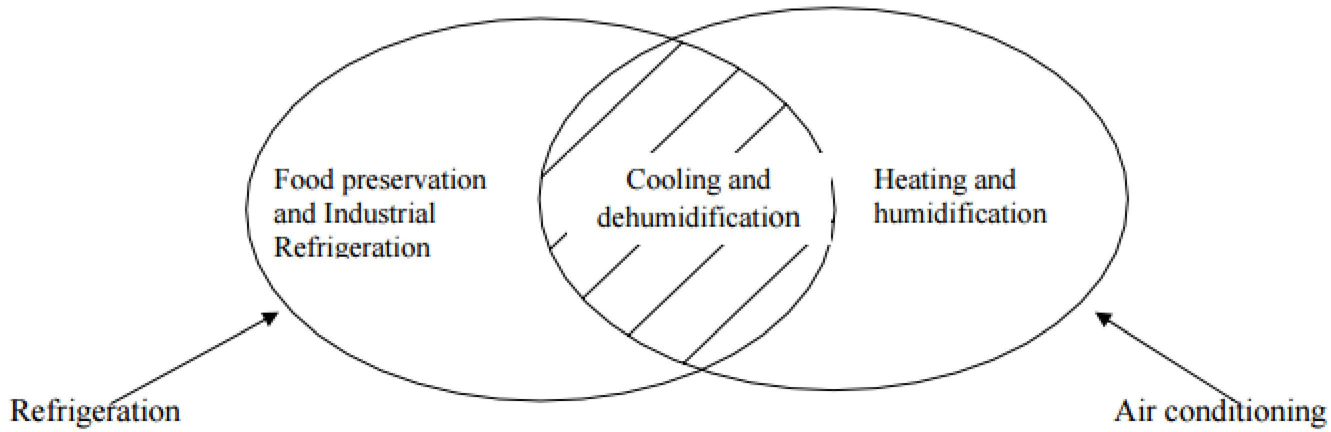
REFRIGERATION AND AIR CONDITIONING

Introduction

- Refrigeration may be defined as the process of achieving and maintaining a temperature below that of the surroundings, the aim being to cool some product or space to the required temperature.
- One of the most important applications of refrigeration has been the preservation of perishable food products by storing them at low temperatures.
- Refrigeration systems are also used extensively for providing thermal comfort to human beings by means of air conditioning.

- Air conditioning refers to the treatment of air so as to simultaneously control its temperature, moisture content, cleanliness, odour and circulation, as required by occupants, a process, or products in the space.
- The subject of refrigeration and air conditioning has evolved out of human need for food and comfort, and its history dates back to centuries.

RELATION BETWEEN REFRIGERATION AND AIR CONDITIONING



- Refrigeration and air conditioning are generally treated in a single subject due to the fact that one of the most important applications of refrigeration is in cooling and dehumidification as required for summer air conditioning.

HISTORY OF REFRIGERATION

Natural refrigeration

In olden days refrigeration was achieved by natural means such as the use of ice or evaporative cooling. In earlier times, ice was either:

1. Transported from colder regions,
2. Harvested in winter and stored in ice houses for summer use or,
3. Made during night by cooling of water by radiation to stratosphere.

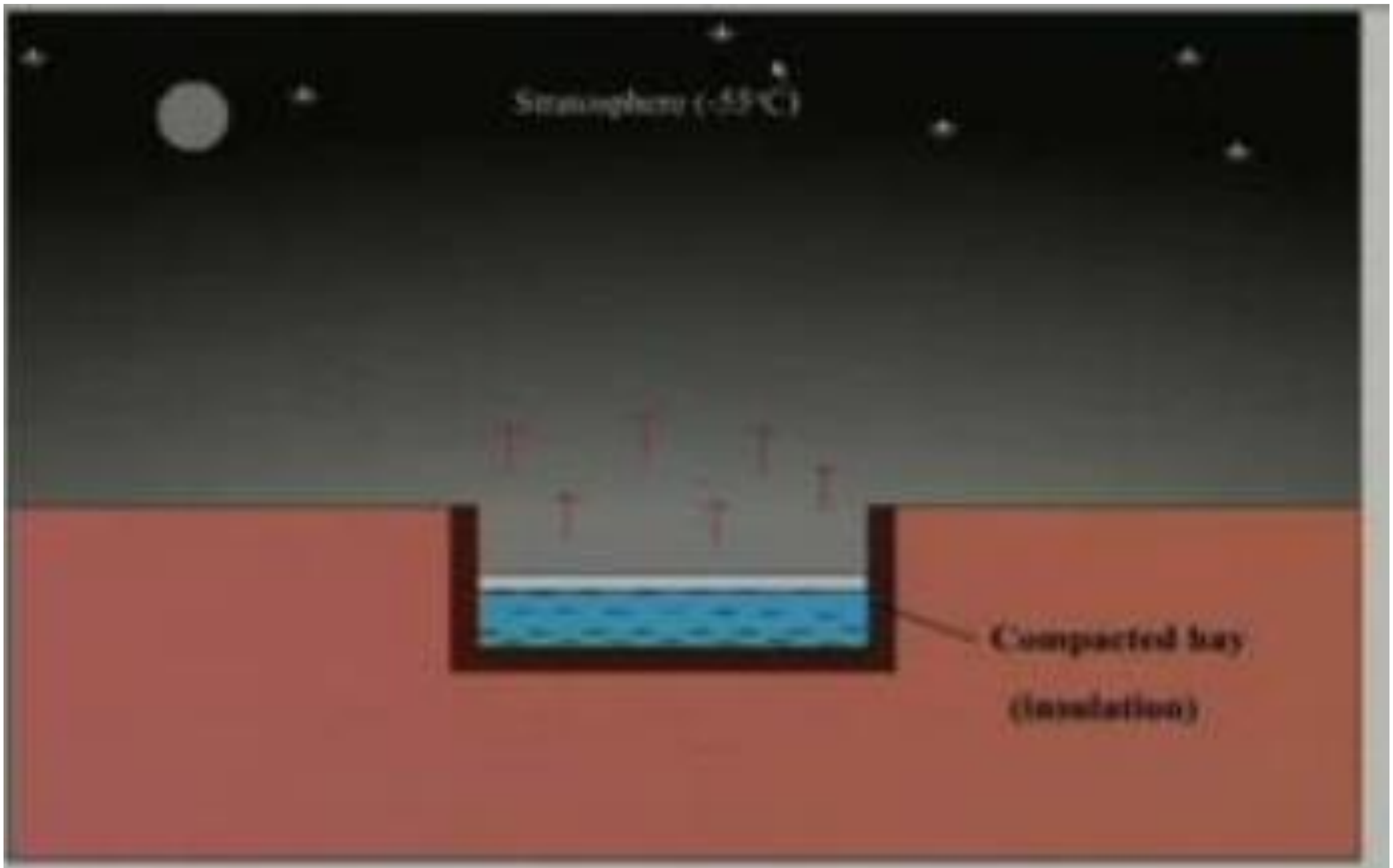
- In Europe, America and Iran a number of icehouses were built to store ice.
- Materials like sawdust or wood shavings were used as insulating materials in these icehouses.
- Later on, cork was used as insulating material. Literature reveals that ice has always been available to aristocracy who could afford it.
- In India, the Moghul emperors were very fond of ice during the harsh summer in Delhi and Agra, and it appears that the ice used to be made by nocturnal cooling.

- In **1806, Frederic Tudor,** (who was later called as the "ice king") began the trade in ice by cutting it from the Hudson River and ponds of Massachusetts and exporting it to various countries including India.
- In India Tudor's ice was cheaper than the locally manufactured ice by nocturnal cooling.
- **The ice trade in North America was a flourishing business.**
- Ice was transported to southern states of America in train compartments insulated by 0.3m of cork insulation.
- Trading in ice was also popular in several other countries such as **Great Britain, Russia, Canada, Norway and France**.
- In these countries ice was either transported from colder regions or was harvested in winter and stored in icehouses for use in summer.
- The **ice trade reached its peak in 1872** when America alone exported 225000 tonnes of ice to various countries as far as China and Australia.
- However, with the advent of artificial refrigeration the ice trade gradually declined.

Art of Ice making by Nocturnal Cooling

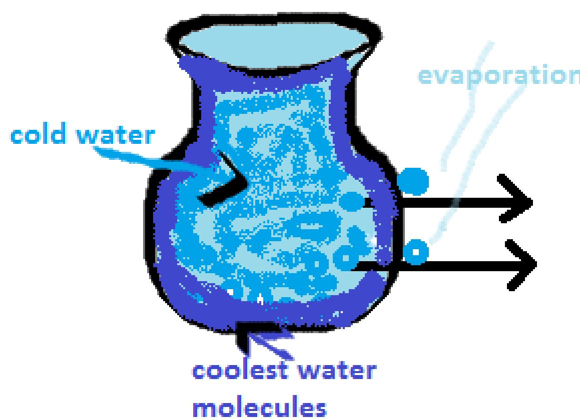
- The art of making ice by nocturnal cooling was perfected in India.
- In this method ice was made by keeping a thin layer of water in a shallow earthen tray, and then exposing the tray to the night sky.
- Compacted hay of about 0.3 m thickness was used as insulation.
- The water looses heat by radiation to the stratosphere, which is at around -55° C and by early morning hours the water in the trays freezes to ice.
- This method of ice production was very popular in India.

Art of Ice making by Nocturnal Cooling



Evaporative Cooling

- Evaporative cooling is the process of reducing the temperature of a system by evaporation of water.
- The water permeates through the pores of earthen vessel to its outer surface where it evaporates to the surrounding, absorbing its latent heat in part from the vessel, which cools the water.
- Eg. - Evaporative cooling by placing wet straw mats on the windows
  - Dessert coolers



Cooling by Salt Solutions

- Certain substances such as common salt, when added to water dissolve in water and absorb its heat of solution from water (endothermic process).
- This reduces the temperature of the solution (water+salt).
- Sodium Chloride salt (NaCl) can yield temperatures up to -20˚C and Calcium Chloride ($CaCl_2$) up to - 50˚C in properly insulated containers.
- However, as it is this process has limited application, as the dissolved salt has to be recovered from its solution by heating.

Artificial refrigeration

- Vapour compression refrigeration system
- Vapour absorption refrigeration system
- Steam jet refrigeration system
- Solar energy refrigeration system

APPLICATION OF REFRIGERATION AND AIR CONDITIONING

Applications of refrigeration

- Food processing, preservation and distribution
- Chemical and process industries
- Special Applications
- Comfort air-conditioning

Food processing, preservation and distribution

- Food processing is one of the classical and most important application of refrigeration
- It is well known that food products can be preserved for a longer time, if stored at low temperatures
- Both live as well as dead products can be preserved for longer times using refrigeration
- Spoilage of foods take place mainly because of two reasons a. bacterial decay b. enzymatic processing

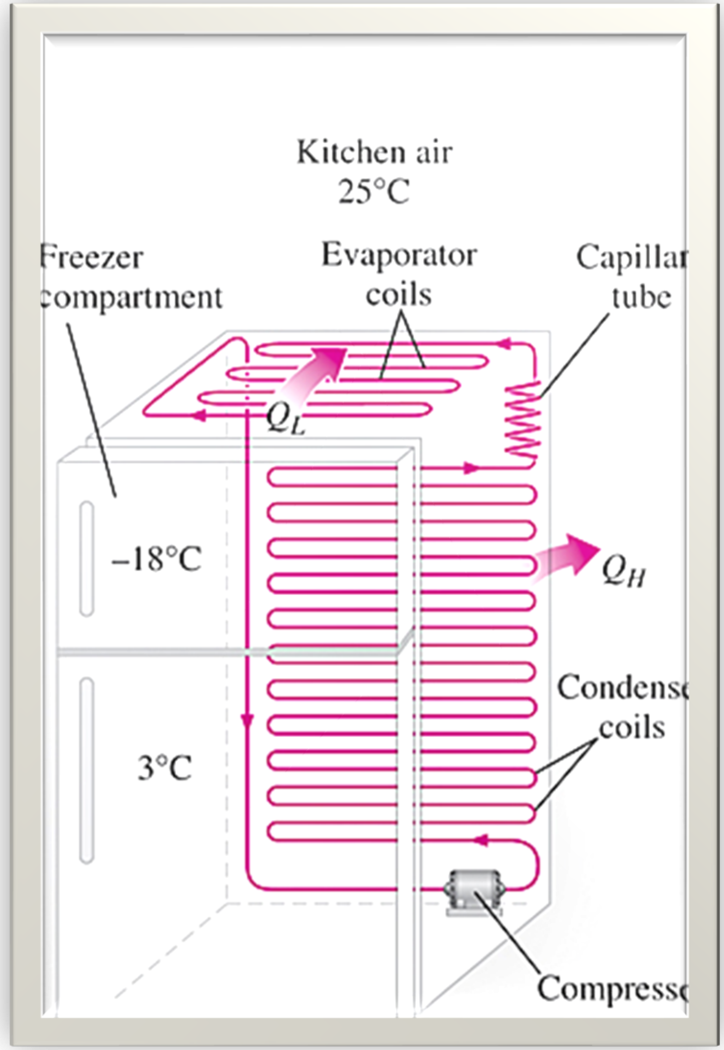
Food processing, preservation and distribution

- **Storage of raw fruits and vegetables**
- **Storage of fish, meat and poultry for longer periods in frozen condition**
- **Dairy products such as milk, butter, ice cream require refrigeration at various temperatures during processing and also during storage**
- **Beverages such as fruit juice, cold drinks, wine, beer etc. also require refrigeration during processing and storage**
- **Processing and distribution of frozen food**
- **Cold chain**

Cold chain

- For effective preservation of food products a cold chain is required
- A typical cold chain for fresh products consists of the following steps:
  - Refrigeration for post harvest treatment
  - Refrigerated transport
  - Refrigeration during food processing
  - Cold storage for storing food
  - Refrigeration for retail supermarkets
  - Refrigeration at end users place

Domestic refrigerator



Application of air conditioning

- Industrial air conditioning
  - Laboratories
  - Printing
  - Manufacturing of precision parts
  - Textile industry
  - Pharmaceutical industries
  - Farm animals
  - Computer rooms
  - Vehicular air conditioning
- Comfort air conditioning
  - Residence
  - Office
  - Theatres
  - Restaurants
  - Hospitals

Air conditioners

Conclusions

- The scope of refrigeration is very wide and applications are very diverse
- Literally thousands of scientists and engineers have contributed towards its development
- Current issues of concern are related to the development of eco-friendly and energy efficient systems that meet the requirement of the end user

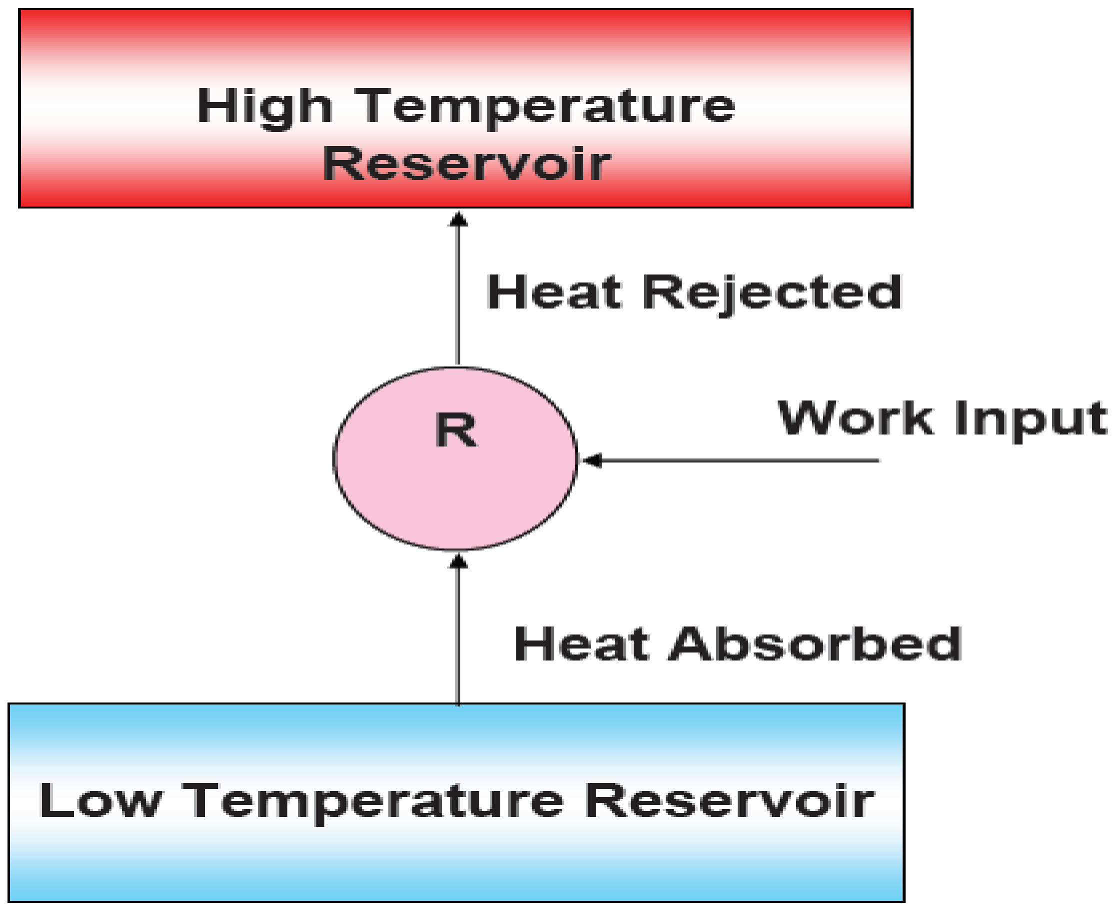
Unit of refrigeration and coefficient of performance

Unit of refrigeration

- The practical unit of refrigeration is expressed in terms of 'tonne of refrigeration' (briefly written as TR).
- A tonne of refrigeration is defined as the amount of refrigeration effect produced by the uniform melting of one tonne (1000 kg) of ice from 0° C in 24 hours.

1 TR = 210 kJ/min or 3.5 kW

Working of a refrigerator



Coefficient of performance

The coefficient of performance (briefly written as C. O. P) is the ratio of heat extracted in the refrigerator to the work done on the refrigerant. It is also known as theoretical coefficient of performance. Mathematically,

$$\text{Theoretical C. O. P} = \frac{Q}{W}$$

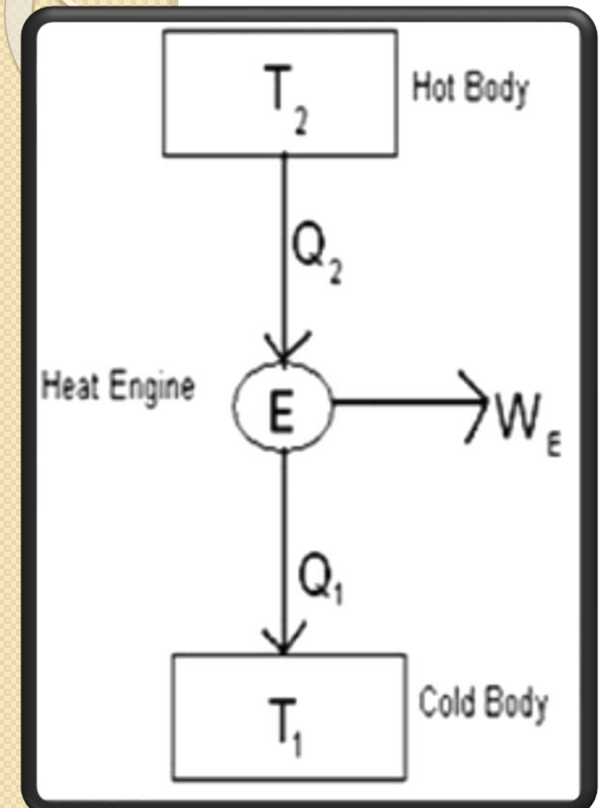
Where Q = Amount of heat extracted in the refrigerator (or the amount of refrigeration produced, or the capacity of a refrigerator),

W = Amount of work done.

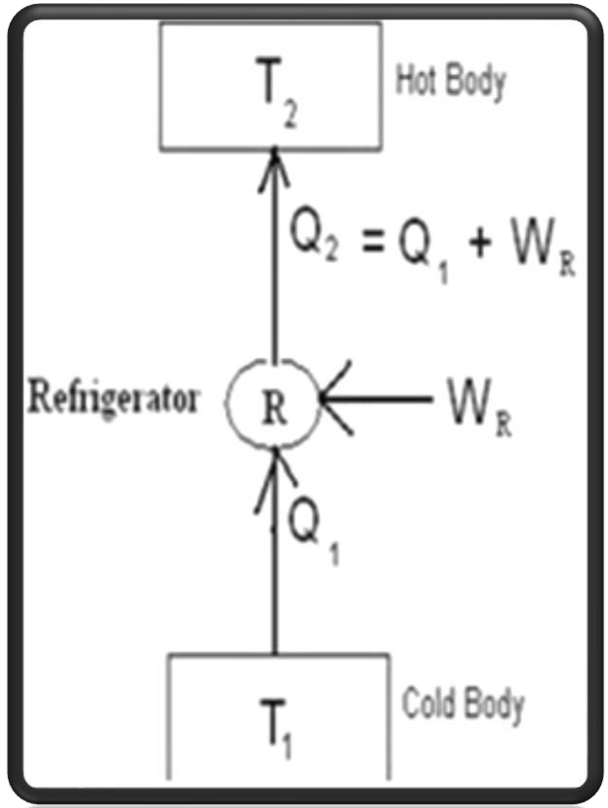
1. For per unit mass, C. O. P. = $\frac{q}{w}$
2. The coefficient of performance is the reciprocal of the efficiency(i.e. $1/\eta$) of a heat engine. It is thus obvious, that the value of C. O. P. is always greater than unity.
3. The ratio of the actual C. O. P to the theoretical C. O. P is known as relative coefficient of performance. Mathematically,

$$\text{Relative C. O. P.} = \frac{\text{Actual C. O. P.}}{\text{Theoretical C. O. P.}}$$

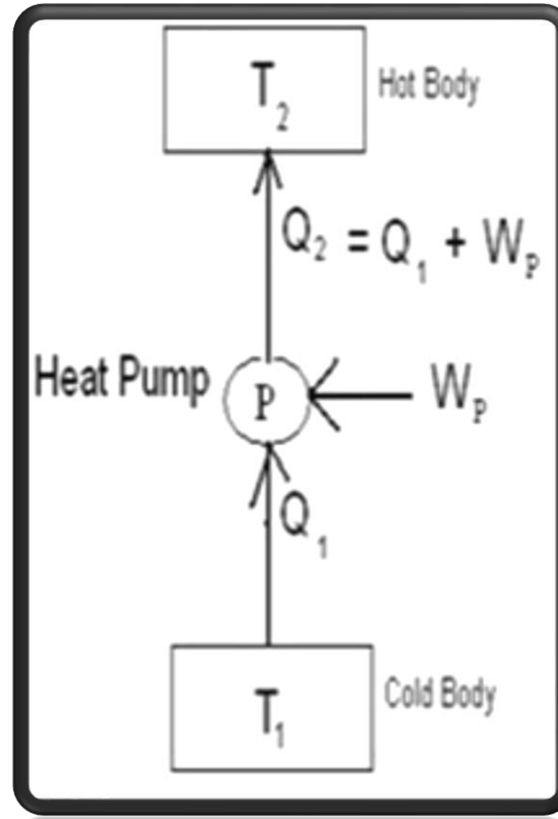
Difference between a Heat Engine, Refrigerator and Heat Pump



Heat Engine



Refrigerator



Heat pump

COP of Heat Engine, Refrigerator and Heat Pump

Heat Engine η_E or $(C.O.P)_E = \dfrac{Workdone}{\text{Heat supplied}} = \dfrac{W_E}{Q_2} = \dfrac{Q_2 - Q_1}{Q_2}$

Refrigerator $(C.O.P.)_R = \dfrac{Q_1}{W_R} = \dfrac{Q_2}{Q_2 - Q_1}$

Heat pump $(C.O.P.)_P = \dfrac{Q_2}{W_P} = \dfrac{Q_2}{Q_2 - Q_1}$

$$= \frac{Q_1}{Q_2 - Q_1} + 1 = (C.O.P.)_R + 1$$