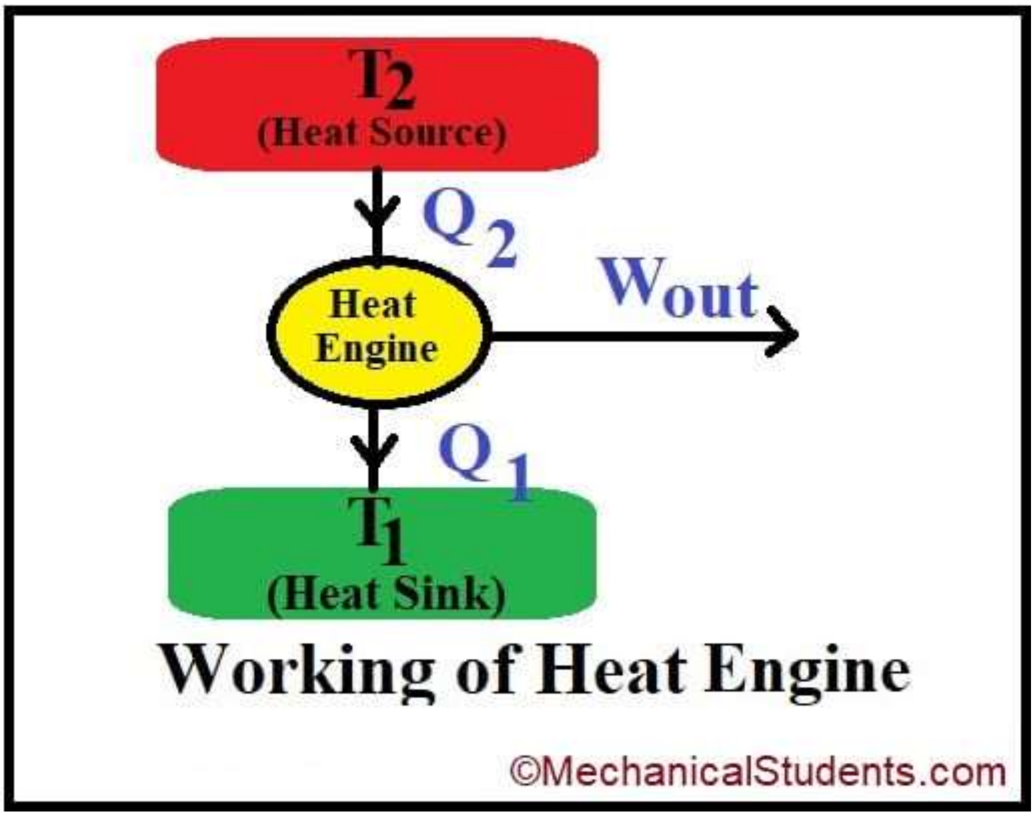
Refrigeration and air conditioning notes

Refrigeration is defined as the process of achieving and maintaining a temperature below that of the surroundings. The aim is to cool some product or space to the required temperature.

Air Conditioning refers to the treatment of air and to simultaneously control its temperature, moisture content, cleanliness, odour and circulation, as required by occupants, a process, or products in the space.

Difference between a Refrigerator, Heat Pump, and Heat Engine

A heat engine is a system that converts Thermal energy into Mechanical Energy.



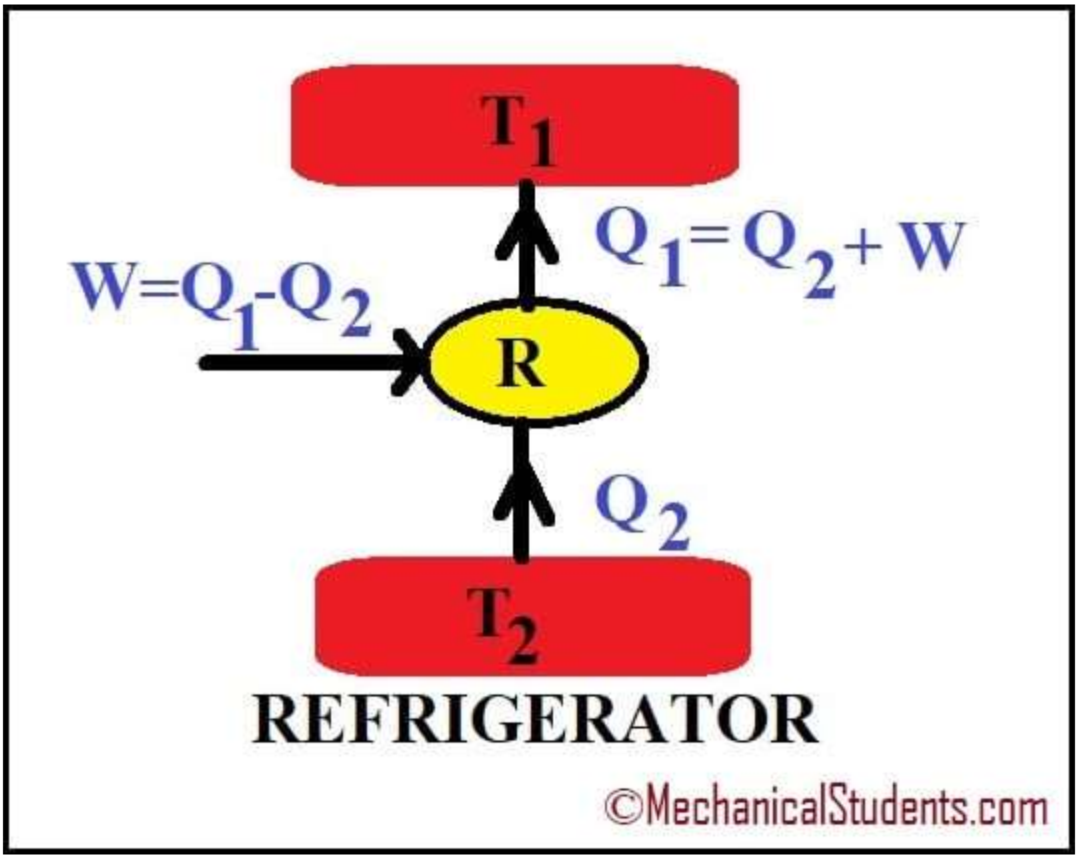
In a heat engine, the heat supplied to the engine is converted into useful work. If **Q2** is the heat supplied to the engine and **Q1** is the heat rejected from the heat engine, then the **network done** by the engine is given by

We = Q2-Q1

So the performance of the engine or Efficiency is given by

Generally, **Efficiency** is calculated as = **We/Q**

A refrigerator is a reversed heat engine, where heat is pumped from low temperature (cold body--> Q1) to high temperature (hot body-->Q2)

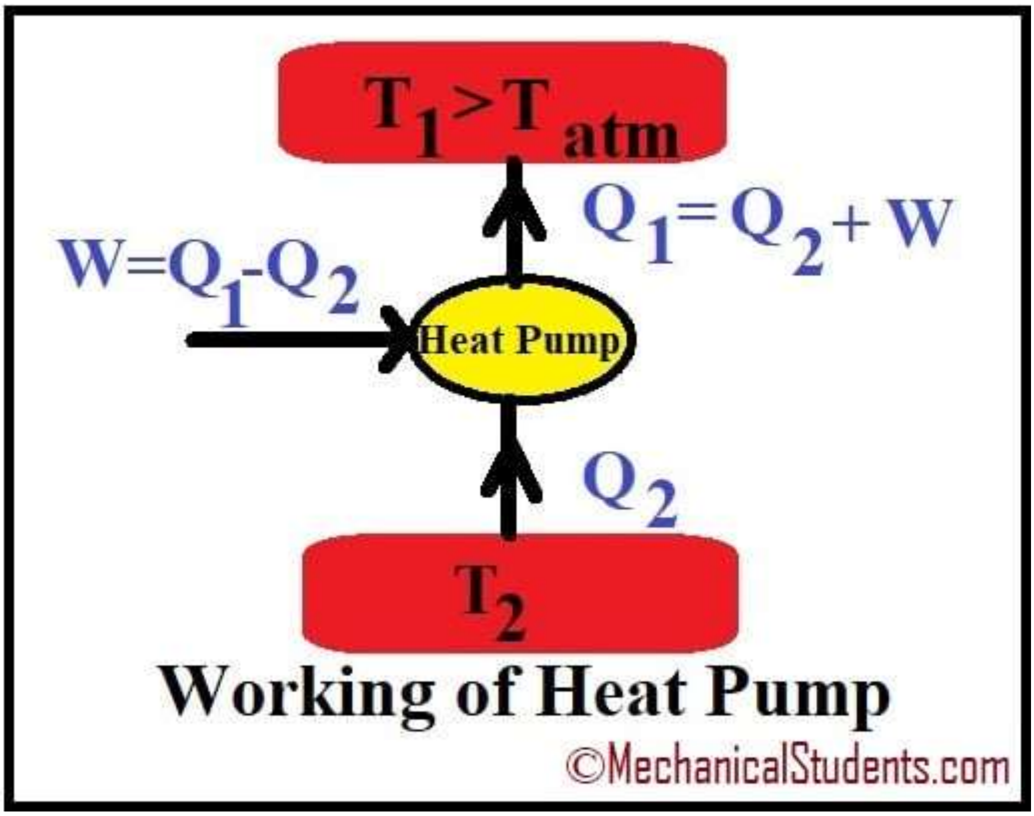


So, Work **WR** is required to be done on the system.

WR = Q2-Q1

The performance of a refrigerator is the "ratio of the amount of heat taken from the Cold body Q1 to the amount of work to be done on the system WR.

Any refrigerating system is a heat pump, which extracts heat from a cold body and delivers it to a hot body.



Thus there is no difference in the operation cycle of a refrigerator and a heat pump.

- The main difference between them is in their operating temperatures.
- A refrigerator works between cold body temperature (T1) and atmospheric temp (Ta) whereas the heat pump operates between hot body temp (T2) and the atmospheric temperature (Ta).
- A refrigerator used for cooling in summer can be used as a heat pump for heating in the winter season.
- so **Wp = Q2-Q1**

Performance of refrigerator and heat pump

COP(Coefficient of performance)

COP is defined as the relationship between the power (kW) that is drawn out of the heat pump as cooling or heat, and the power (kW) that is supplied to the compressor.

the C.O.P is the reciprocal of efficiency and is given as

(C.O.P)R = Q1/ WR = Q1 / (Q2-Q1)----------- for refrigerator

(C.O.P)hp = Q2/ WR = Q2 / (Q2-Q1)------------ for heat pump

Refrigerator	Heat Pump	Heat Engine
A refrigerator is a reversed heat engine, where heat is pumped from a body at low temperature to a body at high temperature.	Any refrigerating system is a heat pump, which extracts heat from a cold body and delivers it to a hot body.	A heat engine is a system which converts Thermal energy into Mechanical Energy.
The **network done** by the refrigerator is given by W**R= Q2-Q1**	The **network done** by the heat pump is given by W**p= Q2-Q1**	The **network done** by the engine is given b We**= Q2-Q1**
The C.O.P. of Refrigerator is **(C.O.P)R = Q1/ WR = Q1 / (Q2-Q1)**	The C.O.P. of heat pump is **(C.O.P)hp = Q2/ WR = Q2 / (Q2-Q1)**	The C.O.P. of heat engine is **(C.O.P)e= (Q2-Q1)/Q2**

Unit of refrigeration

Rating for Refrigeration indicates the rate of removal heat. The unit of refrigeration is expressed in terms of ton of refrigeration (TR). One ton of refrigeration is defined as the amount of refrigeration effect (heat transfer rate) produced during uniform melting of one ton (1000kg) of ice at 0°C to the water at the 0°C in 24 hours.

Calculation for one ton of refrigeration

Latent heat of ice is 335KJ/kg (heat absorbed during melting of one kg ice)
1 Ton of refrigeration, 1TR= 1000*335 in 24 hours

$=(1000\times335)/(24\times60)$ in one minute
$= 232.6$ kJ/min

Theoretically one Ton of refrigeration taken as 232.6kJ/min, in actual practice, it is taken as 210kJ/min.
1 ton of refrigeration approximately equal to 3.5kW.

Lecture note-2

Sub-Refrigeration and air conditioning

Sem- 5th sem diploma mechanical engg

Open and Closed Type of Refrigeration System – Advantages and Application

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Air cycle refrigeration is one of the earliest methods used for cooling. The key features of this method is that, the refrigerant air remain gaseous state throughout the refrigeration cycle. Based on the operation, the air refrigeration system can be classified into

1. Open air refrigeration cycle
2. Closed refrigeration cycle

Open air refrigeration cycle

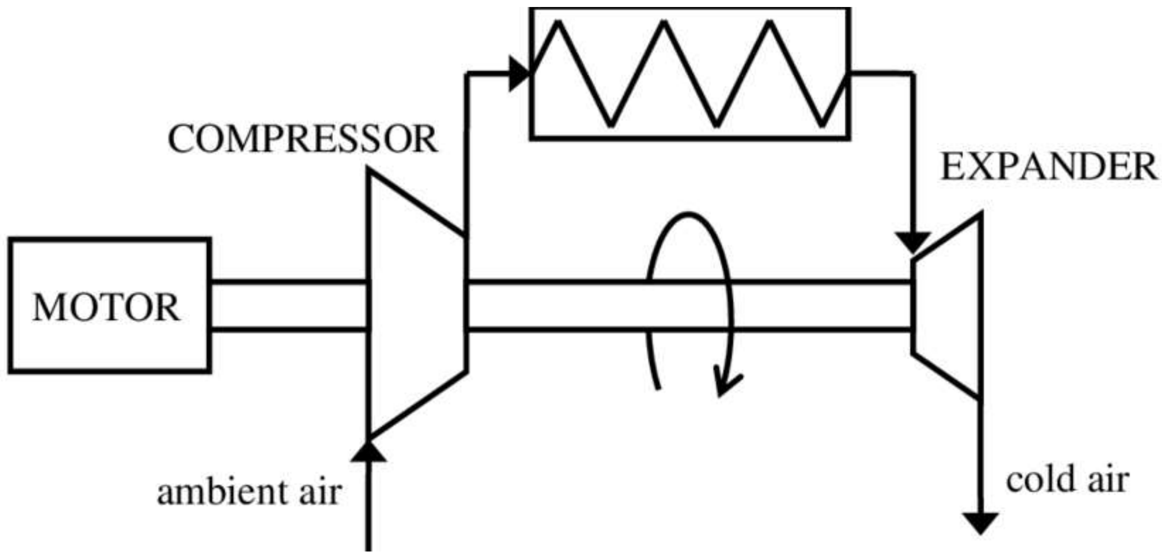
In an open refrigeration system, the air is directly passed over the space is to be cooled, and allowed to circulate through the cooler. The pressure of open refrigeration cycle is limited to the atmospheric pressure. A simple diagram of the open-air Refrigeration system is given below.

Advantages and application

- It eliminates the need of a heat exchanger.
- It is used in aircraft because it helps to achieve cabin pressurization and air conditioning at once

Disadvantages

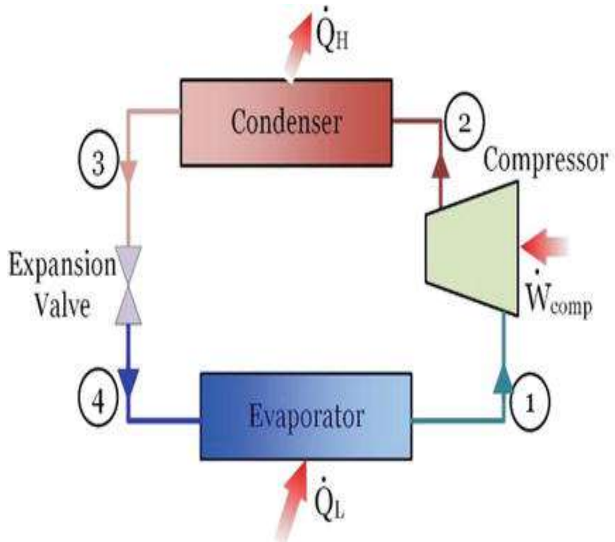
One of the disadvantages of this system is that its large size. The air supplied to the refrigeration system is at atmospheric pressure, so the volume of air handled by the system is large. Thus the size of compressor and expander also should be large. Another disadvantage of the open cycle system is that the moisture is regularly carried away by the circulating air, this leads to the formation of frost at the end of the expansion process and clogs the line, and hence a use of dryer is preferable to the open air refrigeration system.

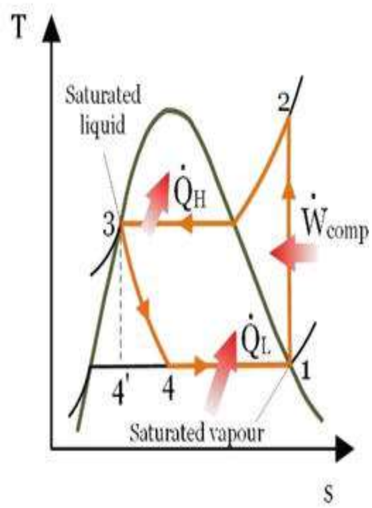


Open air refrigeration system

Closed refrigeration system / Dense air refrigeration cycle

In closed or dense air refrigeration cycle, air refrigerant is contained within pipes and component part of the system at all time. The circulated air does not have to direct contact with the space to be cooled. The air is used to cool another fluid (brine), and this fluid is circulated into the space to be cooled. So the disadvantages listed in open air refrigeration can be eliminated. The advantages of closed air refrigeration system are listed below.





Advantages

- The suction to the compressor may be at high pressure, therefore the volume of air handled by the compressor and expander is low when compared to an open system. Hence the size of compressor and expander is small compared to the open air system.
- The chance of freezing of moister and choke the valve is eliminated.

- In this system, higher coefficient of performance can be achieved by reducing operating pressure ratio.

Lecture note

Sub-Refrigeration and air conditioning

Sem- 5th sem diploma mechanical engg.

Air Refrigerator Working On Bell-Coleman Cycle with PV and TS Diagram (Reversed Brayton or Joule Cycle)

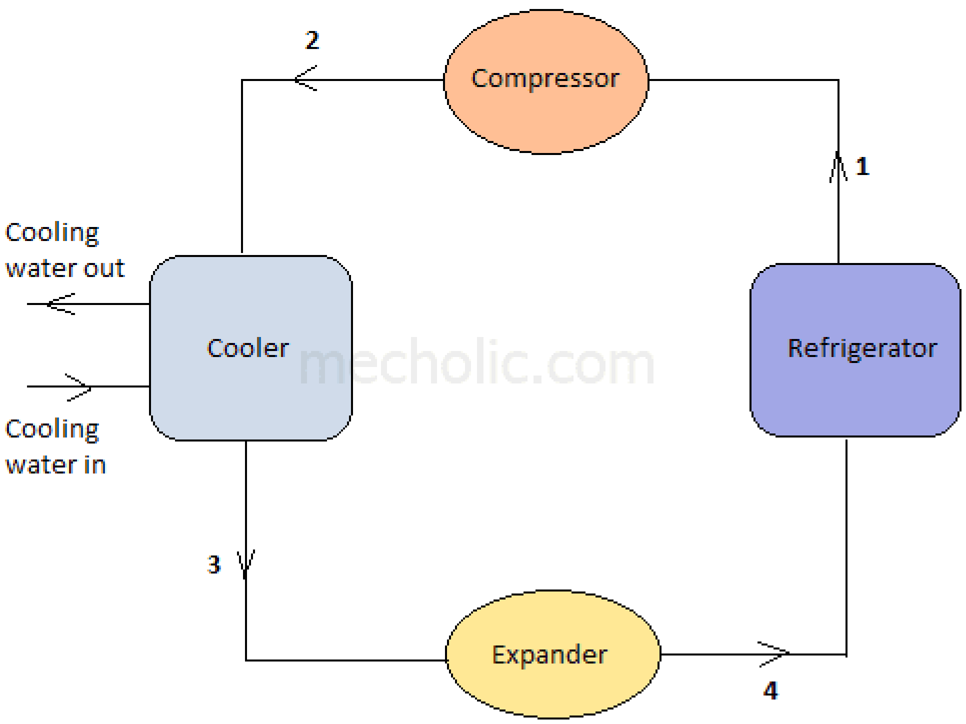
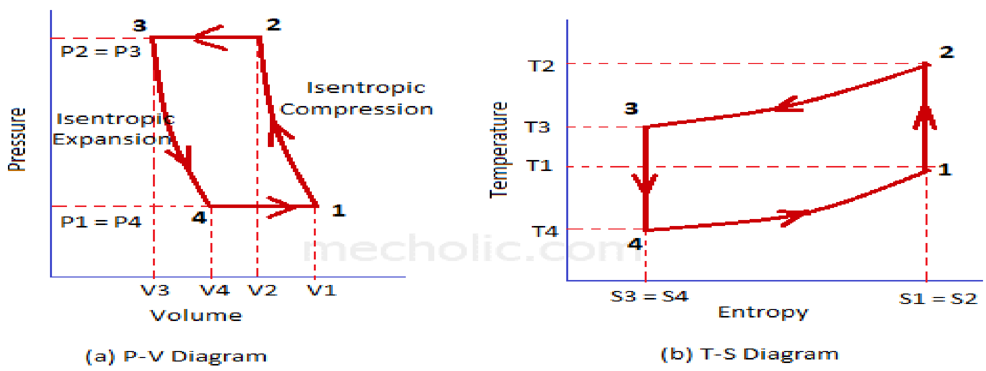
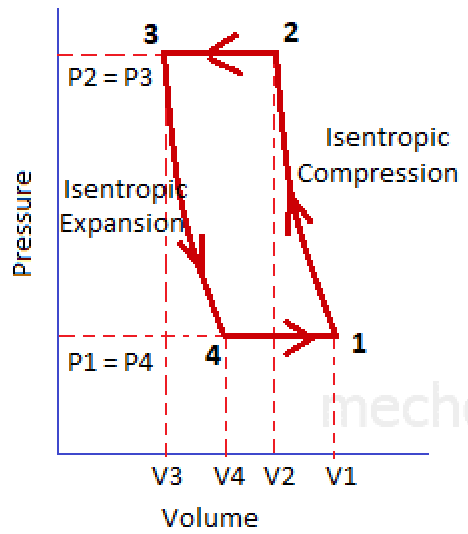


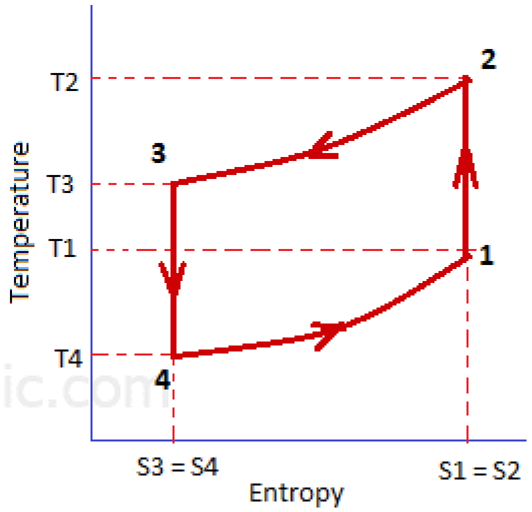
Fig shows a schematic diagram of Bell-Coleman refrigerator (reverse Brayton or joule cycle). This refrigeration system components consists of a compressor, cooler, Expander, and refrigerator. In this process, heat absorption and rejection follows at the constant pressure; the compression and expansion of process are isentropic.

Process in Bell-Coleman refrigeration





(a) P-V Diagram



(b) T-S Diagram

Fig show P-V and T-S diagram of bell coleman refrigerator. Here P_1, V_1, T_1, S_1 represents the pressure, volume, temperature, entropy of air respectively at point 1. And so on. It represents the corresponding condition of air when it passed through the component.

1-2: Isentropic Compression
The Air drawn from refrigerator to air compressor cylinder where it compressed isentropically (constant entropy). No heat transfer by the air. During compression, the volume decreases while the pressure and temperature of air increases.

2-3: Constant pressure cooling process.
The warm compressed air is then passed through cooler, where it cooled down at constant pressure. The heat rejected per kg of air during this process is equal to
$q_{2-3} = Cp(T_2-T_3)$

3-4: isentropic expansion
No heat transfer takesplcae. The air expands isentropically in expander cylinder. During expansion, the volume increases, Pressure P3 reduces to P_4. (P_4 = atmospheric pressure). Temperature also falls during expansion from T_3-T_4.

4-1: Constant pressure expansion
Heat transfer from the refrigerator to air. The temperature increases from T_4 to T_1. Volume increases to V_4 due to heat transfer. Heat absorbed by air per kg during this process is equal to
$q_{4-1} = Cp(T_1-T_4)$

Equation of Coefficient of performance (COP) of Bell Coleman cycle

Heat absorbed during cycle per kg of air $q_{4-1} = Cp(T_1-T_4)$
Heat rejected during cycle per kg of air $q_{2-3} = Cp(T_2-T_3)$
Then the work done per kg of air during the cycle is = Heat rejected – Heat absorbed

$= Cp(T_2-T_3) - Cp(T_1-T_4)$
Coefficient of performance,

$$C.O.P. = \frac{Heat\ absorbed}{Work\ done} = \frac{C_p(T_1 - T_4)}{C_p(T_2 - T_3) - C_p(T_1 - T_4)}$$

$$= \frac{(T_1 - T_4)}{(T_2 - T_3) - (T_1 - T_4)}$$

$$C.O.P. = \frac{T_4(\frac{T_1}{T_4} - 1)}{T_3(\frac{T_2}{T_3} - 1) - T_4(\frac{T_1}{T_4} - 1)} \quad \text{(i)}$$

For isentropic compression process 1-2

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} \quad \text{(ii)}$$

For isentropic expansion process 3-4

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} \quad \text{(iii)}$$

Since, P2 = P3 and P1 = P4, therefore from equation (ii) and (iii)

Substitute equation (iv) in (i)

$$C.O.P. = \frac{T_4}{T_3 - T_4} = \frac{1}{\frac{T_3}{T_4} - 1}$$

$$= \frac{1}{\left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} - 1} = \frac{1}{\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1}$$

$$C.O.P. = \frac{1}{(r_p)^{\frac{\gamma-1}{\gamma}} - 1}$$

$$r_p = Compression\ or Expansion\ ratio = \frac{P_2}{P_1} = \frac{P_3}{P_4}$$