REFRIGERATION AND AIR CONDITIONING

- In this chapter, students will learn about
  (1) Application of Refrigeration and Air conditioning.
  (2) Refrigeration.
  (3) Second Law of Thermodynamics.
  (4) Refrigerant.
  (5) Unit of Refrigeration.
  (6) Refrigeration Cycle.
  (7) Vapour Compression Refrigeration Cycle.
  (8) Domestic Refrigerator.
  (9) Water Cooler.
  (10) Air Conditioning.
  (11) Standard Comfort Conditions.
  (12) Window Air Conditioner.
  (13) Split Air Conditioner.

Application of Refrigeration and Air conditioning

- To Manufacture ice.
- To cool the water.
- To provide comfort air conditioning of shopping complexes, multiplex, offices etc.
- To store and transport food items such as fruits, vegetables, dairy products etc.
- To preserve Medicines etc.
- To liquefy gases like N_2, O_2, H_2, etc.

What is Refrigeration ?

- It is the process of maintaining the temperature of room/compartment below atmospheric temperature.

Can we transfer the Heat from Low Temperature Room/Compartment to High Temperature Atmosphere ??????

- Yes, it is possible but following the second law of thermodynamics.

What is Second Law of Thermodynamics ?

- There are two statements for second law of thermodynamics, but combining them, statement of second of thermodynamics is as under.
- Heat cannot flow from a Colder Body to a Hotter Body ITSELF. We have to use External Agency.

What is refrigerant ?

- It is the working medium used in Refrigeration and Air conditioning system.

Properties of Refrigerants

- Low boiling point.
- Easy to liquefy at moderate pressure & temperature
- Non corrosive to metal / parts & motor winding insulation other insulation
- Not affected by moisture
- Non flammable and non toxic
- Environmentally safe

Various Refrigerants and their Properties

Refrigerants	Properties
NH_3 (Ammonia)	• Highly toxic, flammable, good thermal properties etc. • Mostly used in VARS.
CO_2 (Carbon Dioxide)	• Non-toxic, non-flammable, non-explosive, colourless etc • Used in MARINE refrigeration system.
AIR	• Easily available, non-toxic, safe. • Used in Air Craft Air Conditioning systems.
R-11 (Tri-chloro mono floro Methane, Freon 11)	• Non-toxic, non-flammable, non-corrosive. • Small VCRS systems.
R-12 (Di-chloro Di floro Methane, Freon 12)	• Non-toxic, non-flammable, non-explosive. • Mostly used in domestic VCRS.
R-22	• Non-toxic, non-flammable, non-explosive, less work is required. • Used in Air Conditioning Systems.

What is the Unit of Refrigeration ?

- Unit is "Ton of Refrigeration" (TOR).
- It is defined as "Refrigerating Effect" (also known as heat removed from the low temperature room/compartment, heat removed from the sink) to produce One Ton of ICE at 0 ^{O}C in 24 HOURS from WATER at 0 ^{O}C temperature.
- It is defined as "Refrigerating Effect" produced by melting of 1 ton of ice from and at 0^{o}C in 24 hours.
- 1 TOR = 210 kJ/min. = 3.54 kW
- It is also known as refrigerating capacity.
- Practically, 1 ton capacity refrigerator/air conditioner is able to remove the 3.54 kW of heat from compartment/room.

Refrigeration Cycle

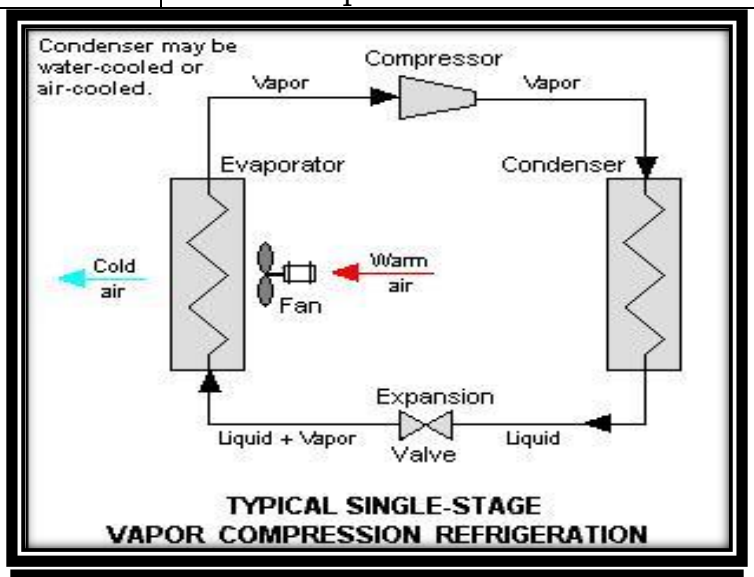
- Refrigeration and air conditioning works on different cycles.
- They are as under.

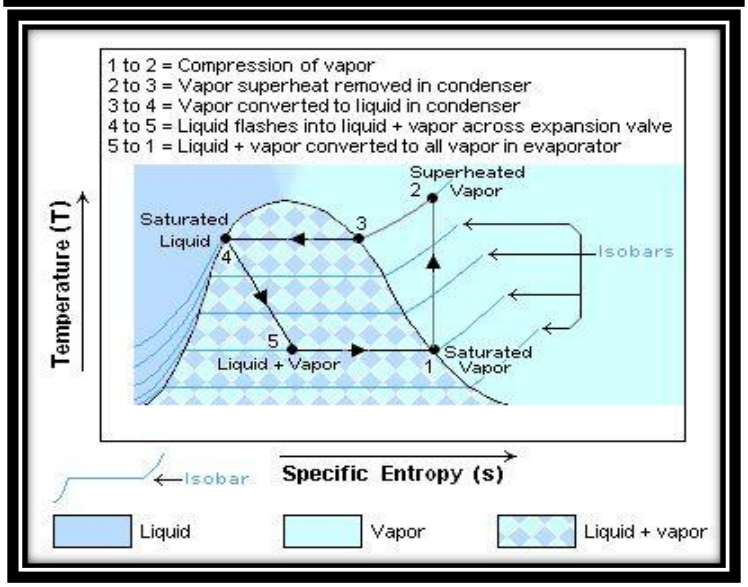
(i) Vapour Compression Refrigeration Cycle. (VCRS)
(ii) Vapour Absorption Refrigeration Cycle. (VARS)
(iii) Air Refrigeration Cycle. (ARS)

Vapour Compression Refrigeration Cycle

- It is made up of four processes carried out in (1) compressor, (2) condenser, (3) expansion valve and (4) evaporator sequentially.

Process	Component	Working
Process 1–2	Compressor	• Low pressure vapour refrigerant enters the compressor. • In the compressor, vapour is compressed to high pressure. • High pressure vapour refrigerant comes out from the compressor.



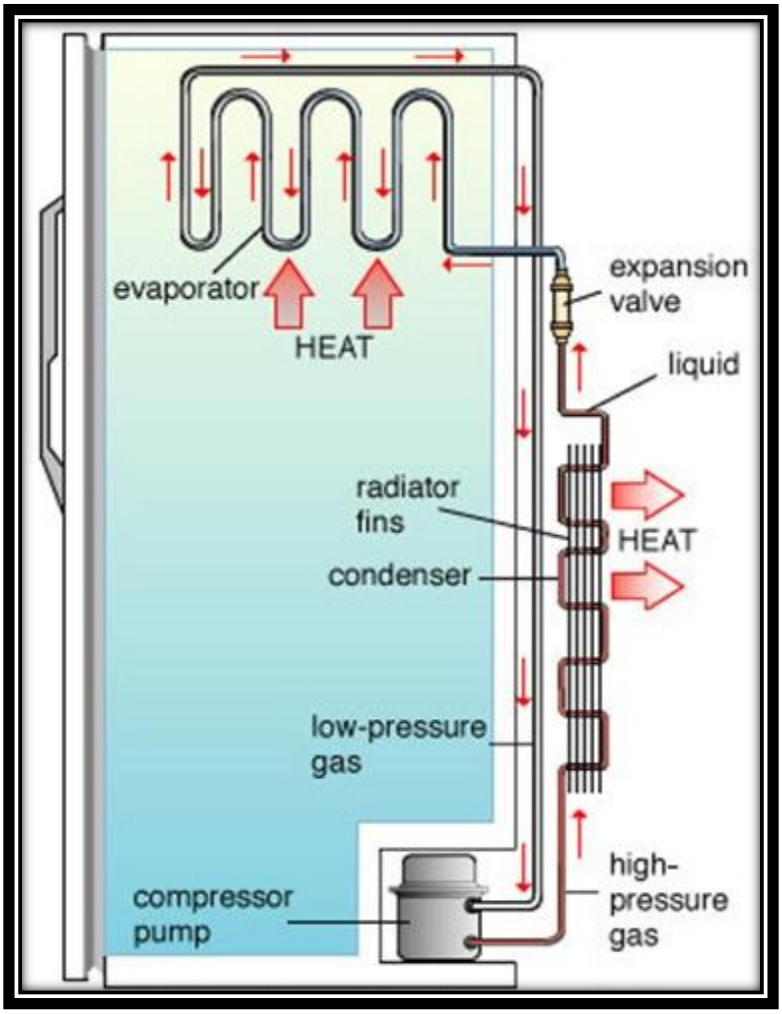


Process 2 – 3	Condenser	• High pressure vapour refrigerant enters the condenser. • In the condenser, vapour refrigerant condenses i.e. vapour refrigerant is converted into liquid refrigerant. • In the condenser, refrigerant cools and air surrounding the condenser is heated. • High pressure liquid refrigerant comes out from the condenser.
Process 3 – 4	Expansion Valve (Expansion Device, Throttling Valve, Throttling Device, Capillary Tube, etc.)	• High pressure liquid refrigerant enters the expansion valve. • In the expansion valve, refrigerant passes through the throttling process. • Due to throttling process, pressure and temperature of the refrigerant reduces and enthalpy of the refrigerant remains same. • After throttling, temperature of the refrigerant reduces to approximately -10^{O}C. • Low pressure liquid refrigerant at low temperature comes out from the expansion valve.
Process 4 – 1	Evaporator	• Low pressure liquid refrigerant at low temperature enters the evaporator. • In the evaporator, liquid refrigerant evaporates i.e. liquid refrigerant is converted into vapour refrigerant. • In the evaporator, refrigerant is heated and air surrounding the evaporator is cooled. • Low pressure vapour refrigerant comes out from the evaporator and enters the compressor. • Thus cycle repeats.

Domestic Refrigerator

- It works on the vapour compression refrigeration cycle.

Construction and working of domestic refrigerator	
Construction	• As we know that, it works on VCRS, it has principally four main components viz., compressor, condenser, expansion valve and evaporator. • It is essential to located the evaporator inside the body where cooling is required, and other components outside the body. • Thus, it has an insulated body which is cooled due to VCRS and a door for opening and closing. • Compressor is situated outside of the body and placed at the back side. Compressor and electrical motor are coupled and sealed properly. This assembly is known as hermetically sealed compressor. • Condenser and capillary tube (i.e. expansion valve) are also located outside of the body and placed at the back side. • Evaporator tubes are situated inside the body and are placed around the freezer compartment.

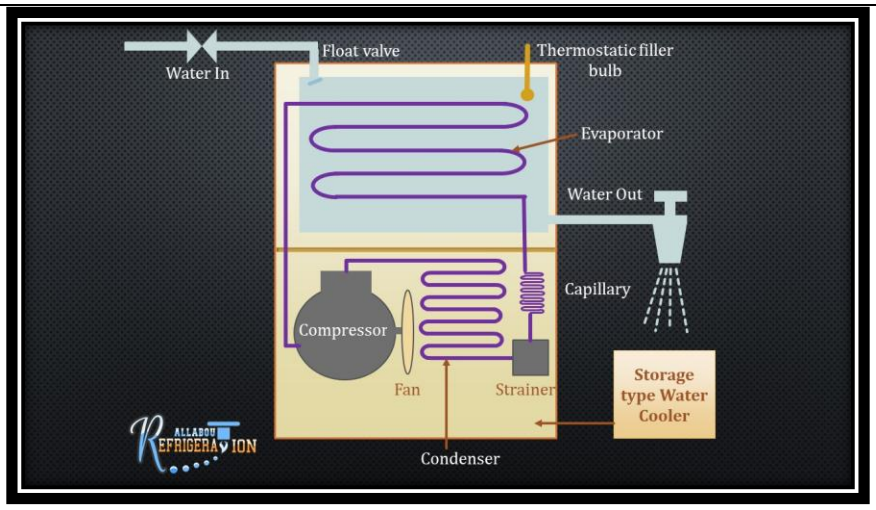


Working	• As electrical power is switched on, compressor starts and it starts compressing the vapour refrigerant. • Then, vapour refrigerant passes through rest of components like condenser, expansion valve and evaporator. • In condenser, refrigerant is condensed due to atmospheric air. • In expansion valve, refrigerant is throttled. • When refrigerant enters the evaporator, its temperature is order of -10 OC. Thus air surrounding the evaporator tube (i.e. in the refrigerator) is cooled. • Evaporated refrigerant from evaporator enters the compressor and cycle continues and we get cooled compartment known as domestic refrigerator.

Water Cooler

- It also works on the vapour compression refrigeration cycle.

Construction and working of water cooler	
Construction	• As we know that, it works on VCRS, it has principally four main components viz., compressor, condenser, expansion valve and evaporator. • It is essential to locate the evaporator inside the body where water is cooled, and other components outside the body. • Thus, it has an insulated body which is cooled due to VCRS and a door for opening and closing. • *Compressor is situated outside of the body and placed at the back side. Compressor and electrical motor are coupled and sealed properly. This assembly is known as hermetically sealed compressor.* • *Condenser and capillary tube (i.e. expansion valve) are also located outside of the body and placed at the back side.* • *Evaporator tubes are situated inside the body where water is cooled.*



Working	• As electrical power is switched on, compressor starts and it compresses the vapour refrigerant. • Then vapour refrigerant passes through rest of components like condenser, expansion valve and evaporator. • In condenser, refrigerant is condensed due to atmospheric air. • In expansion valve, refrigerant is throttled. • When refrigerant enters the evaporator, its temperature is order of -10 ^{O}C. Thus water surrounding the evaporator tube (i.e. in the refrigerator) is cooled. • Evaporated refrigerant from evaporator enters the compressor and cycle continues.

Air Conditioning

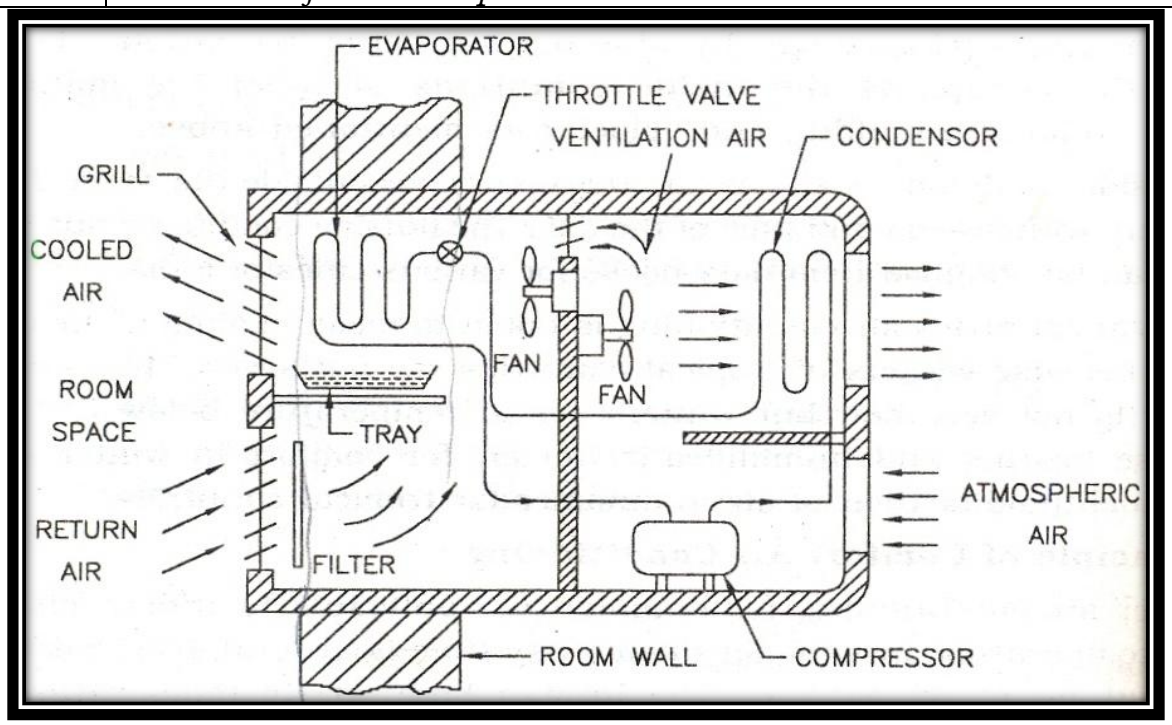
- Air Conditioning includes
  - Cooling or Heating of Air.
  - Addition of moisture in air. (Humidification)
  - Removal of moisture in air. (Dehumidification)
  - Controlling movement of air. (Velocity of air)
  - Cleaning or Filtering of air.
  - Introducing fresh air from outside.
  - Distribution of air.

Standard Comfort Conditions

- Human from various parts of the world feels fine at various atmospheric conditions.
- The human happiness also varies from season to season and place to place.
- An international body has found the standard human comfort conditions at which all the humans will feel better. They are as under.
  - Temperature of air : DBT between 17 ^{O}C to 25 ^{O}C.
  - Relative Humidity : 30 to 70 %.
  - Velocity of air : 0.1 m/s to 0.25 m/s.

Window Air Conditioner

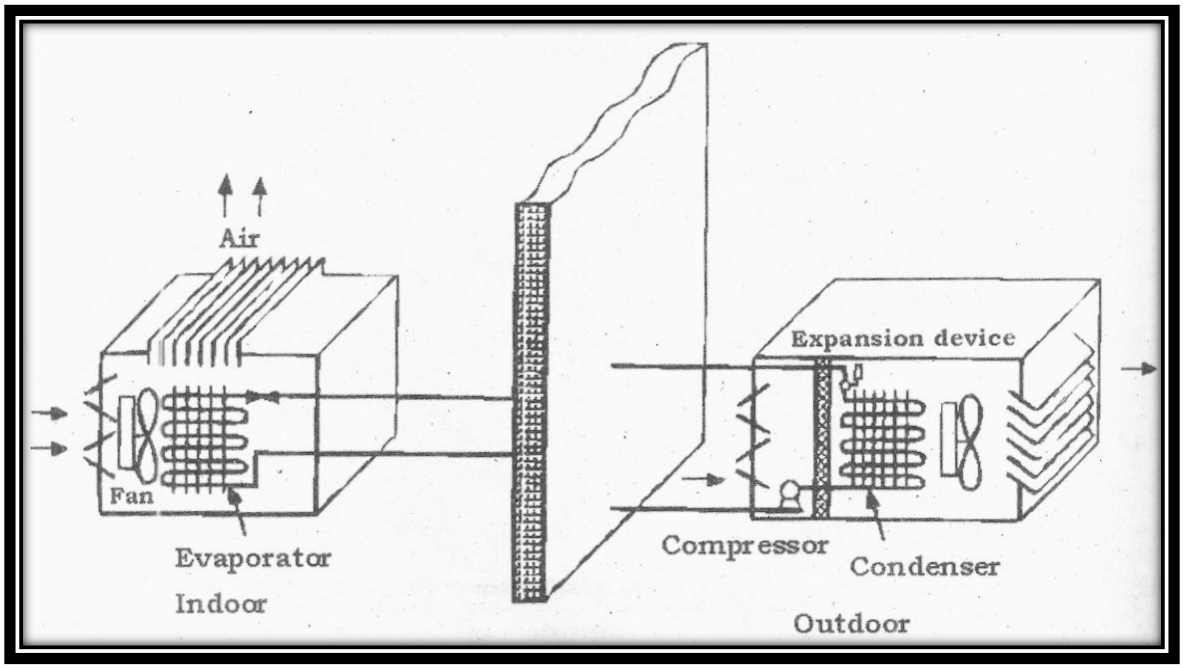
Construction and working of window air conditioner	
Construction	• As we know that, it works on VCRS, it has principally four main components viz., compressor, condenser, expansion valve and evaporator. • It is essential to located the evaporator inside the room where cooling is required, and other components outside the room. • Thus, one body of window air conditioner is divided into two sections. • Hermetically sealed compressor, condenser and expansion valve are also located in one section of the window air conditioner and it is placed outside the room to be cooled. • While, evaporator tubes are placed in another section of the window air conditioner and it is placed inside the room to be cooled. • *The other components are fan, air filter; tray, grill and air vent passage.* • *The function of fan is to pass the air from condenser and evaporator tubes efficiently.* • *The function of tray is to collect the water condensed on the evaporator tube allow it to take away from the room.* • *Air vent passage is a small opening between two sections of the window air conditioner. Its function is introduced the fresh air into the room from atmosphere.*



Working	• Window air conditioner is placed in a window in such a way that, the section containing the compressor, condenser and expansion valve is located outside the room and the section containing the evaporator tubes is located inside the room. • As electrical power is switched on, compressor starts and it starts compressing the vapour refrigerant. • Then vapour refrigerant passes through rest of components like condenser, expansion valve and evaporator. • In condenser, refrigerant is condensed due to atmospheric air. • In expansion valve, refrigerant is throttled. • When refrigerant enters the evaporator, its temperature is order of -10 ^{O}C. • Room air enters the window air conditioner after it is filtered. Room air passes over the evaporator tubes and cooled. Cooled air is circulated to the room with the help of fan and grill. Room air contains some water vapour. When room air is cooled, water vapour is condensed and water is collected in a tray.

Split Air Conditioner

Construction and working of split air conditioner	
Construction	• As we know that, it works on VCRS, it has principally four main components viz., compressor, condenser, expansion valve and evaporator. • It is essential to located the evaporator inside the room where cooling is required, and other components outside the room. • Thus, split air conditioner is divided into two parts. • Hermetically sealed compressor, condenser and expansion valve are also located in one part of the window air conditioner and it is placed outside the room to be cooled. • The outside part of the split air conditioner can be located any where away from the room i.e. on the terrace, above the window, etc. • While, evaporator tubes are placed in another part of the window air conditioner and it is placed inside the room to be cooled. • The other components are fan, air filter, tray, grill and air vent passage. • The function of fan is to pass the air from condenser and evaporator tubes efficiently. • The function of tray is to collect the water condensed on the evaporator tube allow it to take away from the room.



Working	• The part of the split air conditioner containing the compressor, condenser and expansion valve is located outside the room at proper place and the inside part of the split air conditioner containing the evaporator tubes is located inside the room. Both the parts are connected by tubes through which refrigerant passes. • As electrical power is switched on, compressor starts and it starts compressing the vapour refrigerant. • Then vapour refrigerant passes through rest of components like condenser, expansion valve and evaporator. • In condenser, refrigerant is condensed due to atmospheric air. • In expansion valve, refrigerant is throttled. • When refrigerant enters the evaporator, its temperature is order of -10 OC. • Room air enters the window air conditioner after it is filtered. Room air passes over the evaporator tubes and cooled. Cooled air is circulated to the room with the help of fan and grill. Room air contains some water vapour. When room air is cooled, water vapour is condensed and water is collected in a tray.

Reference Books:

(1). Elements of Mechanical Engineering – MCQ and Numerical as per GTU, By Neeraj Chavda, Lap Lambert Academic Publishing, Germany (ISBN : 978-3-330-07021-9)

(2). Elements of Mechanical Engineering – Laboratory Manual (as per GTU), By Neeraj Chavda, Lap Lambert Academic Publishing, Germany (ISBN : 978-620-2-05650-2)

(3). Elements of Mechanical Engineering – Tutorial (as per GTU), By Neeraj Chavda, Lap Lambert Academic Publishing, Germany (ISBN : 978-613-9-82424-3)

(4). Basic Mechanical Engineering (Elements of Mechanical Engineering), By J. P. Hadiya, H. G. Katariya and S. M. Bhatt, Books India Publications.

(5). Thermodynamics: An Engineering Approach Seventh Edition in SI Units, Yunus A. Cengel, Michael A. Boles, McGraw-Hill, 2011.

(6). Basic Mechanical Engineering, By Pravin Kumar, Pearson Publications.

(7). Engineering Thermodynamics, By Rayner Joel.

(8). Thermal Science and Engineering, By Dr. D. S. Kumar, S. K. Kataria & sons Publications.

(9). Fundamental of Mechanical Engineering, By G. S. Sawhney, PHI Publications.

(10). Elements of Mechanical Engineering, By Sadhu Singh, S. Chand Publication.

(11). Elements of Mechanical Engineering, By P. S.Desai and S. B.Soni.