POLITECNICO DI MILANO

Refrigeration Basics, decentralized cooling systems

Ref :Ashrae Handbook of fundamentals

Energy and Environmental Technologies for Building Systems

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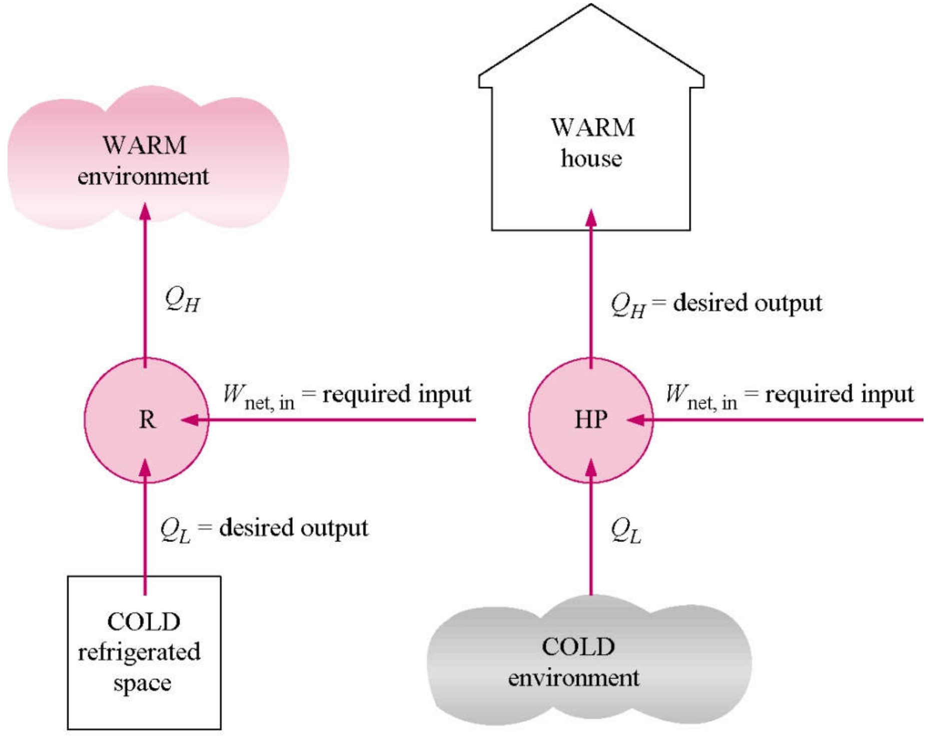
Refrigeration cycle

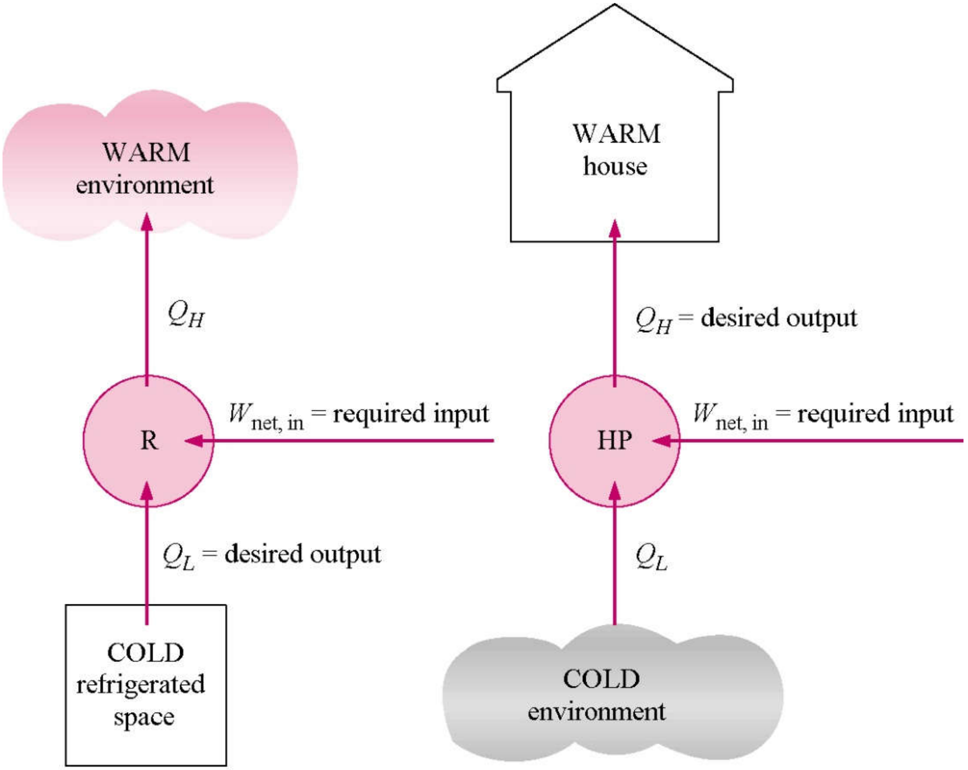
The vapor compression refrigeration cycle is a common method for transferring heat from a low temperature to a high temperature.



(*a*) Refrigerator (*b*) Heat pump

The above figure shows the objectives of refrigerators and heat pumps. The purpose of a refrigerator is the removal of heat, called the cooling load, from a low-temperature medium. The purpose of a heat pump is the transfer of heat to a high-temperature medium, called the heating load.

Refrigeration cycle



(*a*) Refrigerator (*b*) Heat pump

When we are interested in the heat energy removed from a low-temperature space, the device is called a refrigerator. When we are interested in the heat energy supplied to the high-temperature space, the device is called a heat pump. In general, the term heat pump is used to describe the cycle as heat energy is removed from the low-temperature space and rejected to the high-temperature space.

Refrigeration cycle

The performance of refrigerators and heat pumps is expressed in terms of *coefficient of performance* (COP), defined as

$$COP_R = \frac{\text{Desired output}}{\text{Required input}} = \frac{\text{Cooling effect}}{\text{Work input}} = \frac{Q_L}{W_{net,in}}$$

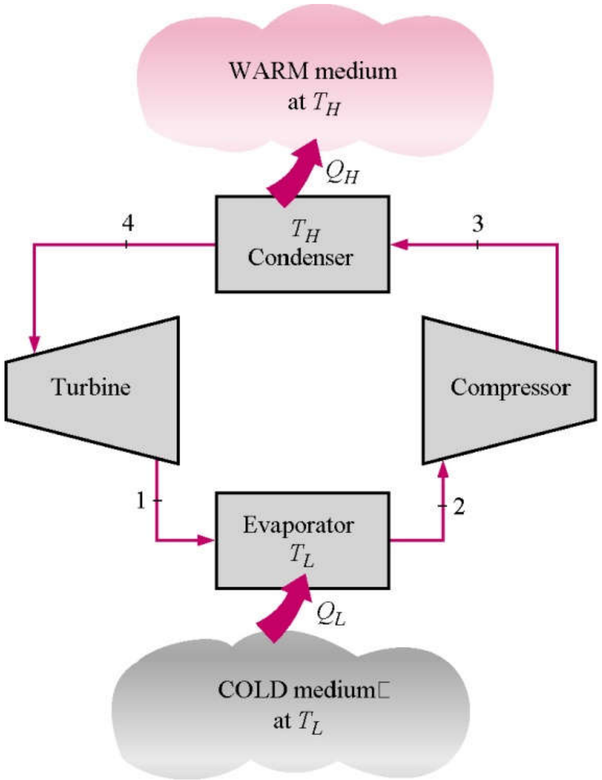
$$COP_{HP} = \frac{\text{Desired output}}{\text{Required input}} = \frac{\text{Heating effect}}{\text{Work input}} = \frac{Q_H}{W_{net,in}}$$

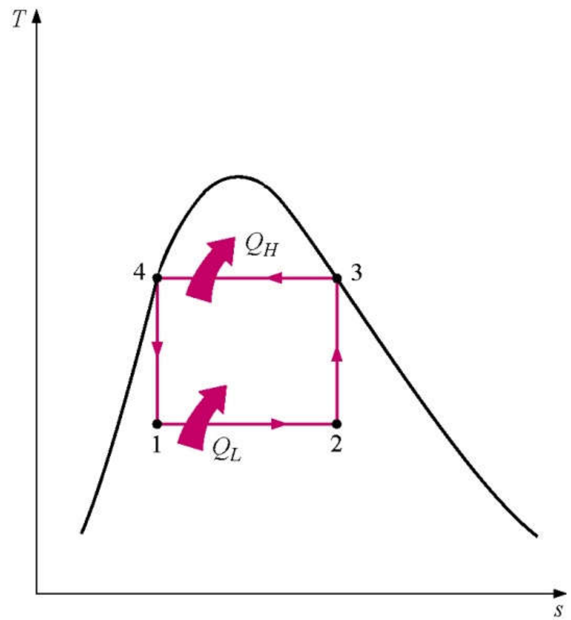
Both COP_R and COP_{HP} can be larger than 1. Under the same operating conditions, the COPs are related by

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

Reversed Carnot Refrigerator and Heat Pump

Shown below are the cyclic refrigeration device operating between two constant temperature reservoirs and the *T-s* diagram for the working fluid when the reversed Carnot cycle is used. Recall that in the Carnot cycle heat transfers take place at constant temperature. If our interest is the cooling load, the cycle is called the Carnot refrigerator. If our interest is the heat load, the cycle is called the Carnot heat pump.





Reversed Carnot Refrigerator and Heat Pump

The standard of comparison for refrigeration cycles is the *reversed Carnot cycle.* A refrigerator or heat pump that operates on the reversed Carnot cycle is called a *Carnot refrigerator* or a *Carnot heat pump,* and their COPs are

$$COP_{R,Carnot} = \frac{1}{T_H / T_L - 1} = \frac{T_L}{T_H - T_L}$$

$$COP_{HP,Carnot} = \frac{1}{1 - T_L / T_H} = \frac{T_H}{T_H - T_L}$$

Notice that a turbine is used for the expansion process between the high and low-temperatures. While the work interactions for the cycle are not indicated on the figure, the work produced by the turbine helps supply some of the work required by the compressor from external sources.

Why not use the reversed Carnot refrigeration cycle?

- Easier to compress vapor only and not liquid-vapor mixture.
- Cheaper to have irreversible expansion through an expansion valve.

Vapor-compression refrigeration cycle

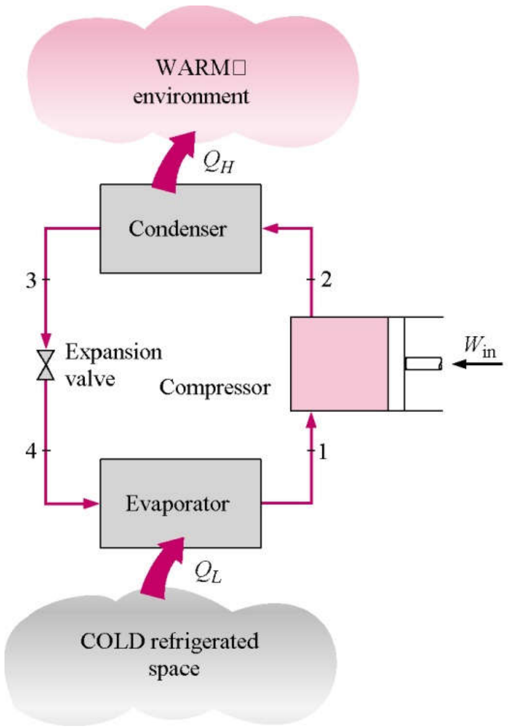
The vapor-compression refrigeration cycle has four components: evaporator, compressor, condenser, and expansion (or throttle) valve. The most widely used refrigeration cycle is the *vapor-compression refrigeration cycle.* In an ideal vapor-compression refrigeration cycle, the refrigerant enters the compressor as a saturated vapor and is cooled to the saturated liquid state in the condenser. It is then throttled to the evaporator pressure and vaporizes as it absorbs heat from the refrigerated space.

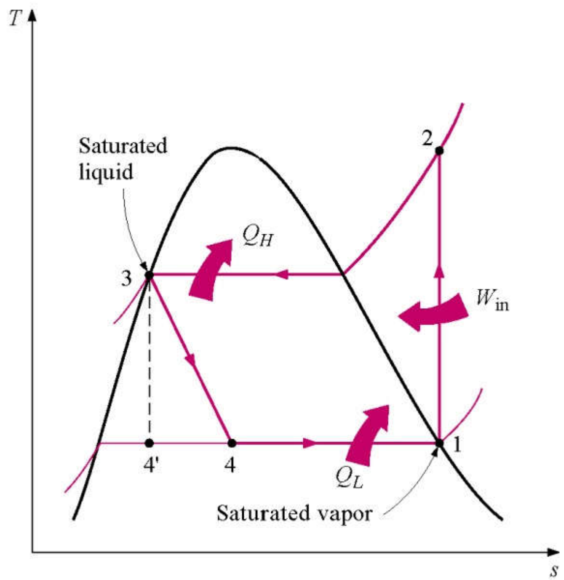
The ideal vapor-compression cycle consists of four processes.

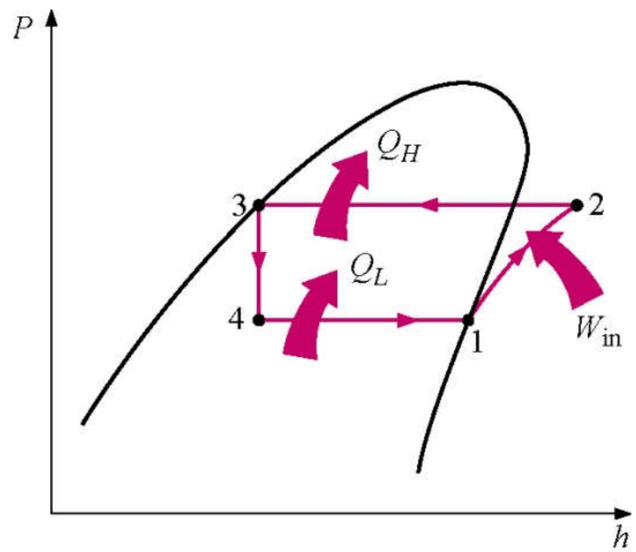
Ideal Vapor-Compression Refrigeration Cycle

Process	Description
1-2	Isentropic compression
2-3	Constant pressure heat rejection in the condenser
3-4	Throttling in an expansion valve
4-1	Constant pressure heat addition in the evaporator

Vapor-compression refrigeration cycle

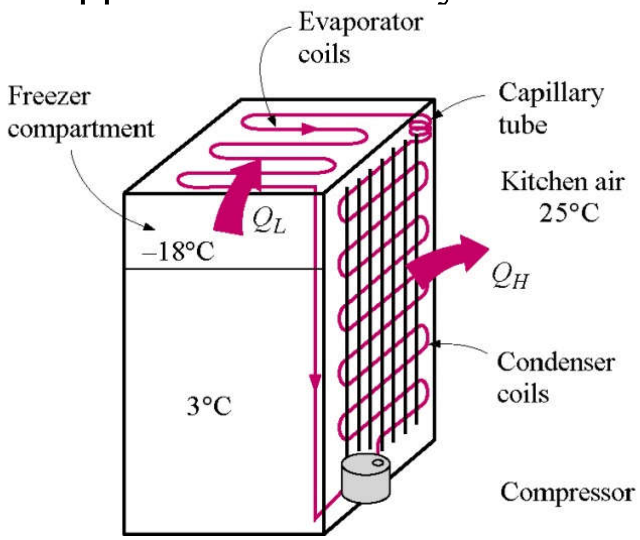






Vapor-compression refrigeration cycle

The ordinary household refrigerator is a good example of the application of this cycle.



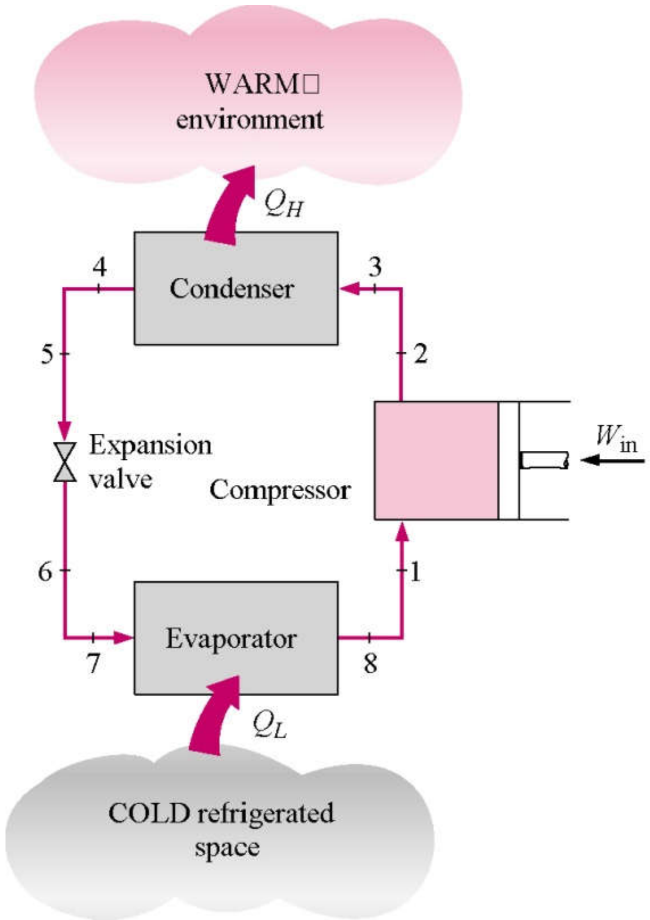
Results of First and Second Law Analysis for Steady-Flow

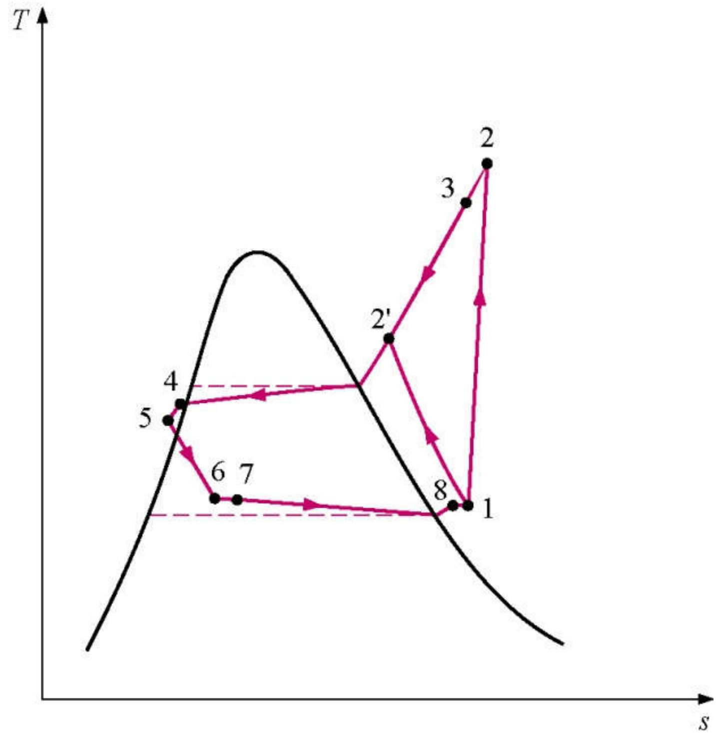
Component	Process	First Law Result
Compressor	s = const.	$\dot{W}_{in} = \dot{m}(h_2 - h_1)$
Condenser	P = const.	$\dot{Q}_H = \dot{m}(h_2 - h_3)$
Throttle Valve	$\Delta s > 0$ $\dot{W}_{net} = 0$ $\dot{Q}_{net} = 0$	$h_4 = h_3$
Evaporator	P = const.	$\dot{Q}_L = \dot{m}(h_1 - h_4)$

$$COP_R = \frac{\dot{Q}_L}{\dot{W}_{net,in}} = \frac{h_1 - h_4}{h_2 - h_1}$$

$$COP_{HP} = \frac{\dot{Q}_H}{\dot{W}_{net,in}} = \frac{h_2 - h_3}{h_2 - h_1}$$

Actual Vapor-Compression Refrigeration Cycle

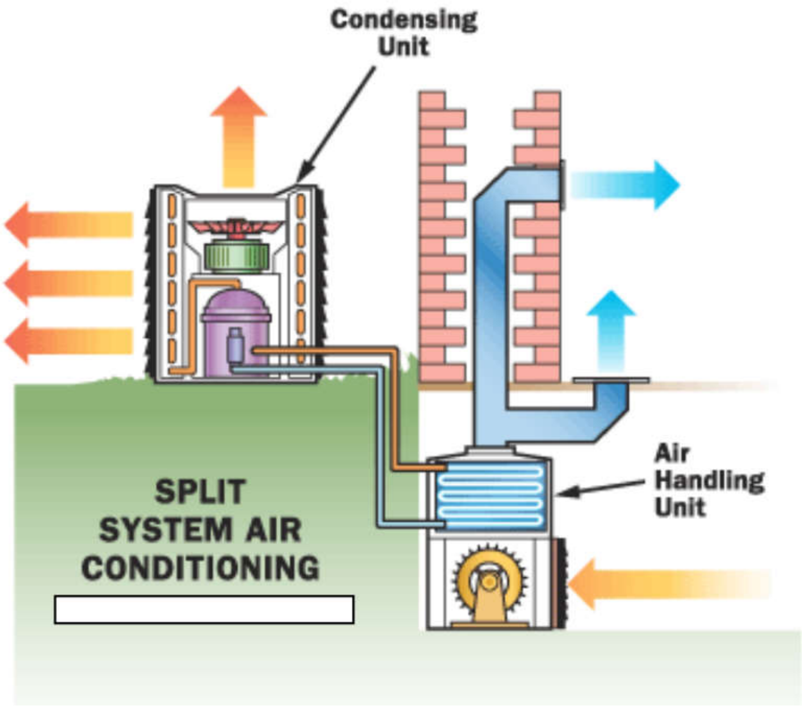


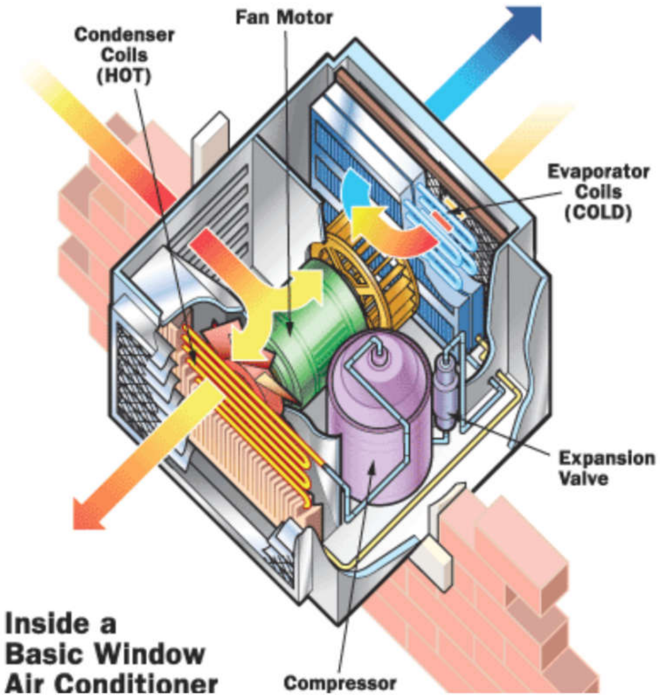


Cooling systems

Types of cooling System

1. Window type
2. Split Type
3. Chiller (Central A/C)

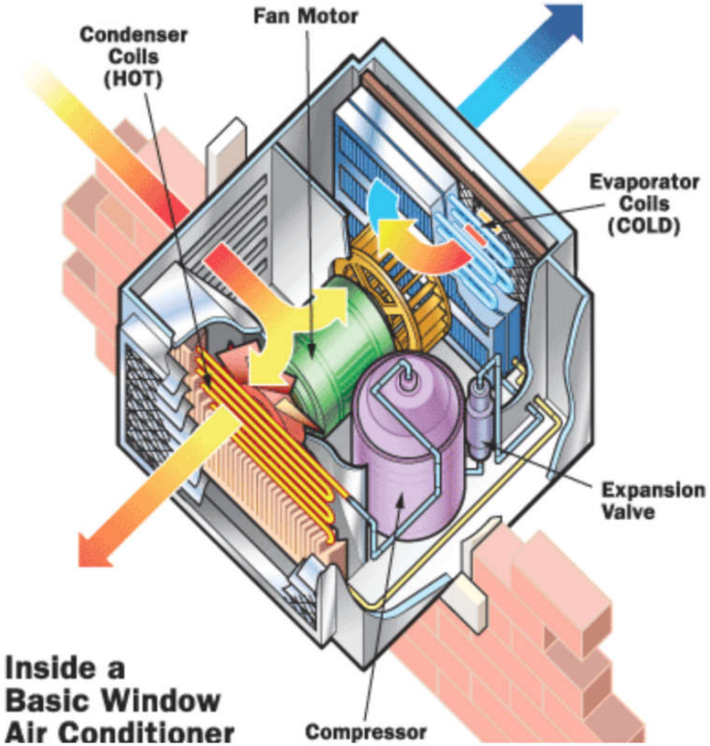




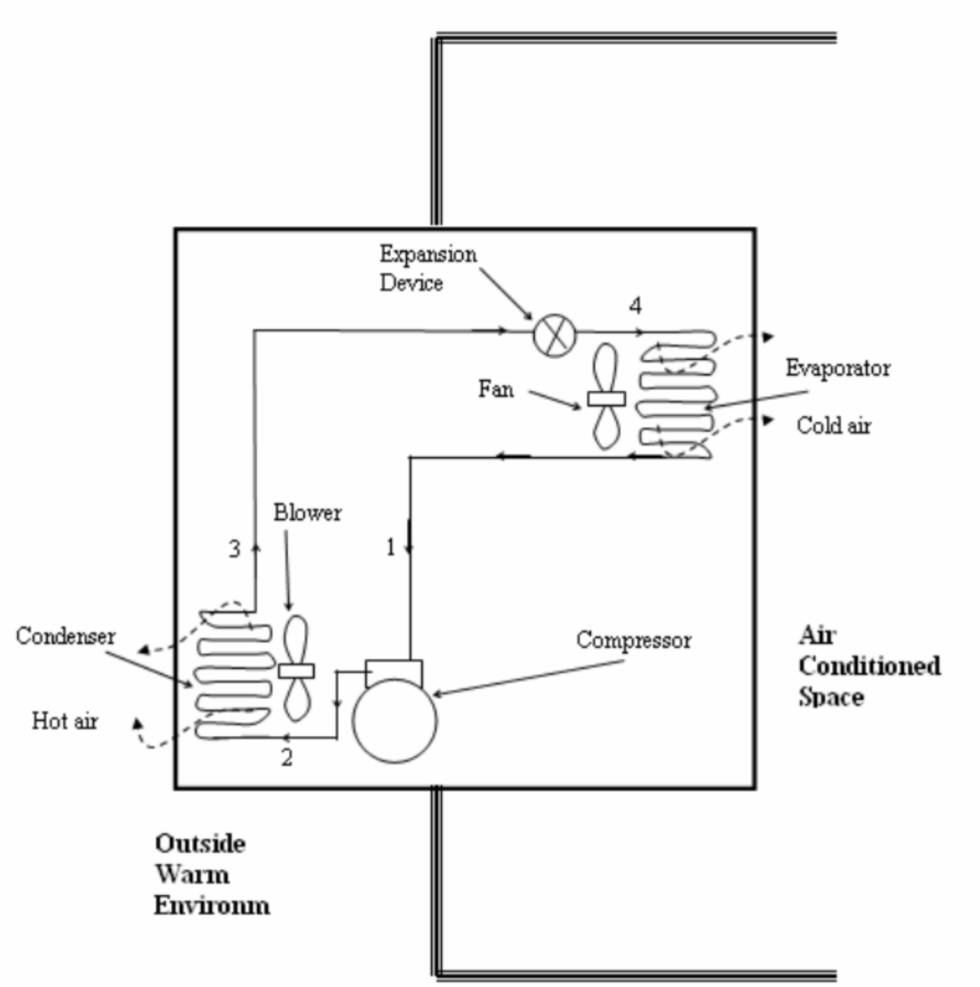
Cooling systems

Window Air conditioner:

Major Components: (i) A compressor, (ii) An expansion valve, (iii) A hot coil, i.e., condenser (on the outside), (iv) A chilled coil i.e., evaporator (on the inside), (v) Two fans and (vi) A control unit. Refrigerant such as R-12 or R-22 are used to provide refrigeration effect. It actually is a vapor compression refrigeration system whose evaporator cools only the air..



Window Air conditioner:



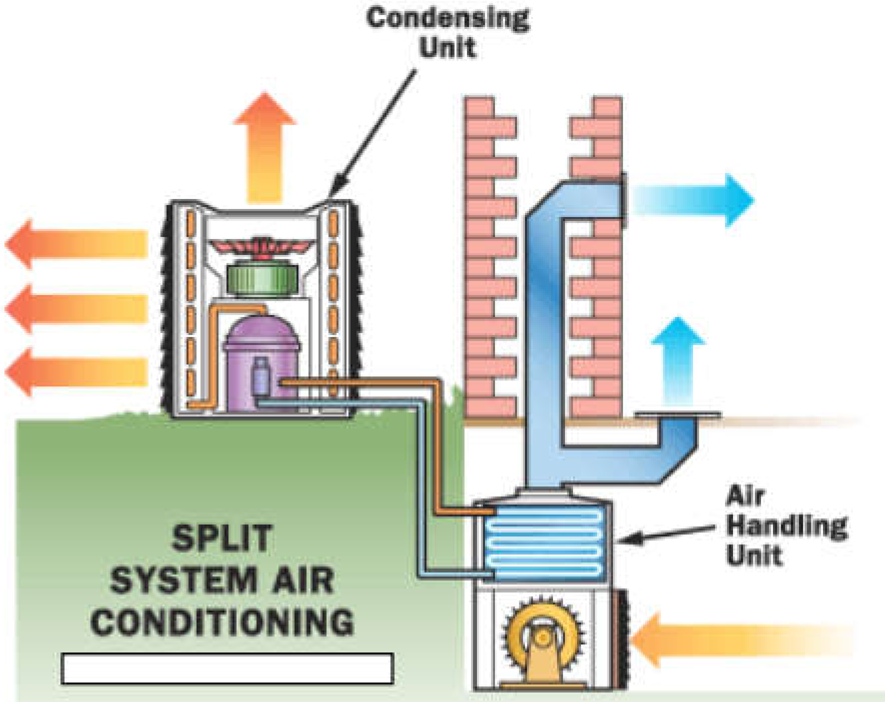
Cooling systems

Split Air Conditioner

Major Components: A split-system air conditioner splits the hot side from the cold side of the system.

Cold side (Fan-coil unit) - Placed inside (i) An expansion valve (ii) A chilled coil placed in Air Handler Unit

Hot side (Condensing Unit)-Placed Outside/Rooftop (iii) A weather-resistant compressor (iv) A hot coil (on the outside) (v) Two fans (vi)Some control logic



Split Air Conditioner