Task 1

Use a weather forecast website, and utilize the psychrometric chart and the formula we went through in the class to determine:

1. the absolute humidity
2. the wet-bulb temperature
3. the mass of water vapor in the air in Class Room A (Aula A) of Piacenza campus in the moment that you are solving this exercise (provide the inputs that you utilized)

Aula a 8*25 m

Air total pressure (1 hPa=0.1 kPa)→ 1020.7 hPa=102.07kPa

$\phi = \frac{m_v}{m_g}$ $\rightarrow m_g$ is the mass of water at sat condition m_v is the mass vapor

From Steam tables I can find the saturation pressure of water at 8° C = 1.072 kPa

TABLE A-2 Properties of Saturated Water (Liquid–Vapor): Temperature Table

H_2O

		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

$\phi = \frac{m_v}{m_g} = \frac{P_v}{P_g} \dashrightarrow P_g = P_{sat} 8\,°C = 1.072\ kPa$

$\phi = \frac{P_v}{P_g} \to P_V = \phi \times P_g = 0.92 * 1.072 = 0.986\ kPa$

$partial\ pressure\ of\ dry\ air\!:\ P_a = P - P_v = 100\ kPa - 0.986\ kPa = 99.013\ kPa$

The absoloute humidity and the real mass of water:

$\omega = 0.622 \frac{P_v}{P_a} = 0.622 \frac{0.986}{99.013} = 0.00659 \to 0.07 \frac{Kg_{vapour}}{kg_{dryAir}}$ the relative humidity ranges from 0 to 1 for saturated air

The mass of water:

For ideal gases we use this formula: $m = \frac{PV}{R_{sp}.T}$

So for air : $m_a = \frac{P_a V_a}{R_a T}$ $\quad R_{sp.} = \frac{R_{global}}{M_{gas}} \quad \to \quad R_a = 0.287, R_v = 0.4615$ (constant values)

Wet-bulb temperature

The wet-bulb temperature is the coldest temperature you can get through evaporative cooling. This can be physically measured by wrapping the bulb of a thermometer in a wet rag; as the water evaporates, latent heat is removed and the temperature drops.

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)

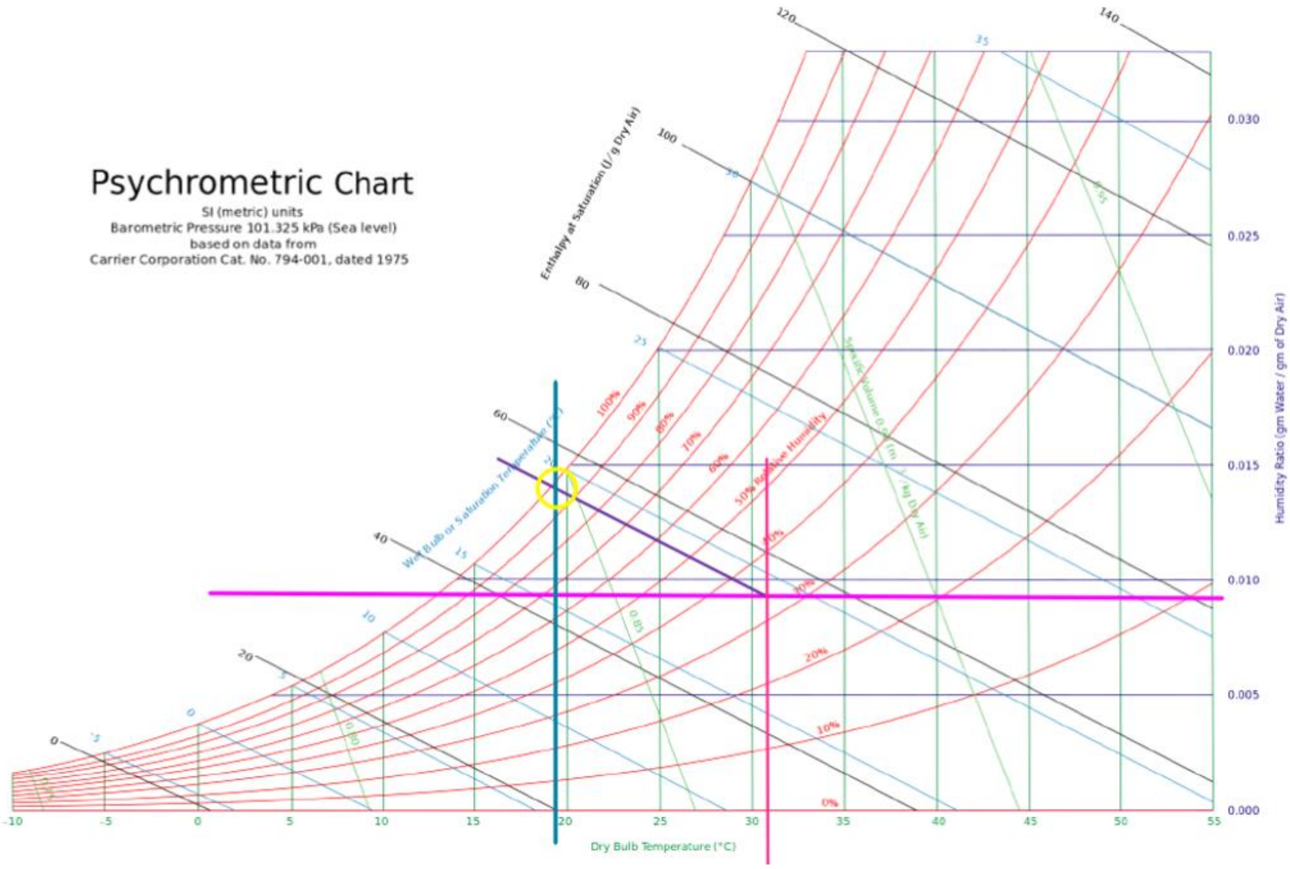
Annual Cooling, Dehumidification, and Enthalpy Design Conditions

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*



<u>To find the web-bulb temperature:</u> read the web-bulb temperature from a Psychrometric chart. From the current point, draw a line parallel to the lines of constant wet-bulb temperature, until you reach the 100% relative humidity line, and then read the temperature. This is illustrates by the blue line on the chart.

The wet bulb temperature is 19 °C

<u>Specfici enthalpy of humid air,</u>
first find the specific enthalpy of dry air , and specific enthalpy of water vapour

$m_a = \frac{99.013*(8*25*4)}{0.287*(273+8)} = \frac{99.013*800}{0.287*281} = 982.186$ kg of dry air   (T is represent temperature in Kelvins)

$m_v = \frac{0.986*(8*25*4)}{0.4615*(273+8)} = \frac{0.986*800}{0.4615*281} = 6.082\ kg$ kg of vapor (T is represent temperature in Kelvins)

$h_a = \ 1.005 * T = 1.005\ * 8 = 8.04 \frac{kJ}{kg_{dryAir}}$ (T is represent temperature in Celsius)

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

$h = h_a + \omega * h_v = \ 8.04 + 0.00659 * 2515.86 = 24.619 \frac{kJ}{kg_{dryAir}}$

Task 2:

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

A building with a height of 2.5m, floor area is 200 mq wall area is 144 mq

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 99.6%	Heating DB 99%	Humidification DP/MCDB and HR 99.6% DP	99.6% HR	99.6% MCDB	99% DP	99% HR	99% MCDB	Coldest month WS/MCDB 0.4% WS	0.4% MCDB	1% WS	1% MCDB	MCWS/PCWD to 99.6% DB 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 0.4% DB	0.4% MCWB	1% DB	1% MCWB	2% DB	2% MCWB	Evaporation WB/MCDB 0.4% WB	0.4% MCDB	1% WB	1% MCDB	2% WB	2% MCDB	MCWS/PCWD to 0.4% DB 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 0.4% DP	0.4% HR	0.4% MCDB	1% DP	1% HR	1% MCDB	2% DP	2% HR	2% MCDB	Enthalpy/MCDB 0.4% Enth	0.4% MCDB	1% Enth	1% MCDB	2% Enth	2% MCDB	Hours 8 to 4 & 12.8/20.6	
	(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 1%	2.5%	5%	Extreme Max WB	Extreme Annual DB Mean Min	Mean Max	Standard deviation Min	Standard deviation Max	n-Year Return Period Values of Extreme DB n=5 years Min	n=5 years Max	n=10 years Min	n=10 years Max	n=20 years Min	n=20 years Max	n=50 years Min	n=50 years 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)

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

$\Delta T_{heating} = 20 - (-4.1) = 24.1\,°C$

$DR = 32.8\,°C$

<u>Internal gains:</u>

$$q_{ig,s} = 136 + 2.2A_{cf} + 22N_{oc}$$

$$q_{ig,l} = 20 + 0.22A_{cf} + 12N_{oc}$$

where

$q_{ig,s}$ = sensible cooling load from internal gains, W
$q_{ig,l}$ = latent cooling load from internal gains, W
A_{cf} = conditioned floor area of building, m^2
N_{oc} = number of occupants (unknown, estimate as $N_{br} + 1$)

$\dot{Q}_{ig_{sensible}} = 136 + 2.2 * A_{cf} + 22\ N_{oc} = 136 + 2.2 * 200 + 22 * 1 + 1 = 620\ W$

$\dot{Q}_{ig_{latent}} = 20 + 0.22 * A_{cf} + 12\ N_{oc} = 20 + 0.22 * 200 + 12 * 1 + 1 = 88\ W$

<u>Infiltration</u>
find the leakage area using table 3:

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

$$A_L = A_{es} A_{ul}$$

where

A_{es} = building exposed surface area, m^2
A_{ul} = unit leakage area, cm^2/m^2 (from Table 3)

good quality → $A_{ul} = 1.4 \frac{cm^2}{m2}$

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

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

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

where

A_L = building effective leakage area (including flue) at reference pressure difference = 4 Pa, assuming discharge coefficient $C_D = 1$, cm^2
IDF = infiltration driving force, L/(s·cm^2)

Table 5 Typical IDF Values, L/(s·cm^2)

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

$IDF_{heating} = 0.073 \frac{L}{s.cm^2}$ → average between 0.077 and 0.069
$IDF_{cooling} = 0.033 \frac{L}{s.cm^2}$ → average between 0.031 and 0.035

Ventilation:

$\dot{V}_{infiltration_{heating}} = A_L \times IDF = \ 481.6 * 0.073 = 35.156 \frac{L}{s}$

$\dot{V}_{infiltration_{cooling}} = A_L \times IDF = 481.6 * 0.033 = 15.892 \frac{L}{s}$

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

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* 1+1 = 17 L/S
$\dot{V}_{inf-ventilation_{heating}} = 35.156 + 17 = 52.156\, L/s$
$\dot{V}_{inf-ventilation_{cooling}} = 15.892 + 17 = 32.892\, L/s$