Week-8

Tuesday, November 26, 2019 9:38 PM

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 thickness to be 13 mm)

low emissivity coating: For effective emissivity of a double layered glass as you see in the diagram with changing the emissivity of window ($\varepsilon = 0.72$) by using a coat of film ($\varepsilon = 0.01$) we can reduce the $\varepsilon_{effective}$ from 5.7 $^{w}/_{m2}$ to 2.5 $^{w}/_{m2}$

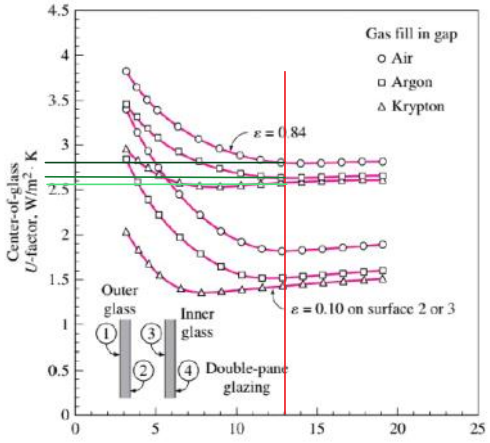
(a) Air space thickness = 13 mm

T_{avg}, °C	ΔT, °C	h_{space}, W/m² · °C * $\varepsilon_{effective}$ 0.72	0.4	0.2	0.1
0	5	5.3	3.8	2.9	2.4
0	15	5.3	3.8	2.9	2.4
0	30	5.5	4.0	3.1	2.6
10	5	5.7	4.1	3.0	2.5
10	15	5.7	4.1	3.1	2.5
10	30	6.0	4.3	3.3	2.7
30	5	5.7	4.6	3.4	2.7
30	15	5.7	4.7	3.4	2.8

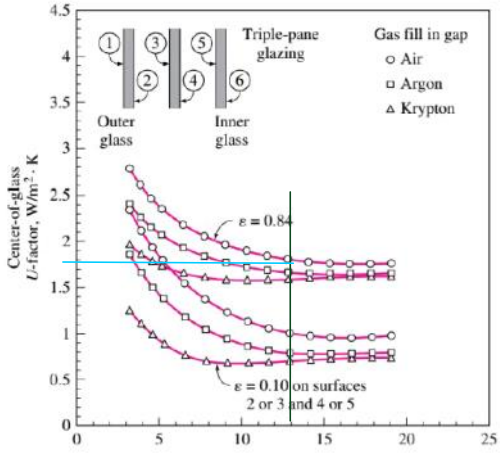
(b) Air space thickness = 6 mm

T_{avg}, °C	ΔT, °C	h_{space}, W/m² · °C * $\varepsilon_{effective}$ 0.72	0.4	0.2	0.1
0	5	7.2	5.7	4.8	4.3
0	50	7.2	5.7	4.8	4.3
10	5	7.7	6.0	5.0	4.5
10	50	7.7	6.1	5.0	4.5
30	5	8.8	6.8	5.5	4.9
30	50	8.8	6.8	5.5	4.9
50	5	10.0	7.5	6.0	5.2
50	50	10.0	7.5	6.0	5.2

changing the gas:
In the following diagram there are 3 different curves that compares the thickness of the fluid between double layered glass and type of fluid.
So by interpreting the diagram we understand that by Krypton is the most efficient gas that we can use for the window to reduce the heat transfer.
In 13mm double layered window ($\varepsilon_{effective}$= 0.84) when we change the gass between the layers of glass from Air to Krypton U-factor is reduced from 2.8 $^{w}/_{m2}$ to 2.58 $^{w}/_{m2}$



adding an extra pane:
By analyzing the diagram and comparing to the previous diagram we conclude that in 13mm double layered window with the emissivity of 0.84 by adding another pane we can reduce U-factor from 2.8 $^{w}/_{m2}$ to 1.8 $^{w}/_{m2}$ and consequently reduce thermal transfer.



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?

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

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

where

q_{fen} = fenestration cooling load, W
A = fenestration area (including frame), m²
CF_{fen} = surface cooling factor, W/m²
U = fenestration NFRC *heating* U-factor, W/(m²·K)
Δt = cooling design temperature difference, K
PXI = peak exterior irradiance, including shading modifications, W/m² [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

$\mathrm{PXI}_{\mathrm{window_{east}}} = \mathrm{T_x}\,\mathrm{E_t} = 747\ {}^{\mathrm{w}}/_{\mathrm{m2}}$

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

$\mathrm{SHGC} = 0.54$

Glazing Type	Glazing Layers	ID[b]	Property[c,d]	Center of Glazing	Frame: Operable: Aluminum	Operable: Aluminum with Thermal Break	Operable: Reinforced Vinyl/Aluminum Clad Wood	Operable: Wood/Vinyl	Operable: Insulated Fiberglass/Vinyl	Fixed: Aluminum	Fixed: Aluminum with Thermal Break	Fixed: Reinforced Vinyl/Aluminum Clad Wood	Fixed: Wood/Vinyl	Fixed: 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

Glazing Type	Glazing Layers	ID[b]	Property[c,d]	Center of Glazing	Frame: Operable: Aluminum	Operable: Aluminum with Thermal Break	Operable: Reinforced Vinyl/Aluminum Clad Wood	Operable: Wood/Vinyl	Operable: Insulated Fiberglass/Vinyl	Fixed: Aluminum	Fixed: Aluminum with Thermal Break	Fixed: Reinforced Vinyl/Aluminum Clad Wood	Fixed: Wood/Vinyl	Fixed: 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

No internal shading so IAC = 1

FFS_{west} = 0.56

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

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%	99.6% DP	99.6% HR	99.6% MCDB	99% DP	99% HR	99% MCDB	0.4% WS	0.4% MCDB	1% WS	1% MCDB		
(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 0.4% DB	Cooling DB/MCWB 0.4% MCWB	Cooling DB/MCWB 1% DB	Cooling DB/MCWB 1% MCWB	Cooling DB/MCWB 2% DB	Cooling DB/MCWB 2% MCWB	Evaporation WB/MCDB 0.4% WB	Evaporation WB/MCDB 0.4% MCDB	Evaporation WB/MCDB 1% WB	Evaporation WB/MCDB 1% MCDB	Evaporation WB/MCDB 2% WB	Evaporation WB/MCDB 2% MCDB	MCWS/PCWD to 0.4% DB MCWS	MCWS/PCWD to 0.4% DB 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)

Based on ASHRAE Standard 55 typical practices are the following:

- For cooling: 24°C db and a maximum of 50 to 65% rh.
- For heating: 20°C db and 30% rh

$$\Delta t_{cooling} = 31.9 - 24 = 7.9\ ^{\circ}C$$

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

DR =11.9 $°C$

West (fixed)

$CF_{window_{west\_Irradiation}} = PXI \times SHGC \times IAC \times FF_S = 747 \times 0.54 \times 1 \times 0.56 = 225.9$

$CF_{windwo_{west}} = U(\Delta t - 0.46\ DR) + PXI \times SHGC \times IAC \times FF_S$
$= 2.84(7.9 - 0.46 \times 11.9) + 225.9 = 6.9 + 225.9 = 232.8$

$Q_{window_{west}} = CF_{window_{west}} \times A_{window_{west}} = 232.8 \times 14.4 = 3352.32\ W$

$HF_{window_{west}} = U_{window_{west}} \times \Delta T_{heating} = 2.84 \times 24.8 = 70.4 \frac{W}{m2}$
$Q_{window_{west}} = HF_{window_{west}} \times A_{window_{west}} = 70.4 \times 14.4 = 1014.2\ W$

South (fixed)

$CF_{windwo_{west}} = U(\Delta t - 0.46\ DR) + PXI \times SHGC \times IAC \times FF_S$
$= 2.84(7.9 - 0.46 \times 11.9) + 662 \times 0.54 \times 1 \times 0.47 = 6.9 + 168 = 174.9$

$Q_{window_{west}} = CF_{window_{west}} \times A_{window_{west}} = 174.9 \times 3.6 = 629.7\ W$

$HF_{window_{west}} = U_{window_{west}} \times \Delta T_{heating} = 2.84 \times 24.8 = 70.4 \frac{W}{m2}$
$Q_{window_{west}} = HF_{window_{west}} \times A_{window_{west}} = 70.4 \times 3.6 = 253.44\ W$

					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

South(Operable)

$CF_{windwo_{west}} = U(\Delta t - 0.46\ DR) + PXI \times SHGC \times IAC \times FF_S$
$= 2.87(7.9 - 0.46 \times 11.9) + 662 \times 0.46 \times 1 \times 0.47 = 7 + 143.12 = 150.12$

2.87(7.9-0.46×11.9)+662×0.46×1×0.47=6.9+225.9

$Q_{window_{west}} = CF_{window_{west}} \times A_{window_{west}} = 150.12 \times 3.6 = 540.43\ W$

$HF_{window_{west}} = U_{window_{west}} \times \Delta T_{heating} = 2.87 \times 24.8 = 71.18 \frac{W}{m2}$
$Q_{window_{west}} = HF_{window_{west}} \times A_{window_{west}} = 71.18 \times 3.6 = 256.23\ W$

Aluminum frame

West (fixed)

$CF_{window_{west\_Irradiation}} = PXI \times SHGC \times IAC \times FF_S = 747 \times 0.54 \times 1 \times 0.56 = 225.9$

$CF_{windwo_{west}} = U(\Delta t - 0.46\ DR) + PXI \times SHGC \times IAC \times FF_S$
$= 3.61(7.9 - 0.46 \times 11.9) + 747 \times 0.56 \times 1 \times 0.56 = 8.7 + 234.3 = 243$

$Q_{window_{west}} = CF_{window_{west}} \times A_{window_{west}} = 232.8 \times 14.4 = 3500.2W$

$HF_{window_{west}} = U_{window_{west}} \times \Delta T_{heating} = 3.61 \times 24.8 = 89.53 \frac{W}{m2}$
$Q_{window_{west}} = HF_{window_{west}} \times A_{window_{west}} = 89.53 \times 14.4 = 1289.2\ W$

South (fixed)

$CF_{windwo_{west}} = U(\Delta t - 0.46\ DR) + PXI \times SHGC \times IAC \times FF_S$
$= 3.61(7.9 - 0.46 \times 11.9) + 662 \times 0.56 \times 1 \times 0.47 = 8.7 + 174.23 = 182.93$

$Q_{window_{west}} = CF_{window_{west}} \times A_{window_{west}} = 182.93 \times 3.6 = 658.55\ W$

$HF_{window_{west}} = U_{window_{west}} \times \Delta T_{heating} = 2.84 \times 24.8 = 70.4 \frac{W}{m2}$
$Q_{window_{west}} = HF_{window_{west}} \times A_{window_{west}} = 70.4 \times 3.6 = 253.44\ W$

South(Operable)

$CF_{windwo_{west}} = U(\Delta t - 0.46\ DR) + PXI \times SHGC \times IAC \times FF_S$
$= 4.62(7.9 - 0.46 \times 11.9) + 662 \times 0.55 \times 1 \times 0.47 = 11.18 + 171.12 = 182.31$

$Q_{window_{west}} = CF_{window_{west}} \times A_{window_{west}} = 182.31 \times 3.6 = 656.3\ W$

$HF_{window_{west}} = U_{window_{west}} \times \Delta T_{heating} = 2.87 \times 24.8 = 71.18 \frac{W}{m2}$

$Q_{window_{west}} = HF_{window_{west}} \times A_{window_{west}} = 71.18 \times 3.6 = 256.23\ W$