Introduction to and RAC

UNIT-3

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.

Lecture No. 16

LECTURE-16

Content:

- Meaning of Refrigeration
- Applications of Refrigeration
- Unit of refrigeration
- Methods of refrigeration.

Refrigeration and Refrigerant

- **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** is a substance used for producing lower temperature.

- Example are NH_3, water, air, R-11, R-12, R-134 etc.

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

Applications of Refrigeration

1. Domestic refrigeration
2. Chemical refrigeration
3. Industrial refrigeration
4. Transport refrigeration
5. Air-conditioning

1 tonne of refrigeration

- It is the amount of heat that is to be removed from one tonne of 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

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

Lecture No. 17

VCRS method

Lecture No. 18

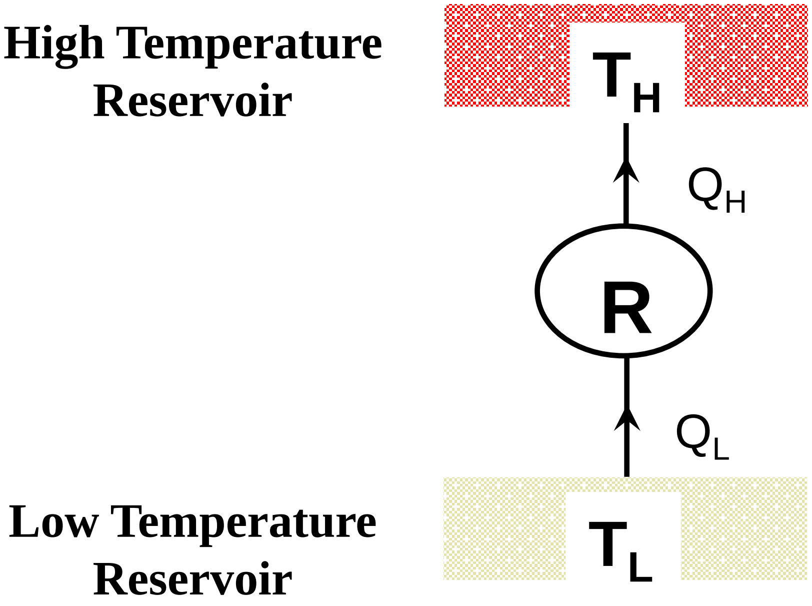
LECTURE-18

Content :

- Concept of Refrigerator
- Concept of Heat pump
- Coefficient of performance.

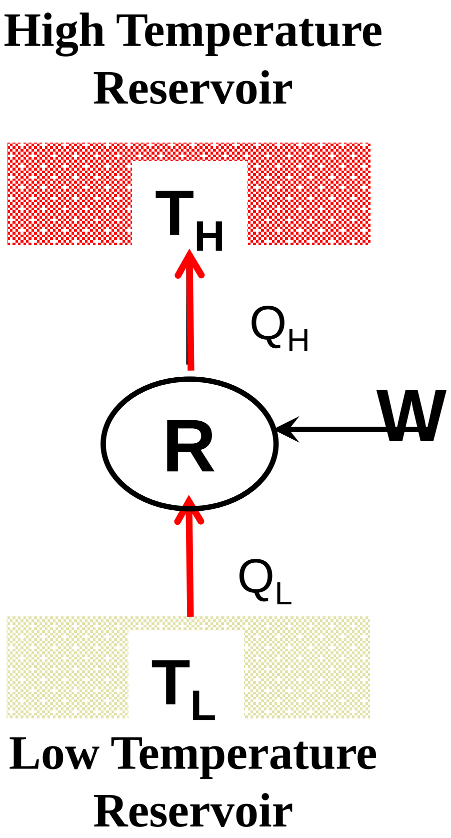
Clausius Statement

"It is impossible to construct a device which operates on a cycle and transfer heat from low temperature body to high temperature body **without any external work**."



Refrigerator

- Refrigerator works 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** as compared to surrounding.



Refrigerator….

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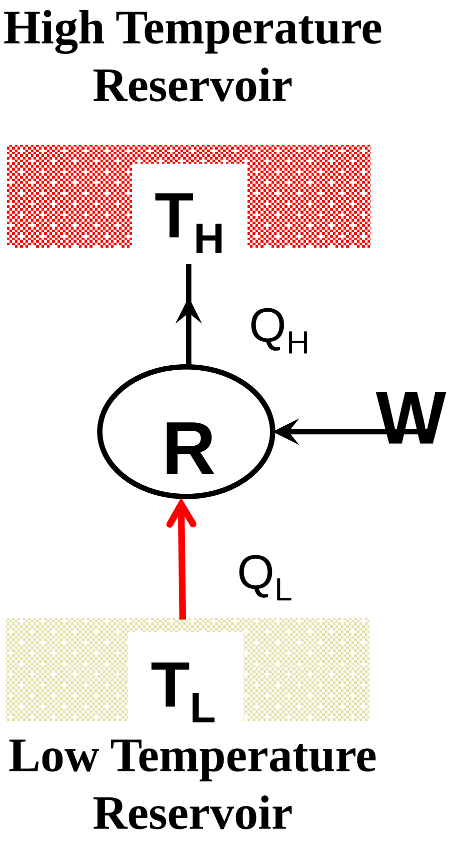


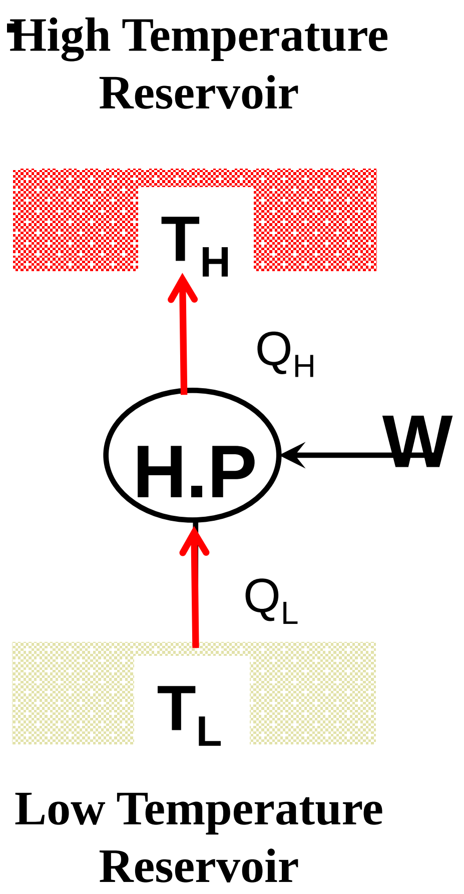
$$COP_R = \frac{Desired\ Effect}{Work\ Required}$$

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

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

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

Heat Pump



- Heat Pump works 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** as compared to surrounding.

Heat Pump…….

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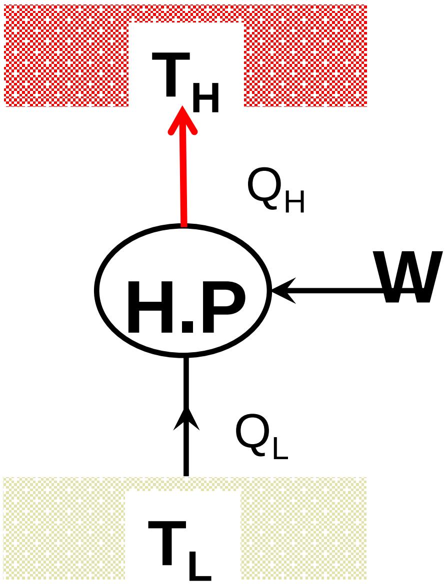

Low Temperature Reservoir

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

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

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

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

Relation between the COP of refrigerator and heat pump

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

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

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

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

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.

- The COP represents the running cost of refrigerator and heat pump.

- Higher the value of COP lower the running cost.

Lecture No. 19

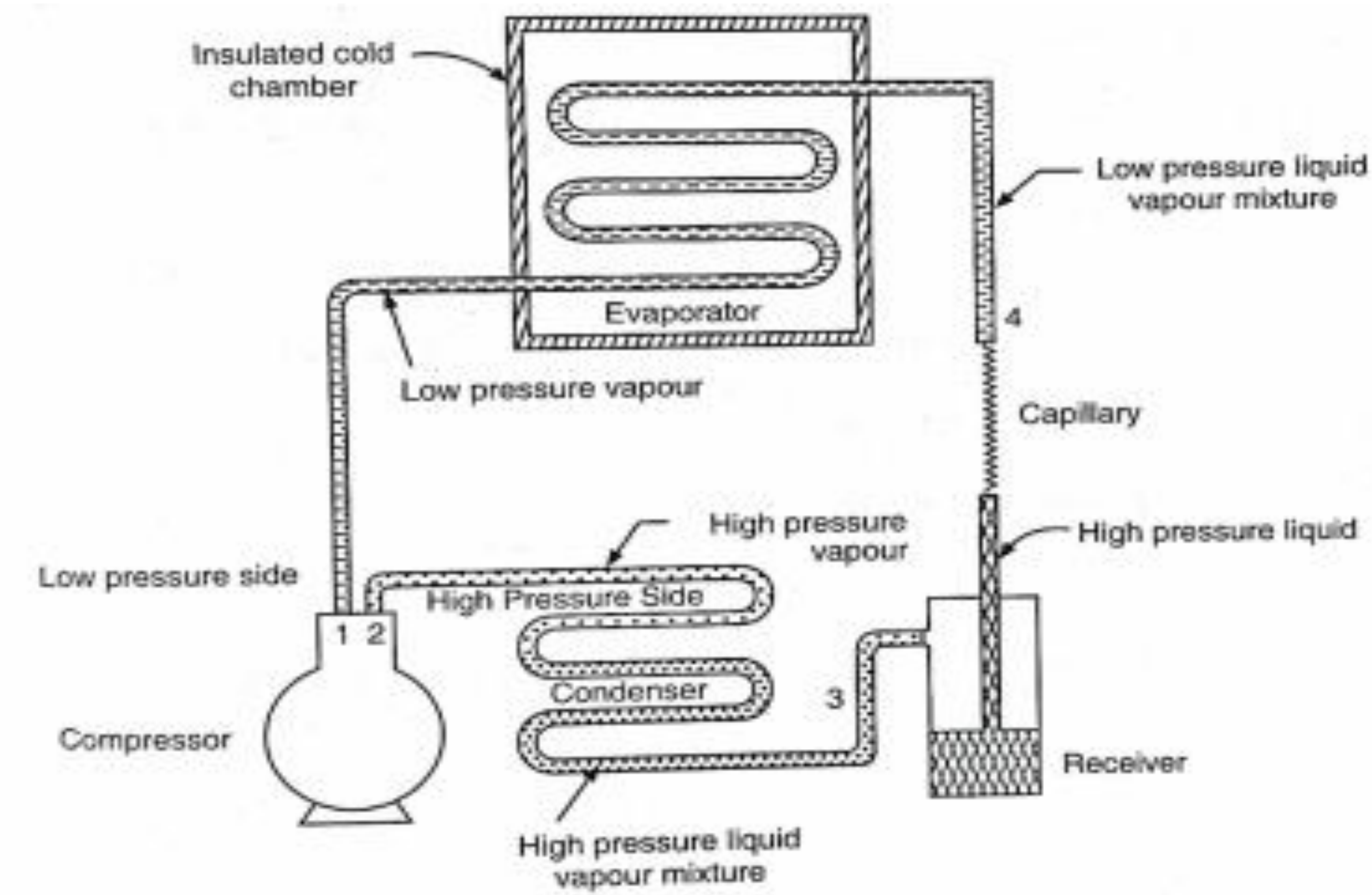
LECTURE-19

Content :

- Construction and Working of domestic refrigerator.

Construction and working of domestic refrigerator

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



Construction and working of domestic refrigerator……..

1. COMPRESSOR:

- It is a mechanical device which transfers mechanical energy to working fluids i.e. refrigerant which is coming from evaporator.
- **Compressor raises the pressure and temperature of the refrigerant.**

Construction and working of domestic refrigerator……..

2. CONDENSER

- It is a type of heat exchanger.
- **The refrigerant enters into the condaenser from the compressor.**
- Condenser rejects the heat from working fluid (refrigerant) by means cooling coils made up of copper into the atmosphere.
- **Due to heat rejection from refrigerant, it converts from gaseous state to liquid state.**
- After condensing refrigerant goes into the expansion devices.

Construction and working of domestic refrigerator……..

3. THROTTLING/EXPANSION DEVICES

- In expansion valve the pressure and temperature decreases which comes from condenser.

- **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.

Construction and working of domestic refrigerator……..

4. EVAPORATOR

- Refrigerant comes from throttling device enters into the evaporator at very low temp and pressure.

- **In evaporator refrigerant goes through cooling coils and heat is absorbed by the refrigerant.**

- Due to this temperature of the refrigerant increases and liquid refrigerant expends and converts into vapours after that refrigerant goes to the compressor.

- **Evaporator works as a heat exchanger between storage space and cooling coils.**

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.

Lecture No. 20

LECTURE-20

Content :

- Formula based numerical problems on cooling load.

Numerical-1

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

Solution

given:

$Q_L = 360$ kJ/min

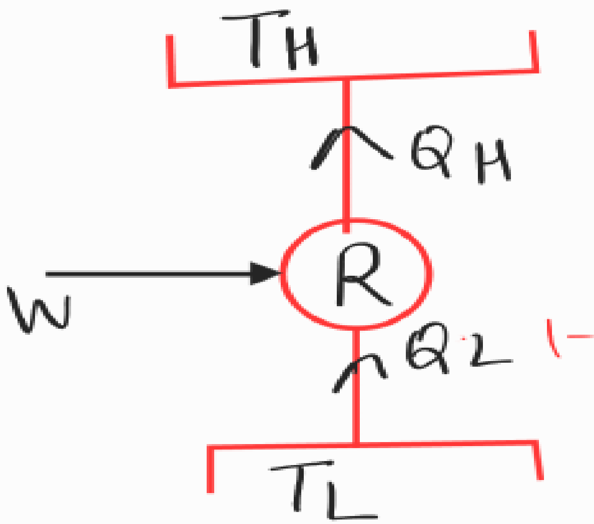
$= 360/60$ kJ/s

$= 6$ kJ/s

$= 6$ kW

$W = 2$ kW

(a) COP = ? (b) Q_H = ?



$(COP)_R = \frac{Q_L}{W} \Rightarrow$

$(COP)_R = \frac{6}{2} \Rightarrow$ $\boxed{(COP)_R = 3}$ Ans

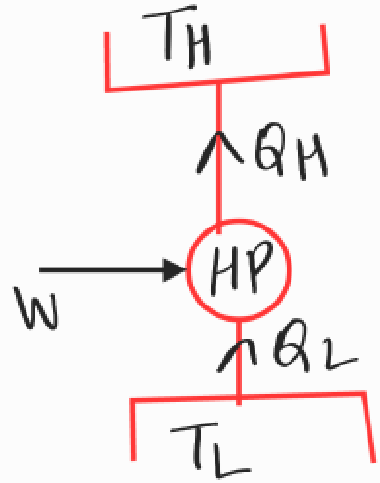
$Q_H = W + Q_L$

$Q_H = 2 + 6 \Rightarrow$ $\boxed{Q_H = 8 \text{ kW}}$ Ans

Numerical-2

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.

Solution



given:

$(COP)_{HP} = 1.7$

$W = 50\ kJ$

(i) $Q_L = ?$ (ii) $Q_H = ?$

$$(COP)_{HP} = \frac{Q_H}{W}$$

$$1.7 = \frac{Q_H}{50} \Rightarrow \boxed{Q_H = 85\ kJ}$$ Ans

$$Q_H = Q_L + W$$

$$85 = Q_L + 50 \Rightarrow \boxed{Q_L = 35\ kJ}$$ Ans

Numerical-3

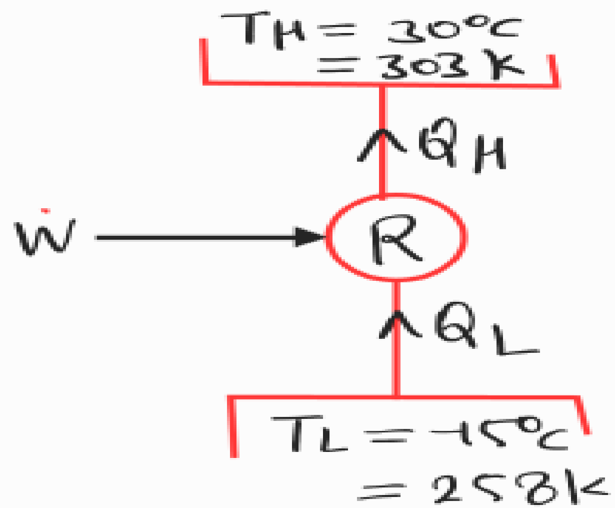
A domestic food freezer maintains a temperature of – 15°C. The ambient air temperature is 30°C. If heat leaks into the freezer at the continuous rate of 1.75 kJ/s what is the least power necessary to pump this heat out continuously?

Solution

given:

$T_L = -15°C$
$= -15 + 273$
$= 258\ K$

$T_H = 30°C$
$= 30 + 273$
$= 303\ K$



$Q_L = 1.75\ kJ/s$

Power $= \dot{W}_{min} = ?$

$$(COP)_{R\,max} = \frac{T_L}{T_H - T_L} = \frac{258}{303 - 258}$$

$$(COP)_{R\,max} = 5.73$$

$$(COP)_{R\,max} = \frac{Q_L}{W_{min}} \Rightarrow 5.73 = \frac{1.75\ kJ/s}{W_{min}}$$

$$\Rightarrow W_{min} = 0.305\ \frac{kJ}{s}$$ Ans

Numerical-4

Find the co-efficient of performance and heat transfer rate in the condenser of a refrigerator in kJ/h which has a refrigeration capacity of 12000 kJ/h when power input is 0.75 kW.

Solution

given:

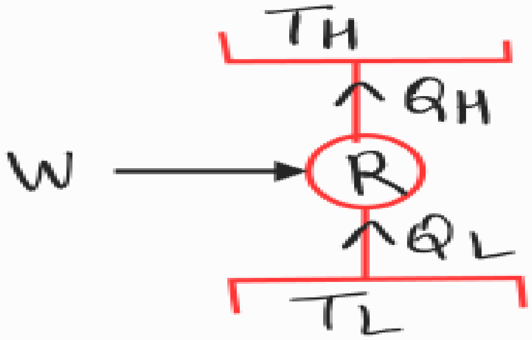
$Q_L = 12000$ kJ/h

$W = 0.75$ kW

$= 0.75$ kJ/s

$= 0.75 \times 3600$ kJ/h

$= 2700$ kJ/h



(i) $(COP)_R = ?$ (ii) $Q_H = ?$

$$(COP)_R = \frac{Q_L}{W} \Rightarrow (COP)_R = \frac{12000 \text{ kJ/h}}{2700 \text{ kJ/h}}$$

$$\Rightarrow \boxed{(COP)_R = 4.44}$$ Ans

$$Q_H = Q_L + W$$

$$= 12000 + 2700$$

$$\boxed{Q_H = 14700 \text{ kJ/h}}$$ Ans

Numerical-5

A fish freezing plant requires 40 tons of refrigeration. The freezing temperature is – 35 °C while the ambient temperature is 30°C. If the performance of the plant is 20 % of the theoretical cycle working within the same temperature limits, calculate the power required.

Solution:

given:

Power = $\dot{W}$ = ?

Refrigerating capacity = 40 tons

Q_L = 40 tons

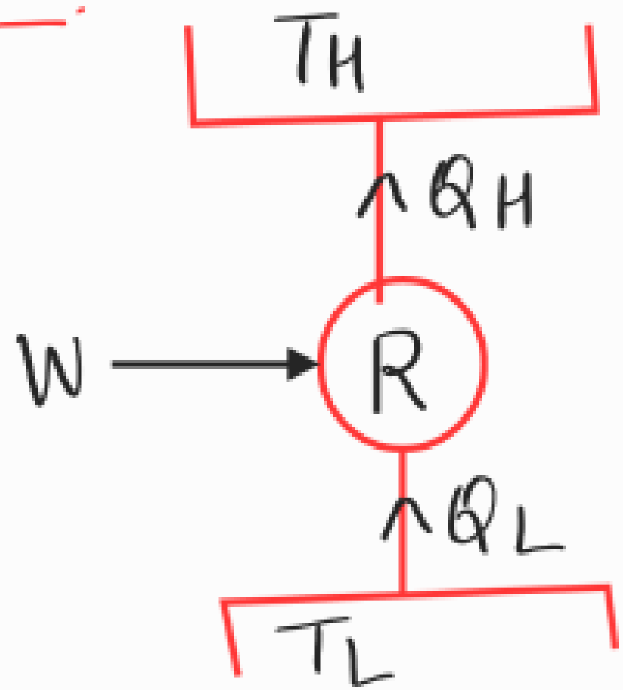
$\because$ 1 T.R = 3.5 kJ/s

$Q_L = 40 \times 3.5$

$Q_L = 140$ kJ/s

$T_L = -35^\circ C \Rightarrow T_L = 238$ K

$T_H = 30^\circ C \Rightarrow T_H = 303$ K



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$$(COP)_{act} = 20\% \text{ of } (COP)_{max} \text{ [given]}$$

$$(COP)_{max} = \frac{T_L}{T_H - T_L} = \frac{238}{303-238}$$

$$(COP)_{max} = 3.66$$

$$(COP)_{act} = 0.2 \times 3.66$$

$$(COP)_{act} = 0.732$$

$$(COP)_{act} = \frac{Q_L}{W}$$

$$0.732 = \frac{140 \text{ kW}}{W}$$

$$\Rightarrow W = 191.2 \text{ kW}$$

Ans

Lecture No. 21

- 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.

Composition of Air

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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

❖ Mixture of these gases are known as dry air.

- 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.

- Air-Conditioning is a process of controlling air temperature, humidity, quality and ventilation in a space (Building or Vehicle).

- Air conditioning can be used in both domestic and commercial environments.

- This process is most commonly used to achieve a more comfortable interior environment, typically for humans and other animals.

- However, air conditioning is also used to cool and dehumidify rooms filled with heat-producing devices, such as computer servers.

- 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.

- 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).

- In air-conditioning, we deals with moist air and **moist air is not a pure substance**.

- The properties of moist air are called **Psychrometric properties** and the subject which deals with the behavior of moist air is known as **psychrometry**.

Lecture No. 22

- It is also known as absolute humidity or humidity ratio and

denoted by ω .

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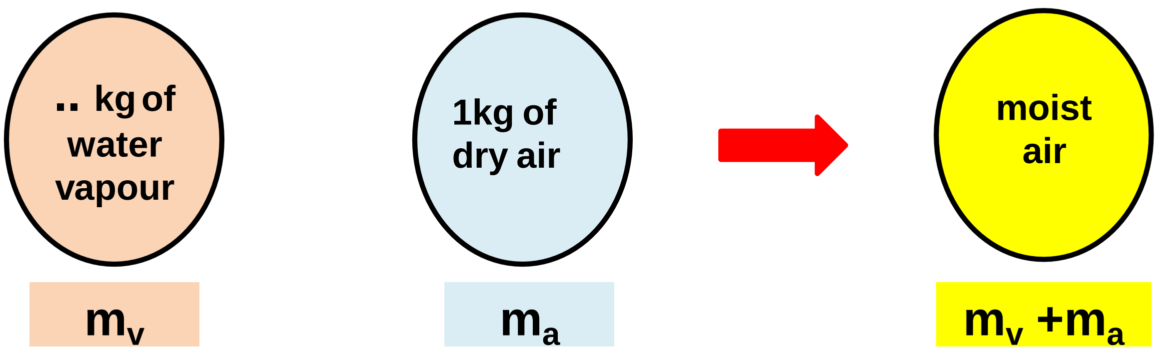
- Specific humidity can be defined as **the mass of water vapor present in a unit mass of dry air**.



Specific humidity

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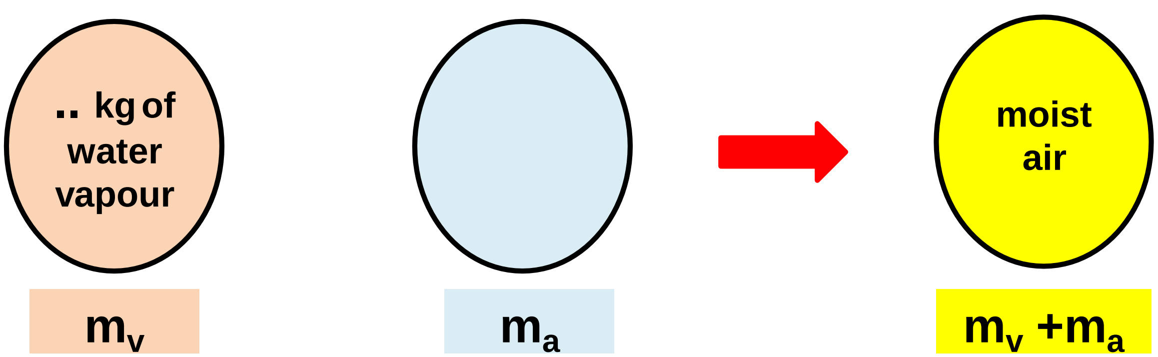

Specific humidity

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- 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

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

Relative humidity

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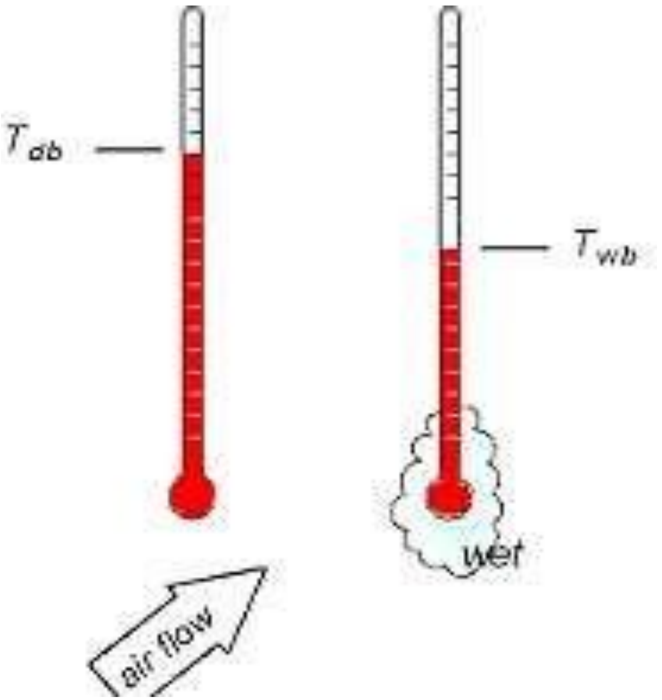
- Relative humidity is the amount of water vapor (vapor pressure) that is in the air. It is a percentage of how much moisture the air could possibly hold.

$$\omega = \frac{\text{mass of water vapor}}{\text{mass of vapor in saturated condition}}$$

$$\Rightarrow \omega = \frac{m_v}{m_{vs}}$$

Dry Bulb Temperature (T_{db} or T) and Wet Bulb Temperature (T_{wb})

- 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.

- Thetemperature which is measured by the wet wick covered bulb is known as wet bulb temperature.

Dew point temperature (T_{dp})

- The air in atmosphere contain 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}.

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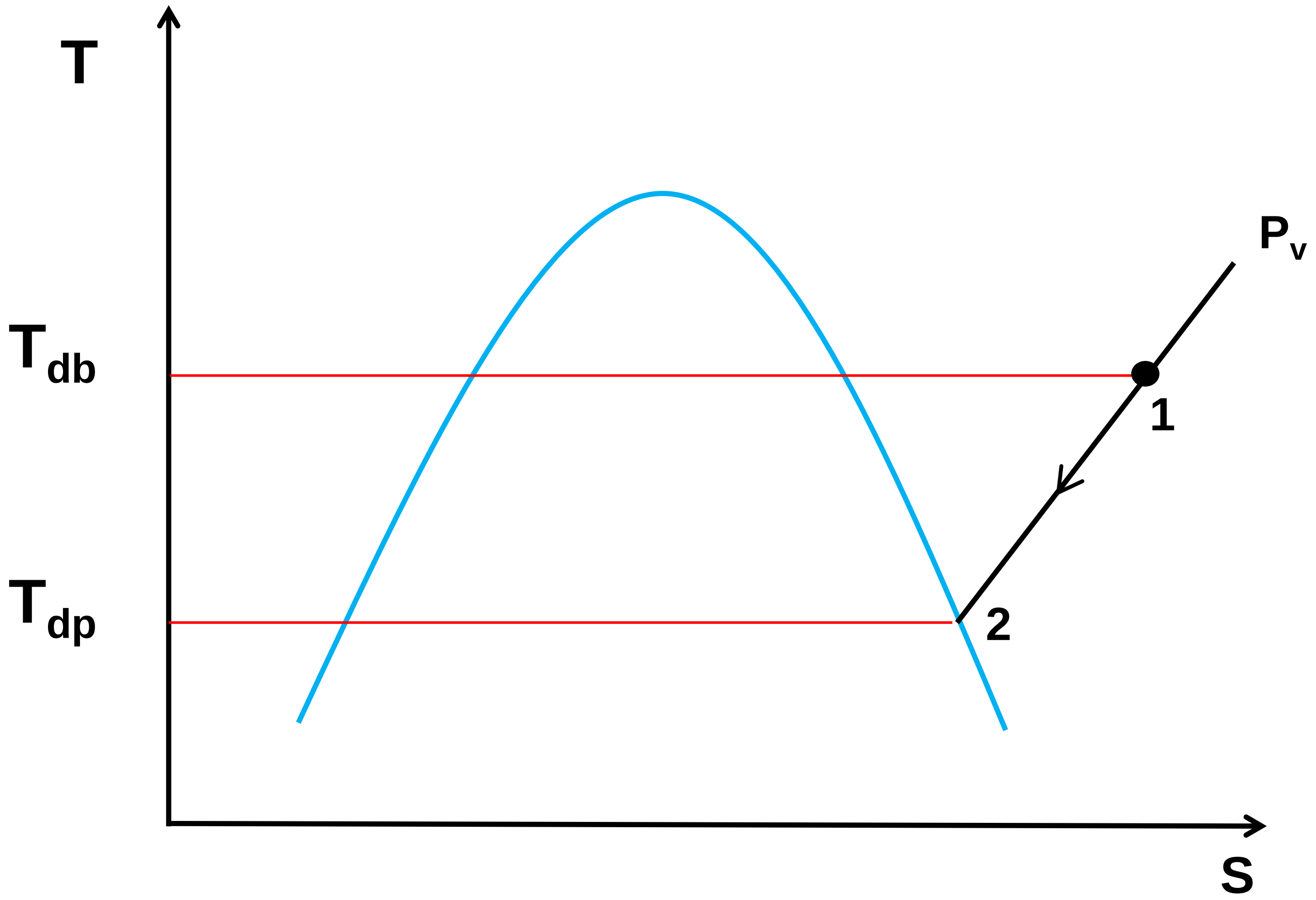
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T_{db}
T_{dp}
P_v
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Lecture No. 23

Comfort Conditioning

Comfort:

- Heating load due to solar energy,
- Electronics devices
- Heat rejected human body
- Ventilation

Industrial:

- Textile mill
- Paper mill
- Pharmaceutical
- Food Industry
- Manufacturing

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.

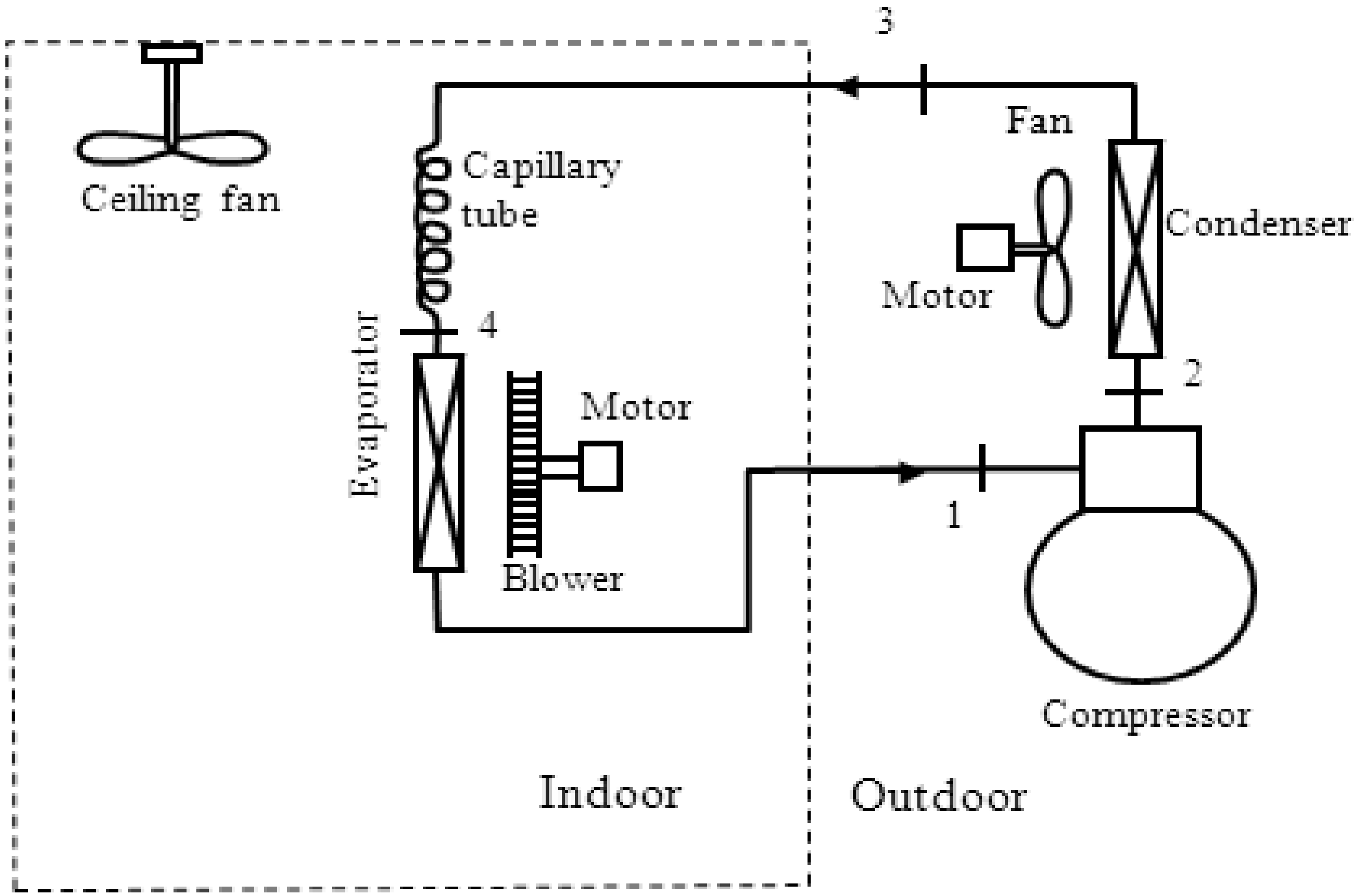
Window Air Conditioner

- 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.

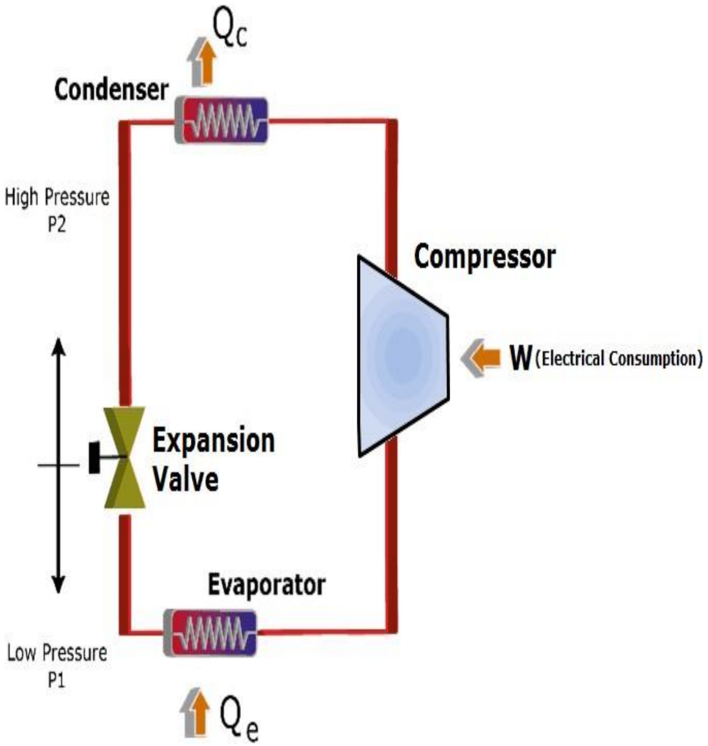
Window Air Conditioner



Window Air Conditioner

Compressor

- ❖The refrigerant enters the compressor at low temperature and pressure in a gaseous state.
- ❖In compressor temperature and pressure of the refrigerant increases.
- ❖The refrigerant leaves the compressor and enters to the condenser.
- ❖Since this process requires work, an electric motor may be used.



Window Air Conditioner…….

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 air-conditioning 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.

Window Air Conditioner…….

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.

Window Air Conditioner…….

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.

Thank You