POLITECNICO
MILANO 1863

Name: Amir Saman Gholami Shamami
Student Number: 10701028
Submission Date: 07/12/2019
Assignment #: 9th Week

Task 1

The first step is to import the relevant data from a certain weather forecast website:

Il tempo oggi in Piacenza
Sabato, 07 Dicembre 2019

	05:00	07:00	10:00	14:00	18:00	19:00	21:00
	Cloud	Sun	PartlyCloud	Sun	Sun	Sun	Sun
Temperatura effettiva	4°C	4°C	6°C	9°C	4°C	4°C	4°C
Temperatura percepita	3°C	3°C	5°C	9°C	3°C	2°C	2°C
Precipitazioni	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm	0 mm
Umidità	96 %	95 %	87 %	71 %	94 %	94 %	90 %
Pressione atmosferica	1019 hPa	1019 hPa	1019 hPa	1018 hPa	1019 hPa	1019 hPa	1020 hPa
Intensità del vento	6 km/h	6 km/h	6 km/h	4 km/h	6 km/h	8 km/h	8 km/h
Direzione del vento	NO	NO	NO	O	S	S	SE

Now the time is almost 10 a.m. and as we see in the table:

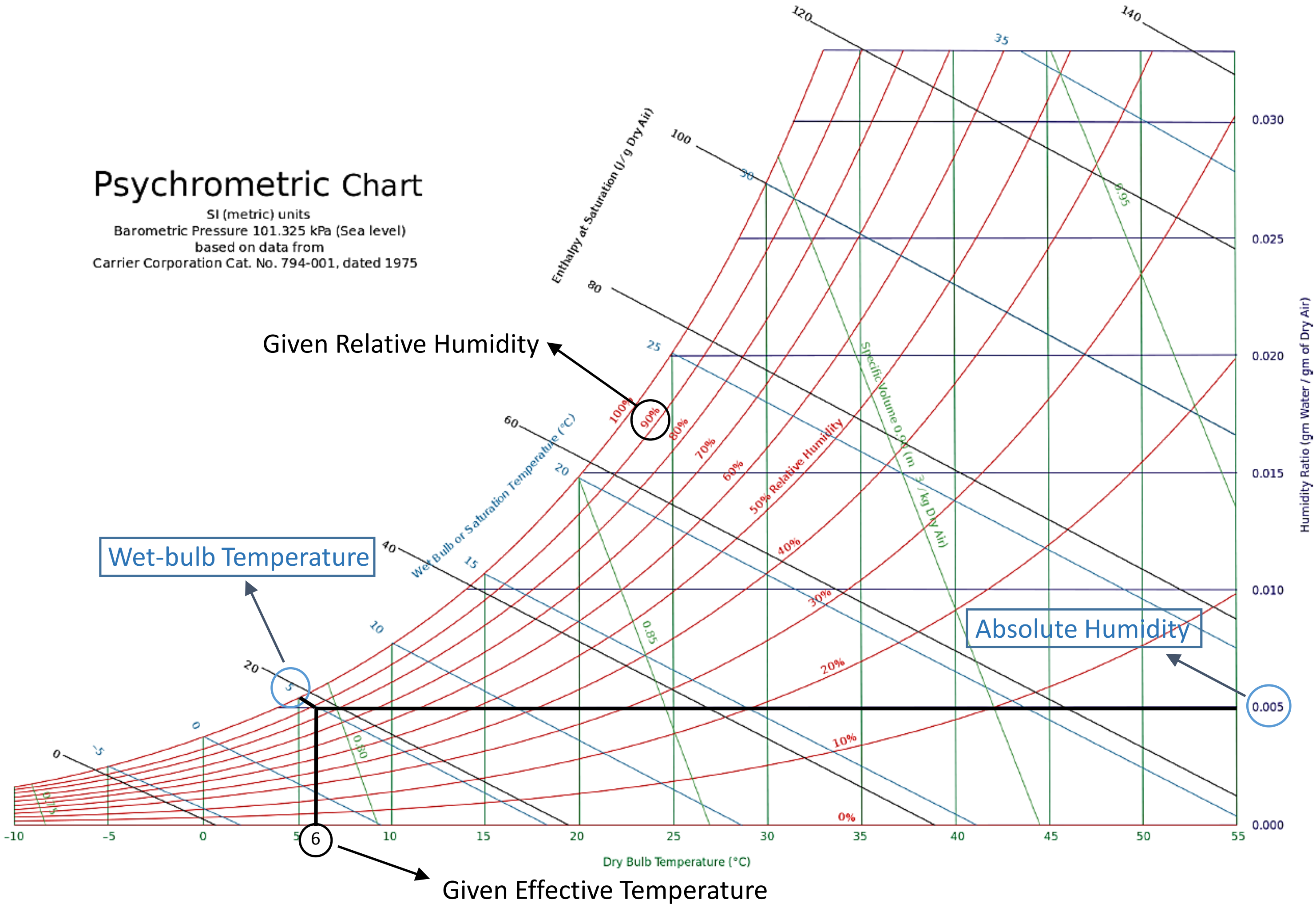
- Relative Humidity (ϕ)= 90%
- Total Air Pressure (P) = 101.8 kPa
- Effective Temperature (T) = 6 °C

1. By plotting the given relative humidity and effective temperature on **Psychrometric Chart** (shown on next page), we can determine:

- Absolute Humidity (ω) = $\boxed{0.005 \frac{kg_{vapor}}{kg_{dryAir}}}$ → 5 grams of water vapor in 1 kg of dry air

- Wet-bulb temperature = $\boxed{5\ °C}$

Name: Amir Saman Gholami Shamami
Student Number: 10701028
Submission Date: 07/12/2019
Assignment #: 9th Week



2. In order to calculate the mass of water vapor in the air, we can use the following formula as we discussed in the class:

$$m_{\mathrm{v}} = \frac{P_{\mathrm{v}} V}{R_{\mathrm{v}} T}$$

Where P_{v} is the partial pressure of the water vapor, V is volume of the room, R_{v} is the gas constant and T is the temperature of the place in Kelvin scale.

- We know from the presentation that $\omega = 0.622 \frac{P_{\mathrm{v}}}{P_{\mathrm{a}}}$ and since the temperature is below 50 °C, water vapor is an ideal gas and P(Total Pressure) = P_{v} + P_{a} therefore P_{a} = P - P_{v}. The mentioned formula can be rephrased as $\omega = \frac{0.622 \times P_{\mathrm{v}}}{P - P_{\mathrm{v}}}$.

POLITECNICO
MILANO 1863

Name: Amir Saman Gholami Shamami
Student Number: 10701028
Submission Date: 07/12/2019
Assignment #: 9th Week

We found out that ω = 0.005 $\frac{kg_{vapor}}{kg_{dryAir}}$ and the total air pressure based on our location is 101.8 kPa then:

$$0.005 = \frac{0.622 \times P_{\mathrm{v}}}{101.8 - P_{\mathrm{v}}} \Rightarrow P_v \approx 0.812 \text{ kPa}$$

- We can imagine that the dimensions of the classroom A are 5×10×6 meter, therefore our volume is equal to 300 $m3$.

- R is a constant number and is possible to be plotted from steam table and for water vapor it equals to $R_v = 0.4615$

- T in our case is equal to 279 °K (6+273)

By substituting the known parameters we can conclude:

$$m_{\mathrm{v}} = \frac{P_{\mathrm{v}}V}{R_{\mathrm{v}}T} \Rightarrow m_{\mathrm{v}} = \frac{0.812 \times 300}{0.4615 \times 279} \approx \boxed{1.9 \text{ Kg}}$$

Task 2

1. First we calculate the internal gains based on the formulas we know from the presentations:

- $\dot{Q}_{ig\ (sensible\ cooling)}$ = 136 + 2.2 A_{cf} + 22 N_{oc} (A_{cf} = conditioned floor area , N_{oc} = Number of occupants)

- $\dot{Q}_{ig\ (latent\ cooling)}$ = 20 + 0.22 A_{cf} + 12 N_{oc} (A_{cf} = conditioned floor area , N_{oc} = Number of occupants)

POLITECNICO
MILANO 1863

Name: Amir Saman Gholami Shamami
Student Number: 10701028
Submission Date: 07/12/2019
Assignment #: 9th Week

And we know from the previous example that the house has one bedroom and its height is equal to 2.5 m, conditioned floor area is 200 m2, wall area is 144 m2 and 2 people are occupying the space. Then:

- $Q_{ig\ (sensible\ cooling)}$ = 136 + (2.2 × 200) + (22 × 2) = $\boxed{620\ W}$

- $Q_{ig\ (latent\ cooling)}$ = 20 + (0.22 × 200) + (22 × 2) = $\boxed{88\ W}$

2. Next we need to calculate the infiltration flow rate. For this purpose we need to know the **effective leakage area (A_L)** of our geometry as well **as infiltration driving forces (IDF)** . A_L can be found as below:

A_L = A_{ul} (unit leakage area) × A_{es} (area of exposed surfaces)

A_{ul} can be taken from Table 3 and A_{es} is equal to sum of conditioned floor area and area of walls.

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

- $A_{ul} = 1.4\ \frac{cm^2}{m^2}$

- $A_{es} = 200 + 144 = 344\ m^2$

$A_L = 1.4 \times 344 = 481.6\ cm^2$

Table 5 Typical IDF Values, L/(s·cm²)

H, m	Heating Design Temperature, °C					Cooling Design Temperature, °C			
	−40	−30	−20	−10	0 4.1	10	30 31.1	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 can also be taken from predefined tables. Based on our height and location (table is on next page), our heating DB is 4.1 °C and our cooling DB is 31.1 °C. If we plot these number on Table 5 then $IDF_{heating} \approx 0.084 \frac{L}{s.cm^2}$ and $IDF_{cooling} \approx 0.032 \frac{L}{s.cm^2}$

POLITECNICO
MILANO 1863

Name: Amir Saman Gholami Shamami
Student Number: 10701028
Submission Date: 07/12/2019
Assignment #: 9th Week

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)

Now we can substitute the known parameters in the final formulas:

-$\dot{V}_{infiltration\ (heating)} = A_L \times IDF_{heating} = 481.6 \times 0.065 \boxed{\approx 31.31\ \frac{L}{s}}$

- $\dot{V}_{infiltration\ (cooling)} = A_L \times IDF_{cooling} = 481.6 \times 0.032 \boxed{\approx 15.42\ \frac{L}{s}}$

3. Ventilation flow rate can be calculated based on the following formula: $\dot{Q}_v = 0.05\ A_{cf} + 3.5(\ N_{br} + 1\ )$ where A_{cf} is again the conditioned floor area and N_{br} is the number of bedrooms.

- $A_{cf} = 200\ m^2$
- $N_{br} = 1$

$\Rightarrow \dot{V}_{ventilation} = 0.05 \times 200 + 3.5(1 + 1) = \boxed{17\ \frac{L}{s}}$

4. Finally we need to calculate the minimum whole building cooling and heating loads. First we find the infiltration-ventilation flow rates and then apply them on the final formulas based on types of internal gains.

infiltration-ventilation flow rate is simply the summation of the two separate known parameters:

- $\dot{V}_{infiltration-ventilation(heating)}$ = 31.31 + 17 = 48.31 $\frac{L}{s}$
- $\dot{V}_{infiltration-ventilation(cooling)}$ = 15.42 + 17 = 32.42 $\frac{L}{s}$

As the values of $C_{sensible}$, C_{latent} and $\Delta\omega_{cooling}$ have been given within the previous example and $\Delta T_{heating}$ = 15.9 and $\Delta T_{cooling}$= 7.1 for the worst case scenarios in Brindisi, Italy then:

- $\dot{Q}_{infiltration-ventilation(heating-sensible)} = C_{sensible} \times \dot{V} \times \Delta T_{heating}$
- $\dot{Q}_{infiltration-ventilation(heating-sensible)} = 1.23 \times 48.31 \times 15.9$

$$\Rightarrow \dot{Q}_{infiltration-ventilation(heating-sensible)} \approx \boxed{945\ W}$$

- $\dot{Q}_{infiltration-ventilation(cooling-sensible)} = C_{sensible} \times \dot{V} \times \Delta T_{cooling}$
- $\dot{Q}_{infiltration-ventilation(cooling-sensible)} = 1.23 \times 32.42 \times 7.1$

$$\Rightarrow \dot{Q}_{infiltration-ventilation(cooling-sensible)} \approx \boxed{283.2\ W}$$

- $\dot{Q}_{infiltration-ventilation(cooling-latent)} = C_{latent} \times \dot{V} \times \Delta\omega_{cooling}$
- $\dot{Q}_{infiltration-ventilation(cooling-latent)} = 3010 \times 32.42 \times 0.0039$

$$\Rightarrow \dot{Q}_{infiltration-ventilation(cooling-latent)} \approx \boxed{380.6\ W}$$