UNIT - II : Introduction to thermal Engg.

* Thermodynamics is a branch of science which deals with relation between heat & work.
  thermo : heat ; dynamics : power.
* A system which allow energy transfer but does not allow mass transfer is called closed system.
* A system which allows mass as well as energy transfer is called as open system.
* A system which neither allows mass transfer nor energy transfer is called isolated system.
* Thermodynamic System :
  It is defined as object in space under thermo-dynamics study.
* Surrounding :
  It is defined as a space outside system. It is part of universe except system.
* Boundary :
  It is defined as surface that seperates system from surrounding, it can be real or imiginary

Heat supplied $(Q) = m \times C \times [dt]$ kW / kJ/s

m = mass
C = speafic heat
$dT = T_2 - T_1$, difference in temp.

$$\text{Work } (W) = \int_1^2 F \times dv \text{ . kJ.}$$

* ZEROTH LAW OF THERMODYNAMICS :-

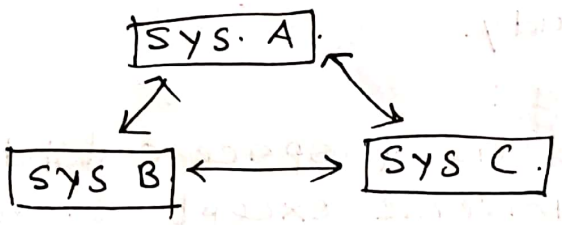
"It states that, if two system's are in thermal equilibrium with third system, then they are in thermal equilibrium with each other"

Consider three bodies A, B, C, which are at different temperature,

→ If A & B are brought in contact with each other & they constitute thermal equilibrium

→ If A & C are brought in contact with each other & they constitute thermal equilibrium

→ If A is in thermal equilibrium with A & C after period of time, B & C will also be in Thermal equilibrium.



* FIRST LAW OF THERMODYNAMICS :-

"It states that, when closed system undergoes a cyclic process, the net heat transfer is equal to net work transfer / cyclic integral of heat transfer is equal to cyclic integral of work transfer"

$$\oint \delta Q = \oint dW.$$

δQ = Amount of heat transfer

δW = Amount of work transfer

* ENERGY CONSERVATION LAW :-

"It states that, "Energy can neither be created nor destroyed, but can be converted from one form to another"

Denoted by dE.

$$\Delta Q = \Delta U + \Delta W$$

First Law Limitations :-

1. First Law provides for all simultaneous processes processed only in one particular direction & reverse such process, energy from external source is required.

2. The Law explains, heat energy and mechanical work are mutually convertible through mechanical energy can be fully converted into mechanical work. Thus there is a limitation on conversion of one form energy into another form of energy.

3. First law provides all necessary conditions for a process to occur, but it doesn't give sufficient conditions namely : direction of process.

* Heat Source : A reservoir that supplies energy in form of heat to system is called heat source.

* Heat sink: A reservoir that absorbs energy in form of heat from a system is called heat sink.

* Heat Reservoir : A reservoir is defined as a source of infinitie heat energy. A finite amount of heat absorbed or rejected from heat reservoir will not affect its temperature, i.e; temp. of reservoir is constant.

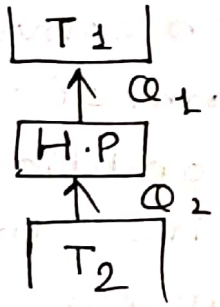
* SECOND LAW OF THERMODYNAMICS :-

* CLAUSIS STATEMENT *

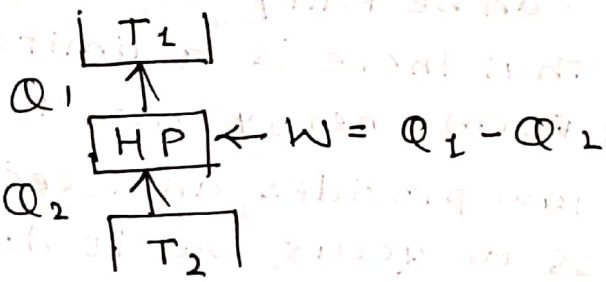
"It is impossible to construct a device that operates on cycle and transfers heat from a lower temperature reservoir to higher temperature reservoir on its own"

→ Heat cannot flow from cold body to hot body without use of external work.

→ It simply states that a refrigerator cannot absorb heat from food & release it to a hotter atmosphere, unless its internal temperature falls below food temperature & for that we need to supply electricity.



Impossible



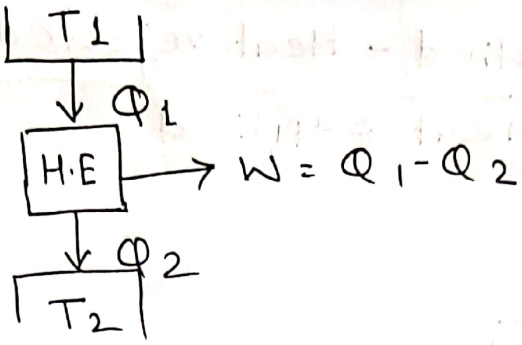
Possible.

* KELVIN PLANCK *

"It is impossible for any device that operates on a cycle to receive heat from single reservior & produce same amount of work"

→ Heat engine receives energy from higher temp. reservoir & rejects leftover heat to lower temp. sink.

→ NO heat engine can have a thermal efficiency of 100% since it cannot produce work equal in amount of heat recived from higher temp. reservoir.

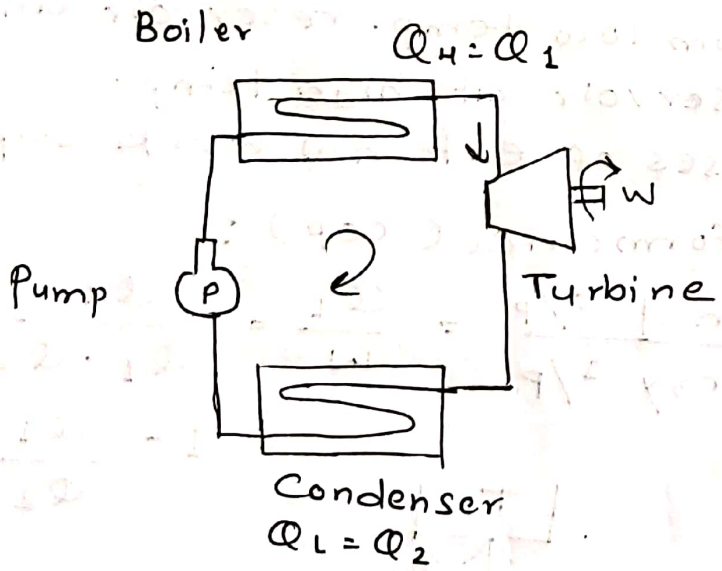


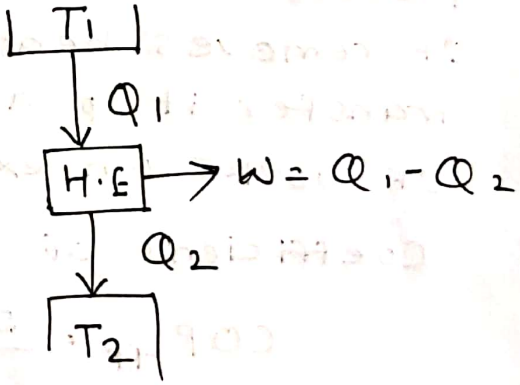
*HEAT ENGINE :-

A heat engine is a system which converts heat into work by taking heat from reservoir (hot) to carry out some work. There is discharge of some heat to sink (cold). In this system, there will also be some waste in form of heat.

(a) It is a device which operates on cyclic process

(b) It produces work continuously at expense of heat input.





HEAT ENGINE.

Ex: I C engine, steam turbine, gas turbine

$$\eta_{HE} = \frac{\text{Work Output}}{\text{Heat Input}}$$

$$= \frac{\text{Heat supplied} - \text{Heat rejected}}{\text{Heat supplied}}$$

$$= \frac{Q_1 - Q_2}{Q_1}$$

$$\boxed{\eta_{HE} = 1 - \frac{Q_2}{Q_1}}$$

Thermal effi. will always be less than unity.

* HEAT PUMP :-

A heat pump is a device which is working in a cycle which transfer heat from a low temp. space to higher temp. region. Objective of heat pump is to maintain a heated space at high temp.

It is a mechanical device operating on cyclic process.

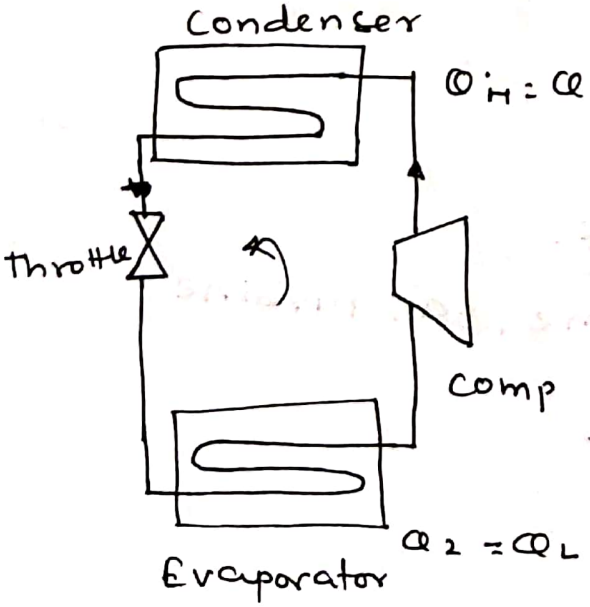
It removes heat from low temp. reservoir and transfer it to a reservoir at high temp.

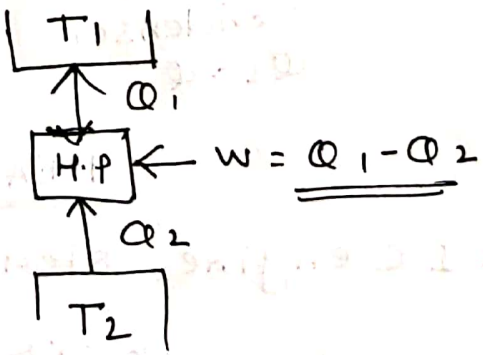
It works on expenses of external work supplied

Coefficient of performance (COP) :

$$COP_{HP} = \frac{\text{Desired } O/P}{\text{Energy } I/P} = \frac{Q_1}{W} = \frac{Q_1}{Q_1 - Q_2}$$

$$= 1 - \frac{Q_1}{Q_2}.$$





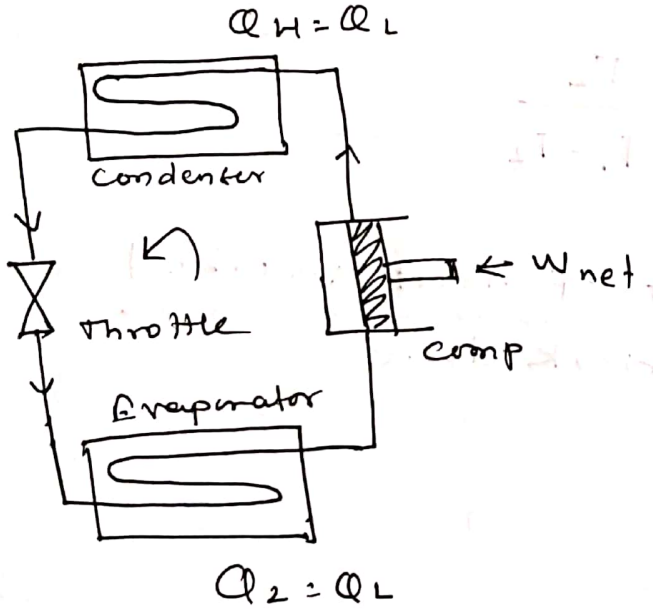
HEAT PUMP.

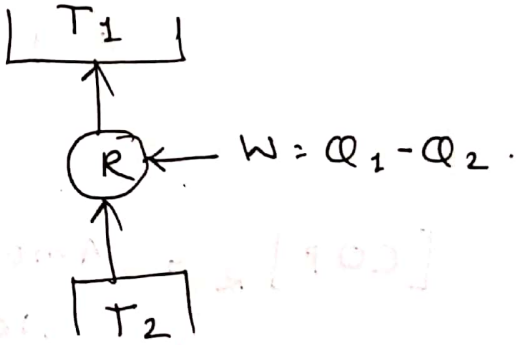
* REFRIGERATOR :-

It is a device which working in a cycle transfer heat from a high temp. region to low temp. region The purpose of refrigerator is to cool the space by absorbing heat from it & to maintain this space temp. lower than that of surroundings.

It is a mechanical device operation on cycle. It removes temp. from low temp. reservoir at high temp.

It works on expenses of external work supplied





COP. of refrigerator =

$$COP_{ref} = \frac{\text{Desired O/P}}{\text{Energy I/P}}$$

$$= \frac{Q_2}{W}$$

$$= \frac{Q_2}{Q_1 - Q_2}$$

$$= \frac{Q_2}{Q_1} - 1.$$

* PROVE : $(COP)_{heat\ pump} = 1 + (COP)_{refri.}$

$$[COP]_{HP} = \frac{\text{Amount of heat Reserved}}{\text{Net work done}}$$

$$= \frac{Q_1}{Q_1 - Q_2} = \frac{T_1}{T_1 - T_2} \quad \text{---- (1)}$$

$$= \frac{T_1 - T_2 + T_2}{T_1 - T_2} \quad \text{--- added \& subtracted } T_2$$

$$= \frac{T_1 - T_2}{T_1 - T_2} + \frac{T_2}{T_1 - T_2}$$

$$= 1 + \frac{T_2}{T_1 - T_2} \quad \text{---- (2)}$$

$$[COP]_R = \frac{\text{Amount of heat absorbed}}{\text{Net work done}}$$

$$= \frac{Q_2}{Q_1 - Q_2}$$

$$= \frac{T_2}{T_1 - T_2} \quad \text{---- (3)}$$

$$\therefore [COP]_{HP} = 1 + \frac{T_2}{T_1 - T_2}$$

but $\frac{T_2}{T_1 - T_2} = [COP]_R$

$$\therefore [COP]_{HP} = 1 + [COP]_R$$

proved !

HEAT ENGINE

Heat engine convert heat energy to useful mechanical energy.

Higher temp reservoir is above atmospheric temp.

Heat is transfered from higher temp. to lower temp. work is obtained during this process.

Effi. is less than 100%.

It uses difference in heat to power mechanical motion.

$$\eta = 1 - \frac{Q_2}{Q_1}$$

HEAT PUMP

Purpose is to reject heat to higher temperature reservoir.

Here lower temp. reservoir is below atmosphere.

Low to high temp.

COP_{HP} is greater than COP_{ref}.

It is to move heat from cold to warmer region

$$COP = \frac{Q_1}{Q_1 - Q_2}$$

REFRIGERATOR.

Purpose is to absorb heat from lower temp. reservoir.

Lower temp. reservoir is space inside refrigerator.

high to low temp.

COP_{ref} is lesser than COP_{HP}.

maintains cool temp.

$$COP = \frac{Q_2}{Q_1 - Q_2}$$

[I] 1st Law of Thermodynamics:

$$\Delta Q = \Delta U + \Delta W.$$

By joules equation $\Sigma \Delta Q = \Sigma \Delta W$.

[II] 2nd Law of Thermodynamics:

$$\eta_{HE} = \frac{Q_1 - Q_2}{Q_1}$$

$$= 1 - \frac{Q_2}{Q_1}.$$

[III] $$COP_{Ref} = \frac{Q_2}{Q_1 - Q_2} = \frac{T_2}{T_1 - T_2}.$$

[IV] $$COP_{HP} = \frac{Q_1}{Q_1 - Q_2} = \frac{T_1}{T_1 - T_2}$$

$$COP_{HP} - COP_{Ref} = 1.$$

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