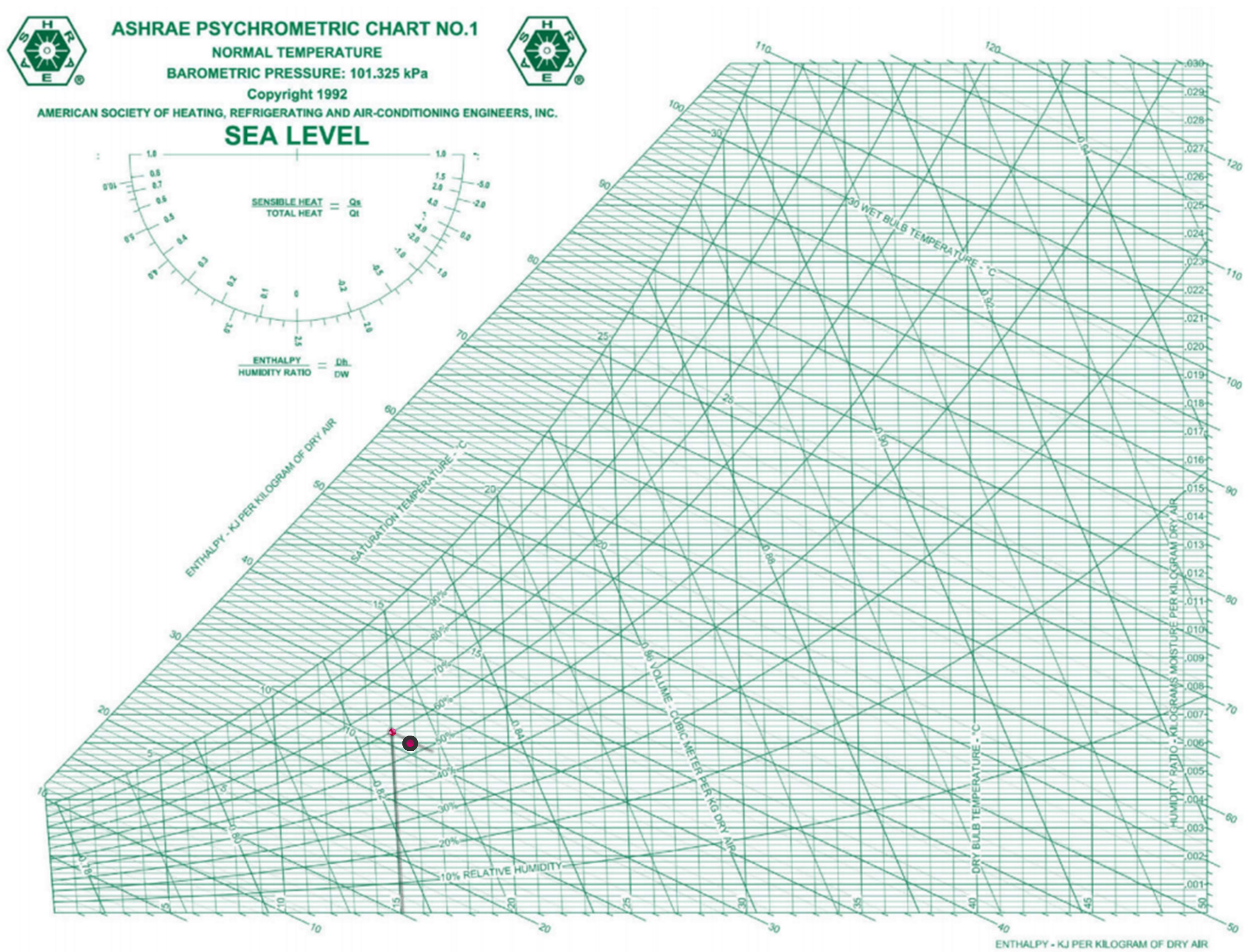
Submission 9 - Technical Environmental Systems

1. **Use a weather forecast website, and utilize the psychrometric chart and the formula we went through in the class to determine the absoloute humidity, the wet-bulb temperature and the mass of water vapour in the air in Classroom A (Aula A) of Piacenza campus in the moment that you are solving this exercise (provide the inputs that you utilized)**

   2nd December 2019, 10:00 pm :

- Effective Temperature, T: 8°C
- Atmospheric Pressure, P: 1020 hPa = 102 kPa
- Relative Humidity, ϕ: 92%

From the psychrometric chart:-



Absolute Humidity, $\omega = 0.006 \left(\frac{kg_{vapour}}{kg_{dryair}}\right)$

Wet-Bulb Temperature $= 7.2\ °C$

Mass of water vapour, $m_v = \frac{P_v V_v}{R_v T}$

$$\phi = \frac{m_v}{m_g} = \frac{P_v}{P_g}$$

At 8 °C, $P_g = 1.07$ kPa (From steam table)

SATURATED STEAM - TEMPERATURE TABLE

T °C	P bar	Spec. vol. m^3=kg Sat. liq. v_f X1000	Sat. vap. v_g	Int. Ener. kJ/kg Sat. liq. u_f	Sat. vap. u_g	Enthalpy kJ/kg Sat. liq. h_f	Sat. vap. h_g	Entropy kJ=(kg°K) Sat. liq. s_f	Sat. vap. s_g
0.01	0.0061	1.0002	206.1	0.01	2376	0.01	2501	0	9.156
4	0.0081	1.0001	157.2	16.79	2381	16.79	2509	0.061	9.051
5	0.0087	1.0001	147.1	21.00	2383	21	2511	0.0762	9.026
6	0.0093	1.0001	137.7	25.21	2384	25.21	2512	0.0912	9.000
8	0.0107	1.0001	120.9	33.61	2387	33.61	2516	0.1212	8.950
10	0.0123	1.0001	106.4	42.01	2389	42.01	2520	0.151	8.901
11	0.0131	1.0007	99.86	46.19	2391	46.19	2522	0.1658	8.876
12	0.0140	1.0007	93.79	50.40	2392	50.4	2523	0.1806	8.852

$P_v = \phi \times P_g = 0.92 \times 1.07 = 0.9844$ kPa

$R_v = 0.4615$

$V\ (\text{Aula A}) = 10 \times 20 \times 3 = 600\ m^2$

Therefore, $m_v = \frac{0.9844 \times 600}{0.4615 \times 281} = 4.55$ kg

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 good construction quality and with the same geometry as that of the example which is located in Brindisi, Italy.**

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)

Room height, h = 2.5 m

Good construction quality

2 occupants, 1 bedroom

Conditioned floor area = 200 m^2 ; wall area $= 144\ m^2$

Internal gains:

$\rightarrow \dot{Q}_{ig_{sensible}} = 136 + 2.2 * A_{cf} + 22\ N_{oc} = 136 + 2.2\ (200) + 22\ (2) = 620$ W

$\rightarrow \dot{Q}_{ig_{latent}} = 20 + 0.22 * A_{cf} + 12\ N_{oc} = 20 + 0.22\ (200) + 12\ (2) = 88$ W

Infiltration:

A_{es} (exposed surface area) $= 200 + 144 = 344\ m^2$

A_{ul} (unit leakage area for Good Quality Construction − table below) $= 1.4\,\frac{cm^2}{m^2}$

Table 3 Unit Leakage Areas

Construction	Description	A_{ul}, cm²/m²
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

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

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

Heating design temperature = 4.1 °C
Cooling design temperature = 31.1 °C

→ Volume: $V_{infilt_{heating}} = A_L \times IDF_{heating} = 481.6 \times 0.065 = 31.304\,\frac{L}{s}$

$V_{infilt_{cooling}} = A_L \times IDF_{heating} = 481.6 \times 0.0317 = 15.266\,\frac{L}{s}$

Ventilation:

$\dot{V}_v = 0.05\ A_{cf} + 3.5\ (N_{br} + 1) = 0.05\ (200) + 3.5\ (1 + 1) = 17\,\frac{L}{s}$

→ $\dot{V}_{inf-ventilation_{heating}} = 31.304 + 17 = 48.304\,\frac{L}{s}$

$\dot{V}_{inf-ventilation_{cooling}} = 15.266 + 17 = 32.266\,\frac{L}{s}$

$\{ C_{sensible} = 1.23;\ C_{latent} = 3010 \}$

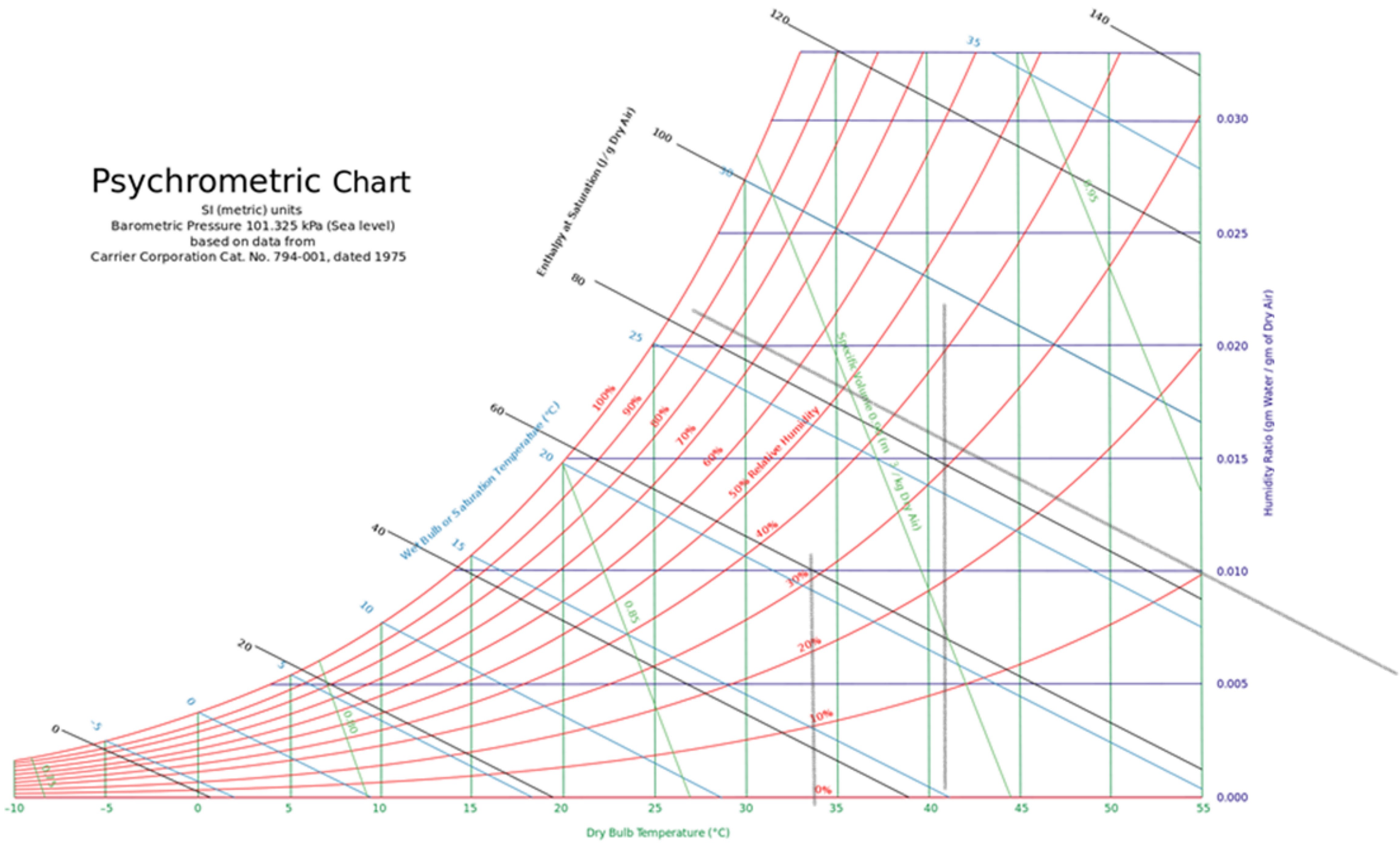
→ Therefore, $\dot{Q}_{inf-ventilation_{cooling_{sensible}}} = C_{sensible}\dot{V}\ \Delta T_{cooling}$

$= 1.23 \times 32.266 \times (31.1 - 24) = \mathbf{281.779\ W}$

$\dot{Q}_{inf-ventilation_{heating_{sensible}}} = C_{sensible}\dot{V}\ \Delta T_{heating}$

$= 1.23 \times 48.304 \times (20 - 4.1) = \mathbf{944.681\ W}$

For latent load calculation , we need $\Delta\omega_{cooling}$
Refering to psychrometric chart (for DB = 31.1 °C, WB = 24.3 °C), $\omega_{out} = 0.016 \mid \omega_{in} = 0.0093$
$\Delta\omega_{cooling} = 0.0067$



$\rightarrow$ Therefore, $\dot{Q}_{\text{inf-ventilation}_{\text{cooling}_{\text{latent}}}} = C_{\text{latent}}\dot{V}\,\Delta\omega_{\text{cooling}}$

$$= 3010 \times 32.266 \times 0.0067 = \mathbf{650.708\ W}$$