AKTU

B. Tech I-Year

Gateway Classes

Semester -I & II

Common to All Branches

Fundamentals of Mech. Engg.(BME101/201)

Unit-3 : ONE SHOT-Refrigeration & Air-Conditioning

Gateway Series for Engineering

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- Long - Short Questions Covered
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- Result Oriented Content

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Fundamentals of Mech. Engg.(BME101/201)

Unit-3

Introduction to Refrigeration &Air-Conditioning

Syallbus

IRefrigeration: 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.


AKTU B.TECH I-YEAR FME
GW
GATEWAY CLASSES
FUND. OF MECHANICAL ENGG.
FINAL REVISION + NOTES
UNIT-3 REFRIGERATION AND AIR-CONDITIONING
QUESTIONS तो यहीं से आएंगे !
LIVE
19 MARCH 10 AM
BY M S TOMER SIR

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

- Refrigeration has numerous applications across various industries and everyday life.
- Its primary purpose is to lower the temperature of a given space or substance.

These are some common applications of refrigeration:

- Food preservation
- Food processing
- Beverage industry
- Pharmaceuticals
- Air conditioning
- Industrial processes
- Ice production
- Cold storage warehouses
- Transport refrigeration
- Laboratories

1 tonne of refrigeration [AKTU]

- It is the amount of heat that is to be removed from one tonne of **water** at zero **(0^{o}C)** in order to convert it into **ice** at 0 ^{o}C 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

- **There are several methods used for refrigeration, each based on different principles and technologies.**

Here are some of the most common methods for refrigeration

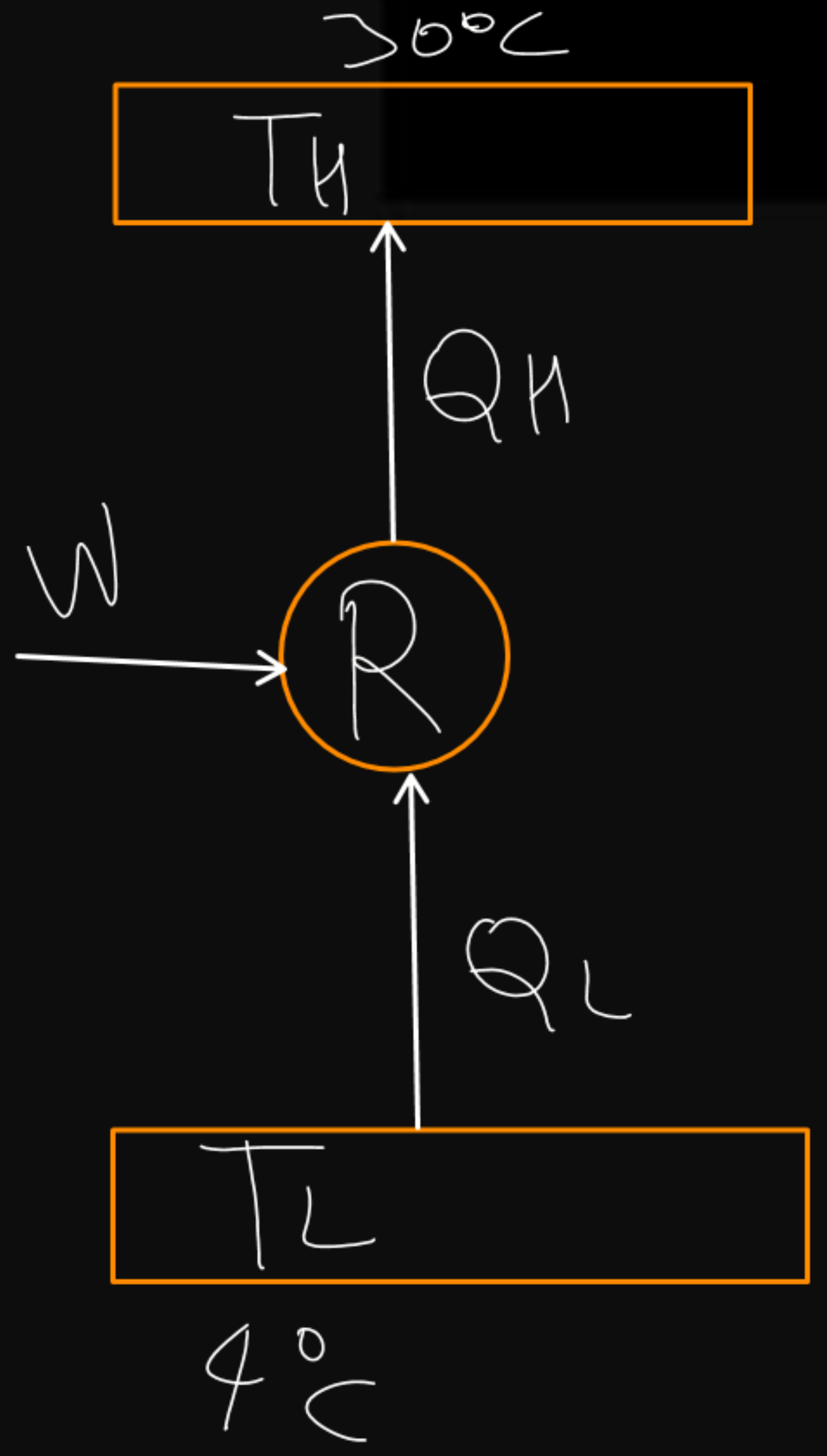
- Vapour Compression Refrigeration
- Absorption Refrigeration
- Thermoelectric Refrigeration
- Evaporative Cooling
- Magnetic Refrigeration
- Air Cycle Refrigeration
- Steam Ejector Refrigeration

Each of these refrigeration methods has its advantages and specific applications. The choice of method depends on factors like cooling requirements, energy efficiency, space limitations, and the specific industry or application involved. Advances in technology continue to improve these methods and open up new possibilities for efficient and sustainable refrigeration solutions.

Refrigerator and Heat Pump. [AKTU : 2020-21]

- **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



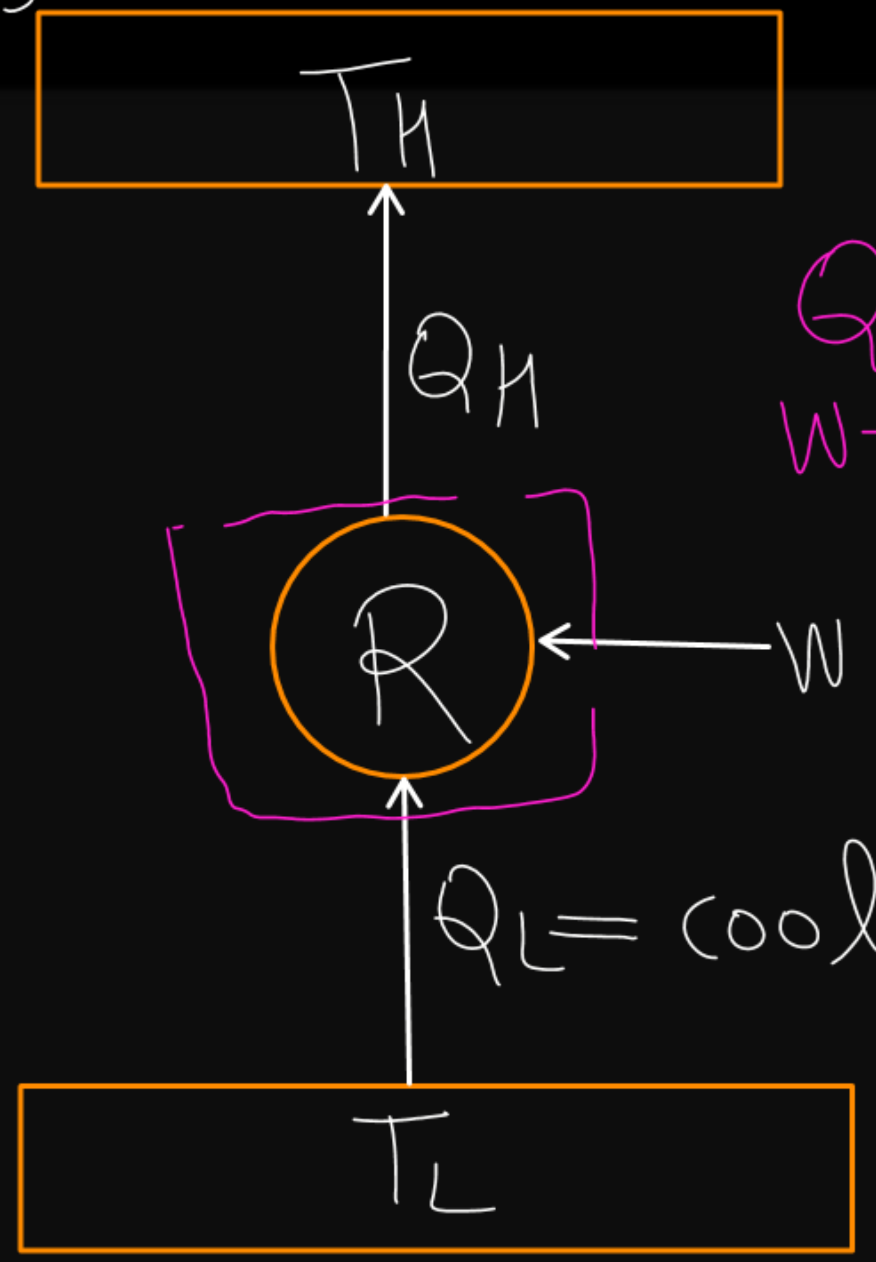
- Refrigerator works on the **Clausius statement.**
- It absorbs the heat from the low temperature medium and rejects heat into high temperature medium by consuming external work.
- Refrigerator used to **maintain low temperature** as compared to surrounding.

surr

Refrigerator

2.5

1.5



$Q_{in} = Q_{out}$

$W + Q_L = Q_H$

$\boxed{W = Q_H - Q_L}$ **

Q_L = cooling effect

Storage

$T \to K$

$$(COP)_R = \frac{T_L}{T_H - T_L}$$

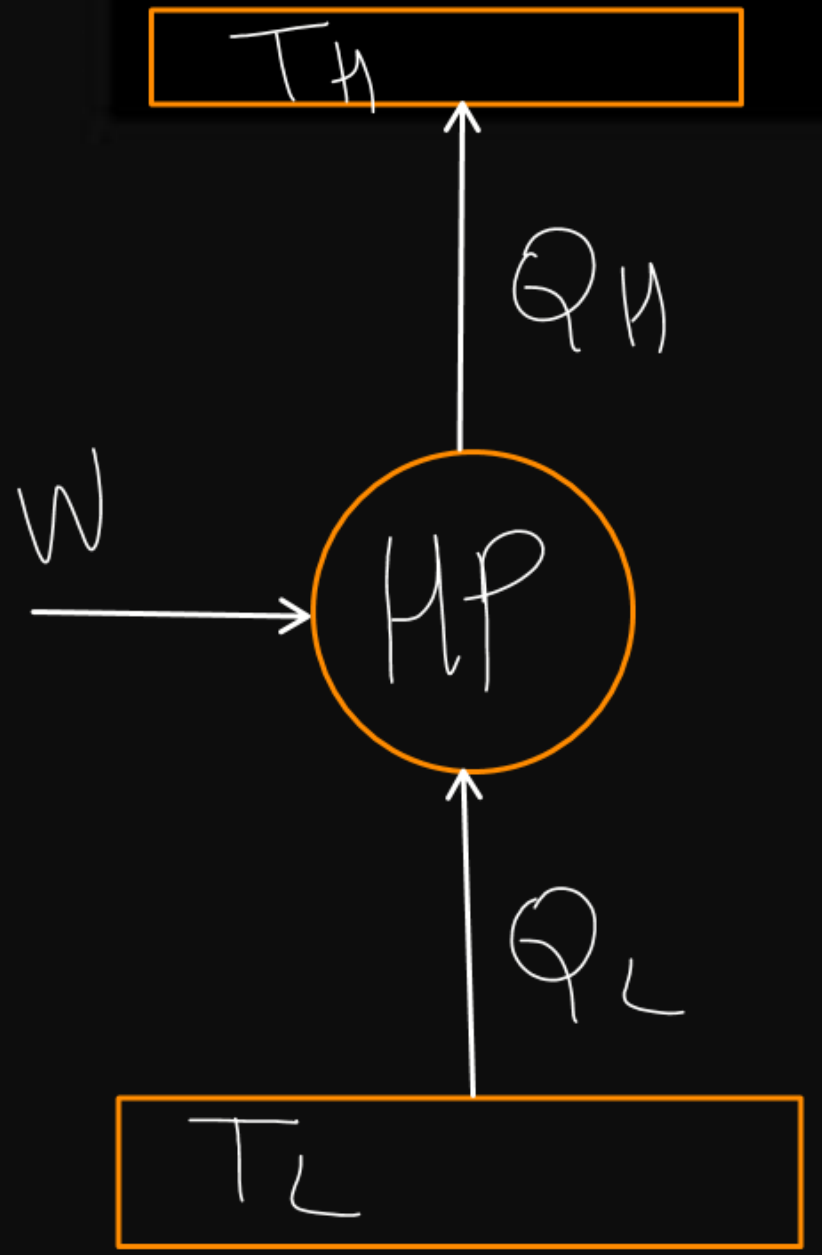
$$COP_R = \frac{\textit{Desired Effect}}{\textit{Work Required}}$$

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

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

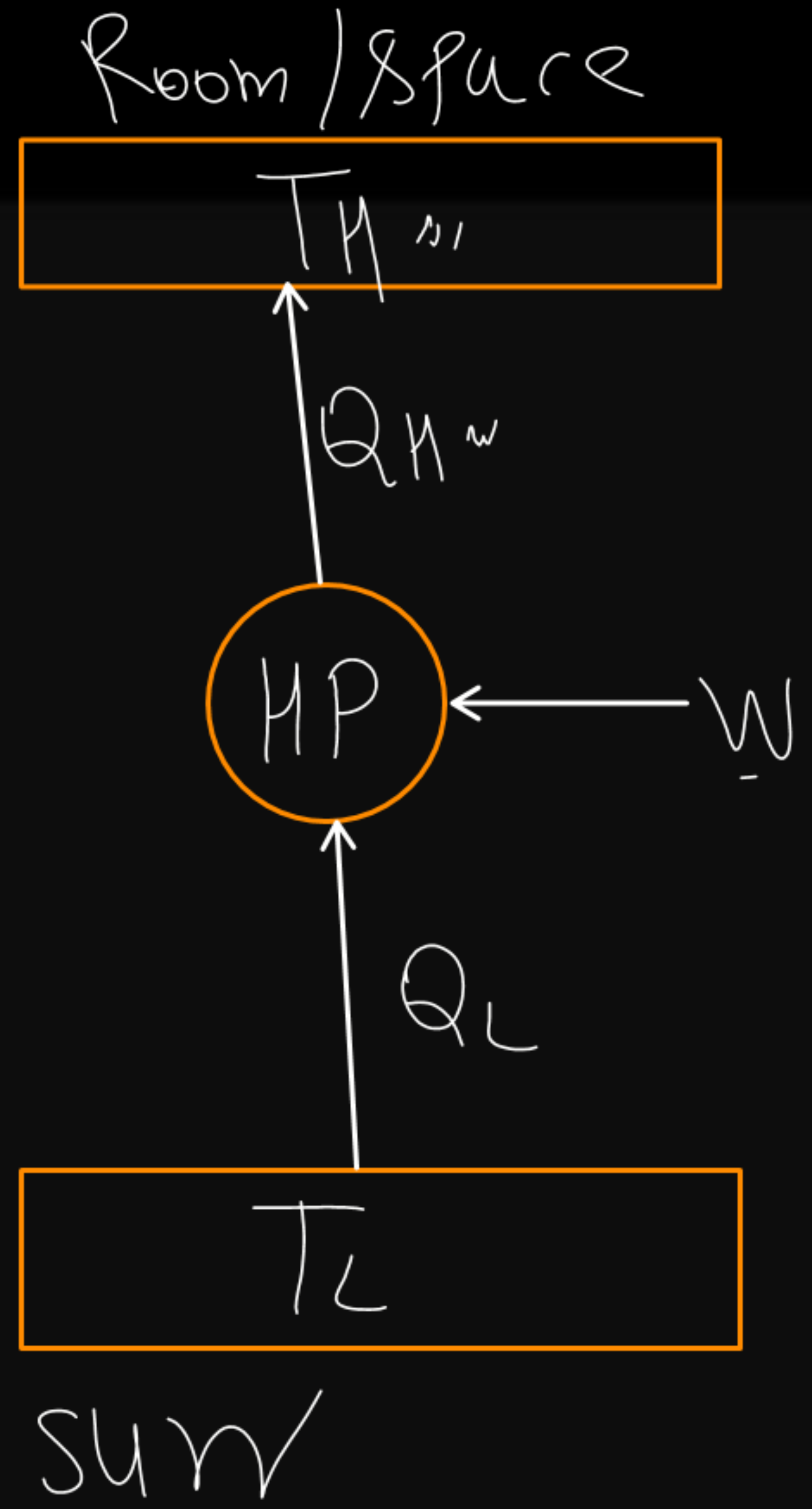
$$\boxed{(COP)_R = \frac{Q_L}{Q_H - Q_L}}$$

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



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

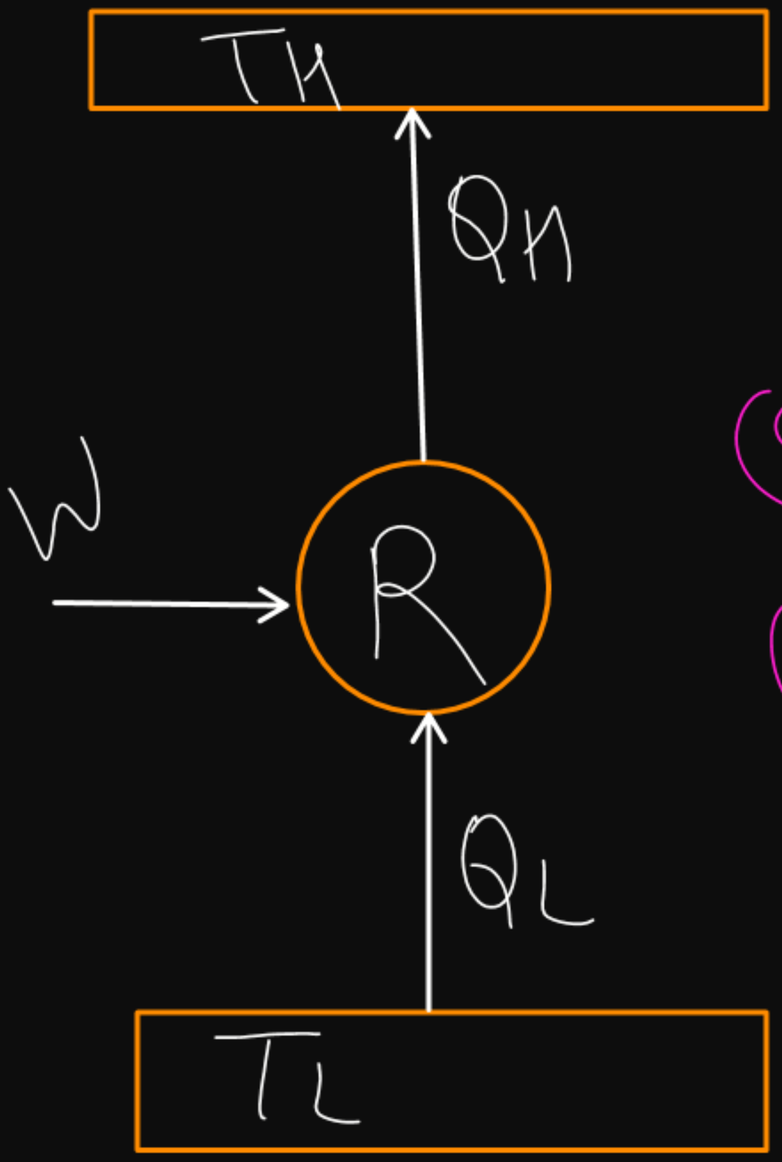
$$COP_{H.P.} = \frac{\text{Heating Effect}}{\text{Work Required}}$$

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

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

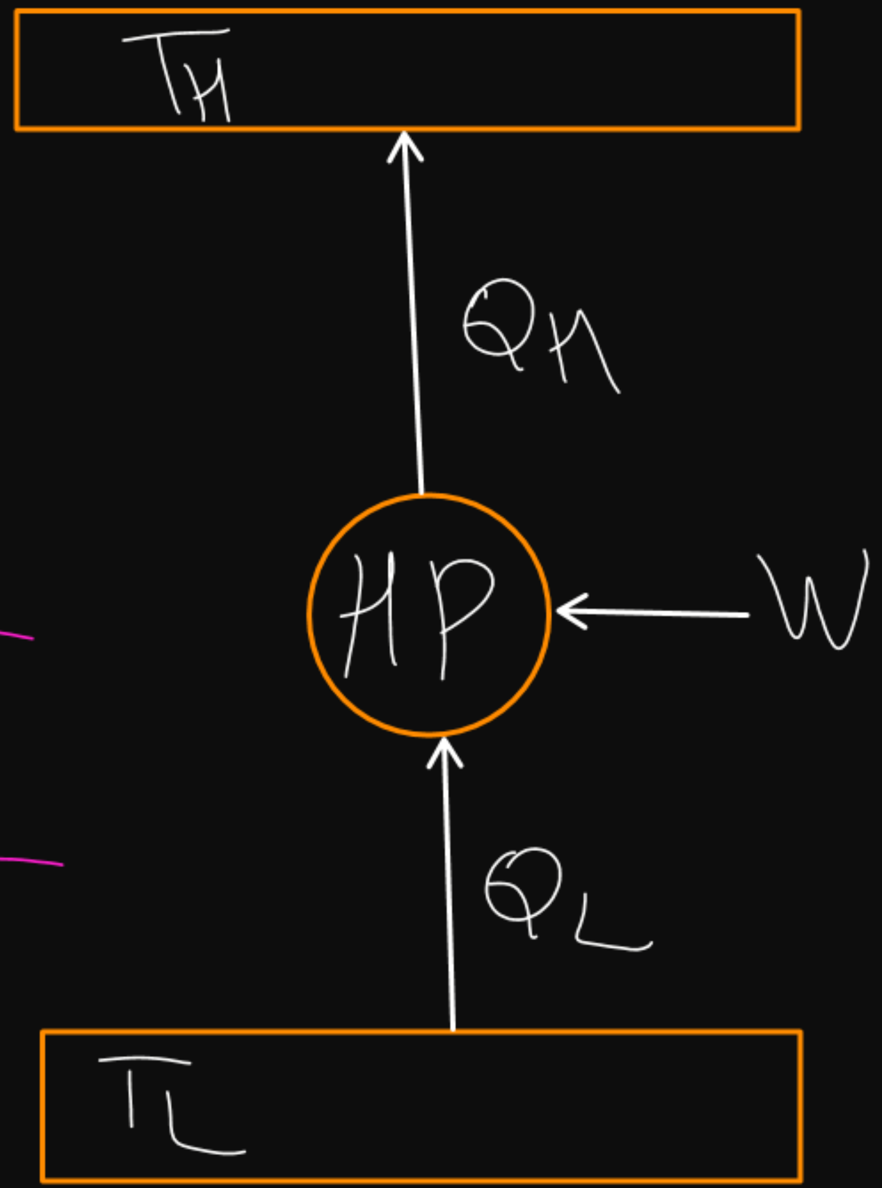
$$(COP)_{HP} = \frac{T_H}{T_H - T_L}$$

Relation between the COP of refrigerator and heat pump



$$(COP)_R = \frac{Q_L}{Q_H - Q_L} \quad \text{--- (I)}$$

$$(COP)_{HP} = \frac{Q_H}{Q_H - Q_L} \quad \text{--- (II)}$$



$$(COP)_{HP} - (COP)_R = \frac{Q_H}{Q_H - Q_L} - \frac{Q_L}{Q_H - Q_L}$$

$$(COP)_{HP} - (COP)_R = \frac{Q_H - Q_L}{Q_H - Q_L} = 1$$

$$\boxed{(COP)_{HP} = 1 + (COP)_R}$$

Coefficient of Performance [AKTU]

- 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 COP indicates a more efficient system, as it produces more cooling or heating for a given amount of energy input.
- Higher the value of COP lower the running cost.

Methods for Refrigeration

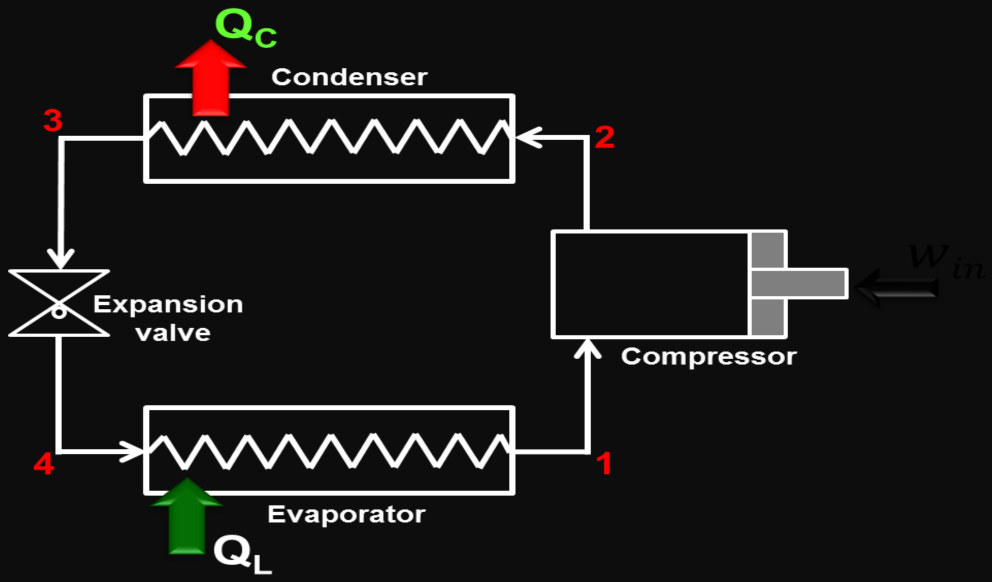
- **There are several methods used for refrigeration, each based on different principles and technologies.**

Here are some of the most common methods for refrigeration

- Vapour Compression Refrigeration
- Absorption Refrigeration
- Thermoelectric Refrigeration
- Evaporative Cooling
- Magnetic Refrigeration
- Air Cycle Refrigeration
- Steam Ejector Refrigeration

Each of these refrigeration methods has its advantages and specific applications. The choice of method depends on factors like cooling requirements, energy efficiency, space limitations, and the specific industry or application involved. Advances in technology continue to improve these methods and open up new possibilities for efficient and sustainable refrigeration solutions.

Vapour Compression Refrigeration System [AKTU]



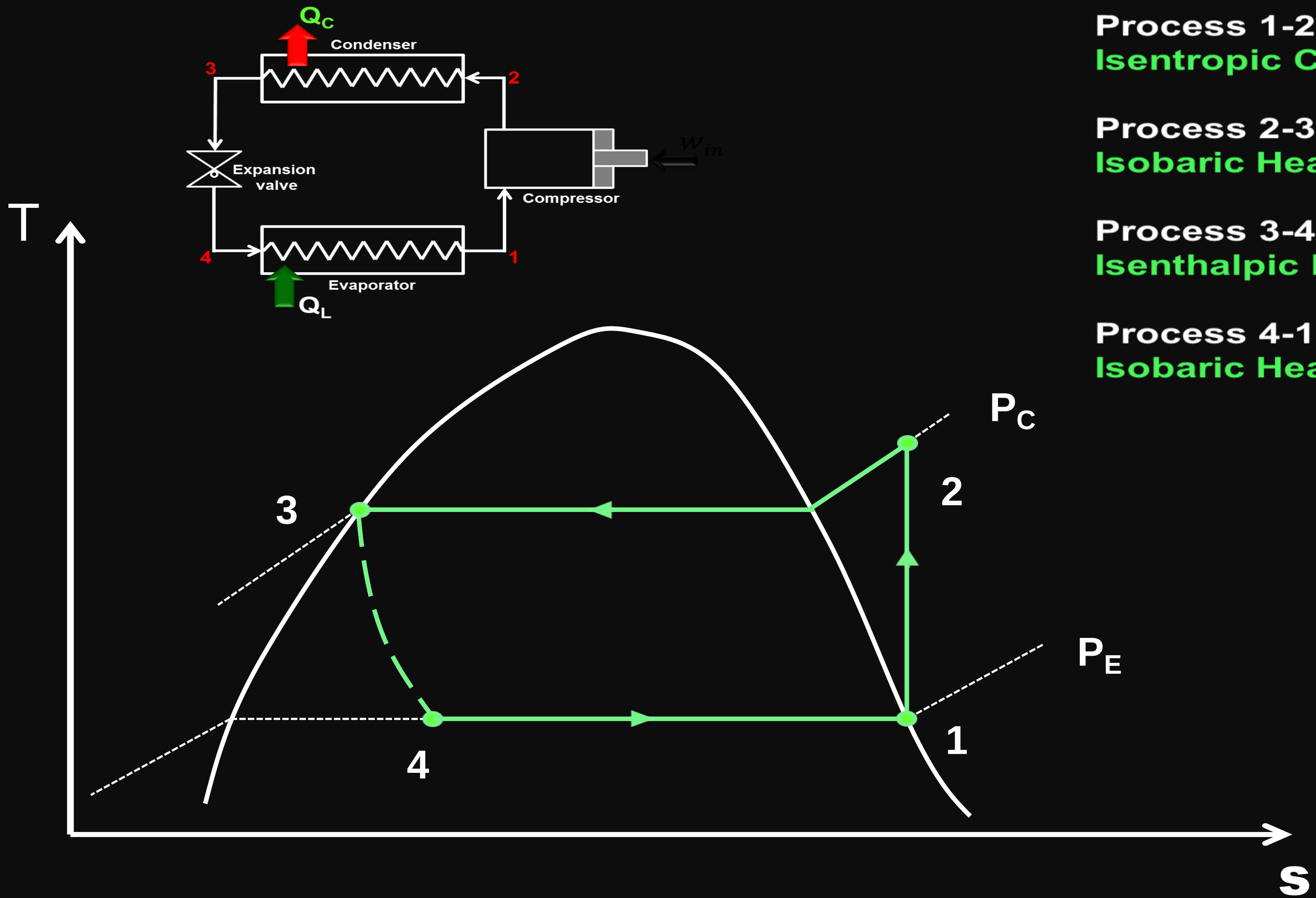
Schematic diagram of single stage vapour compression cycle

Process 1-2
Isentropic Compression

Process 2-3
Isobaric Heat Rejection

Process 3-4
Isenthalpic Expansion

Process 4-1
Isobaric Heat Addition



Process 1-2
Isentropic Compression

Process 2-3
Isobaric Heat Rejection

Process 3-4
Isenthalpic Expansion

Process 4-1
Isobaric Heat Addition

Construction and working of domestic refrigerator [AKTU]

- Refrigerator is a cyclic device which is used to maintain **lower temperature** as compared to surrounding temperature.
- The construction and working of a domestic refrigerator are based on the principles of vapor compression refrigeration.

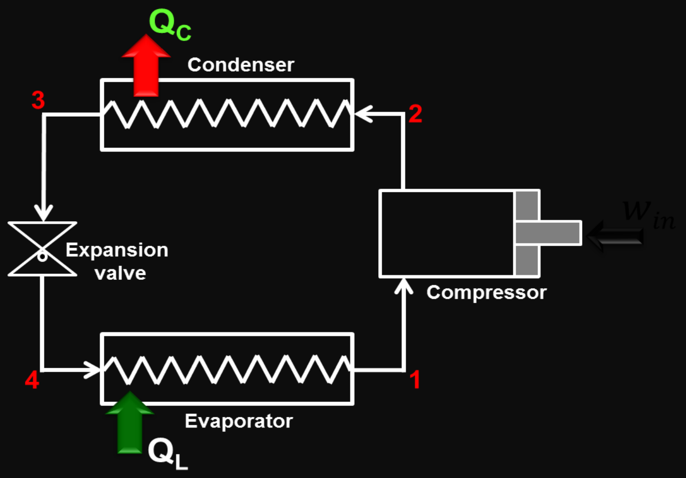
Main components of refrigerator are

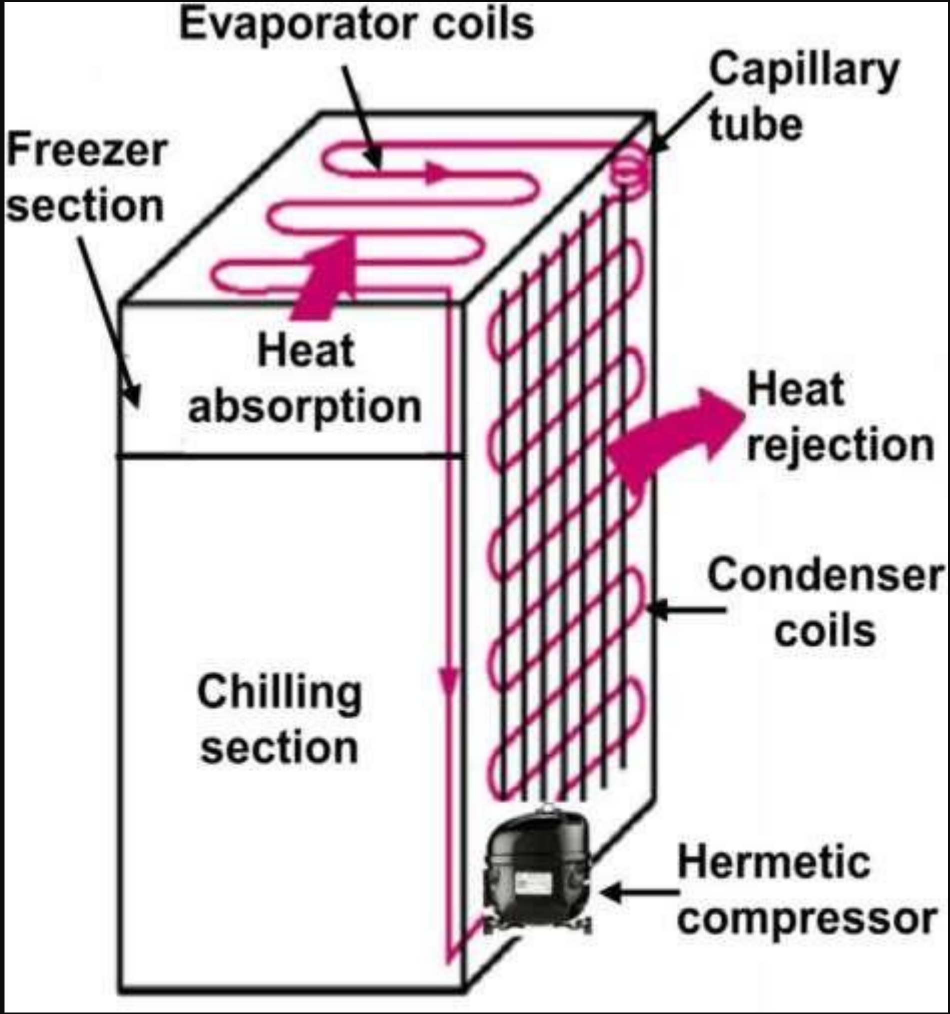
Compressor(1-2)

Condenser (2-3)

Thermal Expansion Valve or Capillary Tube(3-4)

Evaporator(4-1)




Evaporator coils
Capillary tube
Freezer section
Heat absorption
Heat rejection
Condenser coils
Chilling section
Hermetic compressor

COMPRESSOR :

- The compressor is the heart of the refrigeration system.
- It is an electric motor-driven pump that compresses the low-pressure, low-temperature refrigerant gas into a high-pressure, high-temperature gas.

CONDENSER :

- The condenser is a coil or set of coils located at the back or bottom of the refrigerator.
- The high-pressure refrigerant gas from the compressor flows through the condenser, and as it releases heat to the surroundings, it condenses into a high-pressure liquid.

Expansion Valve (Thermal Expansion Valve or Capillary Tube):

- The expansion valve is a small device that creates a pressure drop, allowing the high-pressure liquid refrigerant to expand and turn into a low-pressure, low-temperature mixture of liquid and vapor.
- The capillary tube is a fixed-length narrow tube that serves as an expansion device in some refrigerators.

Evaporator:

- The evaporator is a coil or set of coils located inside the refrigerator's main compartment, usually in the freezer section.
- The low-pressure refrigerant from the expansion valve absorbs heat from the refrigerator's interior, causing it to evaporate into a low-pressure vapor.

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.

Working Process:

The refrigeration cycle starts when the compressor starts running. The entire process involves four stages:

Stage 1 - Compression: **The compressor sucks in low-pressure refrigerant vapor from the evaporator and compresses it to a high-pressure, high-temperature gas.**

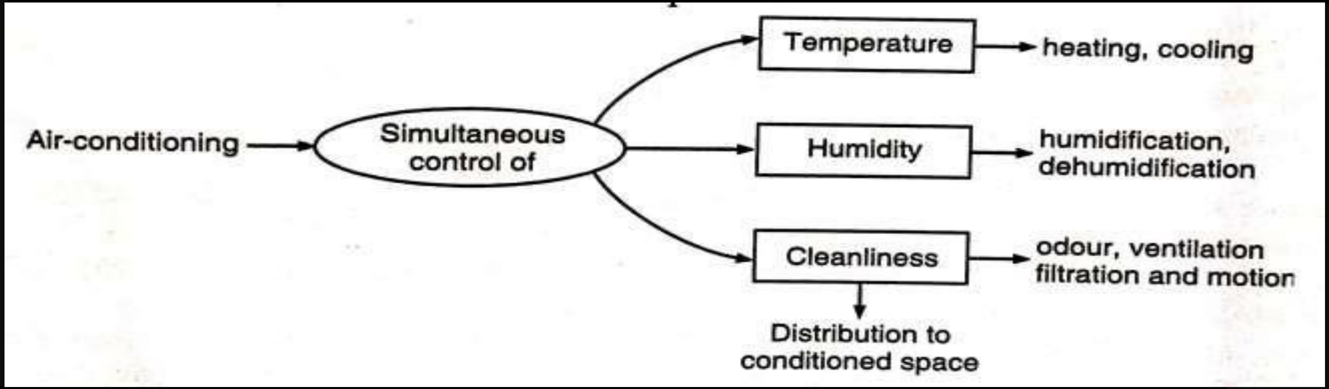
Stage 2 - Condensation: **The high-pressure refrigerant gas flows through the condenser coils where it releases heat to the surrounding air or water, causing it to condense into a high-pressure liquid.**

Stage 3 - Expansion: The high-pressure liquid refrigerant then passes through the expansion valve or capillary tube, where it undergoes a sudden pressure drop, resulting in its expansion into a low-pressure mixture of liquid and vapor.

Stage 4 - Evaporation: The low-pressure refrigerant mixture enters the evaporator coils inside the refrigerator's main compartment. As it absorbs heat from the interior of the refrigerator, it evaporates into a low-pressure vapor.

The cycle then repeats as the low-pressure vapor returns to the compressor, and the process continues to maintain a cool temperature inside the refrigerator.

‘Air-Conditioning’ and its applications [AKTU]



- Air conditioning is a process of controlling and modifying the temperature, humidity, and air quality of an indoor space.

- It is used to create a comfortable and controlled environment for occupants, regardless of the external weather conditions.

‘Air-Conditioning’ and its applications

Air conditioning has a wide range of applications across various sectors

- Residential
- Commercial Buildings
- Hospitals and Healthcare Facilities
- Educational Institutions
- Transportation
- Server Rooms and Data Centers
- Sports Facilities
- Theatres and Auditoriums
- Museums and Art Galleries

(i) Dry Air (ii) Atmospheric air (iii) Saturated air

(i) **Dry air** **:** It is a mixture of nitrogen, oxygen, and small amounts of some other gases.

(ii) **Atmospheric air** **:** Air in the atmosphere normally contains some **water vapor** (or *moisture*), **number of pollutants** and referred as **atmospheric air.**

(iii) **Saturated air** **:** Saturated air is air that holds water vapor at its **highest level** i.e. just about to condense.

Psychrometry?

- Moist air is the mixture of **water vapour and dry air**.

- The properties of moist air are called **Psychrometric properties.**

- The science in which we deal with the **Psychrometric properties** is known as **psychrometry**.

(i) specific humidity (ii) relative humidity

(i) specific humidity:

- Specific humidity can be defined as the mass of water vapor present in a unit mass of dry air.
- It is also known as absolute humidity or humidity ratio and denoted by ω.

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

Unit
kg of water vapour / kg of dry air

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

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

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

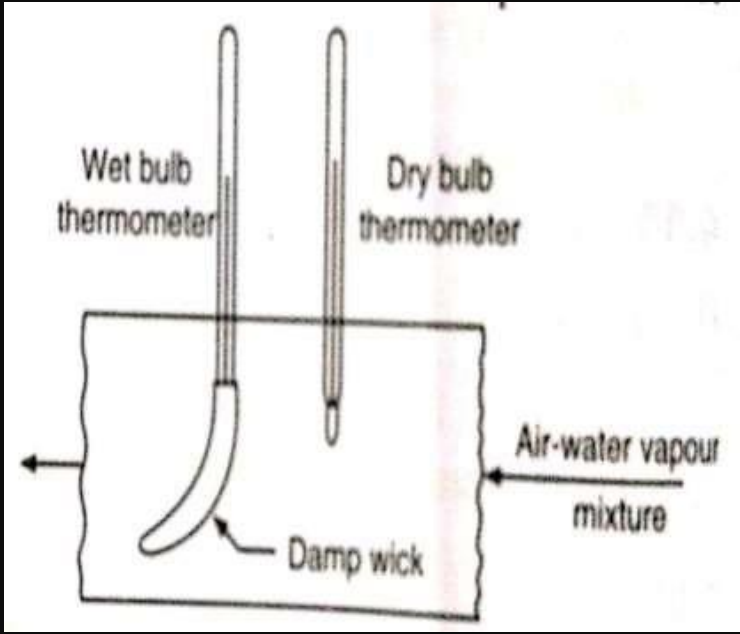
(ii) Relative Humidity(ϕ) [AKTU]

- Relative humidity (RH) is a measure of the amount of moisture in the air relative to the maximum amount of moisture that the air can hold at a given temperature and pressure.
- It is expressed as a percentage. Relative humidity indicates how close the air is to its saturation point.
- When the relative humidity is 100%, the air is saturated, and it cannot hold any more moisture at that temperature and pressure.
- If the relative humidity is less than 100%, the air is not saturated, and there is potential for more water vapor to be added before reaching saturation.

(i) Dry Bulb Temperature [AKTU] (ii)Wet Bulb Temperature [AKTU]

(i) Dry Bulb Temperature

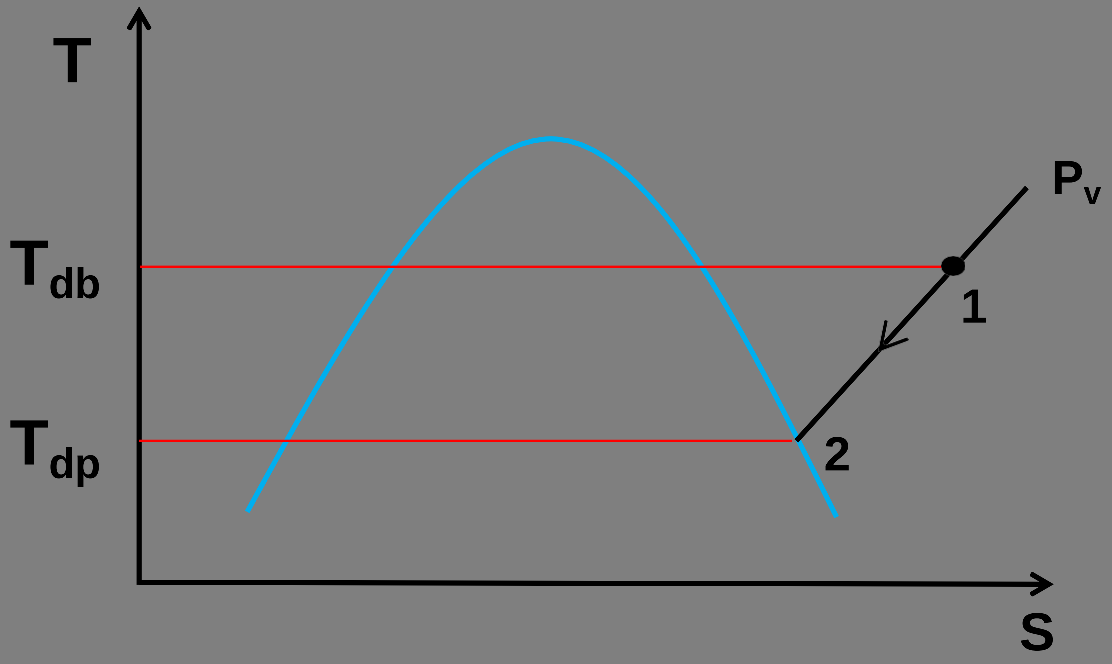
- It refers to the temperature of the air measured by a standard thermometer that is not affected by moisture.
- In other words, it is the ambient air temperature that we commonly refer to when discussing the weather or indoor climate.
- The dry bulb temperature is measured in degrees Celsius (°C) or Fahrenheit (°F).



(ii)Wet Bulb Temperature

- The wet bulb temperature is another important parameter used to measure air temperature, particularly in the context of humidity and cooling processes.
- It is the temperature recorded by a thermometer covered with a water-soaked cloth or wick, exposed to the airflow.
- As water evaporates from the cloth, it cools the thermometer, and the wet bulb temperature is lower than the dry bulb temperature.

(iii) Dew point Temperature [AKTU]



(iii) Dew point Temperature

- The air in atmosphere contain moisture (water vapour).
- If we reduce the temperature of the air at constant pressure, 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}.

Human comfort and conditions for comfort air conditioning ?

- **Human Comfort refers to the control of temperature and humidity of air** and its circulation.
- So that the resulting environment becomes human friendly.
- **General human comfort conditions are to maintained in the range of**

- **Te**mperatures 22 °C to 27 °C
- Relative humidity 40% to 60%
- Air velocity 5 m/min to 8 m/min

Working of window type air-conditioner

- 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.

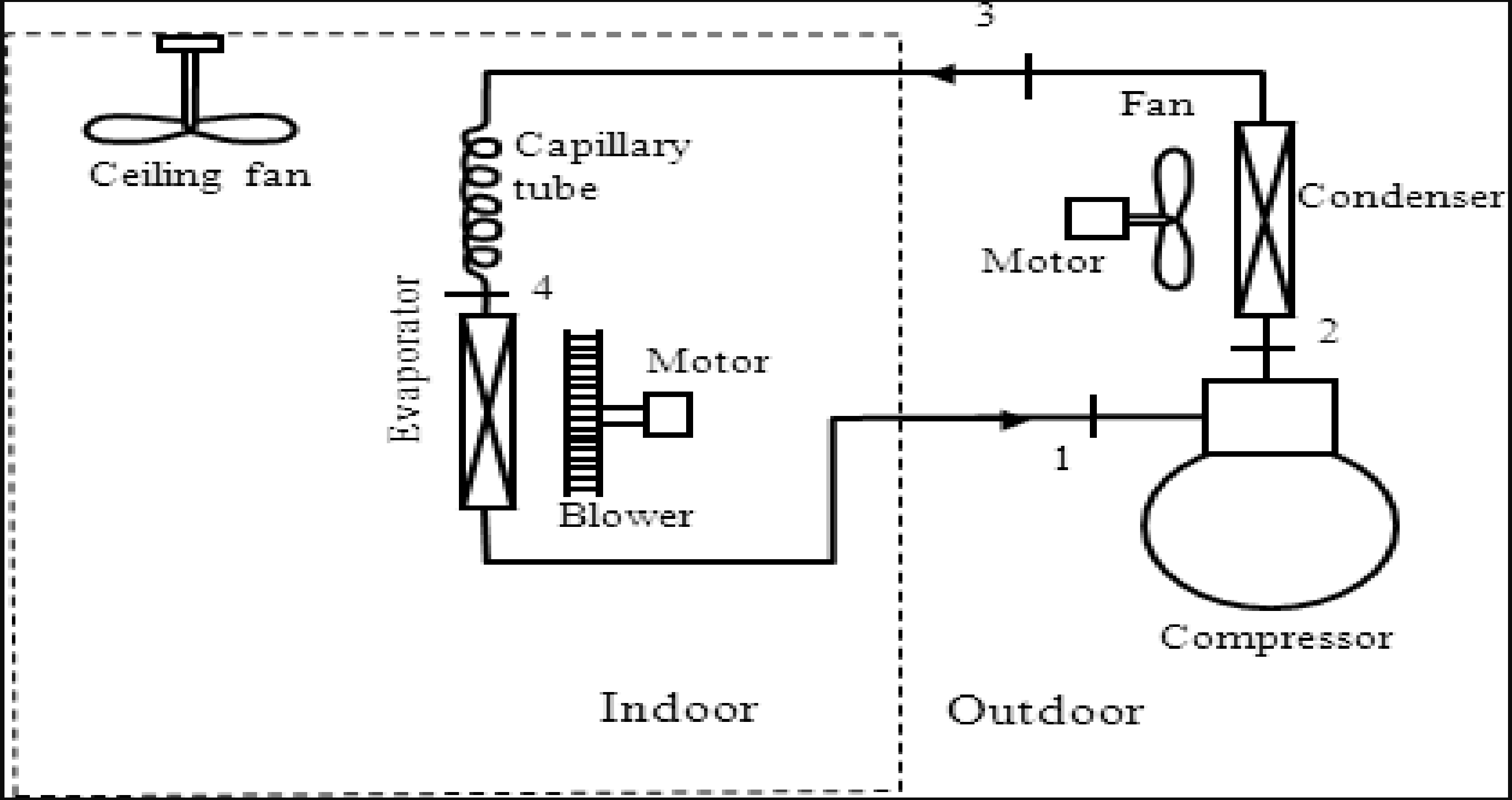
Window Air Conditioner [AKTU]

- 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



Construction of Window Air Conditioner

It consists of various components

1. Compressor:

- The compressor is the main component of the window air conditioner.
- It compresses the low-pressure, low-temperature refrigerant gas and turns it into a high-pressure, high-temperature gas.

2. Condenser:

- The condenser is a coil located on the back or bottom of the air conditioner.
- The high-pressure refrigerant gas flows through the condenser, releases heat to the outside air, and condenses into a high-pressure liquid.

3. Expansion Valve:

- The high-pressure liquid refrigerant then passes through an expansion valve, which is a small device that causes a pressure drop.
- This leads to the expansion of the refrigerant into a low-pressure, low-temperature mixture of liquid and vapor.

4. Evaporator:

- The low-pressure refrigerant mixture enters the evaporator coil located inside the front part of the air conditioner, behind the air intake grille.
- As the warm indoor air is drawn over the evaporator coil by the blower fan, the refrigerant absorbs heat from the air, causing it to evaporate into a low-pressure vapor.

5. Blower Fan:

The blower fan is located inside the air conditioner and is responsible for drawing indoor air over the evaporator coil and then blowing the cooled air back into the room.

Working of Window Air Conditioner

The working of a window air conditioner involves a process called vapor compression refrigeration, which consists of four stages:

1. **Compression:** The compressor sucks in the low-pressure, low-temperature refrigerant vapor from the evaporator and compresses it into a high-pressure, high-temperature gas.
2. **Condensation:** The high-pressure refrigerant gas flows through the condenser coils, where it releases heat to the outdoor air and condenses into a high-pressure liquid.
3. **Expansion:** The high-pressure liquid refrigerant then passes through the expansion valve, causing it to expand rapidly and turn into a low-pressure, low-temperature mixture of liquid and vapor.

4. Evaporation: The low-pressure refrigerant mixture enters the evaporator coil, where it absorbs heat from the indoor air. The warm air becomes cooler as it passes over the cold evaporator coil, and the refrigerant evaporates into a low-pressure vapor.

The process repeats continuously as long as the air conditioner is running, removing heat and humidity from the indoor air and providing a cooling effect.

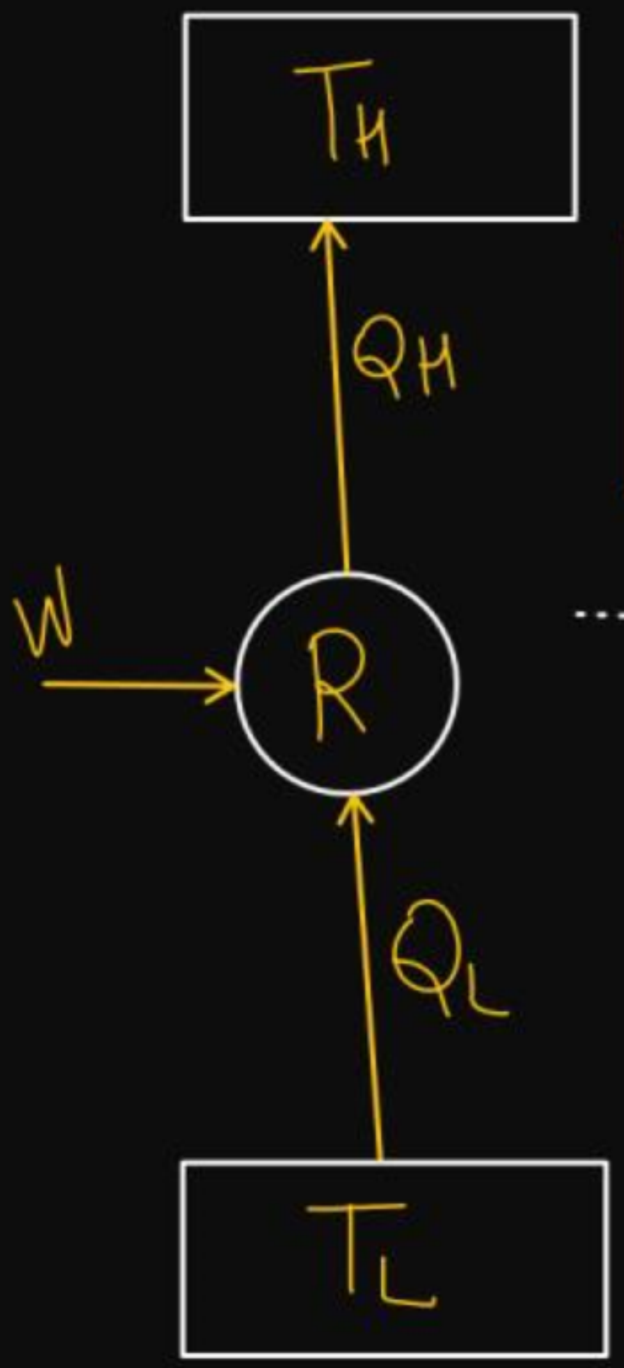
The cooled air is then blown back into the room by the blower fan, while the heat extracted from the indoor air is expelled outside through the condenser.

Specification of Window Air Conditioner

A window air-conditioner is normally specified by the following parameters:

- Cooling Capacity : 1, 1.5 and 2 ton etc
- Overall dimensions : length x width x height
- Voltage and Power Consumption: AC, 220-240 volts
- Control : site or remote
- Fan Speeds
- Dehumidification
- Airflow Direction
- Noise Level

Numerical Problems based on Refrigerator and Heat Pump



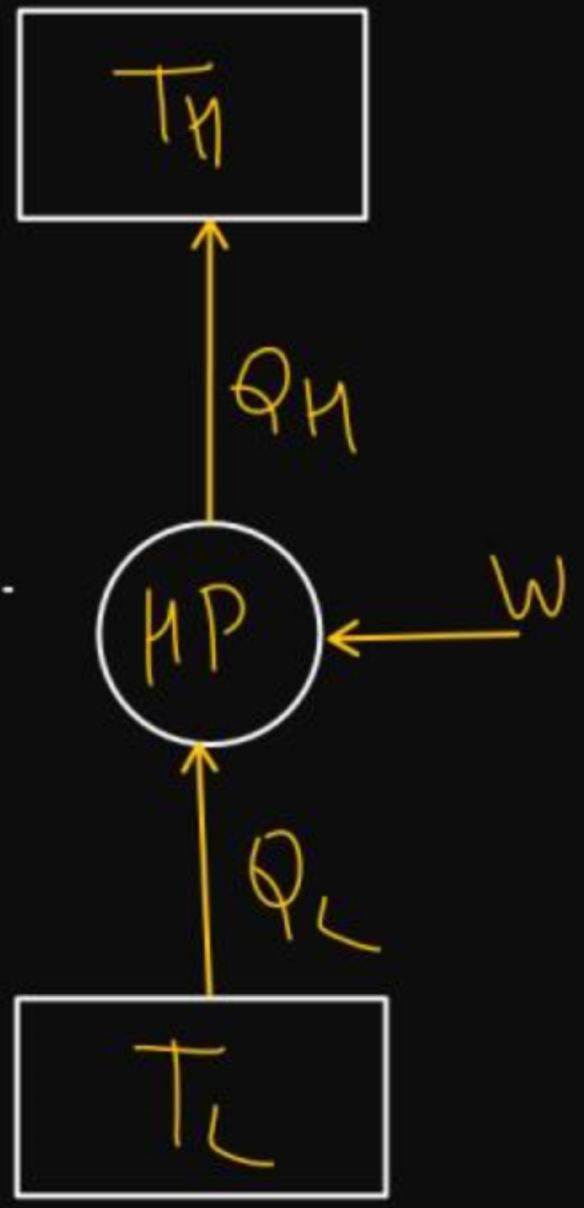
$$(COP)_R = \frac{Q_L}{W} = \frac{Q_L}{Q_H - Q_L} \qquad T \rightarrow K$$

$$\boxed{(COP)_R = \frac{Q_L}{Q_H - Q_L} = \frac{T_L}{T_H - T_L}}$$

$$\boxed{(COP)_{HP} = \frac{Q_H}{W} = \frac{Q_H}{Q_H - Q_L} = \frac{T_H}{T_H - T_L}}$$

$$(COP)_{HP} = 1 + (COP)_R$$

$$\boxed{1\ T.R = 3.5\ kJ/s = 210\ kJ/min}$$



Numerical Problems based on Refrigerator and Heat Pump

GW GATEWAY CLASSES

Q.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.*

given:

$Q_L = 360\ \text{kJ/min},\ W = 2\ \text{kW}$

$= \frac{360}{60} = 6\ \text{kJ/s}$

$= 6\ \text{kW}$

(a) $(COP)_R$ & (b) $Q_H = ?$

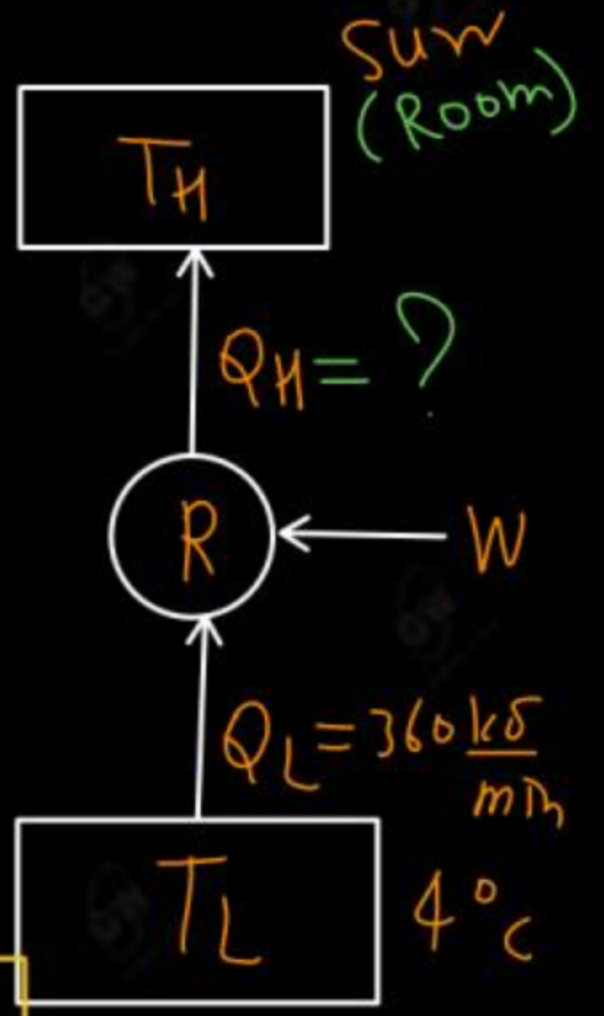
(a) $(COP)_R = \frac{Q_L}{W} = \frac{360\ \text{kJ/min}}{2\ \text{kW}} = \frac{6\ \text{kW}}{2\ \text{kW}}$

$\boxed{(COP)_R = 3}$ Ans

(b) $W = Q_H - Q_L \Rightarrow 2 = Q_H - 6$

$Q_H = 8\ \text{kW} = 8\ \text{kJ/s}$

or $Q_H = 8 \times 60 \Rightarrow \boxed{Q_H = 480\ \text{kJ/min}}$ Ans



Numerical Problems based on Refrigerator and Heat Pump

Q.2 *A heat pump has a COP of 1.7. Determine the heat transferred to and from this heat pump when 50kJ of work is supplied.*

given:

$COP = 1.7$

$W = 50\,kJ$

to find Q_L & $Q_H = ?$

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

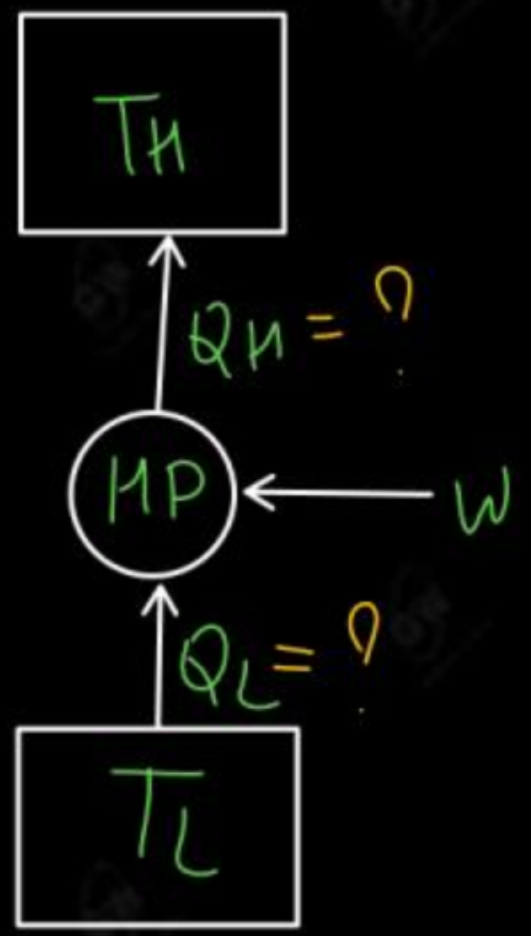
$$1.7 = \frac{Q_H}{50}$$

$\boxed{Q_H = 85\,kJ}$ Ans

$W = Q_H - Q_L$

$50 = 85 - Q_L$

$\boxed{Q_L = 35\,kJ}$ Ans

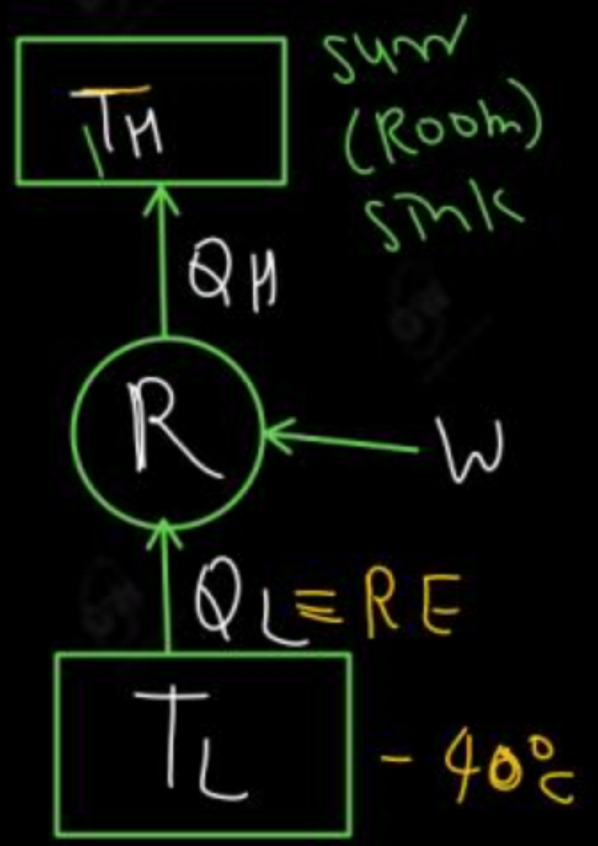


Numerical Problems based on Refrigerator and Heat Pump

Q.3 What is refrigeration effect? 1.5 kW per tonne of refrigeration is required to maintain the temperature of -40°C in the refrigerator. If the refrigeration cycle works on Carnot cycle, determine the followings: **1.** COP of the cycle, **2.** Temperature of the sink, **3.** Heat rejected to the sink per tonne of refrigeration, **4.** Heat supplied and COP, if the cycle if used as a heat pump.

7 Marks $\boxed{\text{AKTU: 2022-23 Even Sem}}$

Ans. The refrigeration effect refers to the amount of heat that is absorbed or extracted from a substance or space during the refrigeration process. In essence, it represents the cooling achieved by a refrigeration system.



given: $Q_L = 1$ tonne, $\because 1\ T.R = 3.5\ kW \Rightarrow \boxed{Q_L = 3.5\ kW}$

$W = 1.5\ kW$; To find 1. $(COP)_R$, (2) $T_H = ?$ (3) $Q_H = ?$

4. $(COP)_{H.P} = ?$ $Q'_H = ?$

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

$$(COP)_R = \frac{3.5\ kW}{1.5\ kW}$$

1. $\boxed{(COP)_R = 2.33}$ Ans

$$(COP)_R = \frac{T_L}{T_H - T_L}$$

$$2.33 = \frac{233}{T_H - 233}$$

$$T_H = 333\ K$$

$$T_H = 333 - 273$$

2. $\boxed{T_H = 60°C}$ Ans

$$Q_H = W + Q_L$$
$$= 1.5 + 3.5$$

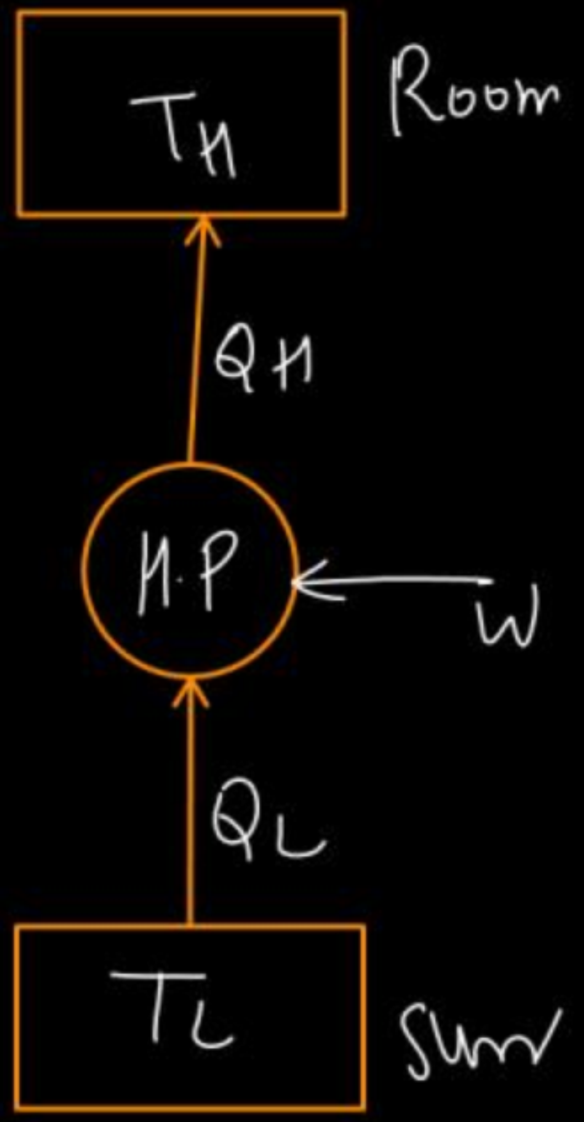
3. $\boxed{Q_H = 5\ kW}$ Ans

$$(COP)_{HP} = 1 + (COP)_R$$

$$(COP)_{HP} = 1 + 2.33$$

4. $\boxed{(COP)_H = 3.33}$ Ans

$\boxed{\text{Heat supplied} = Q_H = 5\ kW}$ Ans



Numerical Problems based on Refrigerator and Heat Pump

Q.4 *A domestic food freezer maintains a temperature of* - 15°C. *The ambient air temperature is* 30°C. It 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 ?

T_L Q_L

given:

$T_L = -15^\circ + 273 \Rightarrow \boxed{T_L = 258 K}$

$T_H = 30^\circ C + 273 \Rightarrow \boxed{T_H = 303 K}$

$Q_L = 1.7 \, kJ/s$

Power = W = ?

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

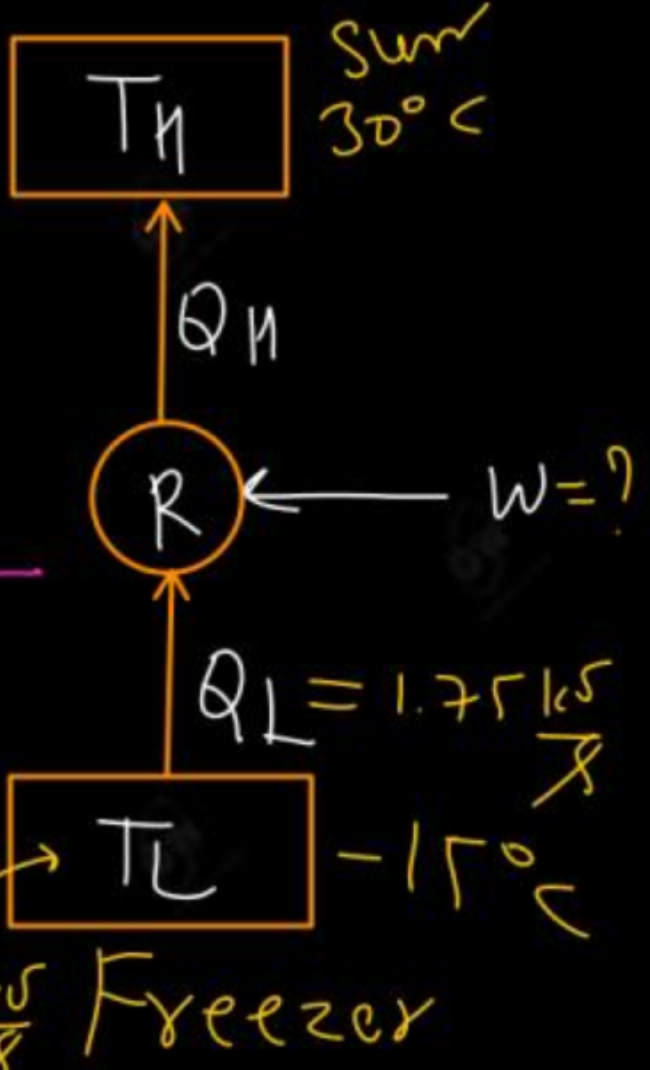
$\underset{\substack{min \\ (least)}}{W} = \frac{Q_L}{(COP)_{max}} \Rightarrow W_{min} = 1.7/5.73$

$\Rightarrow \boxed{W_{min} = 0.296 \, kJ/s}$ Ans

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

$= \frac{258}{303-258}$

$\boxed{(COP)_{max} = 5.73}$



Numerical Problems based on Refrigerator and Heat Pump

Q.5 *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 $\underbrace{12000}_{Q_L}$ kJ/h when power input is 0.75 kW.*

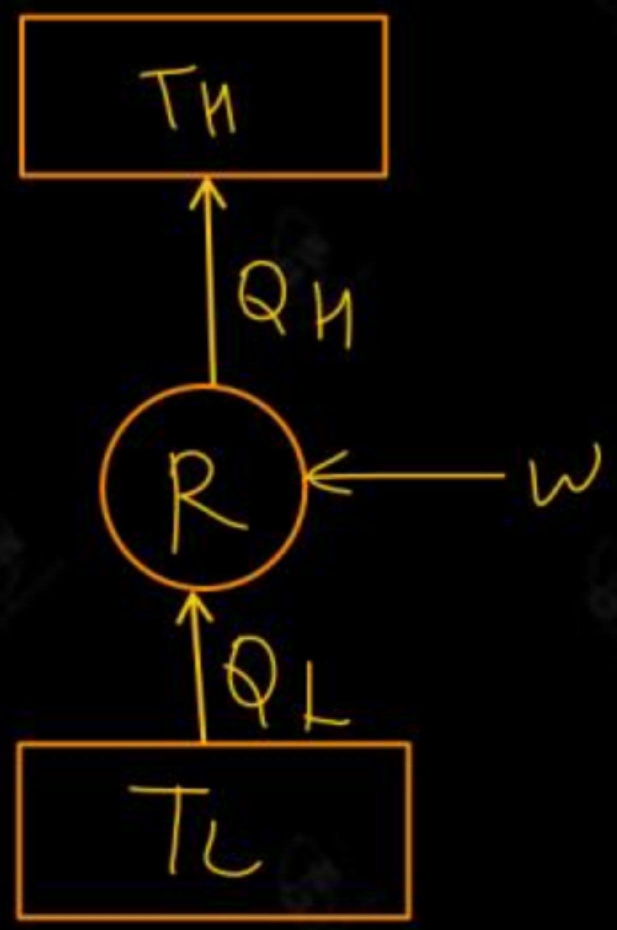
given:

$$\boxed{Q_L = 12000\ \text{kJ/h}}$$

$$W = 0.75\ \text{kW}$$
$$= 0.75\ \text{kJ/s}$$
$$= 0.75 \times 3600\ \text{kJ/h}$$
$$\boxed{W = 2700\ \text{kJ/h}}$$

$$(COP)_R = \frac{Q_L}{W}$$
$$= 12000/2700$$
$$(COP)_R = 4.44$$

$$Q_H = W + Q_L$$
$$Q_H = 2700 + 12000\ [\text{kJ/h}]$$



Q.6 *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.

given: $1\,T.R = 3.5\,kJ/s$

$Q_L = 40\,tons \Rightarrow Q_L = 40 \times 3.5\,\frac{kJ}{s} \Rightarrow \boxed{Q_L = 140\,\frac{kJ}{s}}$

$T_L = -35°C + 273 \Rightarrow T_L = 238\,K$

$T_H = 30°C + 273 \Rightarrow T_H = 303\,K$

Power = W = ?

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

$0.732 = \frac{140}{W} \Rightarrow \boxed{W = 191.25\,\frac{kJ}{s} \text{ or } W = 191.25\,W}$

Ans

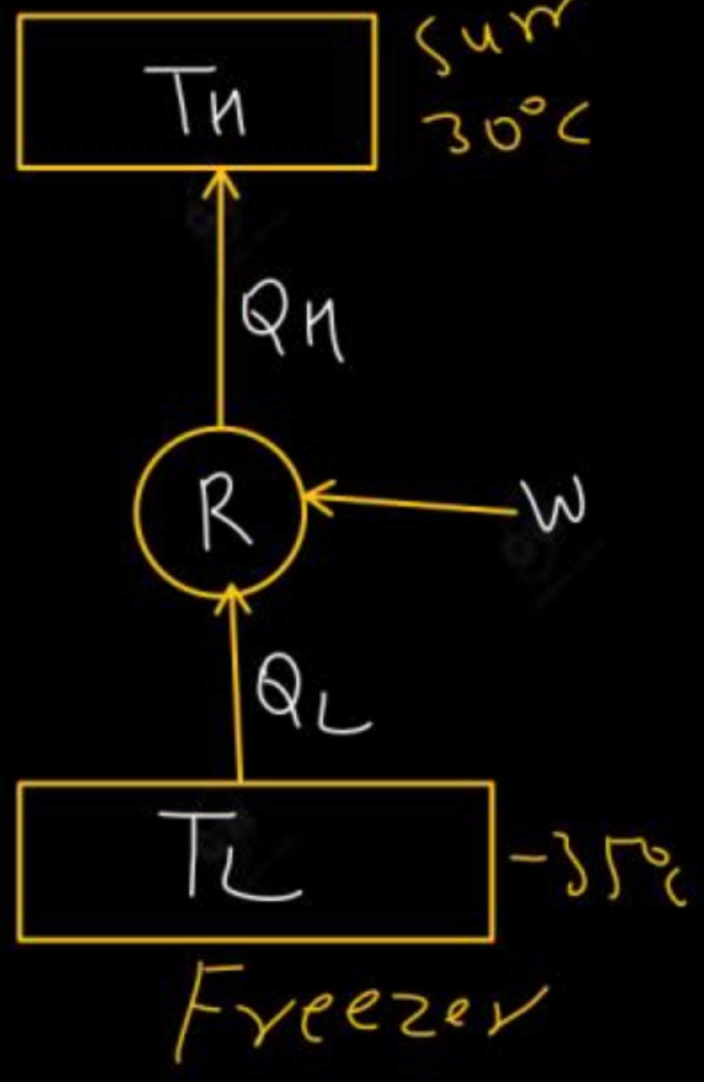
$(COP)_{max} = \frac{T_L}{T_H - T_L}$

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

$= 0.2 \times \frac{T_L}{T_H - T_L}$

$= 0.2 \times \left[\frac{238}{303 - 238}\right]$

$(COP)_{act} = 0.732$



For Pdf Notes

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Thank You