Week 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 U value with respect to a benchmark case of double layer with air and no coating? (keep the gap thickness to be 13 mm)

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

For double pan window, regardless of the thermal resistances of glass layers,

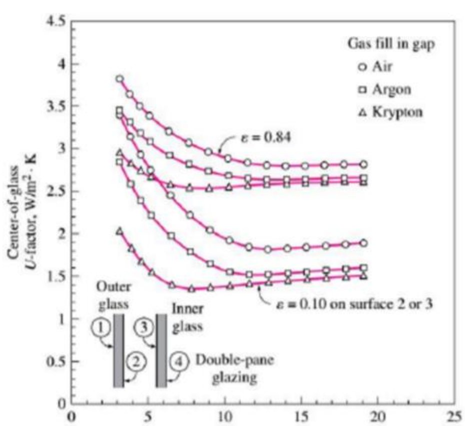
$\frac{1}{U_{double-pane(center\ region)}} \approx \frac{1}{h_i} + \frac{1}{h_{space}} + \frac{1}{h_o}$, $h_{space} = h_{rad,space} + h_{conv,space}$

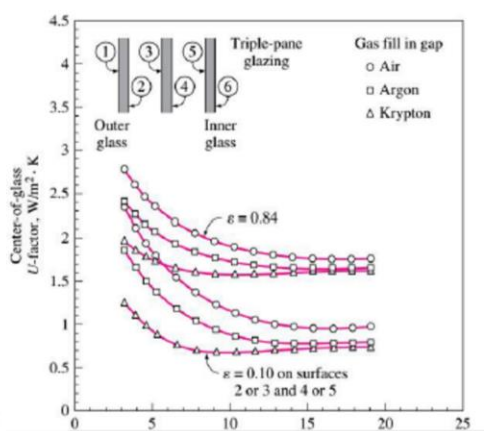
U_{center}, i.e. the h_{space} changes by changing the gas that fills the gap.

By adding an extra pane, the U value of the centre 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 55.6%.

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 thickness 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 centre 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 55.6%





Task 2

Considering 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 sqm on the west, fixed 3.6 sqm on the south and an operable 3.6 sqm 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?

Here,

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)

Temperature difference

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

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

DR = 11.9 °C

WEST WINDOW (FIXED)

Cooling Load: Wooden Frame

A = 14.4 m^2

$\dot{q}_{windowwest} = A \times CF_{windowwest}$

So, $CF_{windowwest} = CF_{windowwest\_heattransfer} + CF_{windowwest\_irridiation}$

$= U(\Delta T - 0.46DR) + PXI \times SHGC \times IAC \times FF_s$

Here, U = 2.84, DR= 11.9, $\Delta T_{cooling} = 7.9$, SHGC = 0.54, IAC = 1 , $FF_s = 0.56$

PXI = $E_D - E_d = 559 + 188 = 747$

$CF_{windowwest} = 2.84(7.9 – 0.46*11.9) + 747*0.54*1*0.56 = 232.78\ \frac{W}{m^2}$

$\dot{q}_{windowwest} = 14.4 \times 232.78 = 3352.07\ W$

Cooling Load: Aluminum Frame

A = 14.4 m^2

$\dot{q}_{windowwest} = A \times CF_{windowwest}$

So, $CF_{windowwest} = CF_{windowwest\_heattransfer} + CF_{windowwest\_irridiation}$
$= U(\Delta T - 0.46DR) + PXI \times SHGC \times IAC \times FF_s$
Here, U = 3.61, DR= 11.9, $\Delta T_{cooling} = 7.9$, SHGC = 0.56, IAC = 1 , $FF_s = 0.56$
PXI = $E_D - E_d = 559 + 188 = 747$
$CF_{windowwest} = 3.61(7.9 - 0.46*11.9) + 747*0.56*1*0.56 = 243.02 \frac{W}{m^2}$
$\dot{q}_{windowwest} = 14.4 \times 243.02 = 3499.47$ W

Heating Load: Wooden Frame

A = 14.4 m^2

$\dot{q}_{windowwest} = A \times CF_{windowwest}$
$HF_{windowwest} = U_{windowwest} \times \Delta T_{heating} = 2.84 \times 24.8 = 70.43 \frac{W}{m^2}$
$\dot{q}_{windowwest} = A \times HF_{windowwest} = 14.4 \times 70.43 = 1014.22$ W

Heating Load: Aluminum Frame

A = 14.4 m^2

$\dot{q}_{windowwest} = A \times CF_{windowwest}$
$HF_{windowwest} = U_{windowwest} \times \Delta T_{heating} = 3.61 \times 24.8 = 89.53 \frac{W}{m^2}$
$\dot{q}_{windowwest} = A \times HF_{windowwest} = 14.4 \times 89.53 = 1289.20$ W

So, The cooling load difference = $3499.47 - 3352.07 = 147.4$ W
The heating load difference = $1289.20 - 1014.22 = 274.98$ W

SOUTH WINDOW (FIXED)
Cooling Load: Wooden Frame

A = 3.6 m^2

$\dot{q}_{windowsouth} = A \times CF_{windowsouth}$
So,
$CF_{windowsouth} = CF_{windowsouth\_heattransfer} + CF_{windowsouth\_irridiation}$

$= U(\Delta T - 0.46DR) + PXI \times SHGC \times IAC \times FF_s$

Here, U = 2.84, DR= 11.9, $\Delta T_{cooling} = 7.9$, SHGC = 0.54, IAC = 1 , $FF_s = 0.47$
PXI = $E_D - E_d = 348 + 209 = 557$
$CF_{windowsouth}$ = 2.84(7.9– 0.46*11.9) + 557*0.54*1*0.47 = 148.26 $\frac{W}{m^2}$
$\dot{q}_{windowsouth} = 3.6 \text{ x } 148.26 = 533.74 \text{ W}$

Cooling Load: Aluminum Frame

A = 3.6 m^2

$\dot{q}_{windowsouth} = A \text{ x } CF_{windowsouth}$
So,
$CF_{windowsouth} = CF_{windowsouth\_heattransfer} + CF_{windowsouth\_irridiation}$
$= U(\Delta T - 0.46DR) + PXI \text{ x } SHGC \text{ x } IAC \text{ x } FF_s$
Here, U = 3.61, DR= 11.9, $\Delta T_{cooling} = 7.9$, SHGC = 0.56, IAC = 1 , $FF_s = 0.47$
PXI = $E_D - E_d = 348 + 209 = 557$
$CF_{windowsouth}$ = 3.61(7.9 – 0.46*11.9) + 557*0.56*1*0.47 = 155.36 $\frac{W}{m^2}$
$\dot{q}_{windowsouth} = 3.6 \text{ x } 155.36 = 559.30 \text{ W}$

Heating Load: Wooden Frame

A = 3.6 m^2

$\dot{q}_{windowsouth} = A \text{ x } HF_{windowsouth}$
$HF_{windowsouth} = U_{windowsouth} \text{ x } \Delta T_{heating}$ = 2.84 x 24.8 = 70.43 $\frac{W}{m^2}$
$\dot{q}_{windowsouth} = A \text{ x } HF_{windowsouth} = 3.6 \text{ x } 70.43 = 253.08 \text{ W}$

Heating Load: Aluminum Frame

A = 3.6 m^2

$\dot{q}_{windowsouth} = A \text{ x } HF_{windowsouth}$
$HF_{windowsouth} = U_{windowsouth} \text{ x } \Delta T_{heating}$ = 3.61 x 24.8 = 89.53 $\frac{W}{m^2}$
$\dot{q}_{windowsouth} = A \text{ x } HF_{windowsouth} = 3.6 \text{ x } 89.53 = 322.31 \text{ W}$

So, The cooling load difference = 559.30- 533.74 $= 25.56$ W
The heating load difference = $322.31 - 253.08 = 69.23$ W

SOUTH WINDOW (OPERABLE)

Cooling Load: Wooden Frame

A = 3.6 m^2

$\dot{q}_{windowsouth} = A \times CF_{windowsouth}$

So,
$CF_{windowsouth} = CF_{windowsouth\_heattransfer} + CF_{windowsouth\_irridiation}$

$= U(\Delta T - 0.46DR) + PXI \times SHGC \times IAC \times FF_s$
Here, U = 2.87, DR= 11.9, $\Delta T_{cooling} = 7.9$, SHGC = 0.46, IAC = 1 , $FF_s = 0.47$
PXI = $E_D - E_d = 348 + 209 = 557$
$CF_{windowwest}$ = 2.87(7.9– 0.46*11.9) + 557*0.46*1*0.47 = 127.38 $\frac{W}{m^2}$
$\dot{q}_{windowwest} = 3.6 \times 127.38 = 458.57\ W$

Cooling Load: Aluminum Frame

A = 3.6 m^2

$\dot{q}_{windowsouth} = A \times CF_{windowsouth}$

So,
$CF_{windowsouth} = CF_{windowsouth\_heattransfer} + CF_{windowsouth\_irridiation}$

$= U(\Delta T - 0.46DR) + PXI \times SHGC \times IAC \times FF_s$
Here, U = 4.62, DR= 11.9, $\Delta T_{cooling} = 7.9$, SHGC = 0.55, IAC = 1 , $FF_s = 0.47$
PXI = $E_D - E_d = 348 + 209 = 557$
$CF_{windowwest}$ = 4.62(7.9– 0.46*11.9) + 557*0.55*1*0.47 = 155.19 $\frac{W}{m^2}$
$\dot{q}_{windowwest} = 3.6 \times 155.19 = 558.68\ W$

Heating Load: Wooden Frame

A = 3.6 m^2

$\dot{q}_{windowsouth} = A \times HF_{windowsouth}$
$HF_{windowsouth} = U_{windowsouth} \times \Delta T_{heating}$ = 2.87 x 24.8 = 71.18 $\frac{W}{m^2}$
$\dot{q}_{windowsouth} = A \times HF_{windowsouth} = 3.6 \times 71.18 = 256.23\ W$

Heating Load: Aluminum Frame

A = 3.6 m^2

$\dot{q}_{windowsouth} = A \times HF_{windowsouth}$
$HF_{windowsouth} = U_{windowsouth} \times \Delta T_{heating}$ =4.62 x 24.8 = 114.58 $\frac{W}{m^2}$

$\dot{q}_{windowsouth} = A \text{ x } HF_{windowsouth} = 3.6 \text{ x } 114.58 = 412.47 \text{ W}$

So, The cooling load difference = 558.68- $458.57 = 100.11 \text{ W}$
The heating load difference = $412.47 - 256.23 = 156.243 \text{ W}$