3rd Sem./MECH/AUTO/AERO DIP IN MECH/ MECH(PROD)/ MECH(MAINT)/ MECH(IND INTG)/ MECH(SWITCH)/ 2021(W)

Th4 Thermal Engg.-1

Full Marks: 80 Time- 3 Hrs

Answer any five Questions including Q No.1& 2

Figures in the right hand margin indicates marks

1. Answer **All** questions 2 x 10

a. Define Point function and Path function.

b. What is mechanical equivalent of heat?

c. Define the Zeroth law of thermodynamics.

d. Explain the Clausius statement of 2nd law of thermodynamics.

e. State the Boyle's law and Charles's law.

f. Define enthalpy.

g. Define Piston speed and state its formula.

h. Draw the P-V and T-S diagram of Otto cycle.

i. Define Cetane number and Octane number.

j. What is meant by Free Expansion?

2. Answer **Any Six** Questions 5X6

a. Explain the Thermodynamic systems.

b. Derive the steady flow energy equation.

c. Differentiate between SI and CI engine.

d. Classify and explain the different types of fuel.

e. Derive the relationship between C_p, C_v and R.

f. Define COP. Derive the relation between COP of Refrigerator and COP of Heat Pump.

g. An ideal gas at 30°C and 1bar is compressed adiabatically from $5m^3$ to $1m^3$. Find the temperature, pressure and work done. Take $\gamma=1.4$

3 Derive the efficiency of Otto cycle with P-V and T-S diagram. 10

4 An ideal diesel cycle operates within the temperature limits of 1700K and 300K and with a compression ratio of 16. Determine the
(a)pressure and temperature at each point in the cycle 10
(b)thermal efficiency of the engine
(c)mean effective pressure

5 Air flows steadily at the rate of 1kg/s through an air compressor entering at 7m/s velocity, 100kPa pressure and specific volume of $0.95m^3/kg$ and leaving at 5m/s, 700kPa and $0.19m^3/kg$. The difference in internal energy between outlet and inlet is 90kJ/kg. Cooling water absorbs heat from the air at the rate of 60kW. 10 Calculate
(a) rate of work input
(b) ratio of inlet and outlet pipe diameter

6 (a) What is the first law of thermodynamics?
(b) Derive the expression for the work done for an Isothermal process. 10

7 Explain the working principle of 2 Stroke and 4 Stroke SI engine with neat sketch. 10

Thermal Engg - I

(1)

(a) Define Point function and Path function.

Ans. Point function - The properties which is in particular point is known as point function.

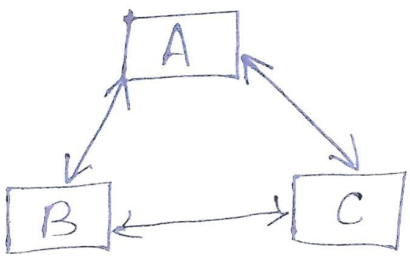
Path function - The properties which are along the path is known as path function.

(b) What is mechanical equivalent of heat ?

Ans. The mechanical equivalent of heat states that motion and heat are mutually interchangable and that in every case, a given amount of work would generate the same amount of heat provided the work done is totally converted to heat energy.

(c) Define the Zeroth law of thermodynamics ?

Ans. It states that if the first system is equilibrium to second and second system is equilibrium to third systems, then all three systems are equilibrium to each other.



(d) Explain the Clausius statement of 2nd law of thermodynamics.

Ans: The Clausius ~~syst~~ statement of 2nd law of thermodynamics state that it is impossible to construct a device the energy flow from lower level to higher level without any external work.

(e) State the Boyle's law and Charles's law.

Ans: Boyle's law - The law states that the absolute pressure of a given mass of a perfect gas varies inversely as its volume when the temperature remains constant.

$$P \propto \frac{1}{V} \quad (T = C)$$

$$P = \frac{C}{V}$$

$$\boxed{PV = C} \qquad P_1V_1 = P_2V_2 \cdots P_nV_n = C$$

Charles's law - The law states that the volume of a given mass of a perfect gas varies directly as its absolute temperature when absolute pressure remains constant.

$$V \propto T \quad (P = C)$$

$$V = CT \qquad \frac{V_1}{T_1} = \frac{V_2}{T_2} \cdots \frac{V_n}{T_n} = C$$

$$\boxed{\frac{V}{T} = C}$$

) Define enthalpy ?

Ans. Enthalpy, a property of a thermodynamic system, is the sum of the system's internal energy and the product of its pressure and volume.

(g) Define Piston speed and state its formula

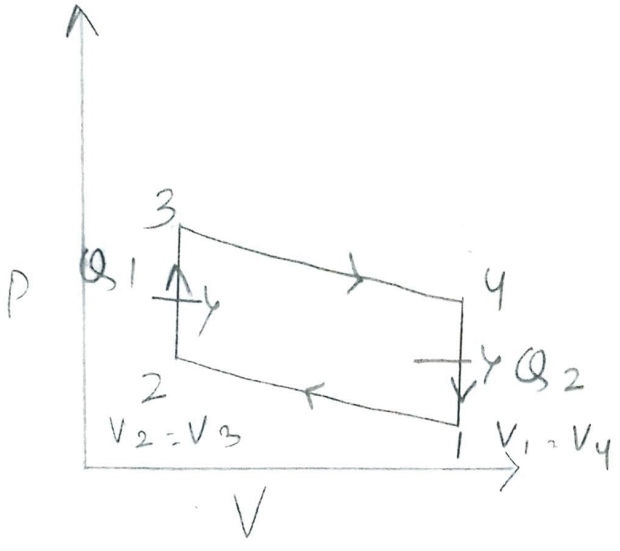
Ans. The mean piston speed is the average speed of the piston in a reciprocating engine.

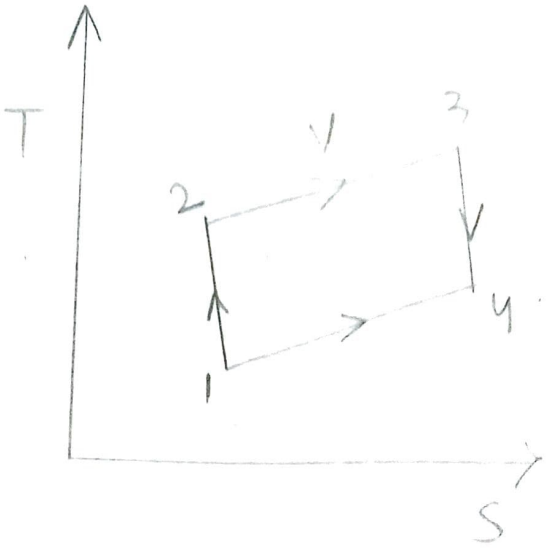
$$MPS = \frac{2LN}{60}$$

MPS - Mean Piston speed
L - Length
N - Revolution per min

(h) Draw the P-V and T-S diagram of Otto cycle.

Ans.





(i) Define Centane number and Octane nu...

Ans. Centane number - a quality indicating the ignition properties of diesel fuel rela... to centane as a standard.

Octane number - a figure indicating the anti-knock properties of a fuel. based on a comparison with a mixture of isoctane and heptane.

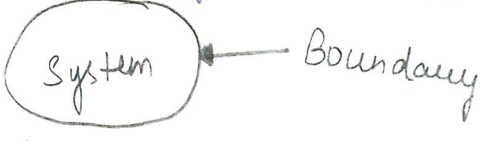
(j) What is meant by free expansion?

Ans In free expansion (a gas) expands in such a way that no heat enters or leaves the system (adiabatic process) and also no work is done by or on the system, then the expansion is called free expansion.

2.

(a) Explain the Thermodynamic Systems.

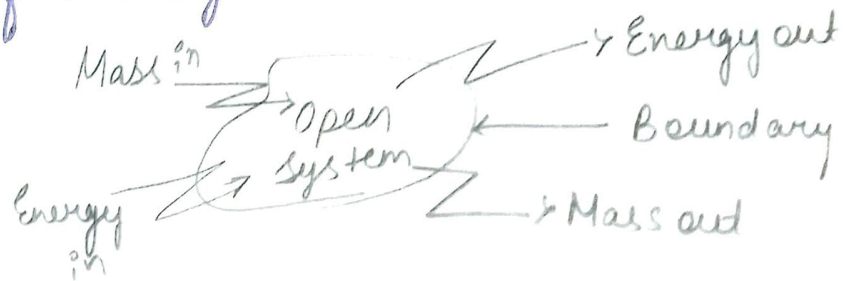
Ans. Thermodynamic System - A thermodynamic system refers to any space or to any matter or group of matter within a prescribed boundary which may be real or imaginary.



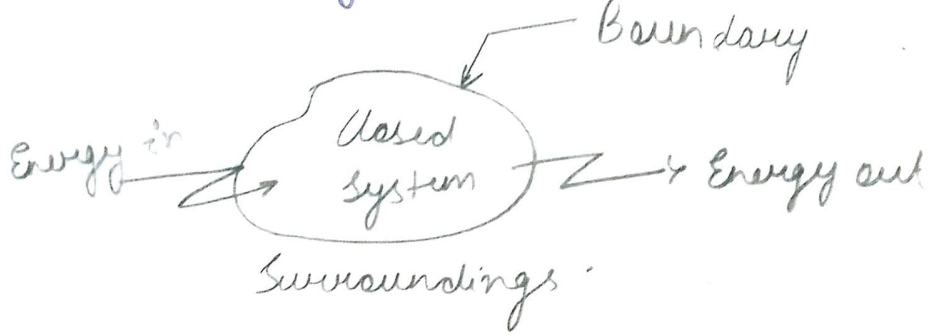
Types of thermodynamic system:-

- Open system
- Closed system
- Isolated system

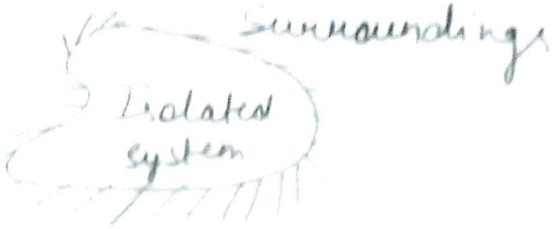
(i) Open system:- An open system is one in which not only energy (heat or work) crosses the system boundary but also matter flows into or out of the system.



(ii) Closed system:- A closed system is a system where only the temperature can be exchanged with surroundings but not mass.

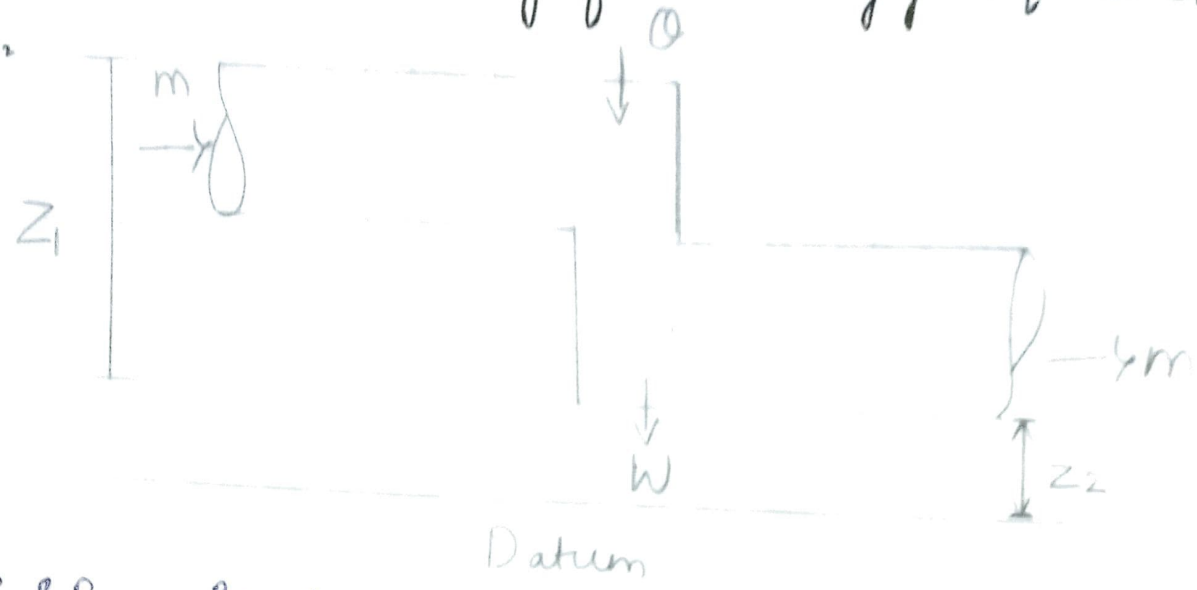


(iii) Isolated system:- An isolated system is that system which exchanges neither energy nor matter with any other system or with environment.



No mass or energy transfer

(b) Derive the steady flow energy Equation thus.



P_1 & P_2 - is inlet pressure and outlet pressure

V_1 & V_2 - is velocity at inlet and outlet.

v_1 & v_2 - Specific volume at inlet and outlet.

h_1 & h_2 - Specific enthalpy at inlet and outlet.

$K.E_1$ & $K.E_2$ - K.E at inlet and outlet

$P.E_1$ & $P.E_2$ - Potential energy in inlet and outlet.

Q - Heat supplied

W - Work transfer.

Steady flow system is a system where mass and energy are constant.

energy at inlet = Energy at outlet

$$KE_1 + PE_1 + H_1 + Q_s = KE_2 + PE_2 + H_2 + W$$

$$\frac{1}{2}mv_1^2 + mgz_1 + mh_1 + Q_s = \frac{1}{2}mv_2^2 + mgz_2 + mh_2 + W$$

$$Q_s - W = \frac{1}{2}m(v_2^2 - v_2^2) + mg(z_2 - z_2) + m(h_2 - h_2)$$

$$Q_s - W = m\left[\frac{1}{2}(v_2^2 - v_1^2) + g(z_2 - z_1) + (h_2 - h_1)\right]$$

For unit mass

$m = 1$

$$\boxed{Q_s - W = \frac{1}{2}(v_2^2 - v_1^2) + g(z_2 - z_1) + (h_2 - h_1)}$$

(c) Differentiate between SI and CI engine.

Ans.

S.I Spark ignition	C.I Compression ignition
- S.I or petrol engine works on otto cycle.	- C.I or disel engine works on disel cycle.
- In S.I engine air & fuel is sucked in suction stroke	- In C.I engine only air is sucked into suction stroke

- Heat is added at constant volume in S.I engine.	- Heat is added at constant pressure in C.I engine.
- Compression ratio of S.I engine 5:1 to 9:1	- Compression ratio of C.I engine is 14:1 to 19:1
- Carburretor is used to supply air and fuel mixture into the engine cylinder.	- Injector is used to inject fuel into the engine cylinder.
- Spark plug is required to ignite the charge in S.I engine.	- There is no such device used in C.I engine to burn fuel.
- Running cost of S.I is higher, due to high cost of petrol.	- It is less as compared to S.I engine.
- They are high speed engines.	- They are low speed engines.

(d) Classify and explain different types of fuels.

Ans. Materials such as coal, gas or oil that is burned to produce heat or power is known as fuel.

On the basis of physical state fuel is divided into 3 types:-

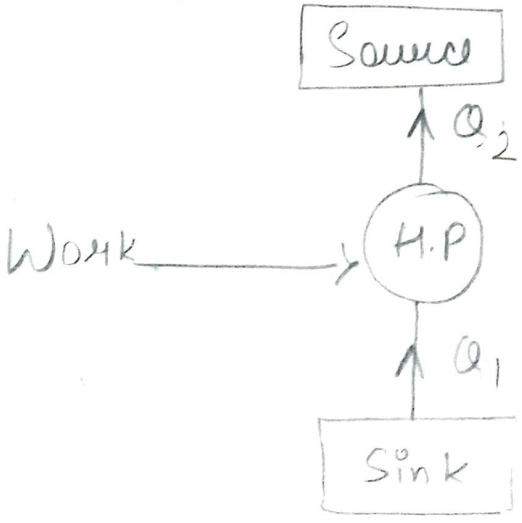
(i) Solid fuel - Solid fuel refers to various forms of solid material that can be burnt to release energy, providing heat and light through the process of combustion.
Ex - Wood, coal, coke, charcoal.

(ii) Liquid fuel - Liquid fuels are combustible that can be harnessed to create mechanical energy, usually producing kinetic energy
Ex - Petrol, disel etc.

(iii) Gaseous fuel - Gaseous fuel means a material that is in the gaseous state at standard atmospheric temperature and pressure conditions and that is combusted to produce heat.
Ex - Natural gas, Petroleum gas etc.

(f) Define COP. Derive the relation between COP of Refrigerator and COP of Heat pump.

Ans. COP if defined as co-efficient of performance.

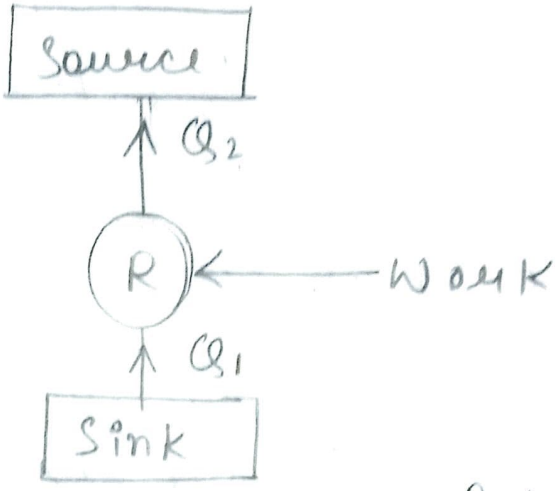


$W = Q_2 - Q_1$

Heat pump

$COP_{H.P}$ = Heat supplied / Work done

$$\boxed{COP_{H.P} = \frac{Q_2}{Q_2 - Q_1}}$$



Refrigerator

COP_R = Heat extracted / Work done

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

The relation between COP of heat pump and of refrigerator is

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

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

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

$$= \frac{Q_2}{Q_2 - Q_1} = \text{COP of heat pump}$$

An ideal gas at 30°C and 1 bar is compressed adiabatically from $5m^3$ to $1m^3$. Find the temperature, pressure and work done. Take $\gamma = 1.4$

Sol. Given data

$T_1 = 30°C = 30 + 273 = 303K$

$P_1 = 1 bar = 1 \times 10^5$

$V_1 = 5m^3$

$V_2 = 1m^3$

$$= \frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma - 1}$$

$$= \frac{303}{T_2} = \left(\frac{1}{5}\right)^{1.4-1}$$

$$= T_2 = 303 \times (5)^{1.4-1}$$

$$T_2 = 576 K$$

$$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^{\gamma}$$

$$= \frac{1 \times 10^5}{P_2} = \left(\frac{1}{5}\right)^{1.4}$$

$$= P_2 = 1 \times 10^5 \times (5)^{1.4}$$

$$P_2 = 951826.96$$

Workdone

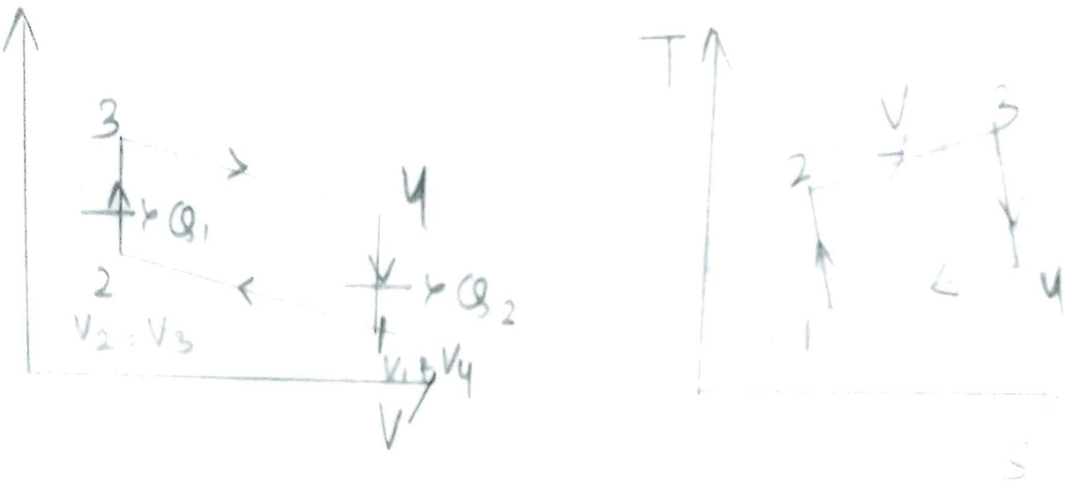
$$\frac{P_2 V_2 - P_1 V_1}{\gamma - 1}$$

$$\frac{951826.96 \times 1 - 1 \times 10^5 \times 5}{1.4 - 1}$$

$$= 1129567.4$$

(3) Derive the efficiency of Otto cycle with P-V and T-S diagram.

Ans.



Two reversal adiabatic process
Two reversal isochoric process.

$$\eta = \frac{O/P}{I/P} = \frac{\text{Work}}{\text{Heat supplied}}$$

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

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

① - ② - Adiabatic compression where entropy is constant where no heat addition and no heat rejection occurs.

② to ③ - Q_1 amount of heat is added at constant volume.

③ to ④ - Adiabatic expansion where entropy is constant where no heat addition and no heat rejection occurs.

P

40 (1) - where Q_2 is exhausted by the exist
ert. at constant volume.

Heat supplied Q_1 - (2 - 3)

$$Q_1 = MC_v (T_3 - T_2)$$

Heat rejected Q_2 = (4 - 1)

$$Q_2 = MC_v (T_4 - T_1)$$

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

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

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

$$= 1 - \frac{T_4 - T_1}{T_3 - T_2}$$

Considering Adiabatic compression (1-2)

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma - 1} \quad \text{---------- (i)}$$

Considering Adiabatic expansion (3-4)

$$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma - 1} \quad \text{---------- (ii)}$$

$$\frac{V_1}{V_2} = \frac{V_4}{V_3} \quad \text{(Constant volume)}$$

$$\frac{V_1}{V_2} = \frac{V_4}{V_3} = \gamma_K \quad (\gamma_K = \text{Compression ratio})$$

from eqn (i)

$$\frac{T_2}{T_1}\left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$= \frac{T_2}{T_1} = (\gamma_K)^{\gamma-1}$$

$$= T_2 = T_1 (\gamma_K)^{\gamma-1} \quad \text{——— (iii)}$$

from eqn (ii)

$$\frac{T_3}{T_4} = \left(\frac{V_3}{V_4}\right)^{\gamma-1}$$

$$= \frac{T_3}{T_4} (\gamma_K{}^{\gamma-1})$$

$$= T_3 = T_4 (\gamma_K{}^{\gamma-1}) \quad \text{——— (iv)}$$

Substituting T_2 & T_3 values in

$$\eta = \frac{1 - (T_4 - T_1)}{T_3 - T_2}$$

$$= 1 - \frac{(T_4 - T_1)}{[T_4 (\gamma_K)^{\gamma-1} - T_1 (\gamma_K)^{\gamma-1}]}$$

$$= \frac{1 - (T_4 - T_1)}{(\gamma_K)^{\gamma-1}(T_4 - T_1)}$$

$$\boxed{\eta_{otto} = 1 - \frac{1}{\gamma_K{}^{\gamma-1}}}$$

where γ_K = Compression ratio

(a) What is the first law of thermodynamics?

Ans. First law of thermodynamics is also known as law of conservation of energy. It has two statement.

Statement 1 - It states that heat & work are mutually one converted to each other.

Statement 2 - The energy can neither be created nor destroyed but can transform from one form to another form.

(b) Derive the expression for the work done for an Isothermal process.

Ans. $W = pdV$

$\delta W = \delta pdV$

$= \int_1^2 W = \int_1^2 d(PV)$

$= \int_1^2 W_{1-2} = \int_1^2 PdV$

$\therefore W_{1-2} = \int_1^2 \frac{P_1 V_1}{V} dV$

$= W_{1-2} = P_1 V_1 \int_1^2 \frac{dV}{V}$

$= W_{1-2} = P_1 V_1 [\ln V]$

$\therefore W_{1-2} = P_1 V_1 [\ln V_2 - \ln V_1]$

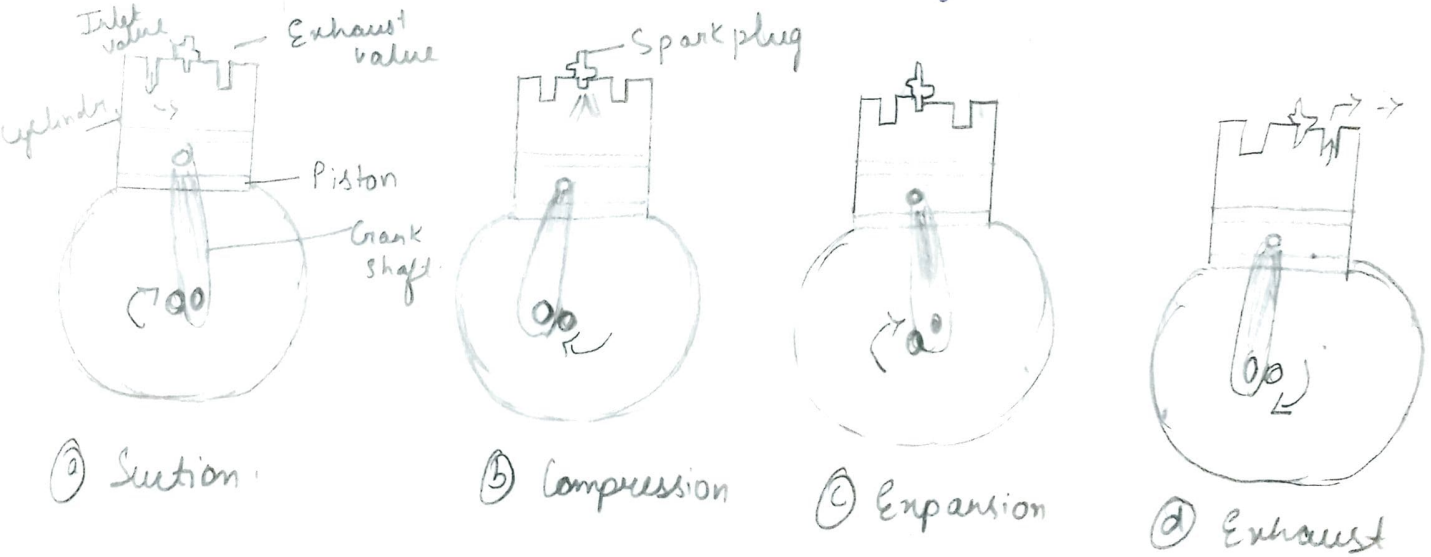
$$= W_{1-2} = -P_1 V_1 \ln\left[\frac{V_2}{V_1}\right]$$

$$\gamma = \frac{V_2}{V_1} \quad (\because \gamma \text{ is equal to expansion ratio.})$$

(7) Explain the working principle of 2 stroke and 4 stroke SI engine with neat sketch.

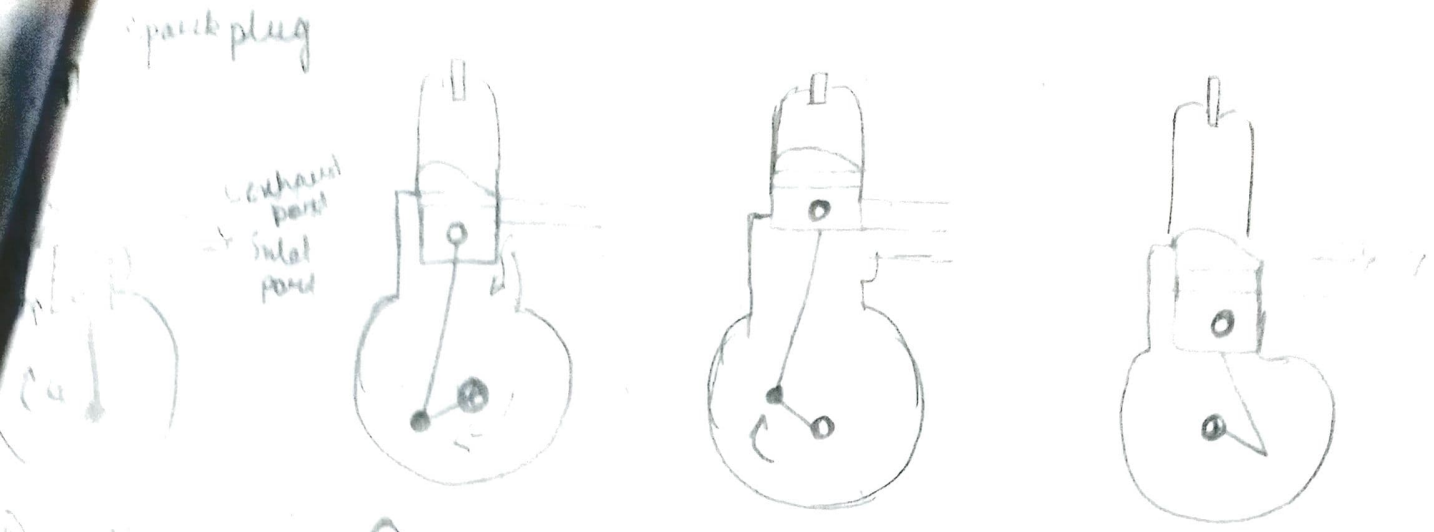
Ans: Four stroke cycle engine.

It is also known as otto cycle. It requires four strokes of the piston to complete one cycle of operation in the engine cylinder.



(a) Suction. (b) Compression (c) Expansion (d) Exhaust

(1) Suction or charging stroke - In this stroke the inlet valve opens and charge is sucked into the cylinder as the piston moves downward from top dead center (TDC). It continues till the piston reaches its bottom



(a) suction (b) compression (c) Expansion (d) Exhaust

Suction stroke - In this stage the piston while going down towards BDC uncovers the transfer port and the exhaust port. The fresh air flows into the engine cylinder from the crank case.

Compression stroke - In this stage, the piston while moving up, first covers the transfer port and then exhaust port. After the air is compressed as the piston moves upwards. In this stage inlet port opens and the fresh air enters in to the crank case.

Expansion stroke - Shortly before the piston reaches the TDC the fuel oil is injected in the form of very fine spray into the engine cylinder through the nozzle known as fuel injection valve. Due to increase pressure the piston is pushed with a great force. The hot burnt gases expand due to high speed of the piston. During the expansion, some of the heat energy produced is converted into mechanical work.

dead centre (BDC)

② Compression stroke - In this stroke both the inlet and exhaust values are closed and the charge is compressed as the piston moves upward from BDC to TDC. As a result of compression the pressure and temperature of the charge increase considerably. This complete the revolution of the crankshaft.

③ Expansion stroke - Shortly before the piston reaches TDC the charge is ignited with the spark plug which let to increase the pressure and temperature inside the cylinder. Due to high pressure the piston is pushed downwards with great force from TDC to BDC. when the both values are closed.

④ Exhaust stroke - In this stroke the exhaust value is opened as the piston moves from BDC to TDC the wast products during combustion is exhausted by the exhaust value into the atmosphere. This completes another cycle of crank shaft.

Exhaust stage - In this stage, the exhaust port is opened and the piston moves downwards. The products of combustion from the engine cylinder are exhausted through the exhaust port into the atmosphere. This completes the cycle, and the engine cylinder is ready to suck the air again.