00	2.87	2.53	3.61	3.22	2.86	2.84	2.72
			SHGC	0.62	0.55	0.55	0.46	0.46	0.46	0.56	0.56	0.54	0.54	0.54
	3	29c	U	1.76	3.80	2.60	2.25	2.19	1.91	2.76	2.39	2.05	2.01	1.93
			SHGC	0.34	0.31	0.31	0.26	0.26	0.26	0.31	0.31	0.30	0.30	0.30
Reflective	1	1l	U	5.91	7.24	6.12	5.14	5.05	4.61	6.42	6.07	5.55	5.55	5.35
			SHGC	0.31	0.28	0.28	0.24	0.24	0.24	0.29	0.29	0.27	0.27	0.27
	2	5p	U	2.73	4.62	3.42	3.00	2.87	2.53	3.61	3.22	2.86	2.84	2.72
			SHGC	0.29	0.27	0.27	0.22	0.22	0.22	0.27	0.27	0.26	0.26	0.26
	3	29c	U	1.76	3.80	2.60	2.25	2.19	1.91	2.76	2.39	2.05	2.01	1.93
			SHGC	0.34	0.31	0.31	0.26	0.26	0.26	0.31	0.31	0.30	0.30	0.30

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

Table 10 Peak Irradiance, W/m²

Exposure		Latitude 20°	25°	30°	35°	40°	45°	50°	55°	60°
North	E_D	125	106	92	84	81	85	96	112	136
	E_d	128	115	103	93	84	76	69	62	55
	E_t	253	221	195	177	166	162	164	174	191
Northeast/Northwest	E_D	460	449	437	425	412	399	386	374	361
	E_d	177	169	162	156	151	147	143	140	137
	E_t	637	618	599	581	563	546	529	513	498
East/West	E_D	530	543	552	558	560	559	555	547	537
	E_d	200	196	193	190	189	188	187	187	187
	E_t	730	739	745	748	749	747	742	734	724
Southeast/Southwest	E_D	282	328	369	405	436	463	485	503	517
	E_d	204	203	203	204	205	207	210	212	215
	E_t	485	531	572	609	641	670	695	715	732
South	E_D	0	60	139	214	283	348	408	464	515
	E_d	166	193	196	200	204	209	214	219	225
	E_t	166	253	335	414	487	557	622	683	740
Horizontal	E_D	845	840	827	806	776	738	691	637	574
	E_d	170	170	170	170	170	170	170	170	170
	E_t	1015	1010	997	976	946	908	861	807	744

With wooden frame:

East window:

$U_{window\ east} = 2.84\frac{W}{m^2}$
$HF_{window\ east}$=$U * \Delta$T= 2.84*24.8=70.432$\frac{W}{m^2}$
$Q_{window\ east}$=$HF_{window\ east} * HF_{window\ east}$=70.432*14.4=1014.22W

There is not any inner shading:
$CF_{fen} = U(\Delta\, t - 0.46DR) + PXI * SHGC * IAC * FF_S$ =2.84*(7.9-0.46*11.9)+(559+188)*0.54*1*0.31=131.93$\frac{W}{m^2}$
$Q_{window\ east}$=$CF_{window\ east} * A_{window\ east}$ = 131.93*14.4=1899.90W

For east window with frame fixed:
$U_{window\ east} = 2.84\frac{W}{m^2}$
$HF_{window\ east}$=$U * \Delta$T= 2.84*24.8=70.432$\frac{W}{m^2}$
$Q_{window\ east}$=$HF_{window\ east} * HF_{window\ east}$=70.432*14.4=1014.22W

There is not any inner shading:
$CF_{fen} = U(\Delta\, t - 0.46DR) + PXI * SHGC * IAC * FF_S$ =2.84*(7.9-0.46*11.9)+(559+188)*0.54*1*0.56=232.782$\frac{W}{m^2}$
$Q_{window\ east}$=$CF_{window\ east} * A_{window\ east}$ = 232.782*14.4=3352.070W

South window:

$U_{window\ east} = 2.84\frac{W}{m^2}$
$HF_{window\ east}$=$U * \Delta$T= 2.84*24.8=70.432$\frac{W}{m^2}$
$Q_{window\ east}$=$HF_{window\ east} * HF_{window\ east}$=70.432*3.6=253.55W

There is not any inner shading:
$CF_{fen} = U(\Delta\, t - 0.46DR) + PXI * SHGC * IAC * FF_S$ =2.84*(7.9-0.46*11.9)+(348+209)*0.54*1*0.47=148.256$\frac{W}{m^2}$
$Q_{window\ east}$=$CF_{window\ east} * A_{window\ east}$ = 148.256*3.6=533.72W

For south window with frame operable:
$U_{window\ east} = 2.87\frac{W}{m^2}$
$HF_{window\ east}$=$U * \Delta$T= 2.87*24.8=71.176$\frac{W}{m^2}$
$Q_{window\ east}$=$HF_{window\ east} * HF_{window\ east}$=71.176*3.6=256.233W

There is not any inner shading:
$CF_{fen} = U(\Delta\, t - 0.46DR) + PXI * SHGC * IAC * FF_S$ =2.87*(7.9-0.46*11.9)+(348+209)*0.46*1*0.47=127.386$\frac{W}{m^2}$
$Q_{window\ east}$=$CF_{window\ east} * A_{window\ east}$ = 127.386*3.6=458.589W

With aluminum frame

East window:

$U_{window\ east} = 3.61\frac{\mathrm{W}}{\mathrm{m}^2}$
$HF_{window\ east}$=$U * \Delta$T= 3.61*24.8=89.528$\frac{W}{m^2}$
$Q_{window\ east}$=$HF_{window\ east} * HF_{window\ east}$=89.528*14.4=1289.20W

There is not any inner shading:
$CF_{fen} = U(\Delta\, t - 0.46DR) + PXI * SHGC * IAC * FF_S$ =3.61*(7.9-0.46*11.9)+(559+188)*0.56*1*0.31=138.437$\frac{W}{m^2}$

$Q_{window\ east}$=$CF_{window\ east} * A_{window\ east}$ = 138.437*14.4=1993.49W

For east window with frame fixed:
$U_{window\ east} = 3.61\frac{\mathrm{W}}{\mathrm{m}^2}$
$HF_{window\ east}$=$U * \Delta$T= 3.61*24.8=89.528$\frac{W}{m^2}$
$Q_{window\ east}$=$HF_{window\ east} * HF_{window\ east}$=89.528*14.4=1289.20W

There is not any inner shading:
$CF_{fen} = U(\Delta\ t - 0.46DR) + PXI * SHGC * IAC * FF_S$ =3.61*(7.9-0.46*11.9)+(559+188)*0.56*1*0.56=243.017$\frac{W}{m^2}$
$Q_{window\ east}$=$CF_{window\ east} * A_{window\ east}$ = 243.017*14.4=3499.445W

South window:
$U_{window\ east} = 3.61\frac{\mathrm{W}}{\mathrm{m}^2}$
$HF_{window\ east}$=$U * \Delta$T= 3.61*24.8=89.528$\frac{W}{m^2}$
$Q_{window\ east}$=$HF_{window\ east} * HF_{window\ east}$=89.528*3.6=322.30W

There is not any inner shading:
$CF_{fen} = U(\Delta\ t - 0.46DR) + PXI * SHGC * IAC * FF_S$ =3.61*(7.9-0.46*11.9)+(348+209)*0.56*1*0.47=155.36$\frac{W}{m^2}$
$Q_{window\ east}$=$CF_{window\ east} * A_{window\ east}$ = 155.36*3.6=559.296W

For south window with frame operable 3.6m^2:
$U_{window\ east} = 4.62\frac{\mathrm{W}}{\mathrm{m}^2}$
$HF_{window\ east}$=$U * \Delta$T= 4.62*24.8=114.576$\frac{W}{m^2}$
$Q_{window\ east}$=$HF_{window\ east} * HF_{window\ east}$=114.576*3.6=412.473W

There is not any inner shading:
$CF_{fen} = U(\Delta\ t - 0.46DR) + PXI * SHGC * IAC * FF_S$ =4.62*(7.9-0.46*11.9)+(348+209)*0.55*1*0.47=155.192$\frac{W}{m^2}$
$Q_{window\ east}$=$CF_{window\ east} * A_{window\ east}$ = 155.192*3.6=558.693W

When calculating the total load, it notable that there is differences between the materials. The main significant difference is in the U factor, that effect on the Q total.