RAJKUMAR GOEL INSTITUTE OF TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

FUNDAMENTAL OF MECHANICAL ENGINEERING

SUBJECT CODE- BME-101 /BME-201

UNIT-III

Introduction to IC Engines and RAC

Syllabus

Refrigeration: Refrigerating effect, Ton of Refrigeration; Coefficient of performance, methods of refrigeration, construction and working of domestic refrigerator, concept of heat pump.

Air-Conditioning: Its meaning and application, humidity, dry bulb, wet bulb, and dew point temperatures, comfort conditions, construction and working of window air conditioner.

Refrigeration

Refrigeration is a process of maintaining lower temperature compare to surrounding temperature.

In order to maintain temperature continuously refrigeration system must run on a cycle.

Refrigerant

Refrigerant is a substance used for producing lower temperature.

Example are NH3, water, air, R-11, R-12, R-135 etc.

Refrigerants absorb heat at a low temperature and reject heat at a higher temperature

Unit of Refrigeration

It is the amount of heat that is to be removed from one tonne water at zero (0^oC) in order to convert it into ice at 0 ^oC in one day (24 hours).

Tonne of refrigeration represents heat transfer rate.

1 T.R. = 3.5 kJ/s 3.5 kW = 210 kJ/min

Topic: Applications of Refrigeration and Methods for Refrigeration

Applications of Refrigeration

- Human Comfort

- Food processing & preservation
- Chemical Industries
- Medical Uses
- Other

Methods for Refrigeration

Natural Refrigeration Methods

- Natural ice for refrigeration
- Evaporative Cooling

Artificial Refrigeration Methods

- Gas refrigeration system
- Vapour Compression refrigeration system
- Vapour absorption system

Other Refrigeration Methods

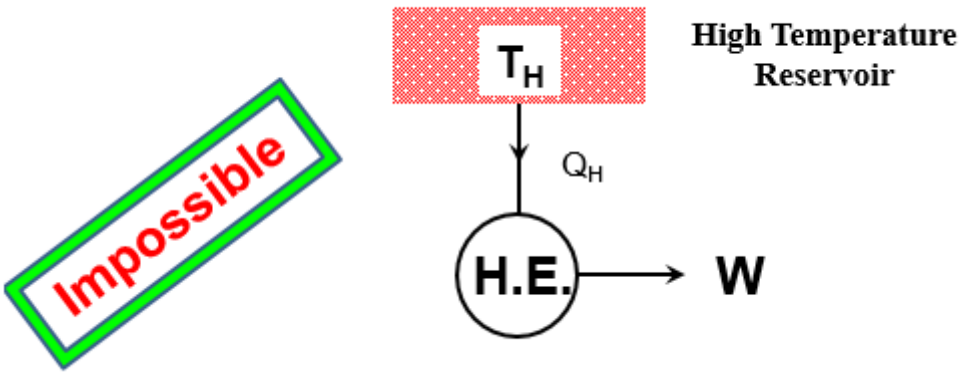
- Thermo-electric refrigeration system
- Steam jet refrigeration system
- Vortex tube refrigeration system
- Magnetic refrigeration system

Topic: Thermal Energy Reservoir

- A body with a relatively large thermal energy capacity is known as thermal reservoir.
- It can supply or absorb finite amounts of heat without undergoing any change in temperature.
- Examples: Sun, Oceans, Lakes, atmospheric air
- **Source:** A thermal reservoir that supplies energy in the form of heat is called a source.
- **Sink:** A thermal reservoir that absorbs energy in the form of heat is called a sink.

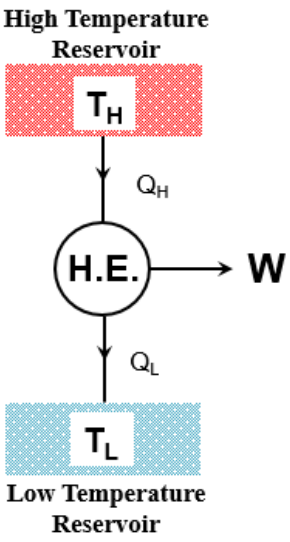
Topic: Kelvin Plank Statement and Heat engine

Kelvin Plank Statement: "It is impossible to construct a device which operates on a cyclic process and the sole effect of which is to absorb energy in the form of heat from a single thermal reservoir and to deliver an equivalent amount of work."



Heat Engine

- Heat engine is a device which is used to convert thermal energy into mechanical power.
- A heat engine is used to produce the maximum work transfer from a given positive heat transfer.
- The measure of success is called the thermal efficiency of the engine and is defined by the ratio of work output to heat input.



$$\eta = \frac{Output}{Input}$$

$$\eta = \frac{Net\ Work}{Heat\ Supplied}$$

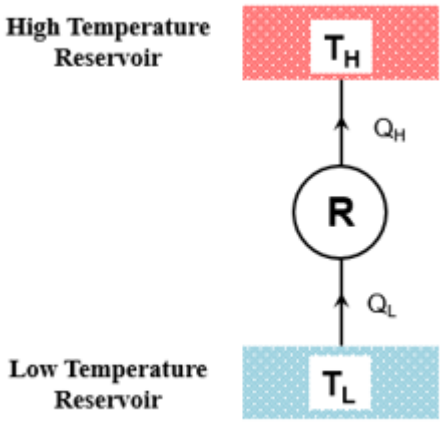
$$\eta = \frac{W_{net}}{Q_H}$$

$$\eta = \frac{Q_H - Q_L}{Q_H}$$

$$\eta = 1 - \frac{Q_L}{Q_H}$$

Topic: Clausius Statement, Refrigerator and Heat pump

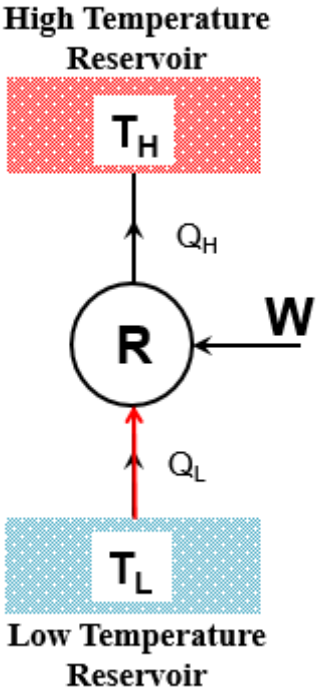
Clausius Statement**:** "It is impossible to construct a device which operates on a cyclic process and transfer heat from low temperature reservoir to high temperature reservoir without any aid of mechanical work."



Refrigerator

- Refrigerator worked on the Clausius statement.
- It absorb the heat from the low temperature medium and rejects heat into high temperature medium by consuming external work.

- Refrigerator used to maintain low temperature.



$$COP_R = \frac{Desired\ Effect}{Work\ Required}$$

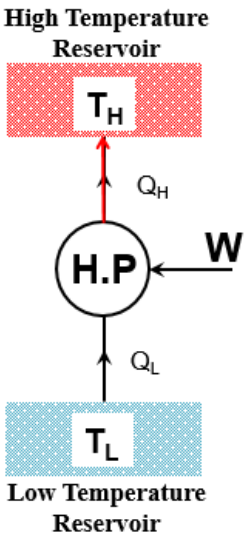
$$COP_R = \frac{Cooling\ Effect}{Work\ Required}$$

$$COP_R = \frac{Q_L}{W}$$

$$COP_R = \frac{Q_L}{Q_H - Q_L}$$

Heat Pump

- Heat Pump worked on the Clausius statement.
- It absorb the heat from the low temperature medium and rejects heat into high temperature medium by consuming external work.
- Heat pump used to maintain **High temperature.**



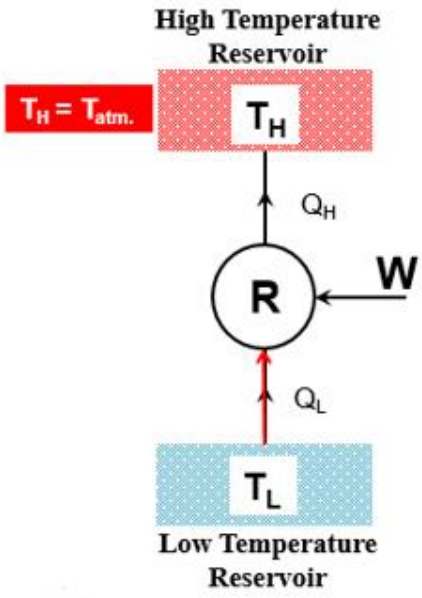
$$COP_{H.P.} = \frac{Desired\ Effect}{Work\ Required}$$

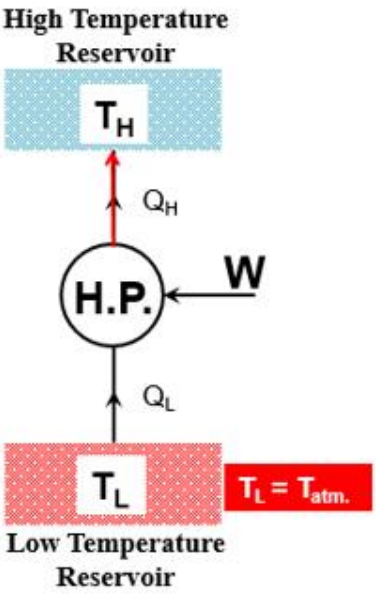
$$COP_{H.P.} = \frac{Heating\ Effect}{Work\ Required}$$

$$COP_{H.P.} = \frac{Q_H}{W}$$

$$COP_{H.P.} = \frac{Q_H}{Q_H - Q_L}$$

Refrigerator & Heat Pump





Proof That $COP_{HP} = 1 + COP_R$

$$COP_{HP} = \frac{Q_H}{W} \quad \Rightarrow \quad COP_{HP} = \frac{Q_H}{Q_H - Q_L}$$

$$\Rightarrow \quad COP_{HP} = \frac{Q_H}{Q_H - Q_L} - 1 + 1 \quad \Rightarrow \quad COP_{HP} = \frac{Q_H - Q_H + Q_L}{Q_H - Q_L} + 1$$

$$\Rightarrow \quad COP_{HP} = \frac{Q_L}{Q_H - Q_L} + 1$$

$$COP_{HP} = COP_R + 1$$

Coefficient of Performance

- The efficiency of a refrigerator and heat pump is expressed in terms of the coefficient of performance (**COP**).
- The value of COP can be greater than unity.
- Thermal efficiency can never be greater than 1.
- Due to which, efficiency of a refrigerator or heat pump expressed by another term COP to avoid the oddity of having efficiencies greater than unity.
- The COP represents the running cost of refrigerator and heat pump.

- Higher the value of COP lower the running cost.

Principle

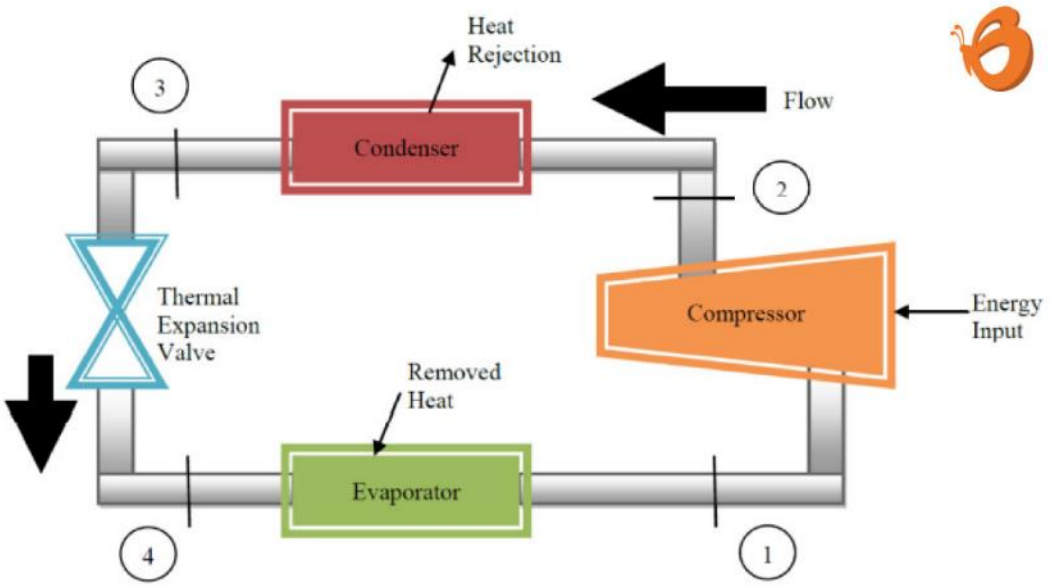
- Both Refrigerator and heat pump worked on the Clausius Statement.
- Both absorb the heat from the low temperature medium and rejects heat into high temperature medium by consuming external work.
- The working of both devices is same, however, both used for different purposes.
- Refrigerator used to maintain low temperature and heat pump is used to maintain the high temperature as compared to atmospheric temperature.

Topic: Construction and working of refrigerator

Refrigerator

Refrigerator is a cyclic device which is used to maintain lower temperature as compared to surrounding temperature.

Construction and working



COMPRESSOR:

It is a mechanical device which transfers mechanical energy to working fluids i.e. refrigerant. Refrigerant comes from evaporator into the compressor. Compressor raises the pressure and temperature of the refrigerant.

CONDENSER:

It is a type of heat exchanger. The refrigerant enters into the condenser from the compressor. Condenser rejects the heat from working fluid (refrigerant) by means cooling coils made up of copper into the atmosphere. Refrigerant comes from compressor is at high temperature and pressure is cooled in condenser. After condensing refrigerant goes into the expansion devices.

THROTTLING/EXPANSION DEVICES:

It is used to reduce the pressure of working fluid which comes from condenser and goes into the evaporator. It also regulates the flow of refrigerant into the evaporator and maintains the flow rate equal to the rate of evaporation in the evaporator. We can regulate and control the temperature of refrigerator using expansion devices by varying the opening as per our requirements.

EVAPORATOR:

It is the storage space or freezer. Refrigerant comes from throttling device enters into the evaporator at very low temp and pressure. In evaporator refrigerant goes through cooling coils. In evaporator heat is absorbed by the refrigerant. Due to this temperature of the refrigerant increases and liquid refrigerant expends and converts into vapours. After that this refrigerant goes to the compressor. Evaporator works as a heat exchanger between storage space and cooling coils. This cycle repeats continuously.

Good practices to minimize the amount of energy consumed by refrigerator

1. Open the refrigerator door the fewest times possible for the shortest duration possible.
2. Cool the hot foods to room temperature first before putting them into the refrigerator.
3. Check the door gasket for leaks
4. Avoid unnecessarily low temperature settings.
5. Avoid excessive ice build-up on the interior surfaces of the evaporator.

Topic: Pure Substance

- A substance that has a fixed chemical composition throughout is called a pure substance. Example: helium (He), and Argon (Ar)
- A pure substance does not have to be of a single chemical element it may be a compound. Example: N_2, CO_2, H_2O, NH_3

- A mixture of various chemical elements or compounds also qualifies as a pure substance as long as the mixture is homogeneous. Example: Air
- Air is a mixture of several gases, but it is often considered to be a pure substance because it has a uniform chemical composition.
- Mixture of these gases are known as dry air.

Composition of Air

Component	Molecular Mass	Part by Volume
N_2	28.02	0.7803
O_2	32.00	0.2099
Ar	39.91	0.0094
CO_2	44.00	0.0003
H_2	2.02	0.0001

Topic: Air-Conditioning

Air-Conditioning is a process of controlling air temperature, humidity, quality and ventilation in a space (Building or Vehicle). Atmospheric air makes up environment in all the air-conditioning systems.

Atmospheric Air

- Dry air is a mixture of nitrogen, oxygen, and small amounts of some other gases.
- Air in the atmosphere normally contains some water vapor (or *moisture*), number of pollutants and referred as atmospheric air.

- The amount of water vapour and pollutants in the atmospheric air vary from place to place.

Moist Air

- For the air conditioning application, the atmospheric air is filtered and in the air-conditioning we deals with moist air.
- Moist air is the mixture of water vapour and dry air.
- The amount of water vapor changes as a result of condensation and evaporation from oceans, lakes, rivers, showers, and even the human body.
- The temperature of air in air-conditioning applications ranges from about **10 to about 50°C**. In this range, dry air can be treated as an **ideal gas** with a constant c_p value of 1.005 kJ/kg·K.
- Moist air pressure (P) is the sum of the partial pressure of dry air (P_a) and that of water vapor (P_v).

Topic : Psychrometry

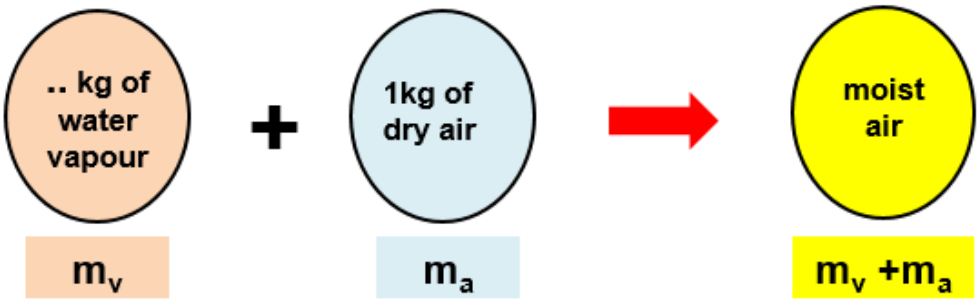
- In air-conditioning, we deals with moist air and moist air is not a pure substance.
- Moist air (mixture of dry air & water vapour) requires three properties to completely define its thermodynamic state, unlike a pure substance which requires only two.
- One of the three properties can be composition of moist air.
- The properties of moist air are called Psychrometric properties and the subject which deals with the behavior of moist air is known as psychrometry.

Topic : Specific Humidity, Dry Bulb Temperature, Wet bulb Temperature, Dew point Temperature

Specific Humidity

- It is also known as absolute humidity or humidity ratio and denoted by ω.

- Specific humidity can be defined as the mass of water vapor present in a unit mass of dry air.



- Specific humidity can also be defined as the ratio of mass of water vapor to the mass of dry air present in the mixture or moist air.

$$\omega = \frac{\text{mass of w. v.}}{\text{mass of d. a.}}$$

Unit
kg of water vapour / kg of dry air

$$\Longrightarrow \omega = \frac{m_v}{m_a}$$

$$\Longrightarrow \omega = \frac{V/v_v}{V/v_a}$$

$$\Longrightarrow \omega = \frac{v_a}{v_v}$$

$$\omega = \frac{\text{mass of w. v.}}{\text{mass of d. a.}}$$

$$\Rightarrow \omega = \frac{m_v}{m_a}$$

$$\Rightarrow \omega = \frac{P_v V / R_v T}{P_a V / R_a T}$$

$$\Rightarrow \omega = \frac{P_v / R_v}{P_a / R_a}$$

$$\Rightarrow \omega = \frac{R_a P_v}{R_v P_a}$$

$$\Rightarrow \omega = \frac{0.287\, P_v}{0.4614 P_a}$$

$$\Rightarrow \omega = 0.622 \frac{P_v}{P_a}$$

According to Dalton's Law:

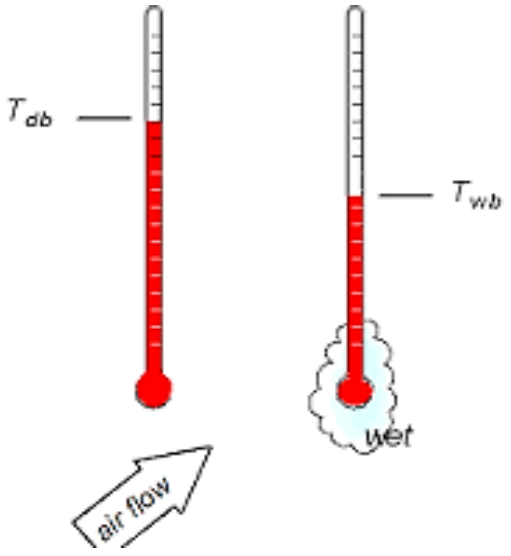
$P = P_a + P_v$

$$\Rightarrow \omega = 0.622 \frac{P_v}{P - P_v}$$

$$\omega = \frac{m_v}{m_a} = \frac{v_a}{v_v} = 0.622 \frac{P_v}{P_a}$$

Dry Bulb & Wet bulb Temperature

- In psychrometry, a psychrometer comprises of a dry bulb and a wet bulb thermometer.



Dry Bulb Temperature (T_{db} or T)

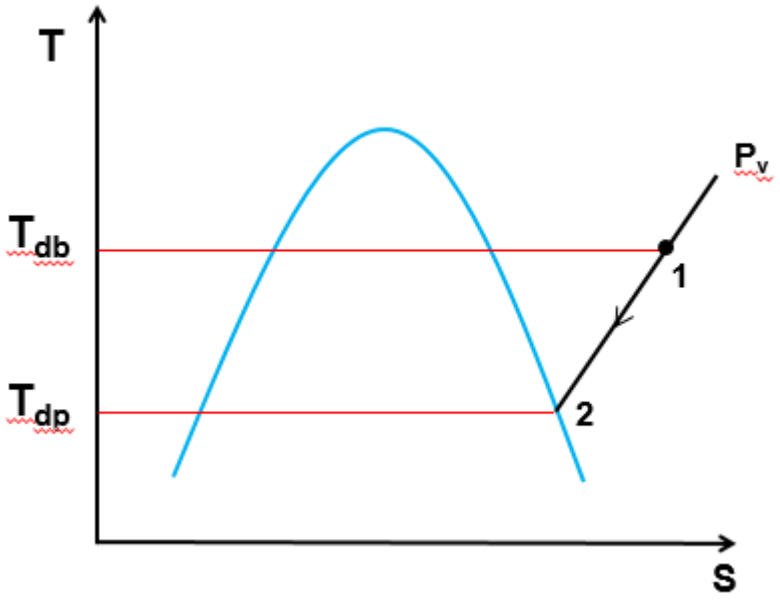
- The dry bulb thermometer has bare bulb which is directly exposed to air and measure the actual temperature.

Wet Bulb Temperature (T_{wb})

- The bulb of wet bulb thermometer is covered by a wick thoroughly wetted by water.
- The temperature which is measured by the wet wick covered bulb is known as wet bulb temperature.

Dew point Temperature

- The air in atmosphere contains moisture (water vapour).
- If we reduce the temperature of the air, moisture get condense.
- The temperature at which first drop of dew is formed or condensation begins when the air is cooled at constant pressure is known as dew point temperature.
- Denoted by T_{dp}.



- As the air cools at constant pressure, the vapor pressure P_v remains constant. Therefore, the vapor in the air (state 1) undergoes a constant-pressure cooling process until it strikes the saturated vapor line (state 2). The temperature at this point is T_{dp}.
- If the temperature drops any further, some vapor condenses out. As a result, the amount of vapor in the air decreases, which results in a decrease in P_v.

- The air remains saturated during the condensation process and thus follows a path of 100 percent relative humidity (the saturated vapor line).
- The ordinary temperature and the dew-point temperature of saturated air are identical.

Topic : Human Comfort

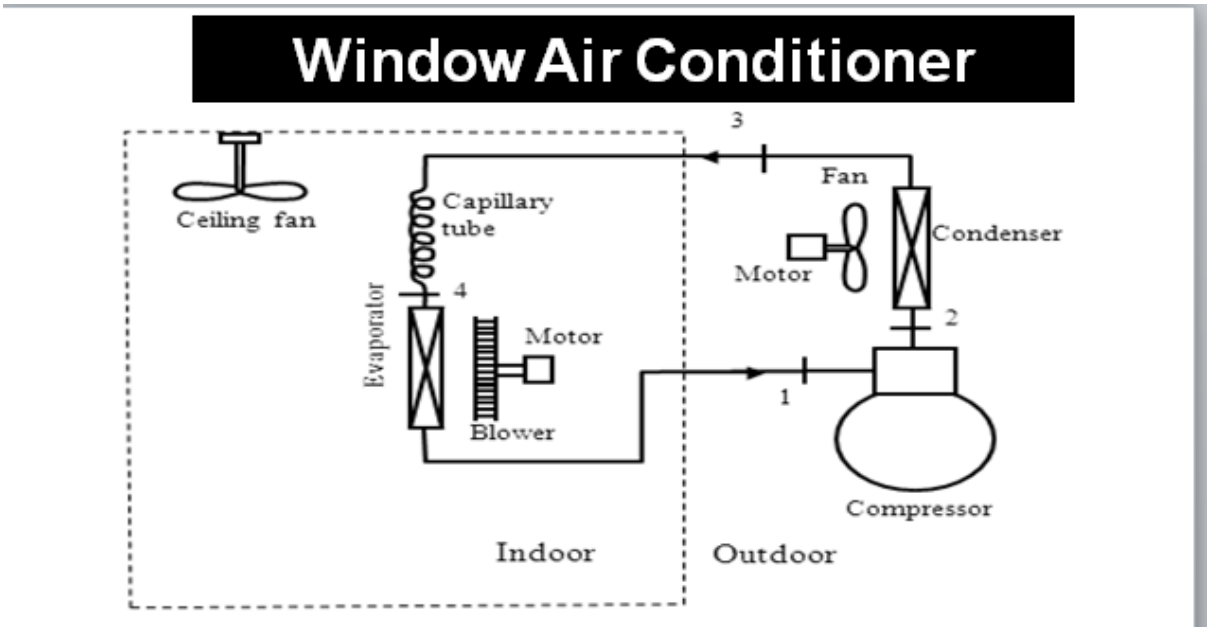
- Human comfort depends upon the ease which body temperature is maintained with dissipation of heat.
- Heat is produced principally by metabolism (oxidation of food) then this heat is used to perform work, loss of heat by convection, radiation and evaporation.
- Therefore, human comfort affected with temperature and humidity of air. Apart from that velocity of air also a factor.
- The Effective Temperature combines effect of DBT & WBT with effect of air movement to yield equal sensation of warmth or cold.
- Effective temperature is a temperature at which same net heat exchange by radiation, convection and evaporation at different humidity.

Topic : Construction and working Window Air Conditioner

Window air conditioner is sometimes referred to as room air conditioner.

It is the simplest form of an air conditioning system and is mounted on windows or walls.

It is a single unit that is assembled in a casing where all the components are located.



Compressor

The refrigerant enters the compressor at low temperature and pressure in a gaseous state.

In compressor temperature and pressure of refrigerant increases.

The refrigerant leaves the compressor and enters to the condenser.

Since this process requires work, an electric motor may be used.

Condenser

It is a kind of heat exchanger in which refrigerant of high pressure and temperature enters which coming from compressor. .

The function of the condenser in a refrigeration system is to transfer heat from the refrigerant to another medium, such as air.

By rejecting heat, the gaseous refrigerant condenses to liquid inside the condenser.

Throttling/Expansion valve

High pressure refrigerant from the condenser enters the throttling device, the pressure and temperature of the refrigerant drops down suddenly.

Throttling valve also controls the amount of the refrigerant flowing through it.

Evaporator

It is a kind of heat exchanger in which refrigerant of low pressure and temperature enters which is coming from throttling valve.

The function of the evaporator is to absorb heat by the refrigerant from the space to be cooled.

By absorbing heat, the refrigerant converts from liquid state to gaseous state.

Filter Drier is used to remove the moisture from the refrigerant.

Drain Pan is used to contain the water that condensate from the cooling coil and is discharged out to the outdoor.

Propeller Fan is used in air-cooled condenser to help move the air molecules over the surface of the condensing coil.

Fan Motor is located here. It has a double shaft where the indoor blower and outdoor propeller fan are connected together.

During operation, a thermostat is mounted on the return air of the unit. This temperature is used to control the on or off of the compressor.

Once the room temperature has been achieved, the compressor cuts off.

For mechanical control type, there is usually a caution to turn on the unit after the unit has turned off for at least 3 minutes.

For electronic control, there is usually a timer to automatically control the cut-in and cut-out of compressor.

The evaporator blower fan will suck the air from the room to be conditioned through the air filter and the cooling coil.

Air that has been conditioned is then discharge to deliver the cool and dehumidified air back to the room. This air mixes with the room air to bring down the temperature and humidity level of the room.

The introduction of fresh air from outside the room is done through the damper which is then mixed with the return air from the room before passing it over the air filter and the cooling coil.

The air filter which is mounted in front of the evaporator acts as a filter to keep the cooling coil clean to obtain good heat-transfer from the coil.

Hence, regular washing and cleaning of the air filter is a good practice to ensure efficient operation of the air conditioner.

Questions

S. No.	Questions
	Refrigeration
1.	Define refrigeration, refrigerant and unit of refrigeration. Also write down the applications of refrigeration.
2.	What are the different methods of refrigeration?
3.	Define refrigerator and heat pump. Derive the relation between the COP of refrigerator and heat pump.
4.	Draw the neat diagram of a domestic refrigerator, showing its various parts. Explain its working also.
5.	The food compartment of a refrigerator is maintained at 4°C by removing heat from it at a rate of 360 kJ/min. If the required power input to the refrigerator is 2 kW, determine (a) the COP of the refrigerator and (b) the rate of heat rejection to the room
6.	A heat pump has a COP of 1.7. Determine the heat transferred to and from this heat pump when 50 kJ of work is supplied.
	Air-Conditioning
7.	Define the term 'air-conditioning'. What are the different applications of air-conditioning?
8.	Define the following (i) Dry Bulb Temperature (ii) Wet Bulb Temperature (iii) Dew point Temperature (iv) Saturated air (v) specific humidity (vi) relative humidity
9.	With the help of neat sketch describe the working of window type air-conditioner.
10.	Explain the factor which affects human comfort. What are the conditions for comfort air conditioning?