Task 1

Use a weather forecast website, and utilize the psychrometric chart and the formula we went through in the class to determine the absolute humidity, the wet-bulb temperature and the mass of water vapor in the air in Class Room A of Piacenza campus at the moment that you are solving this exercise

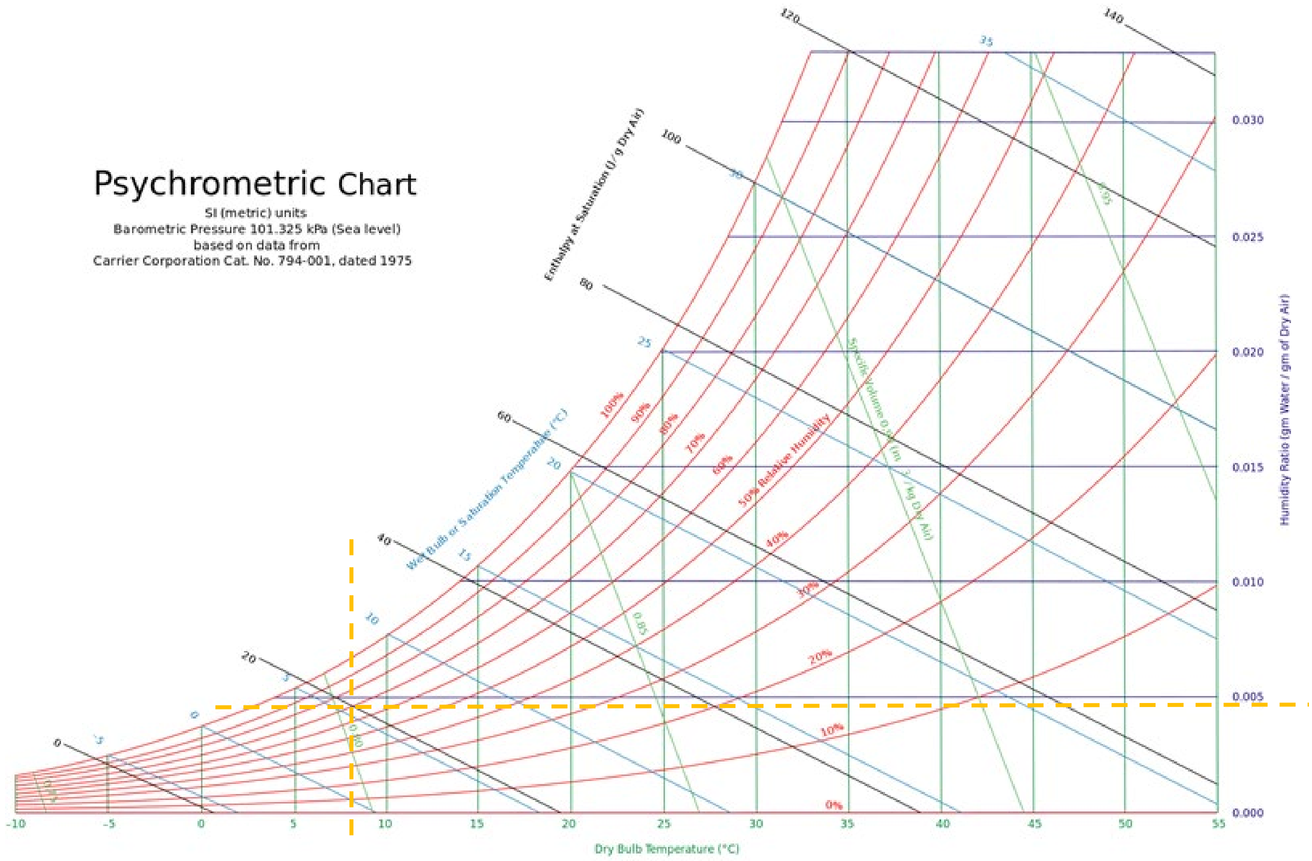
P = 100 kPa
Volume of class A V = 8 * 28 * 5 = 1120 m^3

I choose 16.00pm
Relative humidity = 69%
Air total pressure (1 hPa: 0.1 kPa) = 1025 hPa = 102.5 kPa
Temperature to be utilized = 8°C

From the weather forecast website:

Il tempo oggi in Piacenza
Martedì, 03 Dicembre 2019

	13:00	14:00	16:00	18:00	20:00	21:00	22:00
	LightCloud	LightCloud	PartlyCloud	LightCloud	Sun	Sun	Sun
Temperatura effettiva	9°C	10°C	8°C	6°C	4°C	2°C	2°C
Temperatura percepita	7°C	10°C	6°C	4°C	2°C	0°C	0°C
Precipitazioni	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm
Umidità	67 %	65 %	69 %	70 %	75 %	83 %	87 %
Pressione atmosferica	1025 hPa	1025 hPa	1025 hPa	1026 hPa	1027 hPa	1027 hPa	1028 hPa



In yellow I have highlight in vertical the temperature of 8°C, the intersection with the red curve of 69% of relative humidity and so in horizontal, I have found the humidity ratio.

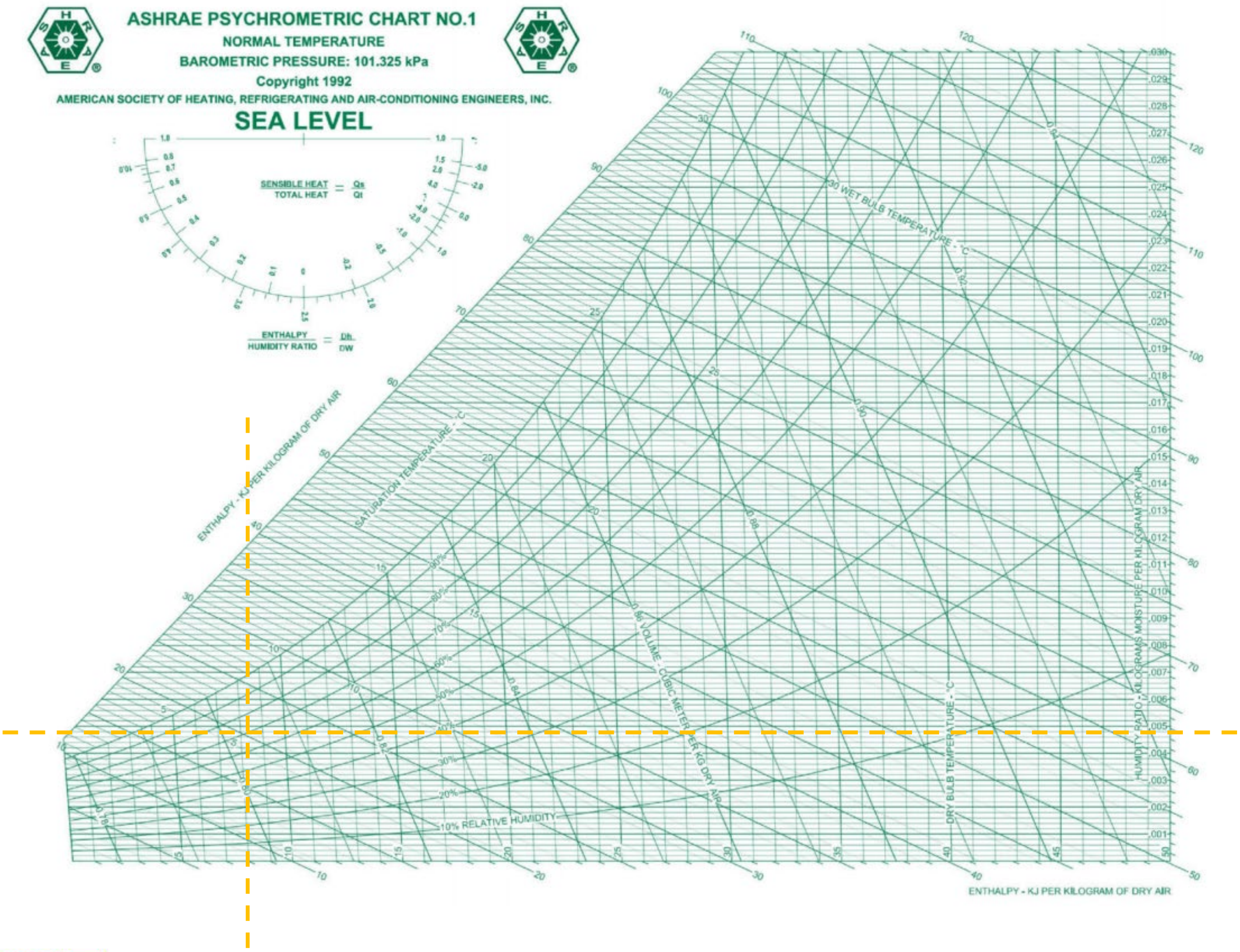


TABLE A-2

Pressure Conversions:
1 bar = 0.1 MPa
= 10^2 kPa

Properties of Saturated Water (Liquid–Vapor): Temperature Table

		Specific Volume m³/kg		Internal Energy kJ/kg		Enthalpy kJ/kg			Entropy kJ/kg · K		
Temp. °C	Press. bar	Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g	Sat. Liquid u_f	Sat. Vapor u_g	Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Sat. Liquid s_f	Sat. Vapor s_g	Temp. °C
.01	0.00611	1.0002	206.136	0.00	2375.3	0.01	2501.3	2501.4	0.0000	9.1562	.01
4	0.00813	1.0001	157.232	16.77	2380.9	16.78	2491.9	2508.7	0.0610	9.0514	4
5	0.00872	1.0001	147.120	20.97	2382.3	20.98	2489.6	2510.6	0.0761	9.0257	5
6	0.00935	1.0001	137.734	25.19	2383.6	25.20	2487.2	2512.4	0.0912	9.0003	6
8	0.01072	1.0002	120.917	33.59	2386.4	33.60	2482.5	2516.1	0.1212	8.9501	8
10	0.01228	1.0004	106.379	42.00	2389.2	42.01	2477.7	2519.8	0.1510	8.9008	10
11	0.01312	1.0004	99.857	46.20	2390.5	46.20	2475.4	2521.6	0.1658	8.8765	11
12	0.01402	1.0005	93.784	50.41	2391.9	50.41	2473.0	2523.4	0.1806	8.8524	12
13	0.01497	1.0007	88.124	54.60	2393.3	54.60	2470.7	2525.3	0.1953	8.8285	13
14	0.01598	1.0008	82.848	58.79	2394.7	58.80	2468.3	2527.1	0.2099	8.8048	14
15	0.01705	1.0009	77.926	62.99	2396.1	62.99	2465.9	2528.9	0.2245	8.7814	15
16	0.01818	1.0011	73.333	67.18	2397.4	67.19	2463.6	2530.8	0.2390	8.7582	16
17	0.01938	1.0012	69.044	71.38	2398.8	71.38	2461.2	2532.6	0.2535	8.7351	17
18	0.02064	1.0014	65.038	75.57	2400.2	75.58	2458.8	2534.4	0.2679	8.7123	18
19	0.02198	1.0016	61.293	79.76	2401.6	79.77	2456.5	2536.2	0.2823	8.6897	19
20	0.02339	1.0018	57.791	83.95	2402.9	83.96	2454.1	2538.1	0.2966	8.6672	20
21	0.02487	1.0020	54.514	88.14	2404.3	88.14	2451.8	2539.9	0.3109	8.6450	21
22	0.02645	1.0022	51.447	92.32	2405.7	92.33	2449.4	2541.7	0.3251	8.6229	22
23	0.02810	1.0024	48.574	96.51	2407.0	96.52	2447.0	2543.5	0.3393	8.6011	23
24	0.02985	1.0027	45.883	100.70	2408.4	100.70	2444.7	2545.4	0.3534	8.5794	24
25	0.03169	1.0029	43.360	104.88	2409.8	104.89	2442.3	2547.2	0.3674	8.5580	25
26	0.03363	1.0032	40.994	109.06	2411.1	109.07	2439.9	2549.0	0.3814	8.5367	26
27	0.03567	1.0035	38.774	113.25	2412.5	113.25	2437.6	2550.8	0.3954	8.5156	27
28	0.03782	1.0037	36.690	117.42	2413.9	117.43	2435.2	2552.6	0.4093	8.4946	28
29	0.04008	1.0040	34.733	121.60	2415.2	121.61	2432.8	2554.5	0.4231	8.4739	29
30	0.04246	1.0043	32.894	125.78	2416.6	125.79	2430.5	2556.3	0.4369	8.4533	30
31	0.04496	1.0046	31.165	129.96	2418.0	129.97	2428.1	2558.1	0.4507	8.4329	31
32	0.04759	1.0050	29.540	134.14	2419.3	134.15	2425.7	2559.9	0.4644	8.4127	32
33	0.05034	1.0053	28.011	138.32	2420.7	138.33	2423.4	2561.7	0.4781	8.3927	33
34	0.05324	1.0056	26.571	142.50	2422.0	142.50	2421.0	2563.5	0.4917	8.3728	34
35	0.05628	1.0060	25.216	146.67	2423.4	146.68	2418.6	2565.3	0.5053	8.3531	35
36	0.05947	1.0063	23.940	150.85	2424.7	150.86	2416.2	2567.1	0.5188	8.3336	36
38	0.06632	1.0071	21.602	159.20	2427.4	159.21	2411.5	2570.7	0.5458	8.2950	38
40	0.07384	1.0078	19.523	167.56	2430.1	167.57	2406.7	2574.3	0.5725	8.2570	40
45	0.09593	1.0099	15.258	188.44	2436.8	188.45	2394.8	2583.2	0.6387	8.1648	45

Steam Table

M_g is the amount of water at sat condition

$P_g = P_{sat} * 8°C = 1.072$ kPa it's the saturation pressure of the water at 8°C calculated by the steam table

$\Phi = \frac{mv}{mg} = \frac{Pv}{Pg}$

$Pv = \Phi * Pg = 0.69 * 1.072 = 0.74$ kPa

Partial Pressure of dry air: $Pa = P - Pv = 100$ kPa – 0.74 kPa = 99.26 kPa

Now, I can calculate the <u>absolute humidity</u>:

$\omega = 0.622 \frac{Pv}{Pa} = 0.622 * \frac{0.74}{99.26} = 0.0046 \frac{Kg\ vapour}{Kg\ airDry}$

To find the mass of water, I can consider the air an ideal gas: so, for air:

$m_a = \frac{Pa * Va}{Ra * T}$ ($Ra = \frac{R\ global}{Mass\ Gas}$ is given in table and its value is 0.287; Rv = 0.4615)

(NB: the temperature T is in Kelvin -> K = °C + 273)

$m_a = \frac{99.26 * 1120}{0.287 * (273+8)} = 1378.49$ Kg of Air Dry

$m_v = \frac{Pv * Va}{Rv * T} = \frac{0.74 * 1120}{0.4615 * (273+8)} = 6.39$ Kg <u>mass of water vapour</u>

For finding the specific enthalpy of humid air, I should first find the specific enthalpy of dry air, and then I can find the specific enthalpy of water vapor (NB: the Temperature is considered in °C)

$h_a = 1.005 * T = 1.005 * 8 = 8.040 \frac{kJ}{Kg\ airDry}$

$h_v = 2501.3 + 1.82 * 8 = 2515.86 \frac{kJ}{Kg\ water}$

$h_{tot} = h_a + \omega * h_v = 8.040 + 0.0046 * 2515.86 = 1.165.34 \frac{kJ}{Kg\ airDry}$ it's how much is the specific energy inside the room

Task 2

Utilize the same methodology we went through in the class and determine the sensible and latent load corresponding to internal gains, the ventilation, and the infiltration in a house with a **good construction** quality
and with the same geometry as that of the example which is located in Brindisi, Italy

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

A building with a height of 2.5 m and a good construction quality, is located in Piacenza, considering two occupants and one-bedroom calculate, and a conditioned floor area of 200 m^2 and wall area is 144 m^2, calculate the internal gains, infiltration, and ventilation loads.

Internal gains:

$\dot{Q}_{ig\_sensible} = 136 + 2.2 * A_{cf} + 22\ N_{oc} = 136 + 2.2 * 200 + 22 * 2 = 620$ W

$\dot{Q}_{ig\_latent} = 20 + 0.22 * A_{cf} + 12\ N_{oc} = 20 + 0.22 * 200 + 12 * 2 = 88$ W

Infiltration:

Table 3 Unit Leakage Areas

Construction	Description	A_{ul}, cm^2/m^2
Tight	Construction supervised by air-sealing specialist	0.7
Good	Carefully sealed construction by knowledgeable builder	1.4
Average	Typical current production housing	2.8
Leaky	Typical pre-1970 houses	5.6
Very leaky	Old houses in original condition	10.4

By the table, I can find that the value of the Unit Leakage Areas in a building of good construction qualities is: $A_{ul} = 1.4 \frac{cm^2}{m^2}$

Exposed surface = Wall area + roof area
$A_{es} = 200 + 144 = 344\ m^2$

$A_L = A_{es} * A_{ul} = 344 * 1.4 = 481.6\ cm^2$

From this table,

Table 5 Typical IDF Values, L/(s·cm²)

H, m	Heating Design Temperature, °C					Cooling Design Temperature, °C			
	−40	−30	−20	−10	0	10	30	35	40
2.5	0.10	0.095	0.086	0.077	0.069	0.060	0.031	0.035	0.040
3	0.11	0.10	0.093	0.083	0.072	0.061	0.032	0.038	0.043
4	0.14	0.12	0.11	0.093	0.079	0.065	0.034	0.042	0.049
5	0.16	0.14	0.12	0.10	0.086	0.069	0.036	0.046	0.055
6	0.18	0.16	0.14	0.11	0.093	0.072	0.039	0.050	0.061
7	0.20	0.17	0.15	0.12	0.10	0.075	0.041	0.051	0.068
8	0.22	0.19	0.16	0.14	0.11	0.079	0.043	0.058	0.074

I find that, for H=2.5, doing the medium between the range in which the temperature is in between (heating: -4.8 °C and cooling: 31.9°C), the specific values are:

$IDF_{heating} = \frac{0.086+0.077}{2} = 0.073$ L/(s*cm²)

$IDF_{cooling} = \frac{0.031+0.035}{2} = 0.033$ L/(s*cm²)

$$Q_i = A_L \mathrm{IDF}$$

where

A_L = building effective leakage area (including flue) at reference pressure difference = 4 Pa, assuming discharge coefficient $C_D = 1$, cm²
IDF = infiltration driving force, L/(s·cm²)

The next passage is to calculate the volume:

$\dot{V}_{infiltration\_heating}$ = AL * IDF = 481.6 $*$ 0.073 = 35.16 L/s
$\dot{V}_{infiltration\_cooling}$ = AL * IDF = 481.6 $*$ 0.033 = 15.89 L/s

$$Q_v = 0.05A_{cf} + 3.5(N_{br} + 1)$$

where

Q_v = required ventilation flow rate, L/s
A_{cf} = building conditioned floor area, m^2
N_{br} = number of bedrooms (not less than 1)

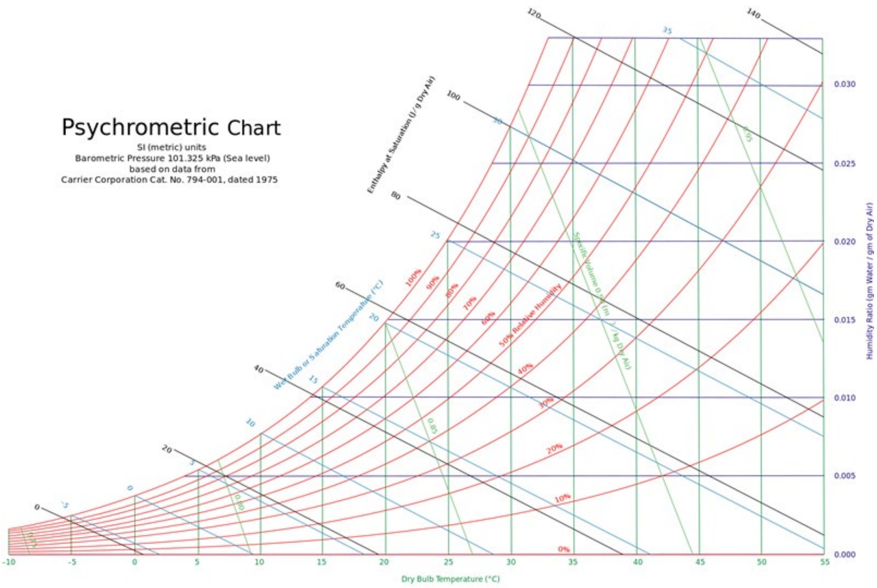
$\dot{V}_{ventilation}$ = 0.05 A_{cf} + 3.5 (N_{br} + 1) = 0.05*200+ 3.5* 2 = 17 L/S

$\dot{V}$ $_{ventilation\ heating}$ = 35.16 + 17 = 52.16 L/S

$\dot{V}$ $_{ventilation\ cooling}$ = 15.89 + 17 = 32.89 L/S

$C_{sensible}$ = 1.23 , C_{latent} = 3010

$\dot{Q}$ $_{inf\text{–}ventilation\_cooling\_sensible}$ =$C_{sensible}$ * $\dot{V}$ * $\Delta T_{Cooling}$ = 1.23 $*$ 32.89 $*$ 7.9 = 319.59 W



By this graphic, I can find the Δω = ω_{out} - ω_{in} = 0.0093 – 0.0132 = 0.0039 $\frac{Kg\ water}{Kg\ airDry}$

ω_{out} = 0.0132 $\frac{Kg\ water}{Kg\ airDry}$

ω_{in} = 0.0093 $\frac{Kg\ water}{Kg\ airDry}$

$\dot{Q}$ $_{inf\text{–}ventilation\_cooling\_latent}$ = C_{latent} * $\dot{V}$ * $\Delta\omega_{Cooling}$ = 3010 $*$ 32.89 $*$ 0.0039 = 386.10 W

$\dot{Q}$ $_{inf\text{–}ventilation\_heating\_sensible}$ = $C_{sensible}$ * $\dot{V}$ * $\Delta T_{heating}$ = 1.23 $*$ 52.16 $*$ 24.8 = 1591.09 W

$\dot{Q}$ $_{inf\text{–}ventilation\_heating\_latent}$ = C_{latent} * $\dot{V}$ * $\Delta\omega_{heating}$ = 3010 $*$ 52.16 $*$ 0.0039 = 612.31 W

Brindisi Weather Data

BRINDISI, Italy WMO#: **163200**

Lat: **40.65N** Long: **17.95E** Elev: **10** StdP: **101.2** Time Zone: **1.00 (EUW)** Period: **86-10** 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)	2	2.9	4.1	-5.1	2.5	7.2	-3.0	3.0	7.4	13.4	10.2	12.4	10.6	3.4	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)	
(2)	8	7.1	32.8	23.6	31.1	24.3	29.9	24.3	27.2	29.7	26.3	29.0	25.6	28.3	4.2	180	(2)

	Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Hours 8 to 4 & 12.8/20.6	
	0.4%			1%			2%			0.4%		1%		2%			
	DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB		
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
(3)	26.3	21.8	29.2	25.4	20.7	28.5	24.7	19.7	27.9	86.0	30.1	82.2	29.1	78.5	28.3	1236	(3)

Extreme Annual Design Conditions

	Extreme Annual WS			Extreme Max WB	Extreme Annual DB				n-Year Return Period Values of Extreme DB								
					Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years		
	1%	2.5%	5%		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
(4)	11.3	9.9	8.7	31.4	0.4	37.3	1.4	3.0	-0.6	39.4	-1.4	41.1	-2.2	42.8	-3.2	44.9	(4)

$\Delta T_{cooling} = 31.1 – 24 = 7.1$ °C

$\Delta T_{heating} = 20 – 4.1 = 15.9$ °C

DR = 7.1 °C

A building with a height of 2.5 m and a good construction quality, is located in Brindisi, considering two occupants and one-bedroom calculate, and a conditioned floor area of 200 m^2 and wall area is 144 m^2, calculate the internal gains, infiltration, and ventilation loads.

<u>Internal gains:</u>

$\dot{Q}_{ig\_sensible} = 136 + 2.2 * A_{cf} + 22\ N_{oc} = 136 + 2.2 * 200 + 22 * 2 = 620$ W

$\dot{Q}_{ig\_latent} = 20 + 0.22 * A_{cf} + 12\ N_{oc} = 20 + 0.22 * 200 + 12 * 2 = 88$ W

<u>Infiltration:</u>

Table 3 Unit Leakage Areas

Construction	Description	A_{ul}, cm^2/m^2
Tight	Construction supervised by air-sealing specialist	0.7
Good	Carefully sealed construction by knowledgeable builder	1.4
Average	Typical current production housing	2.8
Leaky	Typical pre-1970 houses	5.6
Very leaky	Old houses in original condition	10.4

By the table, I can find that the value of the Unit Leakage Areas in a building of good construction qualities is: $A_{ul} = 1.4 \frac{cm\^2}{m\^2}$

Exposed surface = Wall area + roof area
$A_{es} = 200 + 144 = 344\ m^2$

$A_L = A_{es} * A_{ul} = (200 + 144) * 1.4 = 481.6\ cm^2$

From this table,

Table 5 Typical IDF Values, L/(s·cm²)

H, m	Heating Design Temperature, °C					Cooling Design Temperature, °C			
	−40	−30	−20	−10	0	10	30	35	40
2.5	0.10	0.095	0.086	0.077	0.069	0.060	0.031	0.035	0.040
3	0.11	0.10	0.093	0.083	0.072	0.061	0.032	0.038	0.043
4	0.14	0.12	0.11	0.093	0.079	0.065	0.034	0.042	0.049
5	0.16	0.14	0.12	0.10	0.086	0.069	0.036	0.046	0.055
6	0.18	0.16	0.14	0.11	0.093	0.072	0.039	0.050	0.061
7	0.20	0.17	0.15	0.12	0.10	0.075	0.041	0.051	0.068
8	0.22	0.19	0.16	0.14	0.11	0.079	0.043	0.058	0.074

I find that, for H=2.5, doing the medium between the range in which the temperature is in between (heating: 4.1 °C and cooling: 31.1°C), the specific values are:

$IDF_{heating} = \frac{0.069+0.060}{2} = 0.065$ L/(s*cm²)

$IDF_{cooling} = \frac{0.031+0.035}{2} = 0.033$ L/(s*cm²)

$$Q_i = A_L \text{IDF}$$

where

A_L = building effective leakage area (including flue) at reference pressure difference = 4 Pa, assuming discharge coefficient $C_D = 1$, cm²

IDF = infiltration driving force, L/(s·cm²)

The next passage is to calculate the volume:

$\dot{V}_{infiltration\_heating}$ = AL * IDF = 481.6 ∗ 0.065 = 31.30 L/s
$\dot{V}_{infiltration\_cooling}$ = AL * IDF = 481.6 ∗ 0.033 = 15.89 L/s

$$Q_v = 0.05A_{cf} + 3.5(N_{br} + 1)$$

where

Q_v = required ventilation flow rate, L/s
A_{cf} = building conditioned floor area, m^2
N_{br} = number of bedrooms (not less than 1)

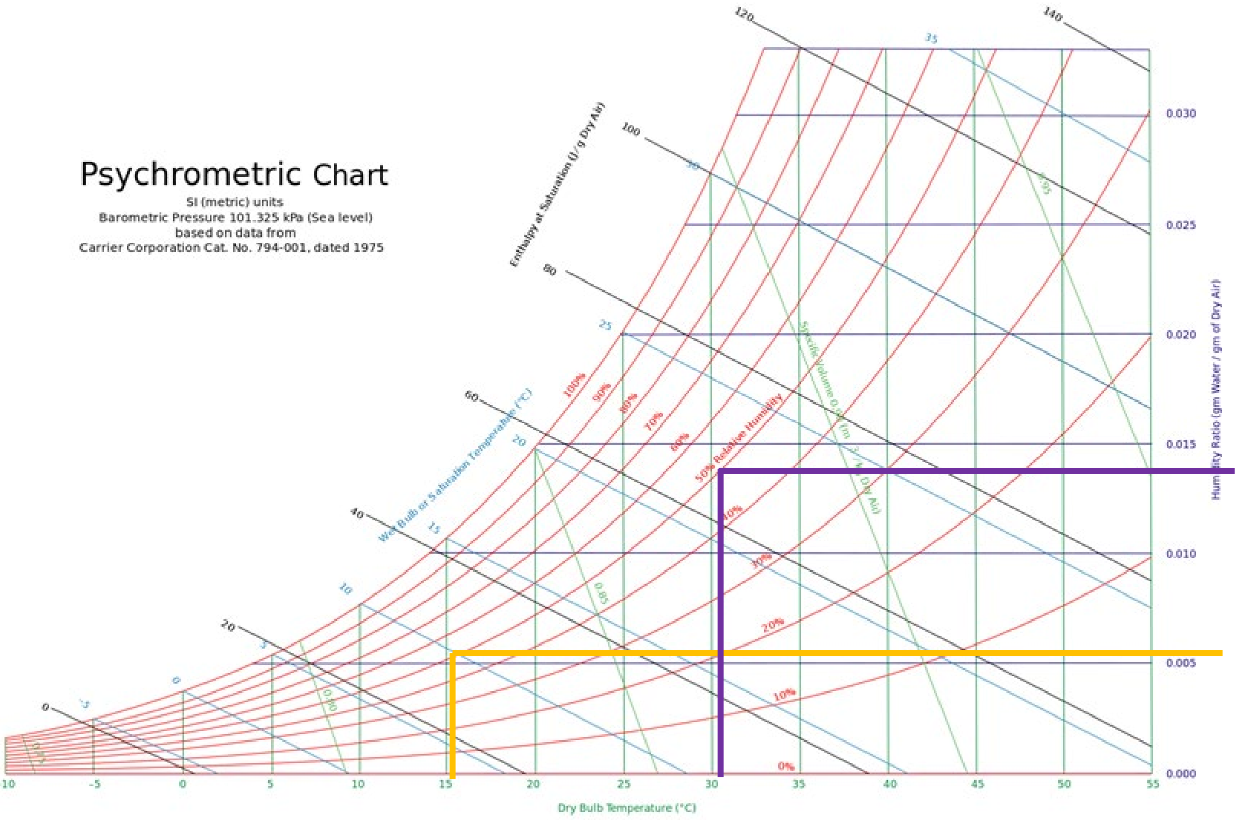
$\dot{V}_{\text{ventilation}}$ = 0.05 A_{cf} + 3.5 (N_{br} + 1) = 0.05*200+ 3.5* 2 = 17 L/S

$\dot{V}_{\text{ventilation heating}}$ = 31.30 + 17 = 48.30 L/S

$\dot{V}_{\text{ventilation cooling}}$ = 15.89 + 17 = 32.89 L/S

C_{sensible} = 1.23 , C_{latent} = 3010

$\dot{Q}_{\text{inf–ventilation\_cooling\_sensible}}$ = C_{sensible} * $\dot{V}$ * $\Delta T_{\text{Cooling}}$ = 1.23 $*$ 32.89 $*$ 7.1 = 287.23 W



By this graphic, I can find the $\Delta\omega = \omega_{out} - \omega_{in}$ = 0.006 – 0.013 = 0.007 $\frac{Kg\ water}{Kg\ airDry}$

ω_{out} = 0.013 $\frac{Kg\ water}{Kg\ airDry}$

ω_{in} = 0.006 $\frac{Kg\ water}{Kg\ airDry}$

$\dot{Q}_{\text{inf–ventilation\_cooling\_latent}}$ = C_{latent} * $\dot{V}$ * $\Delta\omega_{\text{Cooling}}$ = 3010 $*$ 32.89 $*$ 0.007 = 692.99 W

$\dot{Q}_{\text{inf–ventilation\_heating\_sensible}}$ = C_{sensible} * $\dot{V}$ * $\Delta T_{\text{heating}}$ = 1.23 $*$ 48.30 $*$ 15.9 = 944.60 W

$\dot{Q}_{\text{inf–ventilation\_heating\_latent}}$ = C_{latent} * $\dot{V}$ * $\Delta\omega_{\text{heating}}$ = 3010 $*$ 48.30 $*$ 0.007 = 1017.68 W