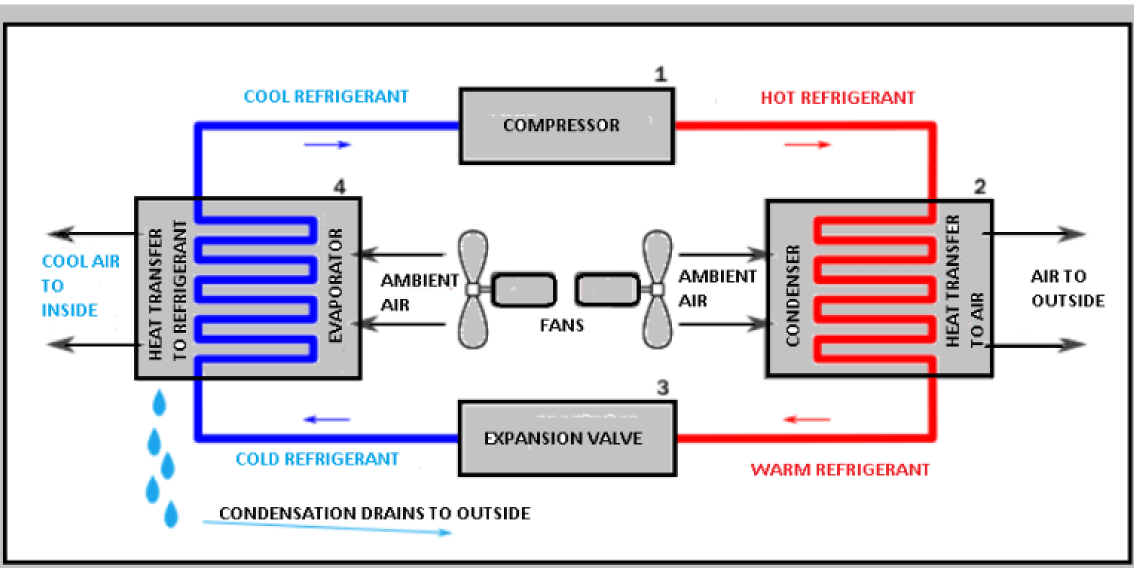
AIR CONDITIONING SYSTEMS

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



WORKING OF AIR-CONDITIONER

Human comfort

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.***

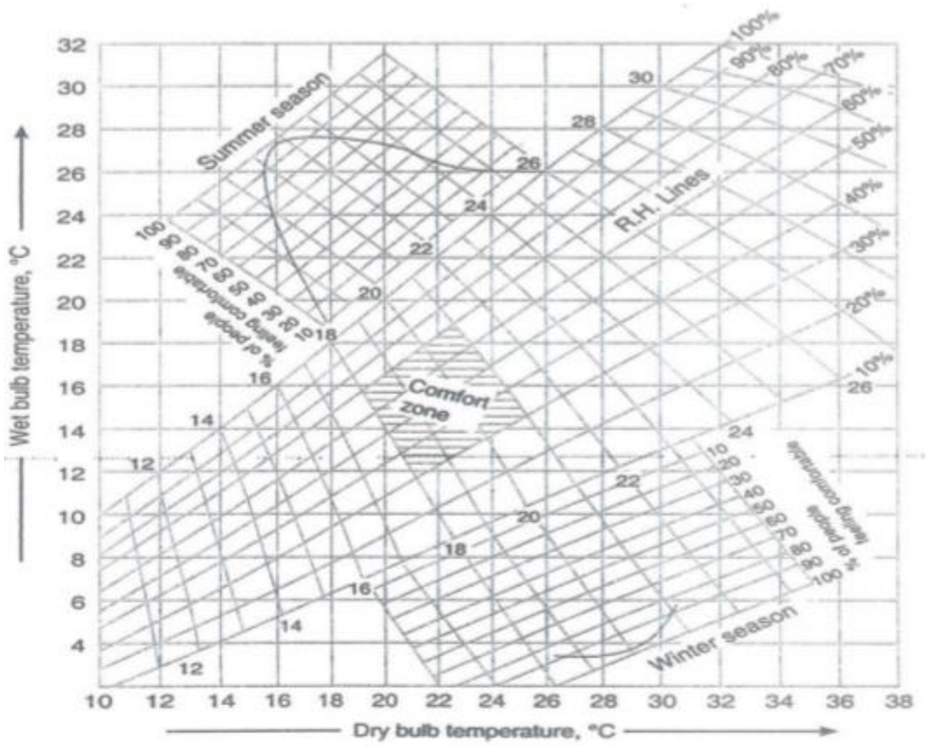
Factors Affecting Human Comfort

1. Effective temperature
2. Heat production and regulation in human body
3. Heat and moisture losses from the human body
4. Moisture content of air
5. Quality and quantity of air
6. Air motion
7. Hot and cold surfaces
8. Air stratification

Effective 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 com binned 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 American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE). In the comfort chart, *the dry bulb temperature is taken as abscissa and the wet bulb temperature of ordinates.*



<u>Heat Production and Regulation in Human Body:</u> 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.

<u>Heat and Moisture Losses from the Human Body:</u> 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.

<u>Moisture Content of Air:</u> 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.

<u>Quality and Quantity of Air:</u> The air in an occupied space should, at all times, be free room toxic, unhealthful ordisagreeable 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 12m/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.

Classification of Air Conditioning Systems

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).

Ex. 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.

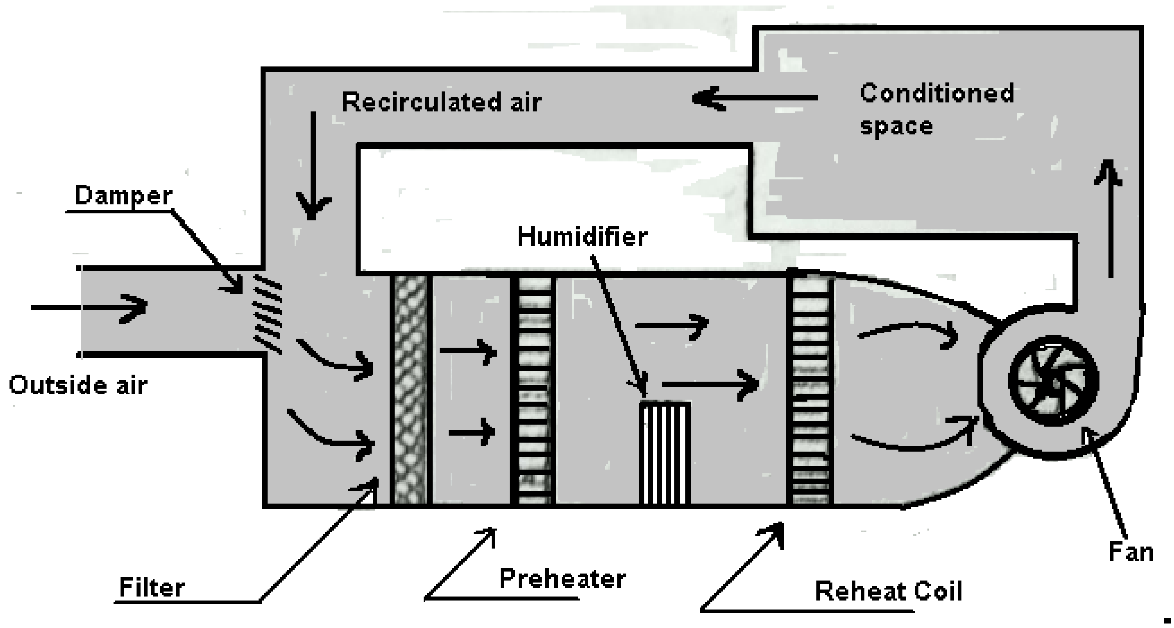
Textile mills, Paper mills, Machine part manufacturing plants, Toolroom, Photographic etc. are using this type of air-conditioning systems.

II. According To A Season of The Year

1. Winter air conditioning system.
2. Summer air conditioning system.
3. Year-round air conditioning system.

Winter Air Conditioning System

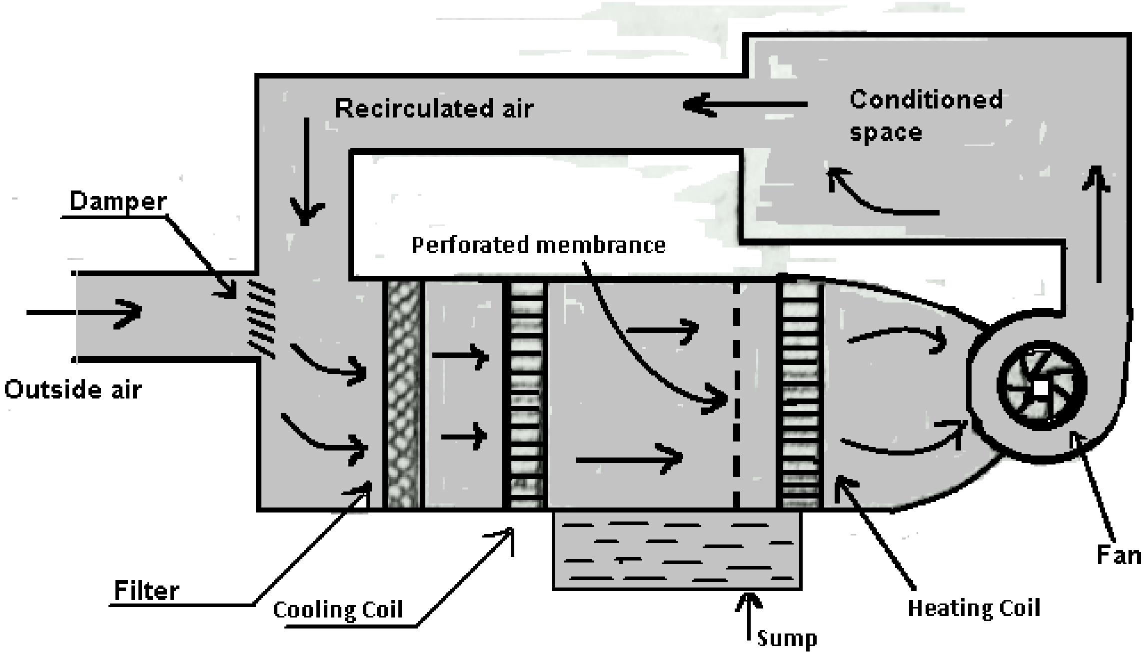
In winter air conditioning system, the air is burnt and heated, which is generally followed by humidification (*Heating and humidification*).



The outside air flows through a damper and mixes with the recirculated air. The mixed air passes through a filter to remove the dirt, dust and impurities. The air now passes through a preheat coil to prevent the possible freezing of water and to control the evaporation of water in the humidities. After that, the air is made to pass through a reheat coil to bring the air to the designed dry bulb temperature. Now, the conditioned air is supplied to the conditioned space by a fan. From the conditioned space, a part of the air is exhausted to the atmosphere by the exhaust fans. The remaining part of the used air is again conditioned and this will repeat again and again.

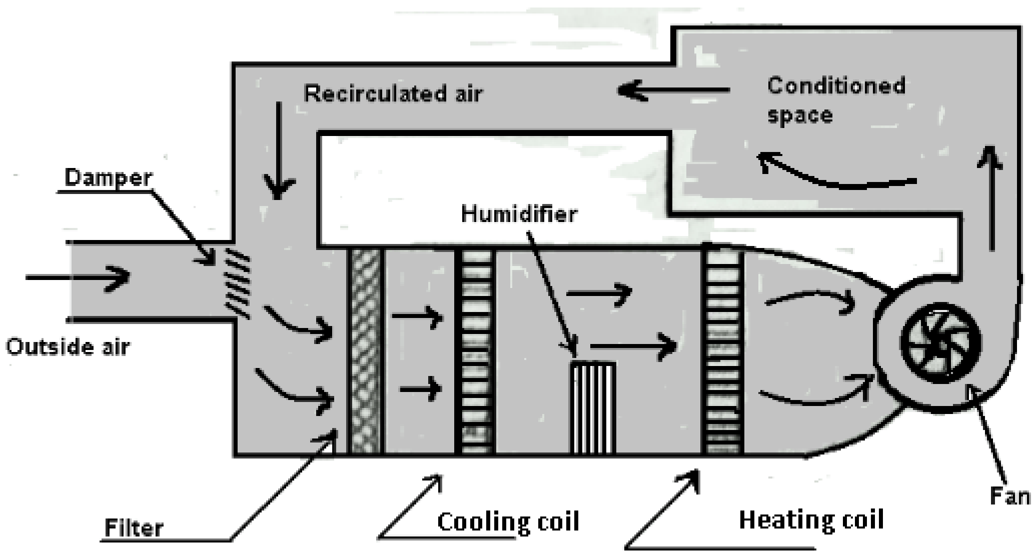
Summer Air Conditioning System

In summer air conditioning system, the air is cooled and generally dehumidified (*Cooling and dehumidifying*). Schematic for a typical summer air conditioning system is arranged. The outside air flows through the damper and mixed with recirculated air (which is obtained from the conditioned space). The mixed air passes through a filter to remove the dirt, dust and impurities. The air now passes through a cooling coil. The coil has a temperature much below the required dry bulb temperature of the air in the conditioned space. The cooled air passes through a perforated membrane and loses its moisture in the condensed from which is collected in the sump. After that, the air is made to pass through a heating coil which heats the air slowly. This is done to bring the air to the designed dry bulb temperature and relative humidity. Now the conditioned air is supplied to the conditioned space by a fan. From conditioned space, a part of the used air is rejected to the atmosphere by the exhaust fan. The remaining air is again conditioned and this repeated for again and again.



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.



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.

III. According To The Arrangement of Equipment

1. The 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.
- 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.
- 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.

The unitary air conditioning systems are of the following two types,

1. *Window unit*
2. *Vertical packed units or PTAC systems*

1 Window Unit

These type of conditioners have a small capacity of 1TR to 3TR and are mentioned through a window or wall. They are employed to condition the air of one room only. If the room is bigger in size, then two or more units are used.

2 Vertical Packed Units or PTAC systems

These type of air conditioner are bigger in the capacity of 5 to 20TR and are adjacent to the space to be conditioned. This unit is very useful for conditioning the air of a restaurant, bank or small office.

PTAC systems are also known as wall split air conditioning systems or ductless systems. These PTAC systems which are widely used in hotels have two separate units, the evaporative unit on the interior and the condensing unit on the exterior, with tubing passes through the wall and connect them together. This minimizes the interior system footprint and allows each room to be adjacent independently.PTAC system may be adapted to provide heating in cold weather, either directly by using an electric strip, gas or other heaters, or by reversing the refrigerant flow to heat the interior and draw heat from the exterior air, converting the air into a heat pump.

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 m^3/min or different zones in a building are to be air-conditioned.

Application of Air-Conditioning

- **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.**

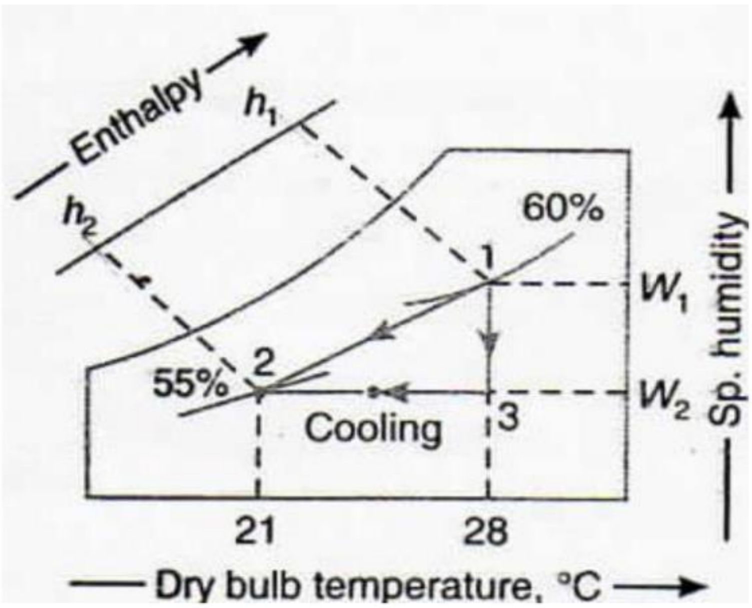
- **The air-conditioning system used in Television-centres, Computer centres and museum for a special purpose.**

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 v2 = 60 m3/min; td2 = 21°C; Ø2= 55%; tdt = 28°C; Ø1 = 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 m3/ kg of dry air

We know that mass of air circulated,

$$m_a = \frac{v_2}{v_{s2}} = \frac{60}{0.845} = 71 \text{ kg / min}$$

∴ Mass of water drained = ma (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

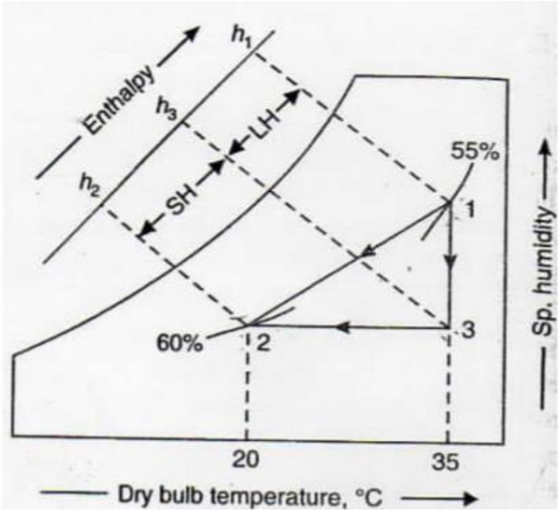
= 1590.4 / 210 = 7.57 TR **Ans**.

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 m3/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 h1= 85.8 kJ/kg of dry air

Enthalpy of air at point 2, $h2$ = 42.2 kJ/kg of dry air

and enthalpy of air at point 3, $h3$ = 57.4 kJ/kg of dry air
We know that sensible heat removed from the air,
SH = ma (h3 - h2) = 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 = ma (h1 - h3) = 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,

$$SHF = \frac{SH}{SH + LH} = \frac{5066.2}{5066.2 + 9465.7} = 0.348 \text{ Ans.}$$

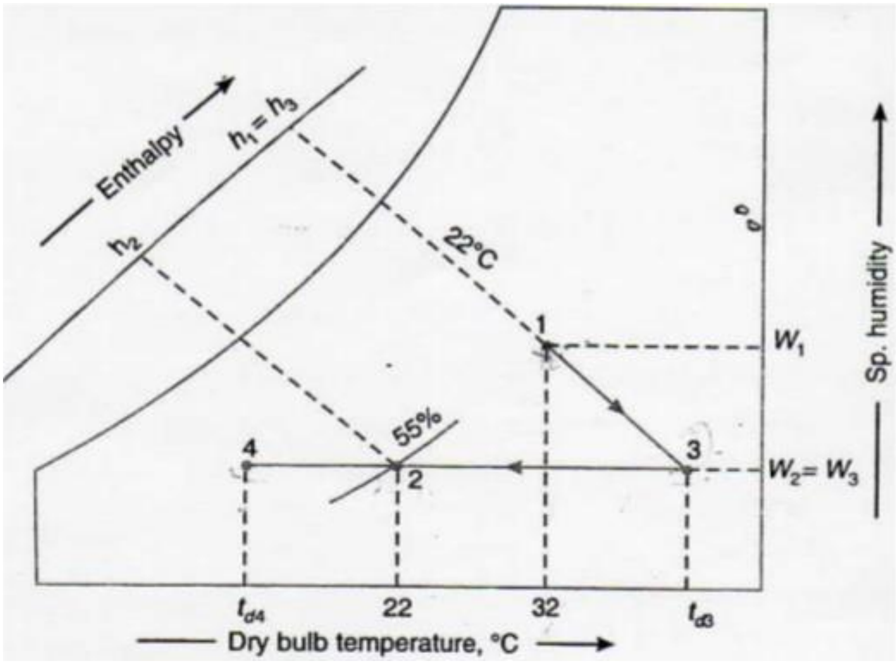
Example 3: *A conference room of 60 seating capacity is to be air conditioned for comfort conditions of 22°C dry bulb temperature and 55% relative humidity. The outdoor conditions are 32°C dry bulb temperature and 22°C wet bulb temperature. The quantity of air supplied is 0.5m^3/min/person. The comfort 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; td_2= 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, td_3 = 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 of dryair

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, vs_1 = 0.881 .m^3/ 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 td_4 = Surface temperature of the cooling coil.

We know that by-pass factor (BPF),

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

$$0.3\,(41 - t_{d4}) = 22 - t_{d4} \quad \text{or} \quad 12.3 - 0.3\,t_{d4} = 22 - t_{d4}$$

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

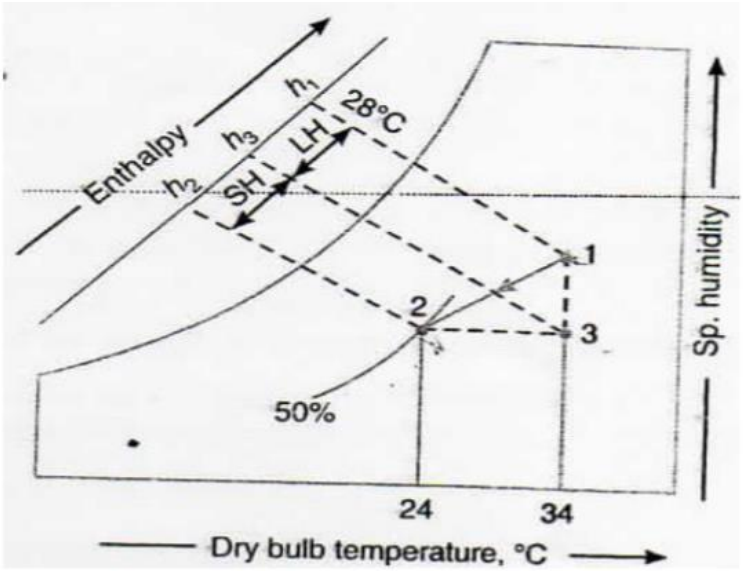
Example 4: *A small office hall of 25-person capacity is provided with summer air conditioning system with the following data:*

- *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 = 125 600 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; td_t = 34°C; tw_l = 28°C; td_2, = 24°C ; $Ø_2$ = 50% ; v_1 = 0.4 m^3/min/person = 0.4 x 25 = 10 m^3/min; S.H. load = 125 600 kJ / h; L.H. load = 42 000 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 m3/ 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 + 125 600 = 132 260 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 = 21 300 kJ / h

∴ Total latent heat of the room, LH = 21 300 +42000=63300 kJ / h

We know that sensible heat factor,

$$SHF = \frac{SH}{SH + LH} = \frac{132\,260}{132\,260 + 63\,300} = 0.676 \text{ Ans.}$$