WEEK 9

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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**, **wet-bulb temperature**, and the **mass of water vapor in the air** in Aula A of Piacenza campus in the moment you are solving this exercise. Provide the input that you utilized.

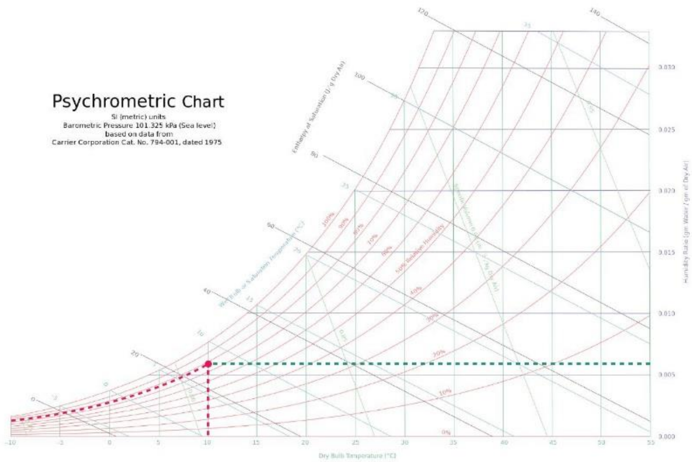
Data Used (December 2, 2019, 1pm)

Source	https://www.meteo-oggi.it/italia/regione-emilia-romagna/tempo-piacenza/
Relative Humidity	79%
Atmospheric Pressure	1016 hPa = 101.6 kPa
Effective Temperature	10°C
Aula A Dimensions	10 x 5 x 4m

	1:00 pm	14:00	4:00 pm	18:00	8:00 pm	21:00	22:00
	PartlyCloud	PartlyCloud	LightCloud	LightCloud	PartlyCloud	Cloud	PartlyCloud
Effective temperature	10 ° C	10 ° C	9 ° C	6 ° C	7 ° C	7 ° C	8 ° C
Perceived temperature	10 ° C	10 ° C	8 ° C	5 ° C	7 ° C	6 ° C	7 ° C
Rainfall	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm
Humidity	79 %	77 %	89 %	90 %	90 %	92 %	91 %
Atmospheric pressure	1016 hPa	1015 hPa	1016 hPa	1017 hPa	1019 hPa	1019 hPa	1020 hPa
Wind intensity	8 km / h	6 km / h	6 km / h	6 km / h	3 km / h	6 km / h	5 km / h
Wind direction	NO	OR	NO	OR	S	SELF	IS
Probability of fog	0 %	0 %	0 %	0 %	0 %	0 %	0 %
Dew point	6 ° C	6 ° C	7 ° C	5 ° C	5 ° C	6 ° C	6 ° C
Clouds	65 %	55 %	16 %	24 %	86 %	100 %	76 %
Low clouds	4 %	0 %	15 %	7 %	38 %	100 %	49 %
Medium clouds	34 %	54 %	2 %	23 %	84 %	85 %	70 %
High clouds	55 %	7 %	0 %	0 %	0 %	0 %	0 %

Psychrometric Chart Method

Using the psychrometric chart and the weather data provided, the following values can be concluded:



Absolute Humidity	0.006
Wet-Bulb Temperature	8°C

Formula Method

Saturation Pressure of Water at 10°C = 1.227 kPa

www.engineeringtoolbox.com says

Water saturation pressure at 10 degree C:

1.227 kPa
0.0123 bar
0.0121 atm
0.178 psi
25.6 psf

$$\phi = \frac{m_v}{m_g} \text{ where } m_g = \text{the mass of water at sat condition}$$

$$\phi = \frac{m_v}{m_g} = \frac{P_v}{P_g} \text{ where } P_g = P_{sat}10°C = 1.227\ kPa$$

Partial Pressure of Water Vapor

$$\phi = \frac{P_v}{P_g} \rightarrow P_v = \phi \times P_g$$

$$P_v = \phi \times P_g$$
$$P_v = 0.79 \times 1.227kPa = 0.97\ kPa$$

Partial Pressure of Dry Air

$$P_a = P - P_v$$
$$P_a = 101.6\ kPa - 0.97\ kPa = 100.63\ kPa$$

Absolute Humidity

$$\omega = (0.622)\left(\frac{P_v}{P_a}\right)$$

$$\omega = (0.622)\left(\frac{0.97\ kPa}{100.63\ kPa}\right)$$

$$\boldsymbol{\omega = 0.0059\frac{kg_{vapor}}{kg_{DryAir}}}$$

Mass of Water Vapor in the Air

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

For air: $m_a = \frac{P_a V_a}{R_a T}$

$$m_v = \frac{P_v V_v}{R_v T} = \frac{(0.97kPa)(10m * 5m * 4m)}{(0.4615)(273K + 10)}$$

$$\boldsymbol{m_v = 1.48kg}$$

Enthalpy

$$h = h_a + \omega h_v$$

where $h_a = C_{pa}T = \left(1.005\frac{kJ}{kg°C}\right)(T\ in\ °C)$ and $h_v = h_g(T) \approx 2501.3 + 1.82T$

$$h = \left(1.005\frac{kJ}{kg°C}\right)(10°C) + \left(0.0059\frac{kg_{vapor}}{kg_{DryAir}}\right)\left[2501.3 + (1.82)(10°C)\frac{kJ}{kg_{vapor}}\right]$$

$$h = 24.91505 = 24.92\frac{kJ}{kg_{DryAir}}$$

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.

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

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

Given Information

Building Height	$2.50m$
Floor Area	$200m^2$
No. of Occupants	2
No. of Bedrooms	1
Wall Area	$144m^2$

Internal Gains

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

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

Infiltration

Find maximum flow of air. Find leakage area and use unit leakage area chart.

Unit Leakage for Good Construction

$$A_{ul} = 1.40\ cm^2/m^2$$

Leakage Area

$$A_l = A_{es}A_{ul}$$
$$A_l = (200m^2 + 144m^2)(1.40\ cm^2/m^2)$$
$$A_l = (344m^2)(1.40\ cm^2/m^2)$$
$$A_l = 481.6cm^2$$

Infiltration Rate

Table 5 Typical IDF Values, L/(s·cm²)

H, m	Heating Design Temperature, °C					Cooling Design Temperature, °C			
	−40	−30	−20	−10	0 (4.1°C)	10	30 (31.1°C)	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

$$Q_i = (A_l)(IDF)$$

$$IDF_{heating} = 0.065\frac{L}{s \times cm^2}$$

$$IDF_{cooling} = 0.032\frac{L}{s \times cm^2}$$

Infiltration Rate - Winter

$$\dot{V}_{i_{heating}} = (481.6cm^2)\left(0.065\frac{L}{s \times cm^2}\right)$$
$$\boldsymbol{\dot{V}_{i_{heating}} = 31.30\ L/s}$$

Infiltration Rate - Summer

$$\dot{V}_{i_{cooling}} = (481.6cm^2)\left(0.032\frac{L}{s \times cm^2}\right)$$
$$\boldsymbol{\dot{V}_{i_{cooling}} = 15.41\ L/s}$$

Ventilation

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

where

Q_v = *required ventilation flow rate* $[L/s]$

A_{cf} = *building conditioned floor area* $[m^2]$

N_{br} = *no. of bedrooms, not less than 1*

$$\dot{V}_{ventilation} = (0.05)(200) + (3.5)(1 + 1) = 17.0\ L/s$$

$$\dot{V}_{infiltration-ventilation_{heating}} = 31.30\ L/s + 17\ L/s$$
$$\boldsymbol{\dot{V}_{infiltration-ventilation_{heating}} = 48.3\ L/s}$$

$$\dot{V}_{infiltration-ventilation_{cooling}} = 15.41\ L/s + 17\ L/s$$
$$\boldsymbol{\dot{V}_{infiltration-ventilation_{cooling}} = 32.41\ L/s}$$

Sensible and Latent Load

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

$$\Delta T_{heating} = 20°C - 4.1°C = 15.9°C$$
$$\Delta T_{cooling} = 31.1°C - 24°C = 7.1°C$$

$$\dot{Q}_{inf-vent_{heating_{sensible}}} = C_{sensible}\dot{V}\Delta T_{heating}$$
$$\dot{Q}_{inf-vent_{heating_{sensible}}} = (1.23)(48.3\ L/s)(15.9°)$$
$$\boldsymbol{\dot{Q}_{inf-vent_{heating_{sensible}}} = 944.60\ W}$$

$$\dot{Q}_{inf-vent_{cooling_{sensible}}} = C_{sensible}\dot{V}\Delta T_{cooling}$$
$$\dot{Q}_{inf-vent_{cooling_{sensible}}} = (1.23)(32.41\ L/s)(7.1°C)$$
$$\boldsymbol{\dot{Q}_{inf-vent_{cooling_{sensible}}} = 283.04\ W}$$

$$\dot{Q}_{inf-vent_{cooling_{latent}}} = C_{latent}\dot{V}\Delta\omega_{cooling}$$
$$\dot{Q}_{inf-vent_{cooling_{latent}}} = C_{latent}\dot{V}(\omega_{out} - \omega_{in})$$
$$\dot{Q}_{inf-vent_{cooling_{latent}}} = (3010)(32.41\ L/s)(0.014 - 0.0095\ kg_{vapor}/kg_{dryair})$$
$$\boldsymbol{\dot{Q}_{inf-vent_{cooling_{latent}}} = 438.99\ W}$$