Submission 8

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 Uvalue, with respect to a benchmark case of double layer with air and no coating. Keep the gas thickness at 13 mm.

$For\ calculating\ the\ Uvalue\ of\ a\ window,\ we\ have\ the\ equation$:

$$Uwindow = \frac{\text{UcenterAcenter + UedgeAedge + UframAfra}mx}{Awindow}$$

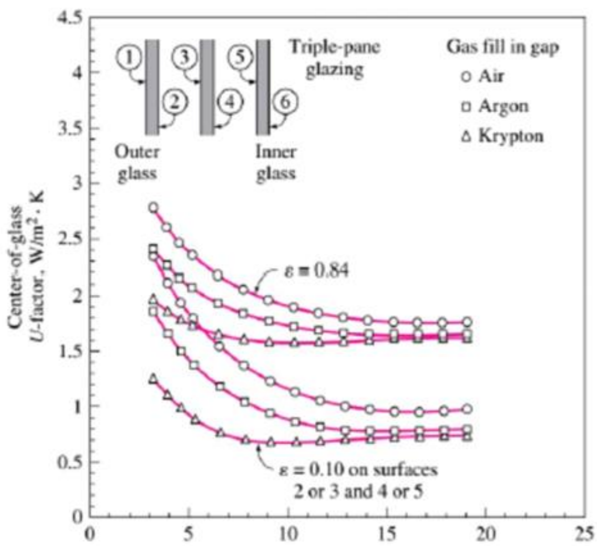
If we have a double pane window, we disregard the thermal resistance of glass layers:

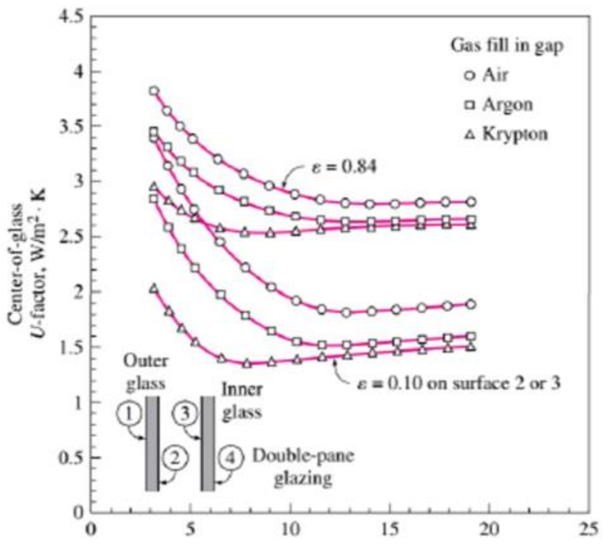
$$\frac{1}{Doublepanel\ (center\ region)} = \frac{1}{hi} + \frac{1}{hspace} + \frac{1}{h0} \quad \text{hspace} = \text{hrad, space} + \text{hconv, space}$$

1) The Ucenter changes by changing the gas that fills the gap (for example, the hspace).
From the diagram o the right, it is possible to understand that if the gap thickness is 13 mm and we change the gas that fills the gap from air to argon, the U-value of the glass' center decreases from 2.8 $\frac{\text{w}}{m2K}$ to 2.65 $\frac{\text{w}}{m2K}$,which signifies that the Uvalue decreases of about the 7.14%.

2) The Ucenter also changes by adding an extra pane.
From the diagram on the right, it is possible to see when the gap thickness is 13 mm and the gas that fills the gap is air, by adding an extra pane the U-value of the glass' center decreases from 2.8 $\frac{\text{w}}{m2K}$ to 1.8 $\frac{\text{w}}{m2K}$,which means that the Uvalue decreases of about the 55.6%.

3) Finally, the Ucenter also changes coating the glass' surfaces with a low-emissivity film.
From the diagram on the right, we can understand that when the gap thickness is 13 mm and the gas which fills the gap is air, by coating the glass' surfaces with a film that has an emissivity of 0.1, the U-value of the glass' center decreases from 2.8$\frac{\text{w}}{m2K}$ to 1.8 $\frac{\text{w}}{m2K}$,which illustrates that the Uvalue decreases of about the 55.6% (same of adding an extra pane).





TASK 2

Considering the house that we analysed in the last two examples, calculate the heating and the cooling load of the other windows that are fixed 14.4 m2 on the West and 3.6 m2 on the South (with an operable 3.6 m2 on the South, the same window and frame type). How much does the total value change, if we change the frame of the window from wood to aluminium?

The examples were:

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 $\frac{W}{m2K}$ for the winter and 0.435 $\frac{W}{m2K}$for thesummer. Find the corresponding heating and cooling load.

2) A fixed heating absorbing double glass layers window (with a wooden frame) at the East side of a building located in Piacenza has a surface of 14.4 m2, only in case there are no internal and external shading factors. Calculate the heating and cooling load of the corresponding window.

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)

1) The first passage is defining the cooling temperature (Tcooling = 24°C) and the heating design temperature (Theating = 20°C).

$\Delta\, Tcooling$ = 31.9 $°C$ − 24 $°C$ = 7.9 $°C$ = 7.9 K
$\Delta\, Theating$ = 20 $°C$ − (−4.8 °) = 24.8 $°C$ = 24.8 K
From the above table, we see that DR = 11.9 °C = 11.9 K

2) The second passage is calculating the cooling load of the fixed window on the West.
$qwindowwest = A\ x\ CFwindowwest;$
$A = 14.4\ m2;$
$CFwindowwest\ (heat\ transfer\ part) = Uwindowwest\ (\Delta\ Tcooling - 0.46\ DR).$
$The\ window\ has\ a\ fixed\ heat\ absorbing\ double\ layer\ glass\ with\ a\ wooden\ frame.$

$Uwindowwest = 2.84\ \frac{\mathrm{w}}{m2K}$
$CFwindowwest(heat\ transfer\ part) = 2.84\ \frac{\mathrm{w}}{m2K}$
$x\ (7.9\ K - 0.46\ x\ 11.9\ K) = 6.89\frac{\mathrm{w}}{m2K}$
$PXIwindowwest = ED + Ed = 559 + 188 = 747$
$SHG = 0.54$
$Since\ there\ is\ no\ internal\ shading, IAC = 1, FFs = 0.56$
$CFwindowwest(irradiation\ part) = PXI\ x\ SHGC\ x\ IAC\ x\ FFs$
$qwindowwest = A\ x\ CF\ windowwest$
$= A\ x\ \mathrm{c}CFwindowwest(heattransferpart) + CFwindowwest(irradiationpart)\mathrm{d}$
$= 14.4\ m2\ x\ (6.89 + 747\ x\ 0.54\ x\ 1\ x\ 0.56)\frac{\mathrm{w}}{m2K}$
$= 3352.07\ W$

3) At this point, we have to calculate the heating load of the fixed window on the West:
$qwindowwest = A\ x\ HFwindowwest = A\ x\ Uwindowwest\Delta\ Theating$
$= 14.4\ m2\ x\ 2.84\ \frac{\mathrm{w}}{m2K}$
$x\ 24.8\ K = 1014.22\ W$

4) When the frame is aluminium:
$Uwindowwest = 3.61\frac{\mathrm{w}}{m2K}$
$; HSGC = 0.56$
$CF\mathrm{e}windowwest(heattransferpart) = U\mathrm{e}windowwest\ (\Delta\ Tcooling - 0.46\ DR)$
$= 3.61\frac{\mathrm{w}}{m2K}$
$x\ (7.9\ K - 0.46\ x\ 11.9\ K) = 8.76\frac{\mathrm{w}}{m2K}$
$Cooling\ load\ q\mathrm{e}windowwest = A\ x\ CF\mathrm{e}windowwest$
$= A\ x\ \mathrm{c}CF\mathrm{e}windowwest(heattransferpart) + CF\mathrm{e}windowwest(irradiationpart)\mathrm{d}$
$= 14.4\ m2\ x\ (8.76 + 747\ x\ 0.56\ x\ 1\ x\ 0.56)\frac{\mathrm{w}}{m2K}$
$= 3499.48\ W$
$Heating\ load\ q\mathrm{e}windowwest = A\ x\ HF\mathrm{e}windowwest$
$= A\ x\ U\mathrm{e}windowwest\ \Delta\ Theating = 14.4\ m2\ x\ 3.61\frac{\mathrm{w}}{m2K}$
$x\ 24.8\ K = 1289.20\ W$

5) Calculating the cooling load of the fixed window on the South:
$qwindowsouth = A\ x\ CFwindowsouth$
$A = 3.6\ m2$
$CFwindowsouth(heattransferpart) = Uwindowsouth\ (\Delta\ Tcooling - 0.46\ DR)$
$The\ window\ has\ a\ fixed\ heat\ absorbing\ double\ layer\ glass\ with\ a\ wooden\ frame.$
$Uwindowwest = 2.84\ \frac{\mathrm{w}}{m2K}$
$For\ example: CFwindowsouth(heattransferpart)$
$= 2.84\frac{\mathrm{w}}{m2K}$
$x\ (7.9\ K - 0.46\ x\ 11.9\ K) = 6.89\frac{\mathrm{w}}{m2K}$
$PXIwindowsouth = ED + Ed = 348 + 209 = 557$
$SHG = 0.55$
$Since\ there\ is\ no\ internal\ shading: IAC = 1$
$FFs = 0.47$
$CFwindowsouth(irradiationpart) = PXI\ x\ SHGC\ x\ IAC\ x\ FFs$
$qwindowsouth = A\ x\ CFwindowsouth$
$= A\ x\ \mathrm{c}CFwindowsouth(heattransferpart) + CFwindowsouth(irradiationpart)\mathrm{d}$

$= 3.6\ m2\ x\ (6.89 + 557\ x\ 0.54\ x\ 1\ x\ 0.47)\frac{W}{m2K} = 553.72$ W

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

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

6) Calculating the heating load of the fixed window on the South:
$qwindowsouth = A\ x\ HFwindowsouth = A\ x\ Uwindowsouth\ \Delta\ Theating$
$= 3.6\ m2\ x\ 2.84\frac{W}{m2K}$ x 24.8 K $= 253.56$ W

7) When the frame is aluminium:
$Uwindowsouth = 3.61\frac{W}{m2K}$
; $HSGC = 0.56$

$CF\text{e}windowsouth(heattransferpart) = U\text{e}windowsouth\ (\Delta\ Tcooling - 0.46\ DR)$
$= 3.61\frac{W}{m2K}$ x (7.9 K $-$ 0.46 x 11.9 K) $= 8.76\frac{W}{m2K}$
$Cooling\ load\ q\text{e}windowsouth = A\ x\ CF\text{e}windowsouth$
$= A\ x$ c$CF\text{e}windowsouth(heattransferpart) + CF\text{e}windowsouth(irradiationpart)$d
$= 3.6\ m2\ x\ (8.76 + 557\ x\ 0.56\ x\ 1\ x\ 0.47)\frac{W}{m2K} = 559.30$ W
$Heating\ load\ q\text{e}windowsouth = A\ x\ HF\text{e}windowsouth$
$= A\ x\ U\text{e}windowsouth\ \Delta\ Theating$
$= 3.6\ m2\ x\ 3.61\frac{W}{m2K}$ x 24.8 K $= 322.30$ W

8) Calculating the cooling load of the operable window on the South:
$qwindowsouth$ = $A\ x\ CFwindowsouth$
A = 3.6 $m2$
$CFwindowsouth(heattransferpart)$ = $Uwindowsouth$ ($\Delta\ Tcooling$ – 0.46 DR)
$The\ window\ has\ an\ operable\ heat\ absorbing\ double\ layer\ glass\ with\ a\ wooden\ frame.$
$Uwindowwest$ = 2.87$\frac{\mathrm{w}}{m2K}$
$For\ example$: $CFwindowsouth(heattransferpart)$
= 2.87$\frac{\mathrm{w}}{m2K}$ x (7.9 K − 0.46 x 11.9 K) = 6.96$\frac{\mathrm{w}}{m2K}$
$PXIwindowsouth$ = ED + Ed = 348 + 209 = 557
$SHGC$ = 0.46
$Since\ there\ is\ no\ internal\ shading,\ IAC$ = 1
FFs = 0.47
$CFwindowsouth(irradiationpart)$ = $PXI\ x\ SHGC\ x\ IAC\ x\ FFs$
$qwindowsouth$ = $A\ x\ CFwindowsouth$
= $A\ x$ c$CFwindowsouth(heattransferpart)$ + $CFwindowsouth(irradiationpart)$d
= 3.6 m2 x (6.96 + 557 x 0.54 x 1 x 0.47) $\frac{\mathrm{w}}{m2K}$ = 553.98

9) Calculating the heating load of the fixed window on the South:
$qwindowsouth$ = $A\ x\ HFwindowsouth$ = $A\ x\ Uwindowsouth\ \Delta\ Theating$
= 3.6 $m2\ x$ 2.87$\frac{\mathrm{w}}{m2K}$ x 24.8 K = 256.23 W

10) If the frame is aluminium:
$Uwindowsouth$ = 4.62$\frac{\mathrm{w}}{m2K}$
; $HSGC$ = 0.55

CFewindowsouth$(heattransferpart)$ = Uewindowsouth ($\Delta\ Tcooling$ – 0.46 DR)
= 4.62 $\frac{w}{m2K}$ x (7.9 K − 0.46 x 11.9 K) = 11.21$\frac{w}{m2K}$ = 553.98$\frac{w}{m2K}$
$Cooling\ load\ q$ewindowsouth = $A\ x\ CF$ewindowsouth
= $A\ x$ cCFewindowsouth$(heattransferpart)$ + CFewindowsouth$(irradiationpart)$d
= 3.6 $m2\ x$ (11.21 + 557 x 0.55 x 1 x 0.47)$\frac{w}{m2K}$
= 558.70 W
$Heating\ load\ q$ewindowsouth = $A\ x\ HF$ewindowsouth
= $A\ x\ U$ewindowsouth $\Delta\ Theating$
= 3.6 $m2\ x$ 4.62$\frac{w}{m2K}$ x 24.8 K = 412.47