UNIT 2 MODES OF HEAT TRANSFER

HEAT TRANSFER

Heat is a type of energy transfers due to temp difference. Heat or Energy transfer takes place from higher temp to lower temp. SI unit for heat is Joule

CONDUCTION

Conduction is method of transfer of heat within body or from one body to other body due to transfer of molecule heat vibrating at there mean position. The bodies thr which the heat transfers must be in contact. There is no actual movement of matter while transfering heat from one location to other. It occurs usually in solid when molecules in structure are held together by intermolecular force of attraction by them.

CONVENCTION

Convenction is mode of heat transfer which occurs mostly in liq & gases. In this method, heat transfer takes place with actual motion of matter from one place to other within body. Often when we boil the H_2O we have seen bubbles in H_2O

RADIATION

Radiation is mode of heat transfer in which medium isn't req. Radiation heat transfer happens from high temp body to low temp body in form of electromagnetic wave. Ex: Sun

FOURIER'S LAW OF HEAT CONDUCTION

The imp conduction for takes place is the presence of temp graident. The relation bet rate of heat flow & temp gradient can be derived from fourier's law

STATEMENT:

It states that rate of heat flow by conduction per unit Area normal to direction of heat flow in any direction is directly proportional to temp gradient in that direction

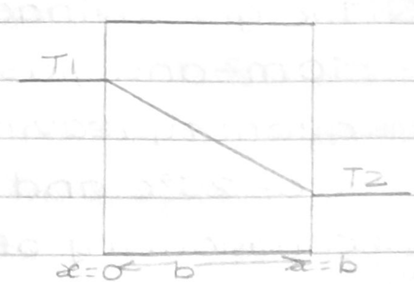
$$\frac{Q}{A} \propto \frac{dT}{dx}$$

constant of propornality (Thermal conductivity)

$$\underset{\text{(J/s or watt)}}{\text{Rate of heat flow}} \leftarrow \frac{Q}{A} = -K\frac{dT}{dx} \rightarrow \text{Temp gradient } \left(\frac{deg}{m}\right)\left(\frac{^\circ C}{m}\right)$$

A → surface area (m^2)

dx → direction



$x = 0$, $x = b$

$T = T_1$, $T = T_2$

$$Q\int_0^b dx = -KA\int_{T_1}^{T_2} dT$$

$$Q(x)_0^b = -KA[T]_{T_1}^{T_2}$$

$$Qb = -KA(T_2 - T_1)$$

$$Q = \frac{-KA}{b}(T_2 - T_1)$$

$$Q = \frac{KA}{b}(T_1 - T_2)$$

ELECTRICAL ANALOG FOR HEAT CONDUCTION

Electrical: con Quantity that flows is electron. Rate of flow is current (I). Driving force potential difference (V). Responsible Factors Resitivity, length of conductor, cross-section area of conductor. Length of conductor. Area normal to direction of heat flow

Heat: Quantity that flows is Heat. Rate of flow is Heat transfer (Q). Driving force Temp difference(t) Width of conductor, Area normal to direction of heat flow are responsible Factor.

$$V = IR$$

$$I = \frac{V}{R}$$

$$R = f(\rho, L, A)$$

$$R = \frac{\rho L}{A}$$

$$I = \frac{V}{\frac{\rho L}{A}}$$

$$Q = \frac{KA}{b}(T_1 - T_2)$$

$$= \frac{KA}{b}\Delta T$$

$$Q = \frac{\Delta T}{(b/KA)} = \frac{\Delta T}{R}$$

Q The glass window of a room has a total area of $10\,m^2$ and glass is of 4 mm. Calculate the heat quantity leaving from room thr glass when inside surface is of 25°C and outside 10°C. Value of thermal conductivity of glass is 0.84 W/m°C.

$A = 10 m^2$

$b = 4 mm$

$T_1 = 25°C$

$T_2 = 10°C$

$K = 0.84 \ W/mK$

$Q = ?$

$$Q = \frac{KA(T_1 - T_2)}{b}$$

$$= \frac{0.84 \times 10 \ (15)}{4 \times 10^{-3}}$$

$$= \frac{12.6 \times 10^4}{4} = 3.15 \times 10^4$$

$$= 31500$$

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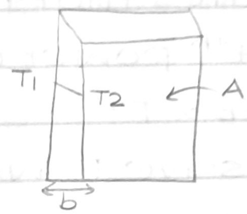
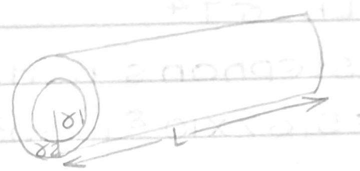
For slab or wall

$$Q = \frac{\Delta T}{\Delta R} = \frac{T_1 - T_2}{(b/KA)}$$



For Hollow cylinder

$$Q = \frac{T_1 - T_2}{\frac{\ln(r_2/r_1)}{2\pi LK}}$$



$A = 2\pi r L$

For sphere

$$Q = \frac{T_1 - T_2}{\frac{r_2 - r_1}{4\pi K r_1 r_2}}$$

$A = 4\pi r^2$

NEWTONS LAW OF COOING

Rate of heat flow in convection process is found by Newtons Law of cooling.

It states that the rate of heat transfer is directly proportional to surface area and temp difference bet the surface & flowing fluid in direction of heat flow.

$$Q \propto A(T - T_F)$$

$$Q = hA(T - T_F)$$

h = convenction of heat transfor

$$Q = \frac{T - T_F}{1/hA} = \frac{\Delta T}{\Delta R}$$

STEPHEN'S BOITZMANN LAW OF RADIATION

It is used to find imessive power of black body

It states that imissive power of black body $\propto$ 4^{th} power of its absoulte temp

$$E_b \propto T^4$$

E_b = emissive power W/m^2

T = absolute temp, K

$$E_b = \sigma T^4$$

σ = stephan's boltzmann's constant

$= 5.67 \times 10^{-8}\ W/m^2K^4$

Q A body having $5m^2$ surface area is maintain at 270°C it exchanges the heat with another surface enclose in at 27°C by radiation. It's emissivity is 0.1, calculate the rate lost of heat by radiation.

$$\begin{array}{r} 273 \\ 270 \\ \hline 543 \end{array} \qquad \begin{array}{r} 273 \\ 27 \\ \hline 300 \end{array}$$

– $Q = \sigma A(\Delta T)^4 \times e$

$= 5.67 \times 10^{-8} \times 5 \times 0.1 \times (500 - 300)$

$= 5.67 \times 10^{-8} \times 5 \times 0.1 \times (625 \times 10^6 - 81 \times 10^6)$

$= 5.67 \times 10^{-8} \times 5 \times 0.1 \times 544 \times 10^6$

$= 1542.24 \times 10^{-2}$

$$\begin{array}{r} 2500 \\ 300 \end{array}$$

Q A 60 watt lamp has a coil temp of 2500 K and room temp of 300 K. Estimate surface area of coil

$E = \frac{Q}{A}$ $\qquad E = \sigma (T)^4$

$= 5.67 \times 10^{-8} \times [(2500)^4 - (300)^4]$

$= 5.67 \times 10^{-8} [3.90625 \times 10^{13} - 81 \times 10^{8}]$

$= 5.67 \times 10^{-8} [3.90625 \times 10^{13} - 0.00081 \times 10^{13}]$

$= 5.67 \times 10^{-8} \times 3.90544 \times 10^{13}$

$= 22.1438 \times 10^{5}$

Q. calculate rate of heat transfer by convection bet roof of area 20x20 m^2 & ambient air. If roof temp is 10°c, air is 40°c assume average heat transfer coefficient for convection as 10 W/m^2K^4. calculate heat flow

— $Q = hA(T - T_f)$

$= 10 \times 400 \times (283 - 313)$

$= 10 \times 400 \times (-30)$

$= -120000$

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INTERNAL COMBUSTION ENGINE

Heat engine is a device which transforms the chemical energy of a fuel into thermal energy & uses it to produce mechanical work.

1) Exetrnal combustion Engine
2) Enternal combustion Engine } TYPES

1) In this engine product of combustion of air and fuel transfers heat to a 2^{nd} fluid which is working fluid of cycle.

2) In this engine the combustion of air & fuel takes place inside the cylinder and are used as motive force.

TYPES:

1) ACC to basic engine design — Resiprocating / Rotatary

2) ACC to Type of pfuel

   * Petrol * Disesl * Gas

3) ACC to strokes no. per cycle

   * 4 strokes * 2 strokes

4) ACC to method of eginition

   * Spark * compression

5) ACC to work cycle

   * Otto cycle * Disesl cycle * Dual-combustion

6) ACC to no. of cyclinder

   * Single * Multi

MAIN COMPONENTS ON RESIPROCATING IC ENGINE

CYlINDER

It is main part of engine in which piston resiprocates to f fro

CYlINDER HEAD

The top end of the cylinder is covered by cylinder Head coin which inlet or exhaust wall spark bulk or enigition system

PISTON

Transmits the force exercted by burning of charge to connecting rod.

PISTON RINGS

These are the housed in piston groow provided on the outersurface of the piston f made up of steel-alloy which retains elastic properties even in high temp.

Types 1) Compression Ring = It is the upper ring of the piston which provides the airtight seal which prevent leakage of burnt gases in lower protion

2) Oil Ring = It is the lower ring which provides effective seal to prevent leakage of oil into cyclinder.

CONNECTING ROD

It converts the resiprocating motion of piostion into circular motion of crank shaft.

CRANK SHAFT

It converts the resiprocating motion into rotatary motion

CRANK CASE

It houses the cyclinder & crank shaft OF IC engine & also serve as a same. sup of lubercating oil.

Fourstrock Engine

cycle of operation completes in four strokes of positon & 2-revolution of piston

1) Suction-strock

During suction-strok, suction wall open, Exhaust wall closes charge consist of fresh air mixed with fuel drawn to cylinder due to vaccum pressure creacted by the movement of piston from top to bottom dead centre

2) Compression strock

Both walls closed fresh charge is compressed into clearence volume of written returned strock of piston and eiginated by the spark of combustion. Hence the pressure and temp is increased due to combustion of fuel.

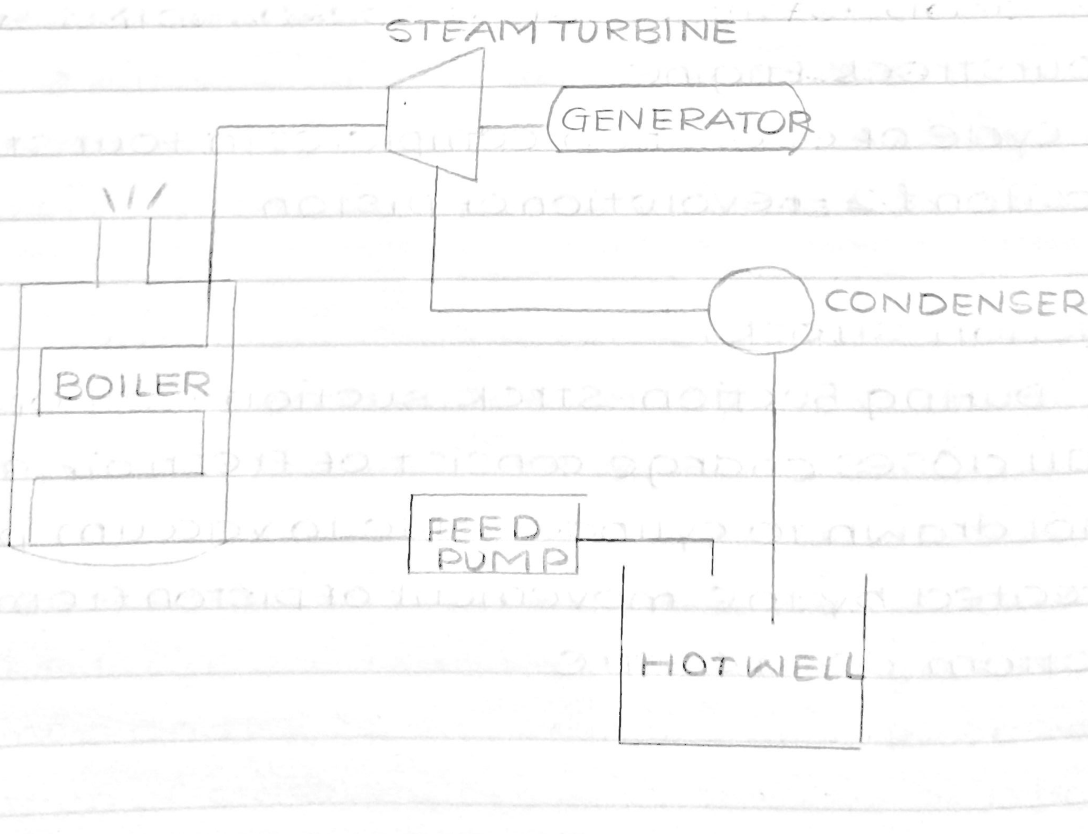
3) Expansion strock

Both walls closed high pressure of burent gases forces the piston towards BDC Hence, the power is obtained at a crank shaft

4) Exhaust strock

Exhaust wall opens suction wall close burnt gases expel out due to movement of piston from BDC to TDC

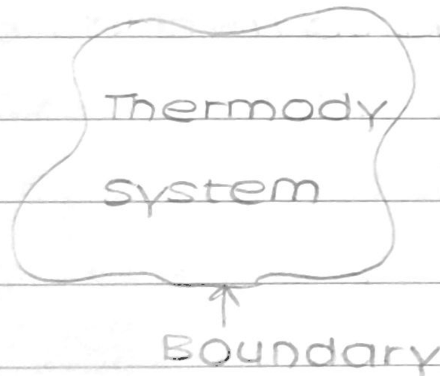
THERMAL POWER PIANT



THERMODYNAMICS

It is the science which deals with the energy interaction (heat & work) and the effect of energy interaction on the properties of system

THERMODYNAMICS SYSTEM, SURROUNDING, BOUNDARY



A Thermodynamic system is defined as space or quantity of matter upon which particular attention is concentrated for the study of work or heat transfer and there conversions.

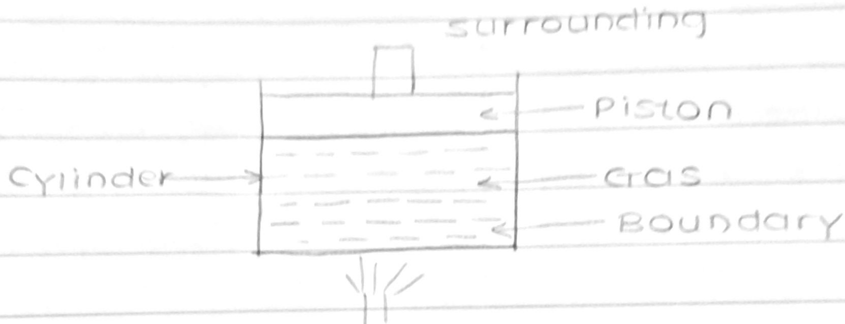
Everything outstand the system which has direct effect on behaviour of system is surrounding.
The system is separted from surrounding by an envolpe which is boundary. The boundary may be real, physical surface or imaginary surface it can be

fixed or moving.

When system and surrounding are put together is universe.

TYPES OF THERMODYNAMICS SYSTEM

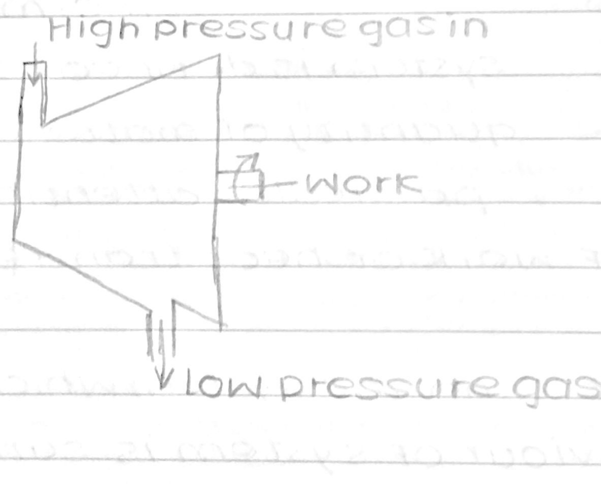
Closed or Non- ~~Folio~~ Flow :



A system is called as closed system when the mass within the boundary of system remains constant when only the energy (heat & work) may transfer across the boundary.

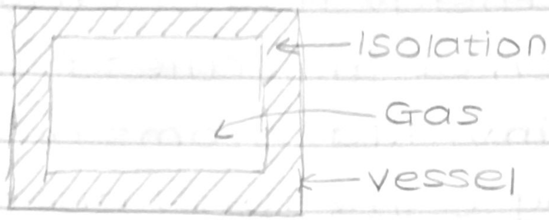
Open :

If mass as well as energy transfer across the boundary of system then it is called as open system



Isolated :

When there is no transfer of mass & energy across the boundary of system



THERMODYNAMICS PROPERTY

Any characteristics of the substance which can be measured or observed

★ INTENSIVE PROPERTY

The properties which are independent of mass of system is called intensive property

Ex: Temp, Pressure

★ EXTENSIVE PROPERTY

The properties which are dependent of mass of system

Ex: Volume, Enthapy, Energy

ENERGY & FORMS OF ENERGY

Energy is defined as capacity to do work and it scalar quantity that can't be observed directly but can be recorded & found by indirect measurements. Energy can be stored into different forms as follows

• Potential Energy of a system is a energy stored in the system due to its position in gravitational field.

$\Delta PE = mgh$ (J/Nm)

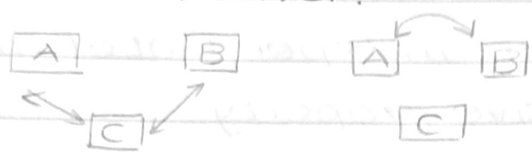
• Kinetic energy of a system is a energy which arises from motion of mass

$\Delta KE = \frac{1}{2}mv^2$

• Internal Energy it is energy arising in the form of motion of molecules & atoms. It is sum of KE of invidual atoms or molecules & it is denoted by 'U'. The total energy of system is Σ total energy = KE + PE + U

ZEORTH LAW OF THERMODYNAMICS

IF 2 systems are in thermal equilibrium with 3rd system then they are in thermal equilibrium with each other.



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FIRST LAW OF THERMODYNAMIC

When system goes cyclic change then algebraic sum of work delievered to surrounding is ∝ algebraic sum of heat taken by surrounding

$\oint dW \propto \oint dQ$

Both heat & work are mutually convertible one into other i.e energy can't be either be created nor destroyed but converted from one form to another.

There is no machine which is capable of producing work without expenditure of machine. energy.

corollaries :

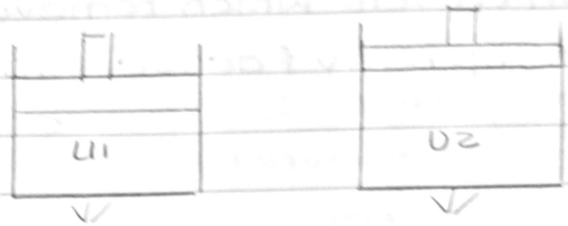
(a) (For a process) The property of a close system is such that the change in total energy ΔE is difference bet the heat supplied & workdone during change in work done

$\Delta E = Q - W$

$Q = \Delta E + W$

$= \Delta U + W$

$= (U_1 - U_2) + W$



(2) (For an isolated system) For a closed system the internal energy remains unchanged if the system is isolated from the surrounding.

$U_2 = U_1$

$\Delta U = U_2 - U_1$

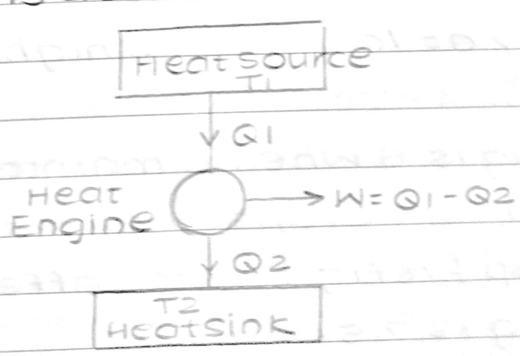
$0 = U_2 - U_1$

$U_2 = U_1$

(3) (PMM-I) perpetual motion machine It is impossible to construct consverse of pmm-1 is also true that is there is no machine which is capable of absorbing work without expenditure of energy.

HEAT ENGINE

It is thermodynamic system operating in the cycle to which net heat is transfer and from which net work is delivered.



η = Efficiency

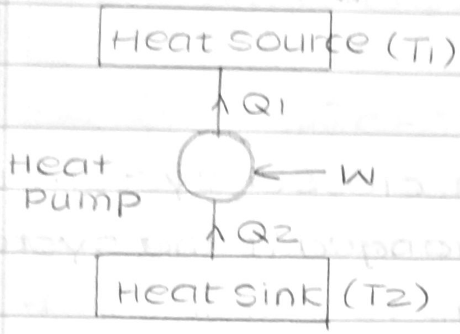
$= \frac{\text{Output}}{\text{input}}$

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

HEAT PUMP

It is thermodynamic system operating in a cycle which removes heat from low temp body & delivers to high temp body.

$(COP)_{pump} = \frac{\text{Desired output}}{\text{Input}}$



$= \frac{Q_1}{W}$

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

$(COP)_{refigerator} = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2}$

SECOND LAW OF THERMODYNAMICS

$(COP)_{PUMP} = (COP)_{Refig} = 1$

Kelvin's Planks Statement:

It states that if it impossible to construct an engine working in a cyclic process whose sole effect is the conversion of all heat energy supplied to it into equivalent amount of work

Clausius Statement:

It states that it is impossible to construct a heat pump working in cyclic process whose sole effect is transfer of heat from body at low temp to high temp

Q The COP of refig is 6 when it maintains the temp of -3°C in an evaporater determine the condenser temp & refigrenation effect. If power req to run refig is 7.5 kWatt.

$$(COP)_{ref} = \frac{T_2}{T_1 - T_2}$$

$$6 = \frac{270}{T_1 - 270}$$

$$6T_1 - 1620 = 270$$

$$6T_1 = 1890$$

$$T_1 = 315\,K$$

$$\begin{array}{r} \overset{4}{270} \\ \times\ 6 \\ \hline 1620 \\ +\ 270 \\ \hline 1890 \end{array}$$

$$(COP)_{ref} = \frac{Q_2}{W}$$

$$6 = \frac{Q_2}{7.5}$$

$$\begin{array}{r} \overset{3}{7.5} \\ \times\ 6 \\ \hline 0 \end{array}$$

$Q_2 = 45$ K watt

Q A reversible heat engine operates on carnot's cycle bet source and sink temp of 225 °C and 25 °C If heat engine receives 40 Kwatt from the source. Find the net work done, heat rejected, efficiency of heat engine

— $T_1 = 225°C$

$T_2 = 25°C$

$W = 40$ Kwatt

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

$$= \frac{T_1 - T_2}{T_1} = \frac{498 - 298}{498} = 0.40$$

$\eta = 40\%$

$$\eta = \frac{W}{Q_1}$$

$$0.40 = \frac{W}{40} \qquad W = 16\,KW$$

Q The COP of a refigerator operating on a reversed carnot cycle is 5.4 when it maintains -5°c in the evaporator. Determine the condenser temp and refrigerating effect if the power req to run the refrigerator is 3.2 KW. Draw the sketch of system.

— $(COP)_{refi} = 5.4$ $\qquad P = 3.2\,KW$

$T_2 = -5°C$

$$(COP)_{refi} = \frac{T_2}{T_1 - T_2} \qquad 5.4 = \frac{268}{T_1 - 268}$$

$$5.4\,T_1 - 1447.2 = 268$$

$$5.4\,T_1 = 1715.2$$

$$T_1 = 317.62\,K$$

$$COP = \frac{Q_2}{W} \qquad 5.4 = \frac{Q_2}{3.2 \times 10^3}$$

$$Q_2 = 17.28\,KW$$