Air Conditioning System

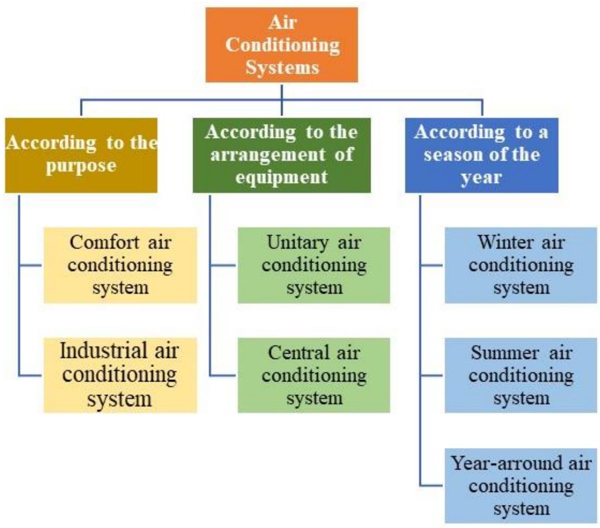
Air conditioning implies conditioning or controlling the air. An efficient air conditioning system is essential to maintain comfort and productivity in both winter and summer months. Engineers in this field strive to create HVAC (Heating, Ventilation, and Air Conditioning) systems that can seamlessly transition between providing warmth during the winter months and delivering cooling relief in the scorching heat of summer. These systems rely on a combination of innovative technologies, such as heat pumps, refrigeration cycles, and sophisticated control systems, to not only regulate indoor temperatures but also optimise energy efficiency and environmental sustainability.

What is Air Conditioning?

Air conditioning can be defined as the synchronised management of temperature, humidity, airflow, and air quality within a confined environment.

Achieving this delicate balance involves a mixture of innovative technologies, including refrigeration cycles, filtration systems, and precision controls. By precisely controlling these factors, air conditioning systems not only enhance comfort but also play a vital role in various sectors, from ensuring the longevity of fresh goods in cold storage facilities to maintaining a comfortable and productive indoor environment for occupants in homes, offices, and industrial settings.

Classification of Air Conditioning Systems



Flow chart for the classification of Air Conditioning System

I. According to the Purpose

1. Comfort air conditioning system.

2. Industrial air conditioning system

Comfort Air Conditioning system

In these types of air conditioning system, the air is brought to the required dry bulb temperature and relative humidity for human health, comfort and efficiency. If sufficient data of the required is not available, then it is assumed to be 21°C dry bulb temperature and 50% relative humidity (Human comfort).

Examples: In homes, offices, shops, restaurants, theatres, hospitals, schools etc. are using air-conditioning systems to give comfort to people.

Industrial Air Conditioning System

In these types of air conditioning system, the inside dry bulb temperature and relative humidity of the air is kept constant for working of the machine and for the manufacturing process.

Examples: Textile mills, Paper mills, Machine part manufacturing plants, Toolroom, Photographic etc. are using this type of air-conditioning systems.

II. According to the Arrangement of Equipment

1. Unitary air conditioning system

2. Central air conditioning system.

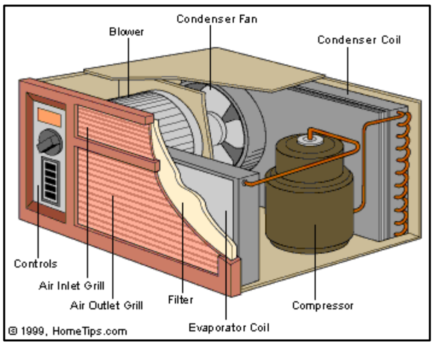
Unitary Air Conditioning System

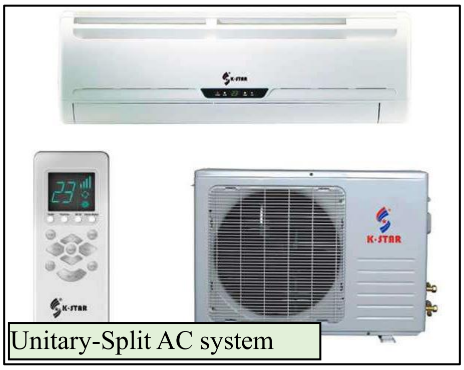
- In unitary air conditioning system, the assembled air conditioner is installed in or adjacent to the space to be conditioned.
- In unitary systems, the common type of one room conditioners, sit in a window or wall opening, with interior controls.
- Interior air is cooled as a fan blows it over the evaporator, and the exterior air is heated as a second fan blows it over the conditioner.
- In this process, heat is supplied from the room and discharge to the environment.
- A large house or building may have several such units, permitting each room to be cooled separately.

Central Air Conditioning System

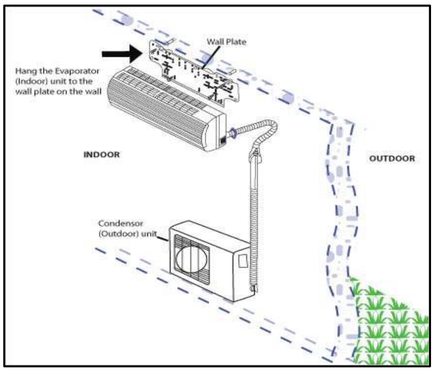
It is a most important type of air conditioning system; it uses when the required cooling capacity **25TR** or more. It uses when the air flow is more than **300 m³/min** or different zones in a building are to be air-conditioned.


Unitary-window AC system

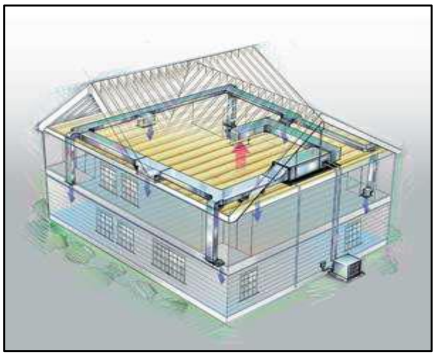




Unitary-Split AC system




Centrlalised AC system



III. According to a Season of The Year

1. Summer air conditioning system.

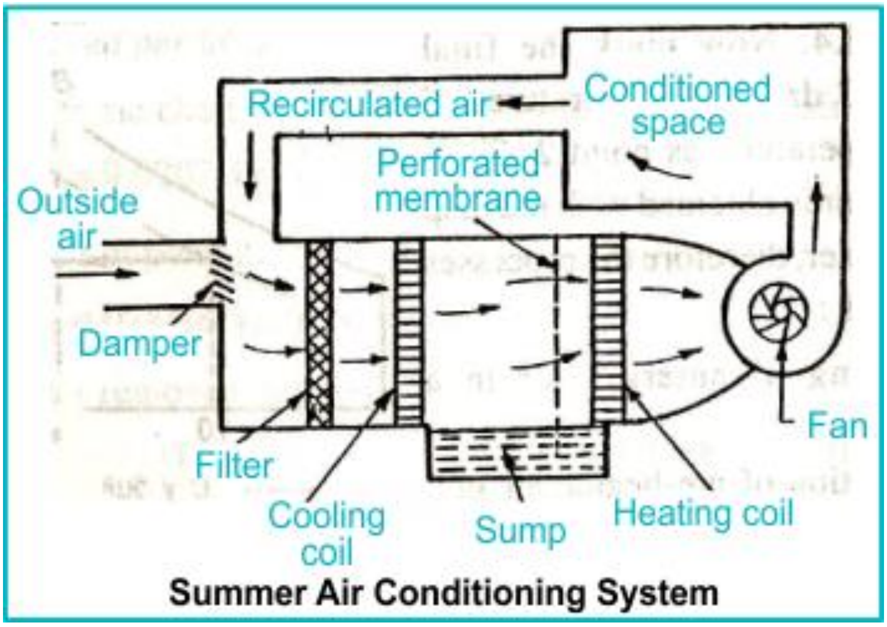
2. Winter air conditioning system.

3. Year-round air conditioning system.

What is Summer Air Conditioning System?

This system is primarily employed in summer air conditioning applications, where the focus is on cooling and dehumidification. The working principle of this system are as follows:

- To initiate the process, outdoor air enters via a damper and blends with recirculated air sourced from the air-conditioned space.
- Before entering the next stage, this combined air stream undergoes filtration to effectively remove dirt, dust, and impurities.



Summer Air Conditioning System

Subsequently, the air passes through a cooling coil, which operates at a significantly lower temperature than the desired dry bulb temperature within the conditioned space. As a result, the cooled air proceeds through a perforated membrane, shedding moisture in the form of condensation, which is then collected in a **sump**.

- To ensure the air meets the requisite dry bulb temperature and relative humidity, it passes through a heating coil, elevating its temperature slightly.
- Finally, the conditioned air is delivered into the conditioned space with the assistance of a fan. Within this space, a portion of the air is exhausted into the atmosphere by exhaust fans or ventilators, while the remainder, referred to as recirculated air, re-enters the conditioning cycle. This cyclic process effectively compensates for the loss of conditioned or used air through exhaust fans or ventilators in the conditioned space.

Advantages of Summer Air Conditioning System

- Provides cooling comfort during hot weather.
- Improves indoor air quality by filtering and dehumidifying.
- Increases productivity and sleep quality.
- Enhances safety by reducing heat-related illnesses.
- Preserves food and prevents heat damage to electronics.

What is Winter Air Conditioning System?

In winter air conditioning system, the air is burnt and heated, which is generally followed by humidification, i.e., focus is on Heating and humidification.

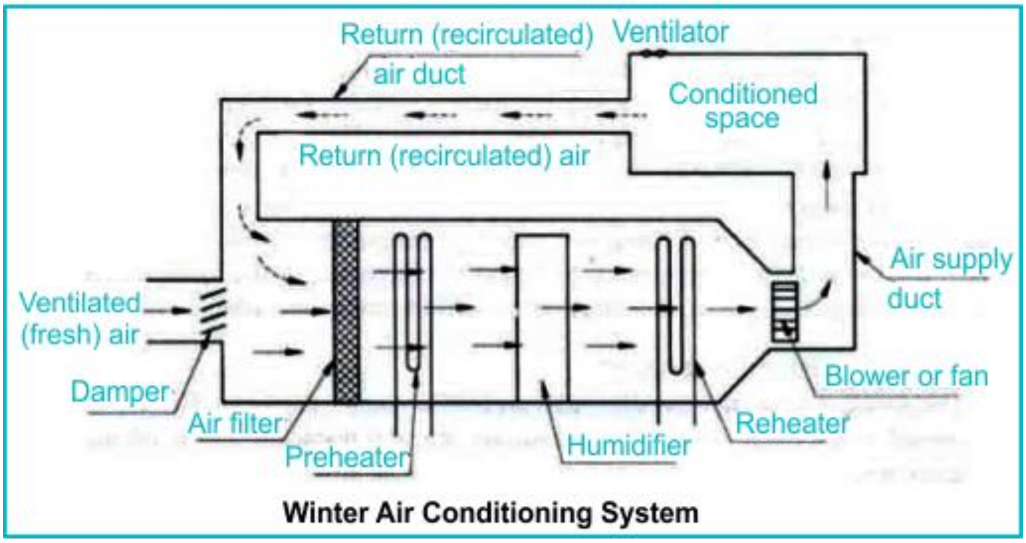


Fig 2: Winter Air Conditioning System

- During the winter air conditioning process, air undergoes a heating phase, often followed by humidification.
- Initially, outside air enters through a damper and blends with the recirculated air, which is extracted from the conditioned space.
- The combined air then traverses a filtration stage to eliminate contaminants like dirt and dust. Subsequently, the air passes through a preheat coil, which serves the dual purpose of averting water freezing and controlling water evaporation within the humidifier.
- Following this, the air is directed through a reheat coil to achieve the desired dry bulb temperature.
- A fan is responsible for distributing the conditioned air into the target space. Within the conditioned space, a portion of used air is expelled into the atmosphere through exhaust

fans or ventilators, while the remaining portion, known as recirculated air, is reintroduced into the conditioning process.

- This cyclical process ensures the maintenance of consistent indoor environmental conditions.

Advantages of Winter Air Conditioning System

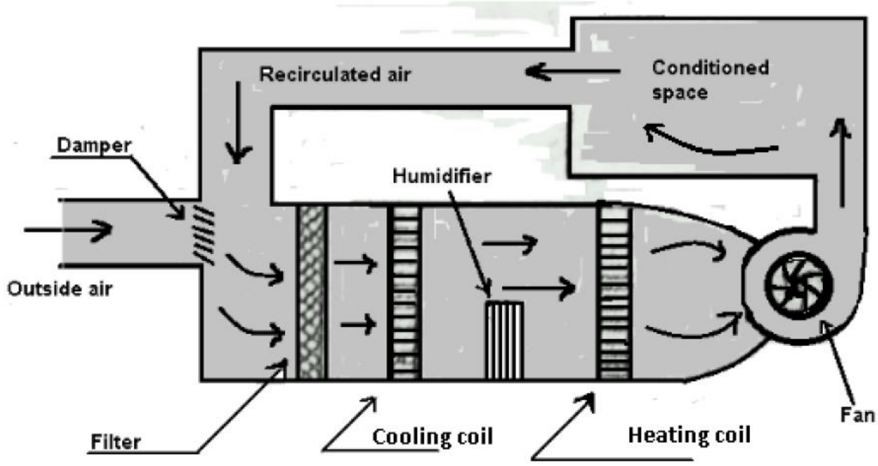
- Provides cooling comfort during hot weather.
- Improves indoor air quality by filtering and dehumidifying.
- Increases productivity and sleep quality.
- Enhances safety by reducing heat-related illnesses.
- Preserves food and prevents heat damage to electronics.

Difference between Summer and Winter Air Conditioning System

ASPECT	SUMMER AIR CONDITIONING SYSTEM	WINTER AIR CONDITIONING SYSTEM
OBJECTIVE	Cooling and dehumidifying the indoor air.	Heating and maintaining comfort during cold weather.
TEMPERATURE CONTROL	Lowers indoor temperature below the external heat.	Increases indoor temperature above external cold.
HUMIDITY CONTROL	Reduces humidity levels to enhance comfort.	May increase humidity to prevent overly dry air.
PRIMARY EQUIPMENT	Cooling coils, refrigerant, and dehumidifiers.	Heating elements, furnaces, and humidifiers.
AIR DISTRIBUTION	Cools and circulates air through the space.	Heats and distributes warm air throughout.
IDEAL RELATIVE HUMIDITY	Maintains relative humidity above 60%.	Maintains relative humidity below 40%.
COMMON COOLING METHODS	Evaporative cooling, refrigeration cycles.	Furnaces, heat pumps, and electrical heaters.
COMMON HEATING METHODS	Furnaces, heat pumps, electrical heaters.	Heat pumps (reversible), electrical heaters.
ENERGY EFFICIENCY	Focuses on cooling efficiency and dehumidification.	Focuses on efficient heating while minimising heat loss.
SEASONAL USE	Typically used during the summer months.	Primarily used during the winter season.
COMFORT PRIORITIES	Cooling, dehumidification, and air quality.	Heating, comfort, and prevention of cold drafts.
ENVIRONMENTAL IMPACT	Emphasises energy-efficient cooling practices.	Prioritises energy-efficient heating solutions.

Year-Round Air Conditioning System

In year-round air conditioning system, it should have equipment for both the summer and winter air conditioning. In this, the outside air flows through the damper and mixed with the recirculated air. The mixed air passes through a filter to remove dirt, dust and impurities.



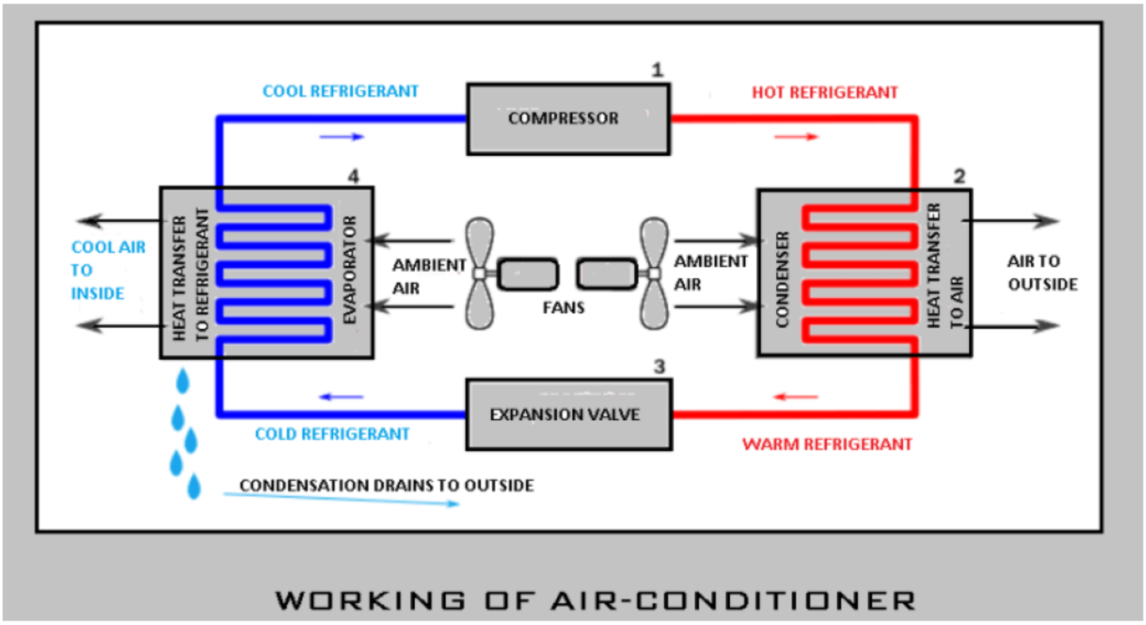
Year-Round Air Conditioning System

In summer air conditioning system, the cooling by operates to cool the air to the desired valve. The dehumidification is obtained by operating the cooling coil at a lower temperature than the dew point temperature.

In winter air conditioning system, the cooling coil is made inoperative and the heating coil operates to heat the air. The spray type humidifier is also used in the dry season to humidify the air.

Factors Affecting the Comfort Air Conditioning or Comfort Parameters

Air conditioning is a system for controlling the humidity, ventilation, and temperature in a building or vehicle, typically to maintain a cool atmosphere in warm conditions.



The human comfort depends upon physiological and psychological condition. The most acceptable definition, from the subject point of view, is given by the *American Society of Heating, Refrigeration and air Conditioning Engineers (ASHRAE)* which states: ***human comfort is that conditions of mind, which expressed satisfaction with the thermal environment.***

The comfort parameters are as follows.

1. Effective Temperature of Air
2. Humidity of Air
3. Purity of Air
4. Motion of Air
5. Heat Production and Regulation in Human Body
6. Moisture Content of Air
7. Quality and Quantity of Air
8. Air Motion
9. Cold and Hot Surfaces
10. Air Stratification

Effective Temperature of Air

Regulating air temperature involves the ability to sustain the desired indoor temperature, irrespective of whether external conditions turn above or below the targeted room temperature. The degree of warmth or cold felt by a human body depends mainly on the following three factors:

1. Dry bulb temperature, 2. Relative humidity and 3. Air velocity

In order to evaluate the combined effect of these factors, the effective temperature is employed. It is defined as that *index which collates the combined effects of air temperature, relative humidity and air velocity on the human body*. The numerical value of effective temperate is made equal to the temperature of stills (i.e., 5 to 8 m/min air velocity) saturated air, which produces the same sensation of warmth or clones as produced under the given conditions. The practical application of the concept of effective temperature is presented by the comfort chart. This chart is the result of research made on different kinds of people subjected to wide range of environmental temperature, relative humidity and air movement by the ASHRAE. In the comfort chart, *the dry bulb temperature is taken as abscissa and the wet bulb temperature of ordinates.*

Humidity of Air

Managing air humidity entails the adjustment of moisture levels within the air, either by increasing or decreasing them depending on the season.

Notably, for effective Summer Air Conditioning, it is essential to maintain a relative humidity level of no less than 60%. Conversely, during Winter Air Conditioning, ensuring that relative humidity does not exceed 40% is critical for optimal comfort and environmental control.

Heat Production and Regulation in Human Body: The rate of heat production depends upon the individual's health, his physical activity and his environment. The rate at which the body produces heat is metabolic rate. The heat production from a normal healthy person when a sleep (called based metabolic rate) is about 60 wtts and it is about ten times more for a person carrying out sustained very hard work.

Heat and Moisture Losses from the Human Body: The heat is given off from the human body as either sensible or latent heat or both. In order to design any air-conditioning system for spaces which human bodies are to occupy, it is necessary to know the rates at which these two forms of heat are given off under different conditions of air temperature and bodily activity.

Moisture Content of Air: The moisture content of outside air during winter is generally low and it is above the average during simmer, because the capacity of the air to carry moisture is dependent upon its dry bulb temperature. This means that in winter, if the cold outside air having a low mist rue content leaks into the conditioned space, it will cause a low relative humidity unless minster is assed to the air by the processes of humidification. In summer, the reveres will take place unless moisture is removed from the inside air by the dehumidification process.

Quality and Quantity of Air: The air in an occupied space should, at all times, be free room toxic, unhealthful fumes such as carbon dioxide. It should also be free from dust and odour.

Air Motion: The air motion which included the distribution of air is very important to maintain uniform temperate in the conditioned space. The air velocity in the occupied zone should not exceed 8 to 12 m/min.

Cold and Hot Surfaces: The cold or hot objects in a conditioned space may cause discomfort to the occupants.

Air Stratification: The movement of the air to produce the temperature gradient from floor to ceiling is termed as air stratification. In order to achieve comfortable conditions in the occupied space, the air conditioning system must be designed to reduce the air stratification to a minimum.

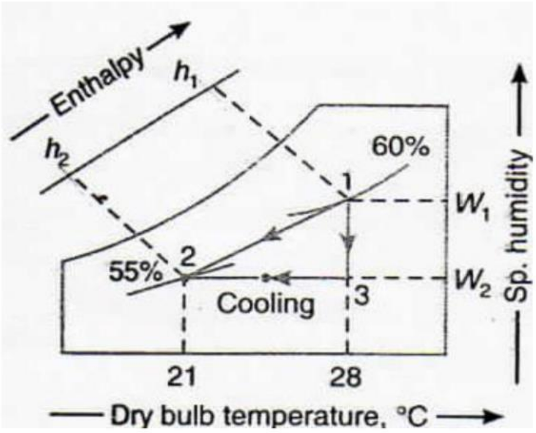
Applications of Air-conditioning System:

- Using air-conditioner is common in food cooking and processing areas. Used in hospital operating theatres to provide comfortable conditions to patients. And many more industries like Textile, Printing, Photographic and much more.
- Air-conditioning system used as the commercial purpose for a human being. Example, in Theatres, Departmental store-room etc.
- Many of transport vehicles use air-conditioning systems such as cars, trains, aircraft, ships etc. This provides a comfortable condition for the passengers.
- The air-conditioning system used in Television-centres, Computer centres and museum for a special purpose.

Numerical Problems

Example 1: *An air conditioning plant is required to supply 60 m of air per minute at a DBT of 21°C and 55% RH. The outside air is at DBT of 28°C and 60% RH. Determine the mass of water drained and capacity of the cooling coil. Assume the air conditioning plant first to dehumidify and then to cool the air.*

Solution: Given $v_2 = 60$ m^3/min; $t_{d2} = 21$°C; $\emptyset_2 = 55\%$; $t_{dt} = 28$°C; $\emptyset_1 = 60\%$



To find the mass of water drained, first of all, mark the initial condition of air at 28°C dry bulb temperature and 60% relative humidity on the 1 h psychrometric chart as point 1, as shown in Fig. Now mark the final condition of air at 21°C dry bulb temperature % and 55% relative humidity as point 2.

From the psychrometric chart, we find that

Specific humidity of air at point 1, $W_1 = 0.0141$ kg/kg of dry air

Specific humidity of air at point 2, $W_2 = 0.0084$ kg / kg of dry air

and specific volume of air at point 2, $v_{s2} = 0.845$ m^3/ kg of dry air

We know that mass of air circulated, $m_a = \frac{v_2}{v_{s2}} = \frac{60}{0.845} = 71$ kg/min

∴ Mass of water drained = $m_a (W_1 - W_2) = 71(0.0142 — 0.0084) = 0.412$ kg / min

= 0.412 x 60 = **24.72 kg / h** **Ans.**

To find the capacity of the cooling coil,

From the psychrometric chart, we find that;

Enthalpy of air at point 1, $h_1 = 64.8$ kJ / kg of dry air

and enthalpy of air at point 2, $h_2 = 42.4$ kJ / kg of dry air

∴ Capacity of the cooling coil= $m_a (h_1 - h_2) = 71(64.8 - 42.4) = 1590.4$ kJ / min

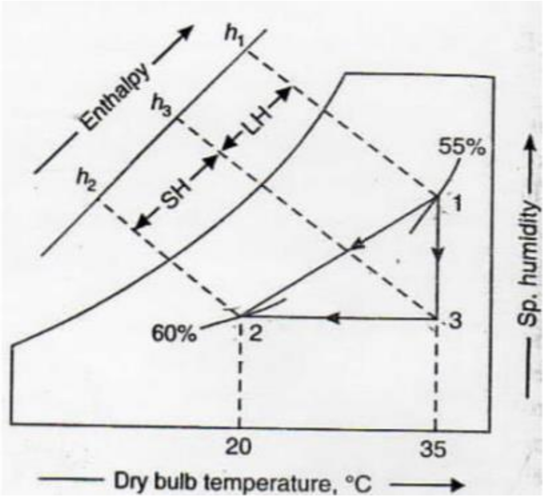
= 1590.4 / 210 = **7.57 TR** **Ans.**

Example 2: *The amount of air supplied to an air-conditioned hall is 300m³/min. The atmospheric conditions are 35°C DBT and 55% RH. The required conditions are 20°C DBT and 60% RH. Find out the sensible heat and latent heat removed from the air per minute. Also find sensible heat factor for the system.*

Solution: Given $v_1 = 300$ m^3/min; t_{d1}, = 35°C; $\emptyset_1 = 55\%$; $t_{d2} = 20$°C; $\emptyset_2 = 60\%$

First of all, mark the initial condition of air at 35°C dry bulb temperature and 55% relative humidity on the psychrometric chart at point 1, as shown in Fig. Now mark the final condition of air at 20°C dry bulb temperature and 60% relative humidity on the chart as point 2. Locate point 3 on the chart by drawing horizontal line through point 2 and vertical line through point 1.

From the psychrometric chart, we find that specific volume of air at point 1, v_{s1} = 0.9 m3/kg of dry air.



∴ To find Mass of air supplied,

Sensible heat removed from the air

From the psychrometric chart, we find that enthalpy of air at point h_1= 85.8 kJ/kg of dry air

Enthalpy of air at point 2, h_2 = 42.2 kJ/kg of dry air

and enthalpy of air at point 3, h_3 = 57.4 kJ/kg of dry air

We know that sensible heat removed from the air,

SH = m_a (h_3 - h_2) = 333.3 (57.4 - 42.2) = 5066.2 kJ/min **Ans.**

Latent heat removed from the air

We know that latent heat removed from the air,

LH = m_a (h_1 - h_3) = 333.3 (85.8 - 57.4) = 9465.7 kJ/min **Ans.**

Sensible heat factor for the system

We know that sensible heal factor for the system,

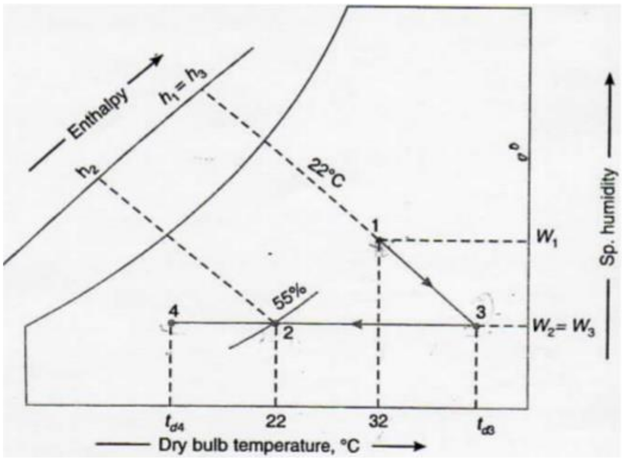
Example 3: *A conference room of 60 seating capacity is to be air conditioned for comfort conditions of 22°C dry bulb temperature and 55% relative humidity. The outdoor conditions are 32°C dry bulb temperature and 22°C wet bulb temperature. The quantity of air supplied is 0.5m3/min/person. The comfort conditions are achieved first by chemical dehumidification and by cooling coil. Determine I. Dry bulb temperature of air at exit of dehumidifier; 2. Capacity of dehumidifier; 3. Capacity and surface temperature of cooling coil, if the by-pass factor is 0.30.*

Solution: Given: Seating capacity = 60; t_{d2}= 22°C; $\emptyset_2$ = 55%; t_{dt} = 32°C; t_{wt} = 22°C

Rate of flow = 0.5 m^3/min / person = 0.5 x 60 = 30 m^3/min

BPF = 0.3.

First of all, mark the outdoor conditions of air re. at 32°C dry bulb temperature and 22°C wet bulb temperature on the psychrometric chart as point 1, as shown in Fig. Now mark the required comfort conditions of air i.e., at 22°C dry bulb temperature and 55% relative humidity, as point 2. In order to find the condition of air leaving the dehumidifier, draw a constant wet bulb temperature line from point 1 and a constant specific humidity line from point 2. Let these two lines intersect at point 3. The line 1-3 represents the chemical dehumidification and the line 3-2 represents sensible cooling.



<u>**1.** Dry bulb temperature of air at exit of dehumidifier</u>

From the psychrometric chart, we find that dry bulb temperature of air at exit of dehumidifier i.e., at point3, t_{d3} = 41°C **Ans**.

<u>**2.** Capacity of dehumidifier</u>

From the psychrometric chart, we find that enthalpy of air at point 1, h_l = = 64.5 kJ/kg dry air

Enthalpy of air at point 2, h_2 = 45 kJ / kg of dry air

Specific humidity of air at point 1, W_1 = 0.0123 kg / kg of dry air

Specific humidity of air at point 3, $W_3 = W_2$ = 0.0084 kg/kg of dry air

and specific volume of air at point 1, v_{s1} = 0.881 .m3/ kg of dry air

$$m_a = \frac{v_1}{v_{s1}} = \frac{30}{0.881} = 34.05 \text{ kg/min}$$

∴ Capacity of the dehumidifier = m_a (W_1 - W_3) = 34.05 (0:0123 - 0.0084) = 0.1328 kg / min = 0.1328 x 60 = 7.968 kg / h **Ans.**

<u>**3.** Capacity and surface temperature of cooling coil</u>

We know that capacity of the cooling coil = m_a (h_3 - h_2) = 34.05 (64.5 — 45) = 664 kJ/min = 664 / 210 = 3.16TR. .... (∵ 1TR = 210 kJ/min) **Ans.**

Let t_{d4} = Surface temperature of the cooling coil.

We know that by-pass factor (BPF),

$$0.3 = \frac{t_{d2} - t_{d4}}{t_{d3} - t_{d4}} = \frac{22 - t_{d4}}{41 - t_{d4}}$$

$$0.3\,(41 - t_{d4}) = 22 - t_{d4}$$

⇨ $12.3 - 0.3\,t_{d4} = 22 - t_{d4}$

⇨ $t_{d4} = \frac{22-12.3}{0.7} = 13.86\ °\text{C}$ **Ans.**

Example 4: *A small office hall of 25-person capacity is provided with summer air conditioning system with the following data:*

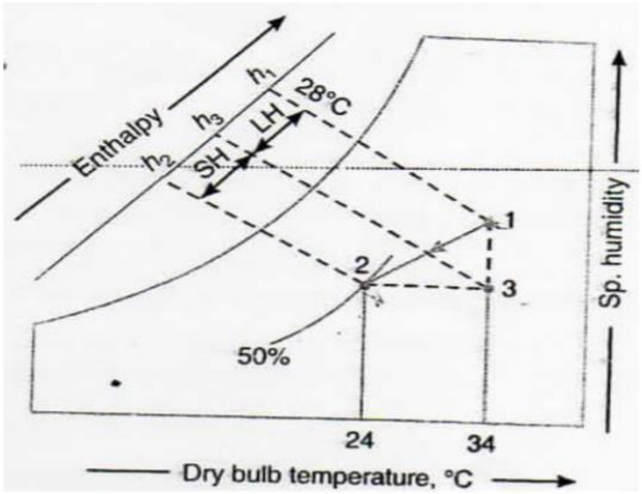
- *Outside conditions = 34°C DBT and 28°C WBT*

- *Inside conditions = 24°C DBT and 50% RH*
- *Volume of air supplied = 0.4 m^3 / min / person*
- *Sensible heat load in room = 125600 k/h*
- *Latent heat load in the room = 42 000 kJ/h*

Find the sensible heat factor of the plant.

Solution: Given Seating capacity = 25 persons; t_{dt} = 34°C; t_{wl} = 28°C; t_{d2}, = 24°C; ϕ_2 = 50% ; v_1 = 0.4 m^3/min/person = 0.4 x 25 = 10 m3/min; S.H. load = 125600 kJ/h; L.H. load = 42000 kJ/h.

First of all, mark the initial condition of air at 34°C dry bulb temperature and 28°C wet bulb temperature on the psychrometric chart as point 1, as shown in Fig. 18.12. Now mark the final condition of air at 24°C dry bulb temperature and 50% relative humidity on the chart as point 2. Now locate point 3 on the chart by drawing horizontal line through point 2 and vertical line through point 1.



From the psychrometric chart, we find that
specific volume at point 1, v_{s1} = 0.9 m^3/kg of dry air
Enthalpy of air at point 1, h_1 = 90 kJ/kg of dry air
Enthalpy of air at point 2, h_2 = 48 kJ/kg of dry air
and enthalpy of air at point 3, h_3 = 58 kJ/kg of dry air
We know that mass of air supplied per min,

$$m_a = \frac{v_1}{v_{s1}} = \frac{10}{0.9} = 11.1 \text{ kg/min}$$

and sensible heat removed from the air = m_a (h_3 - h_2) = 11.1(58 - 48)
= 111 kJ / min = 111 x 60= 6660 kJ/h
Total sensible heat of the room SH = 6660 + 125600 = 132260 kJ / h
We know that latent heat removed from the air = m_a (h_1 - h_3) = 11.1(90 - 58)
= 355 kJ / min = 355 x 60 = 21300kJ / h
∴ Total latent heat of the room, LH = 21300 +42000=63300 kJ / h
We know that sensible heat factor,

$$SHF = \frac{SH}{SH+LH} = \frac{132260}{132260+63300} = 0.676 \text{ kg/min}$$ **Ans.**