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WEEK 9

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

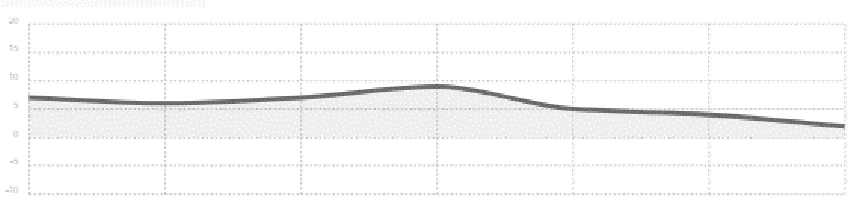
3- The mass of water vapor in the air in Class Room A (Aula A) of Piacenza campus in the moment that you are solving this exercise (provide the inputs that you utilized)

Weather Forecast Website example

Umidità: Relative humidity, Pressione atmosferica: Air total pressure (1 hPa: 0.1 kPa), Temperatura effettiva: temperature to be utilized.

Il tempo oggi in Piacenza
Martedì, 03 Dicembre 2019

	05:00	07:00	10:00	14:00	18:00	19:00	21:00
	Cloud	PartlyCloud	LightCloud	PartlyCloud	Sun	Sun	Sun
Temperatura effettiva	7°C	6°C	7°C	9°C	5°C	4°C	2°C
Temperatura percepita	4°C	3°C	5°C	7°C	3°C	2°C	0°C
Precipitazioni	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm
Umidità	79 %	81 %	75 %	63 %	74 %	75 %	82 %
Pressione atmosferica	1023 hPa	1024 hPa	1025 hPa	1025 hPa	1026 hPa	1026 hPa	1027 hPa
Intensità del vento	15 km/h	12 km/h	13 km/h	13 km/h	8 km/h	8 km/h	8 km/h
Direzione del vento	E	E	E	E	E	E	SE
Probabilità di nebbia	0 %	0 %	0 %	0 %	0 %	0 %	0 %
Punto di rugiada	3°C	3°C	3°C	2°C	1°C	0°C	-1°C
Nuvole	90 %	54 %	34 %	47 %	3 %	3 %	6 %
Nuvole basse	39 %	45 %	33 %	46 %	3 %	3 %	6 %
Nuvole medie	58 %	32 %	12 %	13 %	1 %	2 %	2 %
Nuvole alte	67 %	0 %	0 %	0 %	0 %	0 %	0 %



Solving the exercise at 05:00 PM on Tuesday 03/12/2019

- The relative humidity: 79%
- Air total Pressure: 1023 hPa (102.3 Kpa)
- Temperature to be utilized: 7 C

Estimating Aula A approx. dimensions:

- Length: 20 m
- Width: 8 m
- Height: 5 m

First, let's try to calculate the relative pressure:

$$\phi = \frac{m_v}{m_g} \quad -\!\!\rightarrow m_g \text{the mass of water at sat condition}$$

From Steam tables I can find the saturation pressure of water @ 7 C =1.001 kPa

Reference website:

https://www.engineeringtoolbox.com/water-vapor-saturation-pressure-d_599.html?vA=7&units=C#

$$\phi = \frac{m_v}{m_g} \quad = \frac{P_v}{P_g} -\!\!\rightarrow P_g = P_{sat} 7\,°C = 1.001\ kPa$$

$$\phi \quad = \frac{P_v}{P_g} \rightarrow P_V = \phi \times P_g = 0.79 * 1.001 = 0.79079\ kPa$$

$$\text{partial pressure of dry air: } P_a \ = P \ - P_v = 102.3\ kPa - 0.79079\ kPa = 101.51\ kPa$$

Second, let's try to calculate the absoloute humidity:

$$\omega = 0.622 \frac{P_v}{P_a} = 0.622 \frac{0.79079}{101.51} = 0.00779 \frac{Kg_{vapour}}{kg_{dryAir}}$$

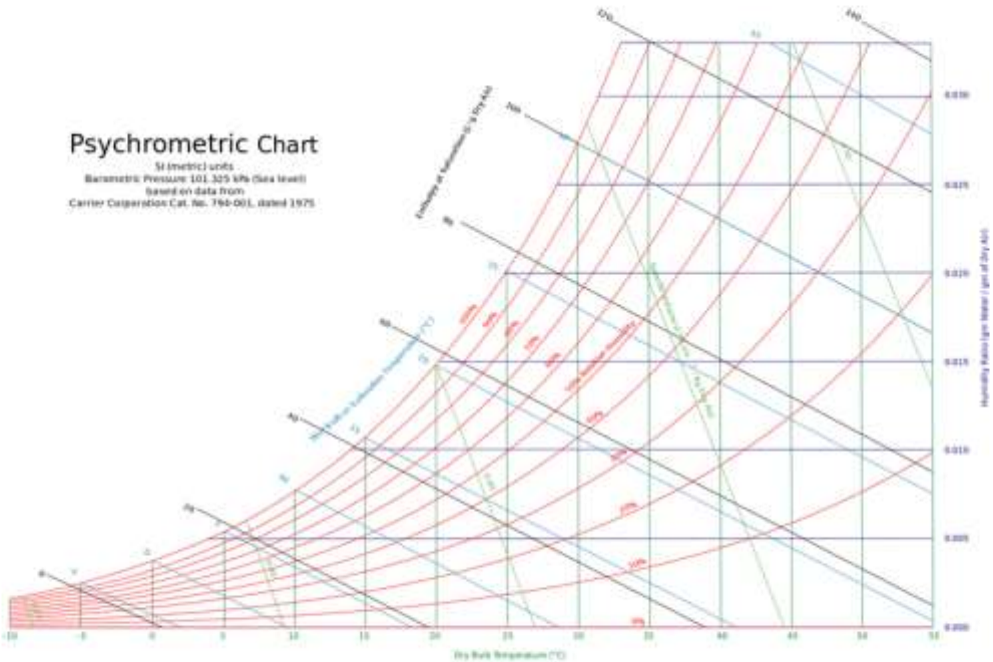
For ideal gases : $m = \frac{PV}{R_{sp.}T}$

So for air : $m_a \ = \frac{P_a V_a}{R_a T}$ $\quad R_{sp.} = \frac{R_{global}}{M_{gas}} -\!\!\rightarrow You\ can\ also\ find\ them\ in\ Tables\ R_a = 0.287,\ R_v = 0.4615$

$$m_a = \frac{101.51 * (20 * 8 * 5)}{0.287 \ * (273 + 7)} = 1010.55\ kg\ of\ dry\ air$$

$$m_v = \frac{0.79079 * (20 * 8 * 5)}{0.4615 \ * (273 + 7)} = 4.895\ kg$$

The mass of water vapor in the air in Class Room A is 4.895 Kg.



From the psychometric chart above, we find that the wet bulb temperature is around 5.7 C

Task 2:

Utilize the same methodology we went through in the class:

Determine

- The sensible and latent load corresponding to internal gains
- The infiltration in a house
- The ventilation loads

With a

- good construction quality
- 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

	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

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

Estimating Aula A approx. dimensions:

- Length: 20 m
- Width: 8 m
- Height: 5 m
- Conditioned floor area 160m2
- Wall area 280m2
- Occupants: 100 persons
- One bedroom space

Calculating Internal gains:

$$\dot{Q}_{ig_{sensible}} = 136 + 2.2 \ * A_{cf} + 22\ N_{oc} = 136 + 2.2 * 160 + 22 * 100 = 136 + 352 + 2200 = 2688\ W$$

$$\dot{Q}_{ig_{latent}} = 20 + 0.22 * A_{cf} + 12\ N_{oc} = 20 + 0.22 * 160 + 12 * 100 = 20 + 35.2 + 1200 = 1255.2\ W$$

Infiltration

Claculating the maximum flow rate of air:

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

For a good construction quality, the average leakage area is 1.4 cm2/m2

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

where

A_{es} = building exposed surface area, m^2

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

Exposed surface = Wall area +roof area

$$A_{es} = 280 + 160 = 440\ m^2$$

$$A_L = A_{es} \times A_{ul} = 440 \times 1.4 = 616\ cm^2$$

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

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, $L/(s \cdot cm^2)$

	Table 5 Typical IDF Values, L/(s·cm²)								
H,	Heating Design Temperature, °C					Cooling Design Temperature, °C			
m	−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

On the 4th row of the above table, we have the H: 5m height.

From the weather data for the city of BRINDISI, we note that:

- Heating DB is 4.1
- Cooling DB is 31.1

$$IDF_{\text{heating}} = 0.066 \frac{L}{s.cm^2}$$

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

Calculate the volume:

$$\dot{V}_{infiltration_{\text{heating}}} = A_L \times IDF = \ \ 616 * 0.066 = 40.656 \frac{L}{s}$$

$$\dot{V}_{infiltration_{cooling}} = A_L \times IDF = \ \ 616 * 0.032 = 19.712 \frac{L}{s}$$

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

where

Q_v = required ventilation flow rate, L/s
A_{cf} = building conditioned floor area, m²
N_{br} = number of bedrooms (not less than 1)

$\dot{V}_{ventilation} = 0.05\ A_{cf} + 3.5\ (N_{br} + 1) =$ 0.05*160+ 3.5* 100 = 8+350=358 L/S

$$\dot{V}_{inf-ventilation_{\text{heating}}} = 40.656 + 358 = 398.656\ L/s$$

$$\dot{V}_{inf-ventilation_{cooling}} = 19.712 + 358 = 377.712\ L/s$$

From the past lessons:

- Cooling Temperature T cooling= 24 C
- Heating Temperature T heating= 20 C

ΔT cooling = 31.1 $°C$ - 24 $°C = 7.1\ °C$
ΔT heating = 20 $°C$ - (-4.1) $°C = 24.1\ °C$

$$\omega_{out} = 0.0132 \frac{kg_{water}}{kg_{dryAir}} \quad (from\ cooling\ DB = 31.1°C)$$

$$\omega_{in} = 0.0093 \frac{kg_{water}}{kg_{dryAir}} \quad (from$$

$$\Delta\omega_{=}0.0132 - 0.0093 = 0.0039 \frac{kg_{water}}{kg_{DryAir}}$$

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

$$\dot{Q}_{inf-ventilation_{cooling_{sensible}}} = C_{sensible}\dot{V}\Delta T_{Cooling} = 1.23\ * 48.8 * 7.9 = 474\ W$$

$$\dot{Q}_{inf-ventilation_{cooling_{latent}}} = C_{latent}\dot{V}\Delta\omega_{Cooling} = 3010\ * 48.8\ *\ 0.0039 = 572.\ 7\ W$$

$$\dot{Q}_{inf-ventilation_{\mathrm{heating}g_{sensible}}} = C_{sensible}\dot{V}\Delta T_{\mathrm{heating}} = 1.23\ * 87.31 * 24.8 = 2663.4\ W$$