LECTURE NOTES

ON

THERMAL ENGINEERING-I

3RD SEMESTER

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THERMODYNAMIC CONCEPT AND TERMINOLOGY :-

Properties of a System :-
All the quantities which identify the state of a system is called properties.

State of a System :- it is the condition of the system at any paticular moment which can be identified by it's properties (P, T, U).

Types of property :-
Intensive → Those property which are Independent of the mass of the System. (Temp, Pressure, density)
Extensive → Those property which are dependent on the mass of the system. (weight, volume).

Path of change of State :-
When a system travels from Intial state to the final state is called Path of State.

Thermodynamic Process :-
When a system changes it's state from one equilibrium state to another through a series of sucessive state is called T.D Process.

Thermodynamic cycle :-
When a Process are performed in a system in such a way that the final state is identical with initial state is called as cycle Process.

Thermodynamic Properties:-

Internal Energy (U):-
The Energy stored inside the body due to it's molecular arrangment & motion of the particular unit -(Joule).

Enthalpy(h):-
it is also a property of the system which is ($h = u + pV$) unit - KJ/Kg.

Entropy(S):-
it is a measure of randomness or dis-order of a system. $\Delta S = \frac{Q}{T}$ - KJ/Kg·Kelvin

Thermodynamic Equilibrium:-
A system is said to be in thermodynamic Equilibrium if it is simultaneously in

1:- Mechanical Equilibrium.
→ No unbalance force on this system.
2:- Thermal Equilibrium.
→ No heat addition / subtraction.
3:- chemical equilibrium.

Quasis-static Process:-
Whenever a Process occurs very slowly with the help of small driving force is called quasis-static process the staties in a quasis-static process is always consider to be in Thermodynamic Equilibrium.

WORK & HEAT IN THERMODYNAMIC

It can be defined as the transmission of Energy from one System to another. it is denoted by Q unit is Joule. it is a path function.

SINGN - CONVERTION:-

(1) Heat flows Into the System is Positive.
(2) Heat flows out of the System is Negative.

Calculation of heat formula:-

$\boxed{Q = m \times cp \times dT}$ where, m = mass
cp = Specific heat at constant Pressure
dT:- change in temperature.

$\boxed{dT = T_2 - T_1}$

(Q) In a System of mass 2Kg is intially at a Temperature of 20°c & the final tem. of the System is 80°c find the heat transfer when $cp = 1.008\ KJ/Kg.K$?

ANS

Given data $m = 2Kg$
$T_1 = 20°c$
$T_2 = 30°c$
$cp = 1.008\ KJ/KgK.$

$\therefore$ Heat $= m \times cp \times dT$
$= 2 \times 1.008 \times 30° - 20°$
$= 2 \times 1.008 \times 10$
$= 20 \times 1.008$
$= 20.16$ Joule

Ans

(Q) A system having mass of 5 kg heat flows In to the system at a temperature of $20^{0}C$ and final temperature of the system is $15^{0}C$, find the heat transfer to the system when $cp = 1.005\ KJ/Kg \cdot K$?

Ans

Given data $m = 5\ Kg$
$T_1 = 20^{0}C$
$T_2 = 15^{0}C$
$cp = 1.005\ Kg \cdot K$

$\therefore$ heat $= m \times cp \times dT$
$= 5 \times 1.005 \times 15 - 20$
$= 5 \times 1.005 \times (-5)$
$= -25 \times 1.005$
$= 25.125$ joule.

Ans

(Q) A system having mass 2 kg and it's tem. at at starting is $80^{0}C$ & final temperature of the system $20^{0}C$ here $cp = 1.005\ KJ/Kg \cdot K$ Heat is flows out of the system?

Ans

Given data $m = 2\ Kg$
$T_1 = 20^{0}C$
$T_2 = 20^{0}C$
$cp = 1.005\ KJ/Kg \cdot K$

$\therefore$ Heat $= m \times cp \times dT$
$= 2 \times 1.005 \times 20 - 20$
$= 2 \times 1.005 \times 0$
$= 0 \times 1.005$
$= 0$

Ans

WORK TRANSEFER:-

it is the of mechanical work in (terms of Energy) from one system to another. it is written as w. unit is a path function.

$$\boxed{\int_1^2 dw = P \times dv}$$

$$\boxed{\int_1^2 P \times dV}$$ where, dw = work transefer.
P = Applying Load.
V = Volume
dv = Volume changes.

SINGN - CONVERTION:-

(1) work done by the system is taken as Positive.
(2) work done on the system is taken as Negative.

IMPORTANT POINT ON HEAT AND WORK:-

(i) Both are path function.
(ii) They have In-exact differantial.
(iii) Both are Boundary phenomenon.
(iv) Both are different forms of Energy.

Exact: $w = w_2 - w_1$

Inexact: $dw = \int_1^2 dw_1 \int_1^2 dw_2$

Calculation of work transfer:-

(Q) The system goes from on state to another In which pressure is Remaning Constant $P = 100 N/m^2$ But the volume changes from $5m^3$ to $2m^3$ find the work tranfer?

Ans Given data $P = 100 N/m^2$
$V_1 = 5m^3$
$V_2 = 2m^3$

$P = 100 \times -3 = -300$ joule Ans

(Q) A system goes from A to B where the volume of pressure & volume is Remaining constant so that $P = 10 N/m^2$ & volume = $10 m^3$, find the work transfer ?

Ans

Given data $P = 100 N/m^2$

$V_1 = 10 m^3$

∴ work transfer = $P \times dV$

$= 10 \times 10 - 10$

$= 10 \times 0$

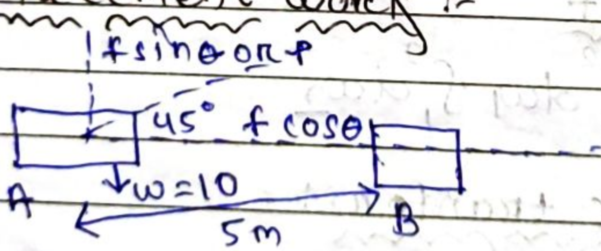
$= 0$ Ans

JOULE'S LAW :-

→ mechanical equivalent of heat :-

According to "joules" experiment Both heat and work and mutually convertible As we know the unit of heat and work are Equal which is joule.

Displacement work :-



$= 10 \cos 45^{\circ} \times 5$

work done :-

$= dw = P \times dV$

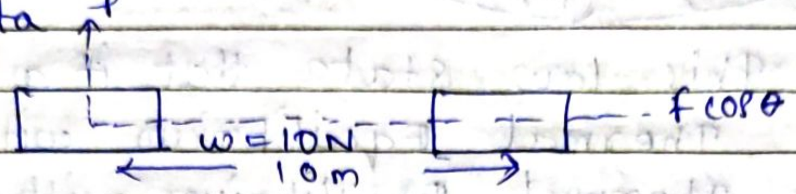
$= \int_1^2 P \times dV$

$= \boxed{f \times ds}$

(Q) find the work done by the body when it goes from A to B which is 10 meter and force of 10 N applied at an angle of 90^0 ?

Ans

Given data



$\therefore$ work done

$= f \times ds$

$= 70 \cos 90^0 \times 10$

$= 0$ Ans

(Q) when work done by a system which $P = 20\ N/m^2$ and volume changes from $6m^3$ to $4m^3$?

Ans Given data

$P = 20\ N/m^2$

$V_1 = 6m^3$

$V_2 = 4m^3$

$\therefore$ work done $= P \times dV$

$= 20 \times 4 - 6$

$= 20 \times -2 = 40$ joule

Ans

(Q) find the heat transfer by a system whose mass is 10 Kg the value of $cp = 1000\ J/Kg \cdot K$ But the temperature is Remaining constant ?

Ans

Given data $m = 10 N$

$T = 0$, $CP = 1000 J/Kg \cdot K$

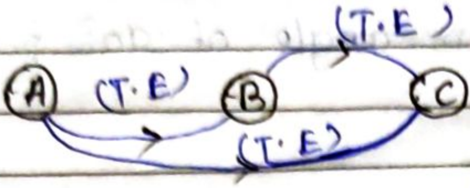
$\therefore$ Heat $= m \times cp \times dT$

$= 10 \times 1000 \times 0$

$= 0$ Ans

chapter no-2

Zorth law of Thermodynamic :-



where, T.E is (Thermal Equilibrium).

This law state that if a body 'A' is in Thermal Equilibrium with 'B' body & also Thermal Equilibrium with 'body 'C' then Both 'B' and 'C' are in Thermal Equilibrium with Each other.

first law of thermodynamics :-

it obeys law of conservation of Energy and it state that Energy Neither been created nor being destroyed it can only changes it's from (machanical Energy to heat Energy).

This law state that during a thermodynamic Process and In a closed cycle The Net heat Transfer is Equal to the Net work done.

$$\boxed{\oint dQ = \oint dW}$$

(Q) In a Thermodynamic cycle the Net heat transfer to a system is 21 joule, -21 joule, 9 joule, -9 joule, 81 joule, 100 joule. find the Net work done by the system ?

Ans

Given

Net heat transfer

$Q_1 = 21$, $Q_2 = -21$, $Q_3 = 9$, $Q_4 = -9$, $Q_5 = 81$,
$Q_6 = 100$.

$\therefore$ Net heat transfer is equal to the net work done

$$= \oint dQ = \oint dW$$

$$\Rightarrow 21 - 21 + 9 - 9 + 81 + 100 = \oint dW$$

$$\oint dW = 181 \text{ joule}$$

Ans

Limitation of 1st law of thermodynamics:-

1:- it does not gives any idea about the direction of the heat flows whether it is from hot body to cold body or cold body to hot body.

2:- As we know heat and work are mutually convertible But in Actual Practice heat can't be converted to work (100%).

3:- Those machines which violates the 1st law of Thermodynamic are called (PMM-1) (Perpetual motion machine of 1st kind).

$(\oint dQ = \oint dW)$

if we take care of the energy

$dQ = dE + dW$

$dE = dQ - dW$ where "E" = total energy.

Kinetic energy $= \frac{1}{2} \times m \times v^2$

Potential energy $= m \times g \times h$

Internal energy $= U$

$$\therefore dE = dQ - dW = \left(\frac{1}{2} \times m \times v^2 + m \times g \times h + U\right) = dQ - dW.$$

state-1	state-2
(1) $\frac{1}{2} \times m \times v_1^2$	(1) $\frac{1}{2} \times m \times v_2^2$
(2) $m \times g \times z_1$	(2) $m \times g \times z_2$
(3) U_1	(3) U_2
total energy 'E' = $\frac{1}{2} \times m \times v_1^2 + m \times g \times z_1 + U_1$	total energy 'E' = $\frac{1}{2} \times m \times v_2^2 + m \times g \times z_2 + U_2$

$$dE = dQ - dW = \left(\frac{1}{2} \times m \times v_1^2 + m \times g \times z_1 + U_1\right) - \left(\frac{1}{2} \times m \times v_2^2 + m \times g \times z_2 + U_2\right)$$

$$\Rightarrow \left(\frac{1}{2} \times m \times v_2^2 - \frac{1}{2} \times m \times v_1^2\right) + (m \times g \times z_2 - m \times g \times z_1) + (U_2 - U_1)$$

$$= \frac{m}{2}(v_2^2 - v_1^2) + m \times g\,(z_2 - z_1) + (U_2 - U_1) = dQ - dW$$

(This Equation is called steady flow energy Equation). (S.F.E.E).

→ if the Kinetic energy of the system is Negligible.

$$m \times g\,(z_2 - z_1) + (U_2 - U_1) = dQ - dW$$

→ if Both Kinetic energy & potential energy of the system is neglected.

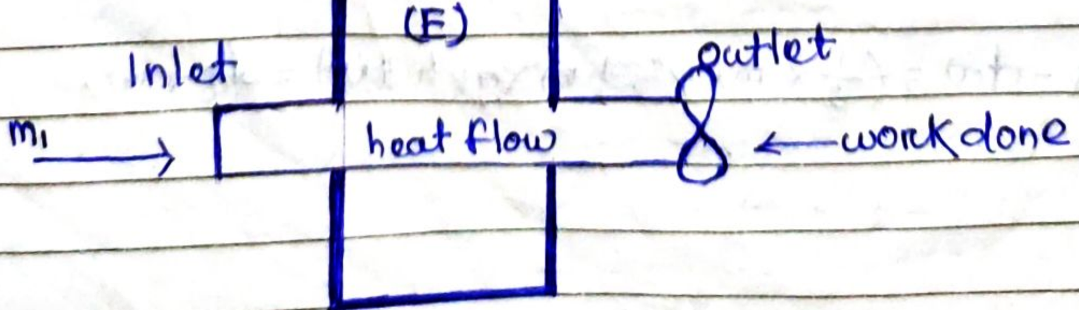
$$(U_2 - U_1) = dQ - dW$$

$$= dU = dQ - dW$$

(This equation is called as energy equation in a Non-flow Process)

* STEADY FLOW ENERGY EQUATION IN A CONTROL VALUME

~ OPEN SYSTEM ~



$$m_1\left[h_1+\frac{v_1^2}{2}+z_1 g\right]+dq=m_2\left[h_2+\frac{v_2^2}{2}+z_2 g\right]+dw$$

APPLICATION OF S.F.E.E TO TOURBINE

Turbin is a work producing device which Gives positive Power output.

→ No Kinetic energy in this process.
→ Neglicible change in Kinetic & Potential Energy.
→ No heat Generate in this process or not heat supply in this process.

$$m_1 \times h_1 = m_2 \times h_2 + w$$
$$\Rightarrow m_1 \times h_1 - m_2 \times h_2 = w$$
if $m_1 = m_2 = m$
$$m(h_1 - h_2) = w$$

APPLICATION OF S.F.E.E TO COMPRESSOR

it is a work consuming device and it Gives Negative power output.

$$-W_c = m(h_1 - h_2)$$
$$\Rightarrow W_c = m(h_2 - h_1).$$

Q) A Turbine obeys S.F.E.E. and mass flow Rate at Inlet and outlet are equal to 5kg/sec the Enthalpy at Inlet is 2000 Kj/Kg and outlet is 180 Kj/Kg. find the work done by the turbine?

Ans Given

$m = 5$ Kg/sec
$h_1 = 2000$ KJ/Kg
$h_2 = 180$ KJ/Kg

∵ the inlet mass & outlet is equal
$m_1 = m_2 = m$
$\Rightarrow m(h_1 - h_2) = w = 5(2000 - 180) = 9100$ KJ/Kg

Ans

(Q) A compressor obey's S.F.E.E in which the mass flow rate at Inlet and outlet are equal which is 5 Kg/sec the Enthalpy at inlet is 1000 KJ/Kg and outlet is 2998 KJ/Kg. Find the work done?

Ans Given

$\therefore m_1 = m_2 = m$

$W = m(h_2 - h_1)$

$= 5(2998 - 1000)$

$= 9990$ KJ/Kg Ans

(Q) A compressor obey's S.F.E.E In which the mass flow rate at Inlet and outlet are equal which is 5 Kg/sec the Enthalpy at Inlet is 1000 KJ/Kg and outlet is 2998 KJ/Kg find the work done?

Ans Given

$m = 5$ kg/sec

$h_1 = 100$ kg/Kg

$h_2 = 2998$ KJ/Kg

$\therefore$ Work done $= m(h_2 - h_1)$

$= 5(2998 - 1000)$

$= 9990$ KJ/Kg Ans

(Q) A compressor obey's S.F.E.E In which the mass flow rate at the Inlet is 5 Kg/sec and at the outlet the flow rate is 10 Kg/sec the value of Enthalpy at Inlet and outlet is 2198 J/Kg and 1998 J/Kg find the work done?

Ans Given $m_1 = 5$ Kg/sec, $m_2 = 10$ Kg/sec

$h_1 = 2198$ J/kg, $h_2 = 1998$ J/Kg

$\therefore$ work done $= w = (m_2 \times h_2 - m_1 \times h_1)$

$w = (10 \times 1998 - 5 \times 2198) = 8990$ J/Kg. Ans

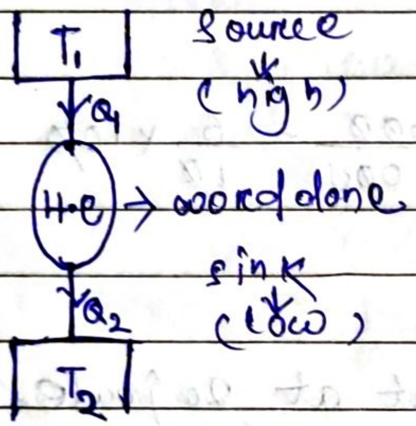
SECOND LAW OF THERMODYNAMICS :-

(1) it tells us about the direction of heat flow.
(2) it also tell us work is a high grade energy & heat is a low grade Energy as their complete conversion is not 100% percent.

KELVIN - PLANK'S STATEMENT :-

According to Kelvin plank's Statement " it is Impossible to construct a heat Engine operating a cycle Exchange heat with a single Thermal Reservior.

Second law of thermodynamics:-



This machines which viloates second law of thermodynamics are called PMM-2 (Prepeltual Motion machine of 2nd Kind).

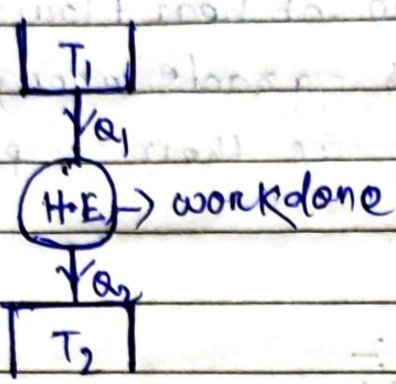
Ex :- Petrol engine or bike engine.

input → Engine → output
(petrol) → (Chemical Energy)
(Mechanical Energy)

Efficiency :-

$$= \frac{\text{output}}{\text{Input}} = \frac{\text{M.E}}{\text{C.E}} = \frac{\text{joule}}{\text{joule}} = \text{unitless.}$$

EFFICIENCY OF HEAT ENGINE :-



$$\eta_{H.E} = \frac{\text{work done}}{\text{Heat Supplied}} = \frac{W}{Q_1}$$

$$\therefore \oint dQ = \oint dW$$

$$= Q_1 - Q_2 = W$$

$$\eta_{H.E} = \boxed{\frac{Q_1 - Q_2}{Q_1} = \frac{T_1 - T_2}{T_1}}$$

(Q)(i) Heat Engine operating between temperature limit of 1000 K and 400K find the efficiency?

Ans Given $T_1 = 1000K$
$T_2 = 400K$

$$\eta_{H.E} = \frac{T_1 - T_2}{T_1} = \frac{1000 - 400}{100} = \frac{600}{1000} = \frac{6}{10} \times 100$$

$$= 60\%$$

(Q)(ii) A Heat engine Release heat at 20 Joule and Heat supply to it is 50 Joule find the Efficiency?

Ans Given $Q_1 = 50$ Joule
$Q_2 = 20$ Joule

$$\therefore W = \frac{Q_1 - Q_2}{Q_1} = \frac{50 - 20}{50} = \frac{3\cancel{0}}{\cancel{5}\cancel{0}} \times \overset{20}{\cancel{100}}$$

$$= 60\%$$

(Q xiii) The the efficiency of a heat engine is 50% & the heat supplied to the engine is 100 joule find the work done ?

Ans

Given
$$\eta = 50\% = \frac{50}{100} = \frac{1}{2}$$
$$Q_1 = 100$$
$$\eta = \frac{W}{Q_1} \Rightarrow W = \eta \times Q_1$$
$$= \frac{1}{\cancel{2}_1} \times \cancel{100}\,50$$
$$= 50 \text{ joule}$$ Ans

(Q xiv) for a heat Engine heat supplied is 100 KJ & efficiency is 34%. find the work done ?

Ans

Given
$$Q_1 = 100$$
$$\eta = \frac{34}{100}, \quad \eta = \frac{W}{Q_1}$$
$$W = \eta \times Q_1$$
$$= \frac{34}{\cancel{100}} \times \cancel{100} = 34 \text{ joule}$$
Ans

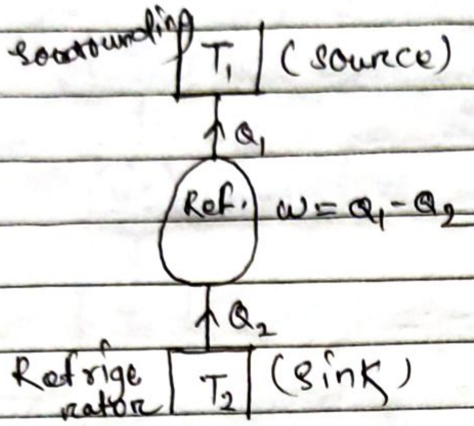
Clausius statement on second law :-

Heat can't be flow from a cold body to heat body or it can be possible with the help of external agent.

• Such type of machines are called PMM-2 (Perpetual motion of machine 2nd kind)

Refrigerator

→ it is the science of maintaining temperature Below then that of sorrounding temperature.



* co-efficient of Performance

$$(C.O.P) = \frac{\text{Desired effect}}{\text{work done}}$$

$$= \frac{Q_2}{Q_1 - Q_2} = \frac{T_2}{T_1 - T_2}$$

(Q1) A Refrigerator works between the Temperature limits of 1000K and 400K find the (C.O.P)?

Ans Given

$T_1 = 1000\,K$

$T_2 = 400\,K$

$$\therefore (C.O.P) = \frac{T_2}{T_1 - T_2}$$

$$= \frac{400}{1000 - 400} = \frac{400}{600} = \frac{2}{3}$$ Ans

(Q2) A Refrigerator works between the work done is 100 KJ and heat supplied to Refrigerator is 50 KJ. find (C.O.P)?

Ans

Given $W = 100\,KJ$,

$Q_2 = 50\,KJ$

$$\therefore (C.O.P) = \frac{Q_2}{Q_1 - Q_2}$$

$$= \frac{50}{100} = \frac{1}{2} = 0.5$$

Ans

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(Q3) A Refrigerator work between the work done is 100 KJ and heat Rejection is 200 KJ find (C.O.P)?

Ans

Given $w = 100\ KJ$

$Q_1 = 200\ KJ$

$\because w = Q_1 - Q_2$

$Q_2 = w + Q_1$

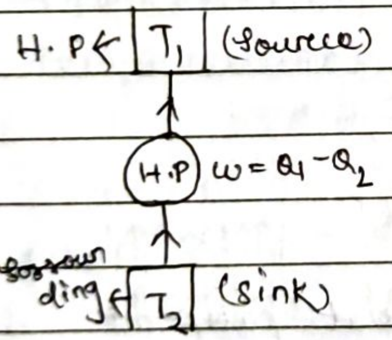
$Q_2 = 100 + 200$

$Q_2 = 300$

$\therefore (C.O.P) = \frac{Q_2}{w} = \frac{3\cancel{00}}{1\cancel{00}} = 3$

Ans

Heat PUMP :- it is a device which maintans the temperature higher than of Sorrounding Temperature.



$\therefore (C.O.P)_{H.P} = \frac{Q_1}{Q_1 - Q_2} = \frac{T_1}{T_1 - T_2}$

$$\boxed{(C.O.P)_{H.P.} = (C.O.P)_{Ref.} + 1}$$

* from the arobe equeation we obsevre that $(C.O.P)_{H.P}$ is alway Greater then Refrigerator.

(Q1) A Heat Pump works between temperature limit of 800 K and 600 K, then find (C.O.P) of the System?

Ans Given $T_1 = 800\ K$, $T_2 = 600\ K$

$\therefore (C.O.P) = \frac{T_1}{T_1 - T_2} = \frac{800}{800-600} = \frac{\cancel{800}^{4}}{\cancel{200}_{1}} = 4$

Ans

(Q2) if the c.o.p of a heat pump is 5, find the c.o.p of a Refrigerator?

Ans Given

c.o.p of heat pump is 5

$\therefore (C.O.P)_{H.P} = (C.O.P)_{Ref.} + 1$

$(C.O.P)_{Ref} = (C.O.P)_{H.P} - 1$

$= 5 - 1$

$= 4$ Ans

(Q3) A Heat Pump work done is 100 joule the heat Rejected by the Heat pump is 300 joule, find the c.o.p?

Ans

Given $w = 100$ joule

$Q_1 = 300$ joule

$\therefore C.O.P = \frac{Q_1}{w} = \frac{300}{100} = 3$

Ans

(Q4) The heat supplied to the Heat pump is 80 joule and work done is 100 joule find the (c.o.p) of the system?

Ans

Given $Q_2 = 80$ joule

$w = 100$ joule.

$\therefore w = Q_1 - Q_2$

$Q_1 = w + Q_2$

$Q_1 = 100 + 80 = 180$

$\therefore (C.O.P) = \frac{Q_1}{Q_1 - Q_2}$

$= \frac{180}{100} = \frac{9}{5} = 1.8$ Ans

29th oct 2023

PROPERTIES OF PERFECT GAS,

In Reality there is no perfect Gas But During our studies we consider all Gases as (perfect or ideal) this gas must be obeys some laws which are experimentally found.

(1) BOYLE'S LAW:-

For a Given mass of perfect gas absolute Pressure of a gas is inversly Proportional to volume But at constant temperature.

$$P \propto \frac{1}{V} = PV = \text{constant.}$$

$\downarrow\uparrow P \propto V \uparrow\downarrow$ - directly proportional.
$\downarrow\uparrow P \propto \frac{1}{V} \downarrow\uparrow$ - Inversly Proportional.

(2) charle's law:-

for a given mass of ideal gas volume of a gas is directly Proportional to temperature at constant pressure.

$V \propto T = (P \text{ costant})$

$= V = C \cdot T$

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

(3) Gay-Laccack's law:-

for a given mass of ideal gas absolute Pressure is directly proportional to temperature and constant volume.

$P \propto T$ (V = costant)

$\Rightarrow P = C \cdot T$

$\Rightarrow \frac{P}{T} = C$

→ the three laws are combine togather to from perfect gas equeation or also called a ideal gas equation.

$P \propto \frac{1}{V}$

$V \propto T$

$P \propto T$

$\rightarrow P \propto \frac{T}{V} = PV \propto T$

$PV = C \cdot T$

$\frac{PV}{T}$ = Constant.

(Q1) for a percect gas the temperature Remains constant the pressure at initial stage is 10 N/m² and volume is 5m³ the final Pressure is 20 N/m². find the final volume of the gas?

Ans Given

$P_1 = 10\ N/m^2$ $\quad P_2 = 20\ N/m^2$

$V_1 = 5m^3$ $\quad V_2 = ?$

$\therefore P \propto \frac{1}{V} = PV =$ constant

$P_1V_1 = P_2V_2$

$= \frac{P_1V_1}{P_2} = V_2 \Rightarrow \frac{\cancel{10} \times \cancel{5}}{\cancel{20}} = \frac{5}{2} = 2.5m^3$

Ans

(Q2) In case of an ideal gas the initial volume and temperature are $1 m^3$ and 300K find the final temperature when volume changes to $2 m^3$?

Ans Given $V_1 = 1 m^3$ $V_2 = 2 m^3$
$T_1 = 300 K$ $T_2 = ?$

$\therefore V \propto T = (P \text{ costant})$
$\Rightarrow V = C \cdot T$
$\Rightarrow \frac{V}{T} = C \Rightarrow \frac{V_1}{T_1} = \frac{V_2}{T_2}$

$= \frac{1}{300} = \frac{2}{T_2}$

$= T_2 = 600 K$ Ans

(Q3) for a given mass of ideal gas the initial temperature is 1000K, volume is $2 m^3$ and Pressure is $10 N/m^2$. find the final pressure where the final volume is $4 m^3$ and temperature is 600K ?

Ans
Given $T_1 = 1000K$ $T_2 = 600K$
$V_1 = 2 m^3$ $V_2 = 4 m^3$
$P_1 = 10 N/m^2$ $P_2 = ?$

$\therefore P \propto \frac{T}{V} = PV \propto T$
$PV = C.T$
$\frac{PV}{T} = C = \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

$= \frac{\cancel{10} \times \cancel{2}^{1}}{\cancel{1000}_{50}} = \frac{P_2 \times \cancel{4}^{2}}{\cancel{600}_{300}}$ $= 50 \times 2P = 300$
$= 100P = 300$
$= \frac{\cancel{100}}{\cancel{300}} = 3 N/m^2$

(Q4) for a given mass of ideal gas the pressure at initial and final stage is 20 N/m2 and 30 N/m2. the final temperature is 600K find the initial temperature ?

Ans Given

$$P_1 = 20\ N/m^2 \quad , \quad P_2 = 30\ N/m^3$$
$$T_1 = ? \qquad T_2 = 600K$$

$\therefore P \propto T$ (V = constant)

$$= P = C \cdot T$$
$$= \frac{P}{T} = C$$

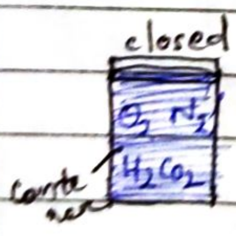
$$= \frac{P_1}{T_1} = \frac{P_2}{T_2} = \frac{20}{T_1} = \frac{\cancel{30}}{\cancel{600}} = T_1 = 400K$$

Ans

7th Nov 2022

Dalton's law of Partial pressure

According to this law the total Pressure exerted by a sum of gas is equal to their sum of partical Pressure of each Indivisual gases.



$$\boxed{P_T = P_{O_2} + P_{N_2} + P_{H_2} + P_{CO_2}}$$

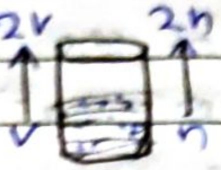
Avogadro's law :-

Equal volume of Gas contains equal no. of moleccules if they are taken at same temperature and Pressure.

$\therefore V \propto n$ n = number of molecules.

$V = cn$

$\frac{V}{n}$ = constant



(Q.) For a gas contains 2×10^3 molecules has volume of $2m^3$. Now if the volume changes to $6m^3$ find the no. of molecules?

Ans Given

$V_1 = 2m^3$, $V_2 = 6m^3$

$n_1 = 2\times10^3$, $n_2 = ?$

$\therefore V \propto n$

$V = c.n$

$\frac{V}{n}$ = Constant

$\frac{V_1}{n_1} = \frac{V_2}{n_2} = \frac{\cancel{2}}{\cancel{2}\times10^3} = \frac{6}{n_2}$

$= \frac{1}{1000} = \frac{6}{n_2}$

$= n_2 = 6\times1000$

$= 6\times10^3$

Ans

characteristics gas equation:- (modified equation)

$\frac{PV}{T} = C = PV = CT$

let 1 kg of ideal gas is taken so it is difficult to use the above equation so we use the modified equation.

which is $\boxed{PV = MRT}$

where m = mass of the gass / no. of moles.
R = charastoric gas constant.

$$PV = mRT$$

$$R = \frac{PV}{mT} = \frac{N/m^2 \times m^3}{Kg \times Kelvine} = \frac{N \cdot m}{Kg \cdot K}$$

$$= \frac{joule}{Kg \cdot K} = J/Kg \cdot K$$

(Q1) for a ideal gas the pressure is 20 pascal having volume of 1 m^3 and temperature of 100 Kelvin find the value of mass of the Gas when R = 0.287 J/Kg.K ?

Ans

Given
P = 20 pascal
V = 1 m^3
T = 100 K
R = 0.287 J/Kg.K

$$\therefore PV = mRT$$

$$m = \frac{PV}{RT} = \frac{\cancel{20} \times 1}{0.287 \times \cancel{100}} = 0.65$$

Ans

Universal Gas constant :-
it is the product of charasteris Gas constant with moleccular mass

$$\therefore R_u = R \times M$$

Generally $R_u = 8.314$ J/Kg.K
it is same for all the gases.

Ex :- oxygen (O_2)

2 × 8 = 16 , $R_u = R \times M$

$$= R = \frac{R_u}{M} = \frac{8.314}{16} = 0.519 J/Kg.K$$

$CO_2 = 44$

$R_u = RM$

$R = \frac{R_u}{m} = \frac{8.314}{44} = 0.18895\ J/Kg \cdot K$

(Q2) for a ideal gas $P = 20\ N/m^2$, $v = 2m^3$, $m = 2\ Kg$ and $T = 100K$ find the value of R?

Ans

Given $P = 20\ N/m^2$

$V = 2m^3$

$m = 2\ Kg$

$T = 100K$

$R = ?$

$\therefore PV = MRT$

$R = \frac{PV}{MT} = \frac{\cancel{20} \times \cancel{2}}{\cancel{2} \times \cancel{100}_5} = \frac{1}{5} = 0.2\ J/kg \cdot K$

Ans

15th Nov 2022

Enthalpy:-(h)

it is also one of the property of the system

$h = u + PV$ where,

V = Volume

there unit is KJ/Kg.

P = pressure

u = internal Energy.

(Q) In a thermodynamic system having $5\ N/m^2$ of Pressure and $2m^3$ volume having Internal Energy of 1860 J/Kg. find the enthalpy?

Ans

Given $P = 5\ N/m^2$, $V = 2m^3$, $u = 1860\ \cancel{kg}/Kg$.

$\therefore h = U + PV$

$= 1860 + 5 \times 2 = 1860 + 10$

$= 1870\ \cancel{kg}/Kg$.

TYPES OF THERMODYNAMIC PROCESS

(ISOBARIC)	(ISOCHORIC)	(ISOTHERMAL)	Polytropic
(1) P = costant	(2) V = constant	(3) T = costant	
(1) $dw = P \times dV$	(1) $dw = P \times dV$		
(2) $dQ = mc_p dT$	$= P \times (V_1 - V_2)$		
(3) $dU = mc_p dT$	$= P \times (V_1 - V_1) = 0$		
	(2) $dQ = mc_v dT$		
	(3) $dU = mc_v dT$		

(3) Constant temperature (isothermal process):-

(i) $dw = P \times dV$

(ii) $dQ = Mc_v dT$

$= Mc_v (T_2 - T_1)$

$= Mc_v (T_1 - T_1)$

$= 0$

$PV = MRT$
$P = \frac{MRT}{V}$

$dU = mc_v(dT)$
$= 0$

(iii) we know $dQ = du + dw$
if we take $du = 0$
$dQ = dw$
$T = C,\ P \propto \frac{1}{V}$
PV = constant.

$\uparrow P_1V_1 = P_2V_2$

(1) ———— (2)
P_1V_1 $\quad$ P_2V_2

According to boyle's law.

$PV = P_1V_1 = P_2V_2$
$\downarrow$
$PV = P_1V_1$
$P = \frac{P_1V_1}{V_1}$

(i) $dw = P \times dV$
$= dw = \frac{P_1V_1}{V} \times dV$

$$dw = P_1 V_1 \int_1^2 \frac{dV}{V}$$

$$= \int \frac{dV}{V} \ln|V|$$

$$dw = P_1 V_1 \ln[V_1]_1^2$$

$$dw = P_1 V_1 [\ln(V_2) - \ln(V_1)]$$

$PV = P_1V_1 = P_2V_2$

$P_1V_1 = P_2V_2$

$PV = MRT$

$$w = P_1 V_1 \ln\left(\frac{V_2}{V_1}\right)$$

$$w = P_1 V_1 \ln\left(\frac{P_1}{P_2}\right)$$

$$w = MRT \ln\left(\frac{P_1}{P_2}\right)$$

$$w = MRT \ln\left(\frac{V_2}{V_1}\right)$$

(Q) find the work done in a constant temperature process whose intial pressure and volume is $2\ N/m^2$ & $5m^3$ and the volume changes to $3m^3$?

Ans

Given $P_1 = 2\ N/m^2$, $V_2 = 3m^3$
$V_1 = 5m^3$

$$\therefore w = P_1 V_1 \ln\left(\frac{V_2}{V_1}\right)$$

$$= 2\times5 \ln\left(\frac{3}{5}\right)$$

$$= 10 \ln\left(\frac{3}{5}\right)$$

$$= 10[\ln 3 - \ln 5]$$

$$= -5.1082 \text{ Joule}$$

Ans

15th Nov 2022

Specific Heat:-

The amout of heat Required to Raise the temperature of a unit mass

Sabtance through 1°C.

→ If the above process Done at Constant Pressure is called (cp).

→ if the above process Done at Constant volume is called (Cv).

for gases.

$Cp = 1.005 \ KJ/Kg \cdot K$.

$Cv = 0.717 \ KJ/Kg \cdot K$.

Relation ships :-

(1) $\frac{Cp}{Cv} = \gamma$ (Adiabatic index)

(2) $Cp - Cv = R$

For dia-atomic gas ($\gamma = 1.4$) O_2, H_2, H_2

for Tric-atomic gas ($\gamma = 1.67$) CO_2.

Single atom ($\gamma = 1.3$) = He, Ne, Ar.

Polytropic Process:-

it is written by the Equation.

PV^n = Constant.

where n is a constant term

$$\text{work done} = \frac{P_1V_1 - P_2V_2}{n-1}$$

$PV = mRT$

$P_1V_1 = mRT_1$

$P_2V_2 = mRT_2$

$$= \frac{mRT_1 - mRT_2}{n-1}$$

$$= \frac{mR(T_1 - T_2)}{n-1}$$

(Q) A Thermodynamic Process governs by the Equation $PV^{1.3} = C$, where intial and final Pressure and volume are $P_1 = 10 N/m^2$, $V_1 = 5m^3$, $P_2 = 5 N/m^2$, $V_2 = 1m^3$ find the work done by the process.

Ans

Given equation

$PV^{1.3} C$

$P_1 = 10 N/m^2$, $V_1 = 5m^3$

$P_2 = 5 N/m^2$, $V_2 = 1m^3$

$\therefore$ work done $= \dfrac{P_1V_1 - P_2V_2}{n-1}$

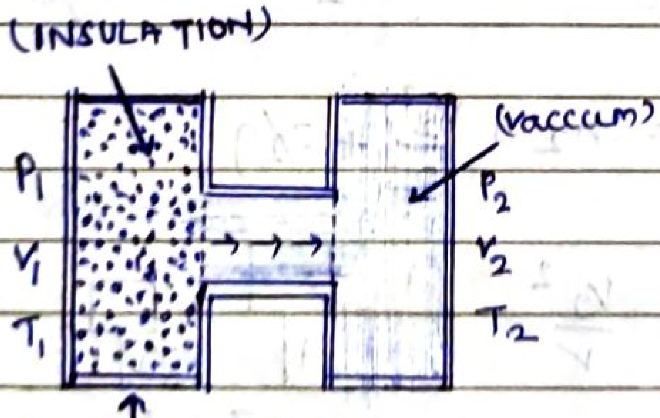
$= \dfrac{10\times5 - 5\times1}{1.3-1}$

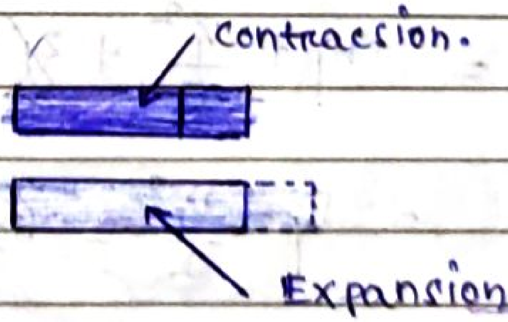
$= \dfrac{50-5}{0.3}$

$= \dfrac{45}{0.3} = 150$ joule Ans

18th Nov 2022

Free Expansion process :-





No heat transfer

$dQ = 0$

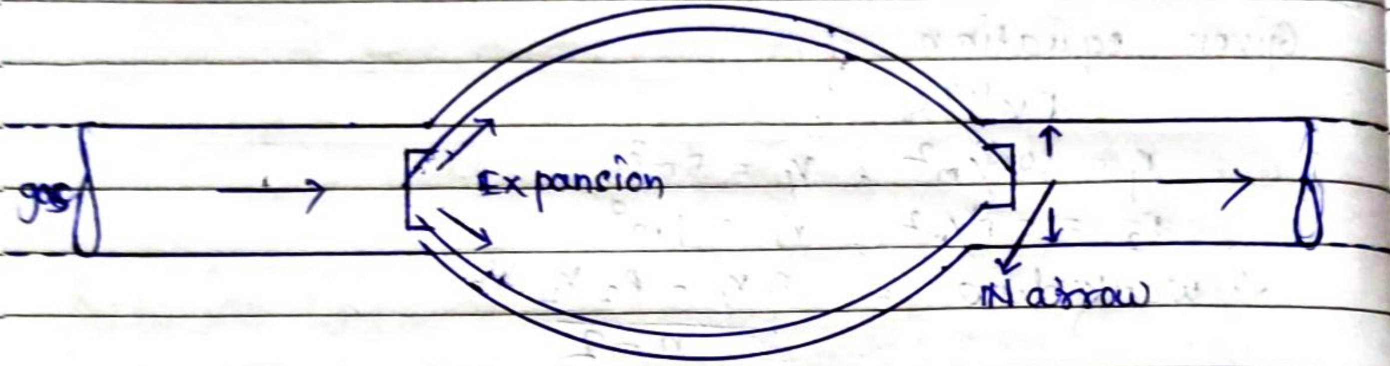
work done $= dW = 0$

$0 = du + 0$

$du = 0 \rightarrow$ internal energy.

THROTTILING PROCESS:-

A Perfect gas Expanded in an orifice or Narrow Throat.



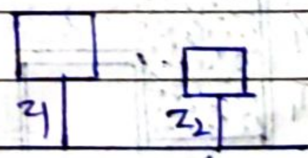
it is an Irr-reversible steady flow Process

No heat transfer = $dQ = 0$
No work done = $dw = 0$

$$h_1 + \frac{v_1^2}{2} + z_1 g + \frac{dQ}{dt} = h_2 + \frac{v_2^2}{2} + z_2 g + \frac{dw}{dt}$$

$$= h_1 + \frac{v_1^2}{2} + \cancel{z}g = h_2 + \frac{v_2^2}{2} + \cancel{z_2}g$$

$$= h_1 = \frac{v_1^2}{2} = h_2 + \frac{v_2^2}{2}$$



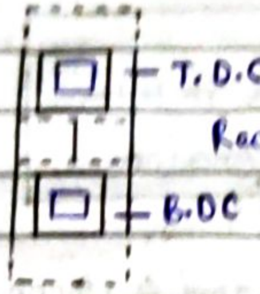
$z_1 = z_2$

here the velocities are Negligible $v_1 = v_2$
$h_1 = h_2$ (h is constant)

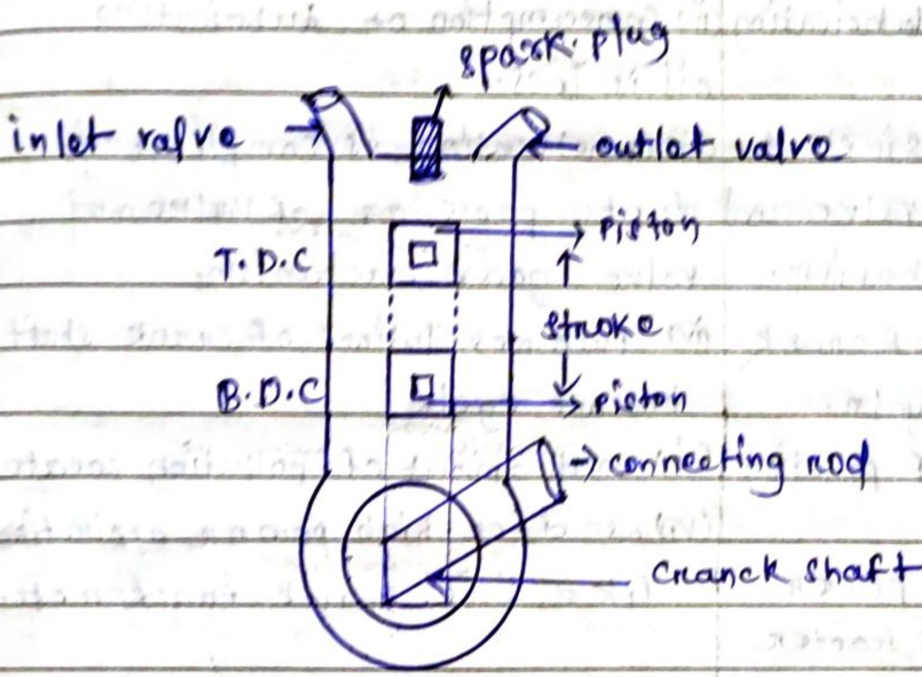
(In a throttiling Process Enthalpy Remains Constant).

ENGINE

(T.D.C → B.DC - 1 stroke)



ic-engine - Internal combustion Engine
EC engine - External combustion Engine



(1) Suction Process.
(2) Compression :- Pressure & temperature ↑ grawoth
(3) Expansion / woorking.
(4) Exhaust stroke.

Engine Basic Nomenclature :-

(i). Piston Area :- $\frac{\pi}{4} \times D^2$ (D = Diameter of the Bore)
(ii) stroke :- Distance from (T.D.C to B.D.C) → (L)
(iii) Bore :- it is the diameter of the cylinder (D)
(iv) Piston speed :- $V_p = \frac{2 \times L \times N}{60}$
(v) R.P.M :- (Rovolation Per minute) N.

SI Engine	CI Engine
Spark ignition Engine petrol engine	Compression inition Diesel Engine

* Defferentce between 2 stroke engine and 4 stroke engine

2 stroke engine	4 stroke engine
(i) cycle is compleated in two strokes of piston.	(i) cycle is completed in four strokes of piston
(ii) consumption of lubricating oil is more.	(ii) comsumption of lubricating oil is less.
(iii) construction is simple due to absence of valve and valve gear machanism.	(iii) construction is complicated due to pressure of valve and valve gear machanism.
(iv) one revolutions of crank shaft in one cycle.	(iv) two revolutions of crank shaft in one cycle
(v) large amout of pollation create.	(v) small amout of pollution create
(vi) used for low power application like scooter moter cycle, auto rickshaw etc.	(vi) used for high power applications like bus, truck, tractor etc.

:- FUELS :-

Any subtance which Release (Heat / Energy) After combution is known as fuel.

:- Calorific value of a fuel :- (Heat value)

it is defined as the quantity of Heat Relesed by the complete combustion of 1 unit of fuel (unit is Kg/kg)

→ GENERAL FUEL USED :-

Petrol	Diesel
(i). it is a crude oil.	(i) it is also a crude oil.
(ii). it is a volatile fule.	(ii) it is a Non-volatile fule.
(iii) Better combusition.	(iii) Good combusion.
(iv) high Calorific value.	(iv) low calorific value.
(v) low thermal Efficiency.	(v) high Efficiency.
(vi) calorific value is - 44,000 KJ/Kg.	(vi) calarific value - 40,000 KJ/Kg.
(vii) high cost.	(vii) cheaper.

L.P.G	C.N.G
→ liquified petrolium Gas.	→ Compressed natural gas.
→ Low cost	→ methane, Ethane, Butane
→ Butane + Propane.	→ compressing in a cylinder
→ Environment friendly.	
→ Hazadious problems	

:- Rating of ic engine fuels :-

S.I Engine	C.I Engine
→ octane Number.	→ cetane Number
→ Combination of Iso-octane and n-heaptne)	→ (cetane and α-methyle heaptane).
→ Iso-octane (100 octane Num)	→ Cetane = 100 (cetane Num.)
→ N-heaptane ('0' octane Number)	→ α-methyle heaptane = '0' (cetane N.)
→ Petrol - 50-65	→ Diesel (40-55)

÷Air standrad cycles:-

Here the working meduim is air.
These are theoritical cyeles.
value of air
$\gamma = 1.4$
$C_p = 1.005$ KJ/Kg·K
$C_v = 0.718$ KJ/Kg·K
used to compare the performace of Actul Engines.

÷Assumptions:-

(i). Air behaves as Perfect Gas.
(ii). No. chemical Reaction occours during the Process.
(iii). All the Process are Externally and internally Reversible.
(iv). The working medium at the end of the Process Remains unchanged.

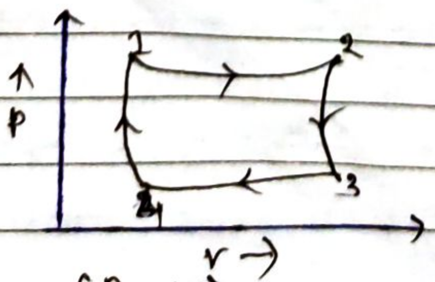
Efficiency:- (η):-

$$\eta = \frac{\text{out Put}}{\text{in put}}$$

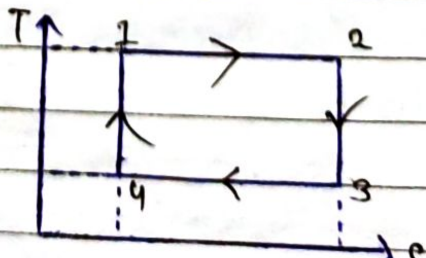
$$\text{efficiency cycle} = \left(\frac{\text{Total work done}}{\text{Heat supply}}\right).$$

÷CARNON CYCLE:-

→ Costant - Temperature cycle.
→ Introduced by - Sadi carnot.
→ it is consist of four Process.
→



(P~v)



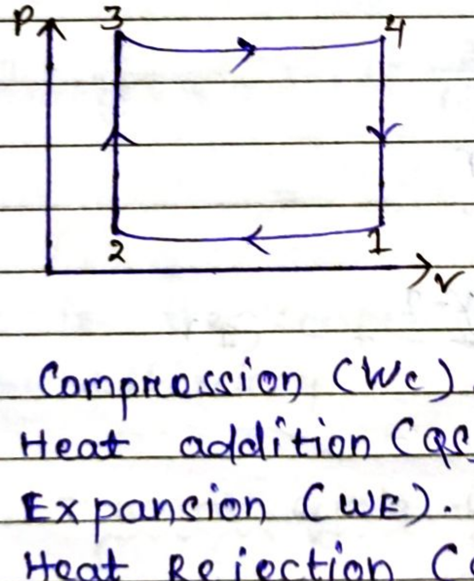
(T~S)

:PROCESS:-

Sl.
(1). (1-2) → Isothermal Expansion (constant temperature)
(2). (2-3) → Reversible Adiabatic / Isoentropic expansion, Heat Constant (Q = 0)
(3). (3-4) → Isothermal compression.
(4). (4-1) → Isoentropic compression.

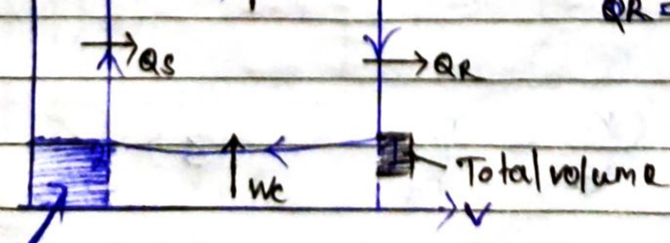
:OTTO CYCLE:-

* Also known as constant volume cycle.
* Intro-duced by Nickolos "otto", who first buit a succesful I.C Engine.
* it is used as a working cycle in Petrol Engine.
* it is also having four process.



$(2-3) = V = C$
$(4-1) = V = C$
1-2 an 3-4 is Reversible Adiabatic

1-2 → Compression (Wc).
2-3 → Heat addition (QS).
3-4 → Expansion (WE).
4-1 → Heat Rejection (QR).



clearance volum

$\therefore Q = m \times C_V \times dT$
$Q_S = mC_V dT = mC_V(T_3 - T_2)$
$Q_R = mC_V dT = mC_V(T_1 - T_4)$

(1-2) ~~cpr~~ compression Ratio
$\frac{V_1}{V_2}$

$$\eta = \frac{W_{net}}{Q_S} = \frac{Q_S - Q_R}{Q_S} \quad \left[\oint dQ = \oint dw . \right.$$

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

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

$$\frac{V_1}{V_2} = \frac{\text{Total volume of the cylinder}}{\text{clearnce volume.}}$$

1-2 → Adiabatic
2-3 → $V = C$
3-4 → Adiabatic
4-1 → $V = C$

PV^{γ} = constant

$PV = MRT$

Process - (1-2)

$PV = RT$

$$\frac{PV}{T} = C$$

$$\frac{P_1 V_1^{\gamma}}{T_1} = \frac{P_2 V_2^{\gamma}}{T_2}$$

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

Process (3 - 4) :-

$$\frac{P_3 V_3^{\gamma}}{T_3} = \frac{P_4 V_4^{\gamma}}{T_4} \Rightarrow \frac{V_2}{V_3} = \frac{T_2}{T_3} \text{ - - - - } (2)$$

Process (2 - 3) :-

$$\frac{P_2 V_2}{T_2} = \frac{P_3 V_3}{T_3} \Rightarrow \frac{V_2}{V_3} = \frac{T_2}{T_3} \text{ - - - - } (3)$$

Process (4-1) :-

$$\frac{P_4 V_4}{T_4} = \frac{P_1 V_1}{T_1} \Rightarrow \frac{T_4}{T_1} = \frac{V_4}{V_1} \quad \text{-----} \; (e_1)$$

After putting all the values

$$\eta_{otto} = 1 - \frac{1}{(r_k)^{\gamma - 1}}$$

where r_k is known as compression ratio

$$(r_k) = \frac{V_1}{V_2}$$

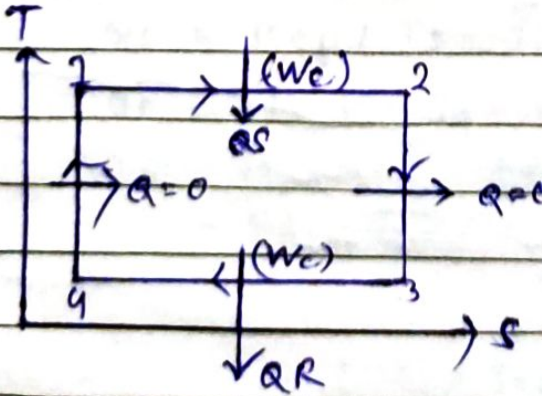
Ex:- $\frac{V_1}{V_2} = 8 \quad \gamma = 1.4$

$$\eta = 1 - \frac{1}{(8)^{1.4-1}} = 1 - \frac{1}{(8)^{0.4}} = \frac{(8)^{0.4} - 1}{(8)^{0.4}} \times 100$$

$$=$$

* higher is the compression ratio, higher will be the efficieny.

Carnot cycle (efficiency):-



(1-2) - Isothermal expansion.
(2-3) - Adiabatic expansion.
(3-4) - Isothermal compression.
(4-1) - Adiabatic compression.

when, $T = C$, $u = mc_v dT = 0$.

$dq = dw$

$w = P_1 V_1 \ln\left(\frac{P_1}{P_2}\right)$, $MRT_1 \ln\left(\frac{P_1}{P_2}\right)$

$= P_1 V_1 \ln\left(\frac{V_2}{V_1}\right)$, $MRT_1 \ln\left(\frac{V_2}{V_1}\right)$

→ in a Adiabic Process heat is costant.
then w, is

$w_{1-2} = P_1 V_1 \ln\left(\frac{P_1}{P_2}\right)$, $P_1 V_1 \ln\left(\frac{V_2}{V_1}\right)$

$w_{3-4} = P_1 V_1 \ln\left(\frac{P_3}{P_4}\right)$, $P_1 V_1 \ln\left(\frac{V_4}{V_3}\right)$

$$\eta_{carnot} = \frac{W_{net}}{Q\ supplied}$$

$$= \frac{Q_S - Q_R}{Q_S}$$

$\left[PV = MRT,\ P_1 V_1 \ln\left(\frac{V_2}{V_1}\right) = MRT_1 \ln\left(\frac{V_2}{V_1}\right) \right.$

$$= \frac{MRT_1 \ln\left(\frac{V_2}{V_1}\right) - MRT_3 \ln\left(\frac{V_4}{V_3}\right)}{MRT_1 \ln\left(\frac{V_2}{V_1}\right)}$$

$$= \frac{T_1 \ln\left(\frac{V_2}{V_1}\right) - T_3 \ln\left(\frac{V_4}{V_3}\right)}{T_1 \ln\left(\frac{V_2}{V_1}\right)}$$

$$= \frac{T_1 - T_3}{T_1}$$

$\eta = -1 - \frac{T_3}{T_1} = 1 - \frac{T_L}{T_H}$ where, T_L = lower Temp.
T_H = higher Temp.

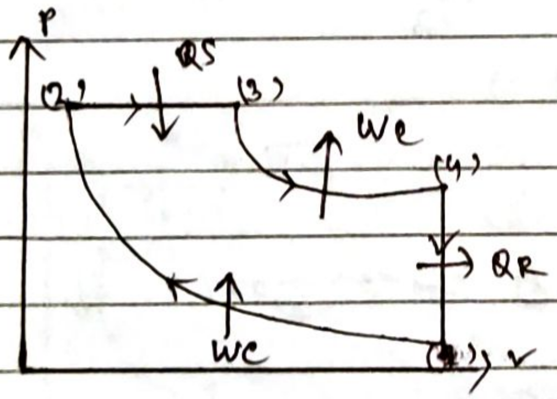
→ (1-2) - Isothermal expansion = ($r_e = \frac{V_2}{V_1}$)
→ (3-4) - Isothermal Compression = ($r_K = \frac{V_3}{V_4}$)

* out of all cycles, carnot cycle is having Maximum Efficiency.

:- DIESEL CYCLE :-

Developed by Rudolph diesel. used in the diesel engine vehicles. since in diesel Engine air compressed only, the compression Ratio is very high. Generally for diesel engine it's 16 to 20. and petrol engine it's 6 to 10

→ it is consist of four Process.



(1-2) - Reversible Adiabatic Compression process
(2-3) - Constant pressure process
(3-4) - Riversible Adiabatic Expansion process
(4-1) - Constant volume process

$$Q_S = mc_p(T_2 - T_3)$$

$$Q_R = mc_v(T_4 - T_1)$$

$$\eta = \frac{W_{net}}{Q_{supplied}} = \frac{Q_S - Q_R}{Q_S}$$

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

$$= \frac{\dfrac{m c_p (T_3 - T_2) - m c_v (T_4 - T_1)}{m c_p}}{m c_p (T_3 - T_2) / m c_p}$$

$$\left[\ \gamma = \frac{c_p}{c_v} \qquad \frac{c_v}{c_p} = \frac{1}{\gamma}\right.$$

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

Efficiency of Process

Process (1-2):-

$P V^{\gamma} = \text{Constant}$

$$\frac{P_1 V_1^{\gamma}}{T_1} = \frac{P_2 V_2^{\gamma}}{T_2}$$

Process (2-3):-

$$\frac{P_2 V_2}{T_2} = \frac{P_3 V_3}{T_3} = \frac{V_2}{V_3} = \frac{T_2}{T_3}$$

Process (3-4):-

$P V^{\gamma} = \text{Constant}$

$$\frac{P_3 V_3^{\gamma}}{T_3} = \frac{P_4 V_4^{\gamma}}{T_4}$$

Process (4-1):-

$$\frac{P_4 V_4}{T_4} = \frac{P_1 V_1}{T_1} = \frac{P_4}{P_1} = \frac{T_4}{T_1}$$

$$\eta_d = 1 - \frac{1}{\gamma} \times \frac{1}{(r_k)^{\gamma - 1}} \times \frac{r_c^{\gamma} - 1}{r_c - 1}$$

where,

r_k = Compression Ratio = $\dfrac{V_1}{V_2}$

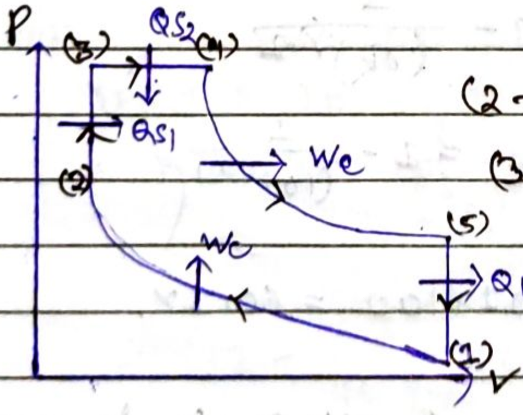
r_c = Cut off Ratio = $\dfrac{V_3}{V_2}$

Expantion Ratio $= (r_e) = \frac{V_3}{V_4}$

→ if the compression Ratio increases the Efficiency of Diesel cycle increases (vice-versa).
→ if the cut off Ratio increases the Efficiency of Diesel cycle decrease.

:- Dual cycle :- (Trinkler cycle)

first introduced by Gustav Trinkler
it is also known as Limited Pressure or mix Cycle.
Here both the process of otto and diesel cycle can be seen.
it is consisting of five process.



(1-2) - Reversible Adiabatic Compression Process.
(2-3) - constant volume process.
(3-4) - Constant Pressure Process.
(4-5) - Reversible Adiabatic Expansion process
(5-1) - constant volume Process

$Q_{supply} = Q_{S1} + Q_{S2}$
$= mc_v \times (dT) + m \times c_p \times (dT)$
$= m \times c_v \times (T_3 - T_2) + m \times c_p \times (T_4 - T_3)$

$Q_{rejection} = m \times c_v \times (dT) = m \times c_v \times (T_5 - T_1)$

$$\eta_{Dual} = \frac{W_{net}}{Q_{supply}} = \frac{Q_S - Q_R}{Q_S}$$

$$= \frac{m \times c_v \times (T_3 - T_2) + m \times c_p \times (T_4 - T_3) - m \times c_v \times (T_5 - T_1)}{m \times c_v \times (T_3 - T_2) + m c_p \times (T_4 - T_3)}$$

$$\eta_{dual} = \frac{1 - \frac{m c_v (T_5 - T_1)}{m c_v}}{\frac{m c_v (T_3 - T_2)}{m c_v} + \frac{m c_p (T_4 - T_3)}{m c_v}}$$

$$\boxed{\frac{c_p}{c_v} = \gamma}$$

$$= \frac{1 - (T_5 - T_1)}{(T_3 - T_2) + \gamma (T_4 - T_3)}$$

Solved Problems on ottocycle

(Q) In an air strandrad otto cycle the compression Ratio is 10 find the Efficiency of the cycle?

Ans

Given

$r_K = 10$

$$\therefore \eta = 1 - \frac{1}{(r_K)^{\gamma - 1}}$$

$$= 1 - \frac{1}{(10)^{1.4-1}} = 1 - \frac{1}{(10)^{0.4}}$$

$$= \frac{(10)^{0.4} - 1}{(10)^{0.4}} = 0.601 \times 100 = 60.1\%$$

(Q2) when the efficiency of ottocycle is 51%. findout the compression Ratio?

Ans

Given

$$\eta = 51\% = \frac{51}{100} = 0.51$$

$$\therefore \eta = 1 - \frac{1}{(r_K)^{\gamma - 1}}$$

$$0.51 = 1 - \frac{1}{(r_K)^{1.4-1}}$$

$$= \frac{1}{(r_K)^{0.4}} = 1 - 0.51$$

$$= \frac{1}{(r_K)^{0.4}} = 0.49$$

$$= \frac{1}{0.49} = (r_K)^{0.4}$$

$$= 2.04 = (r_K)^{0.4}$$

$$= 2.04^{1/0.4} = r_K$$

$$r_K = 5.94$$ Ans.

(Q3) In an air strandrad otto cycle the compression Ratio is 5.94 find the Efficiency of the cycle?

Ans

Given

$$r_K = 5.94$$

$$\therefore \eta = 1 - \frac{1}{(r_K)^{\gamma-1}}$$

$$= 1 - \frac{1}{(5.94)^{1.4-1}}$$

$$= 1 - \frac{1}{(5.94)^{0.4}}$$

$$= \frac{(5.94)^{0.4} - 1}{(5.94)^{0.4}}$$

$$= 0.5096734363$$

$$= 51\ \%$$

(Q4) The Heat Rejection and heat supply process in otto cycles are 20kw and 80 kw find out the efficiency of the cycle?

Ans

Given $Q_R = 20kw$

$Q_S = 80kw$

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

$$= 1 - \frac{\cancel{20}^{1}}{\cancel{80}_{4}}$$

$$= \frac{3}{4} = 0.75 \times 100$$

$$= 75\%$$

(Q5) An engine working on otto cycle has efficiency of 73% it has a clearnce volume of $0.05 m^3$ and swept volume $0.5 m^3$ in Both the cases find the compression Ratio?

Ans

Given $\eta = 73\% = \frac{73}{100} = 0.73$

$$\therefore \eta = 1 - \frac{1}{(r_K)^{\gamma - 1}}$$

$$= 0.73 = 1 - \frac{1}{(r_K)^{0.4}}$$

$$= \frac{1}{(r_K)^{0.4}} = 1 - 0.73$$

$$= \frac{1}{(r_K)^{0.4}} = 0.27 \Rightarrow \frac{1}{0.27} = (r_K)^{0.4}$$

$\Rightarrow 3.70 = (r_K)^{0.4}$

$\Rightarrow 3.70^{0.4} = r_K$

$\Rightarrow r_K = 1.68$

Again given

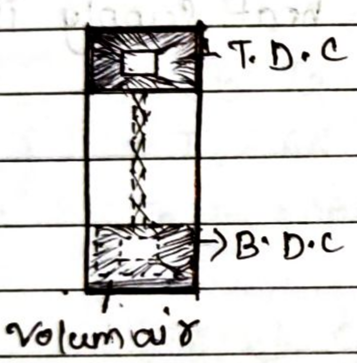
$C_v = 0.05 m^3$

$C_s = 0.5 m^3$

$\therefore r_K = \frac{V_1}{V_2} = \frac{V_s + V_c}{V_c} = \frac{0.5 + 0.05}{0.05} = 11$

Ans

ENGIN works on otto cycle :-



Total volume / (V_1) / Swept volume (V_s)

Clearance volume = (V_c)

$r_K = \frac{V_1}{V_2} = \frac{V_s + V_c}{V_c}$

$r_K = \frac{\text{Total volume } (V_1)}{\text{clearance volume } (V_2)}$

:- otto cycle solved problems :-

15th Dec 2022

(Q1) An otto cycle operates with volumes $0.04 m^3$ and $0.4 m^3$ at T.D.C and B.D.C if the power output is 100 Kw, find the heat input ?

Ans

Given

clearence volume $(V_c) = 0.04 m^3$

Swept volume $(V_s) = 0.4 m^3$

Q rejection = 100 kw.

$\therefore r_K = \frac{V_1}{V_2} = \frac{V_s + V_c}{V_c} = 11$

$$\eta = 1 - \frac{1}{(r_K)^{\gamma-1}}$$

$$= \eta = 1 - \frac{1}{(11)^{1.4-1}} = 1 - \frac{1}{(11)^{0.4}}$$

$= 0.61 \times 100$

$= 61\%$

$$\therefore \eta = \frac{W.D}{\text{Heat Supply}} = Q_s = \frac{\text{work done}}{\eta}$$

$$= \frac{100}{0.601} = Q_s = 166$$

Ans

(Q2) In an otto cycle at the begining of isoentropic Compression has pressure 1 bar and temp. is 15°c The Compression Ratio is 8. the heat supply is 1008kJ find, (i) efficiency.
(2) work done
(3) heat rejection
(4) maximum temp.

Ans

Given

$r_K = 8$, $Q_s = 1008$ KJ/S, $T_1 = 25 + 273 = 288$K

(1) $r_K = 1 - \frac{1}{(r_K)^{\gamma-1}} = 1 - \frac{1}{(8)^{0.4}}$

$= 0.56 \times 100$

$= 56\%$

(2) work done $= \eta \times Q_s$

$= 0.61 \times 1008 = 614.$

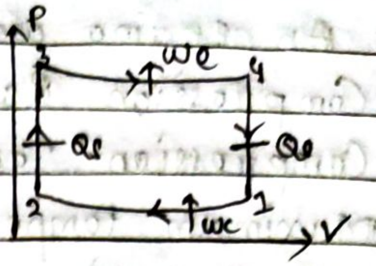
(3) heat rejection = $W = Q_s - Q_R$

$= 614. = 1008 - Q_R$

$Q_R = 1008 + 614.$

$= 1622$ Ans

(4) Maximum temperature. (T_3)



$P_1 = 7$ bar, $T_1 = 288K$

$r_K = \frac{V_1}{V_2} = 8$; $Q_s = 1008$ K

$$\frac{P_1 V_1^{\gamma}}{T_1} = \frac{P_2 V_2^{\gamma}}{T_2} \Rightarrow \frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

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

$$= \frac{T_2}{288} = (8)^{1.4-1}$$

$$= T_2 = 288 \times (8)^{0.4}$$

$$= 661\ K$$

$$T_3 = (T_3 - T_2) = 1008$$

$$= T_3 - 661 = 1008$$

$$T_3 = 1008 + 661 = 1669K$$ Ans

Diesel cycle solved Problems

(Q1) An Engine working in a diesel cycle having Compression Ratio 12 and Cutt of Ratio is 6 find out it's Efficiency?

Ans

Given

$r_K = 12$, r_c = Cutt of Ratio = 6

$$\therefore \eta_d = 1 - \frac{1}{\gamma} \times \frac{1}{(r_K)^{\gamma-1}} \times \frac{r_c^{\gamma} - 1}{r_c - 1}$$

$$= 1 - \frac{1}{1.4} \times \frac{1}{(12)^{1.4-1}} \times \frac{6^{1.4}-1}{6-1}$$

$$= 1 - \frac{1}{1.4} \times \frac{1}{(12)^{0.4}} \times \frac{6^{0.4}}{5} = 0.89 \times 100 = 89\%$$

Ans

(Q2) An Engine working in a diesel cycle having Compression Ratio 14 and at the begining of Compression Temperature is 15°c and P = 1 MPa The Maximum temperature is 1550°c find out the Cutt of Ratio, cycle efficiency, Heat suppled.

Ans

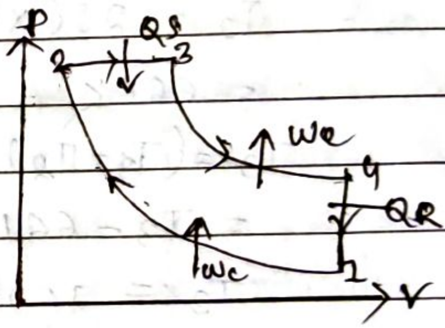
Given

$r_K = 14 = \frac{V_1}{V_2}$

$T_1 = 15° + 273 = 288K$

$P_1 = 1MPa = 1 \times 10^6 \ Pa$

$T_3 = 1550° + 273 = 1823K$



$\frac{v_1^{\gamma}}{T_1} = \frac{v_2^{\gamma}}{T_2} = \frac{v_2}{v_1}$

$= \frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{\gamma - 1}$

$= \frac{T_2}{288} (14)^{1.4-1}$

$= T_2 = 288 \times (14)^{0.4}$

$= 827K$

(2 - 3) = P = C, Cutt of Ratio

$\left(\frac{v_2}{T_2} = \frac{v_3}{T_3}\right) \Rightarrow \frac{T_3}{T_2} = \frac{v_3}{v_2}$

$r_c = \frac{1823}{827} = 2.21$

Heat Supply (QS) $= T_3 - T_2$

$= 1823 - 827$

$= 996$

$$\text{Efficiency } (\eta) = 1 - \frac{1}{1.4} \times \frac{1}{(r_K)^{\gamma-1}} \times \frac{r_c^{\gamma-1}}{r_c - 1}$$

$$= 1 - \frac{1}{1.4} \times \frac{1}{(14)^{1.4-1}} \times \frac{(221)^{1.4-1}}{221-1}$$

$$= 1 - \frac{1}{1.4} \times \frac{1}{(14)^{0.4}} \times \frac{(221)^{0.4}}{220}$$

$$= 0.99 \times 100 = 99\%$$

→ CARNOT CYCLE SOLVED PROBLEMS :-

(Q1) What is the maximum percentage of heat that can be converted into work by a heat engine when the heat is available at 127°C and the Atmospheric temperature is 27°C?

Ans

Given

$$T_H = 127 + 273 = 400K$$
$$T_L = 27 + 273 = 300K$$

$$\therefore \eta = 1 - \frac{T_L}{T_H} = 1 - \frac{300}{400} = 0.25 \times 100 = 25\%$$

(Q2) The temperature limits for a carnot cycle using as a working substance are 420°C and 10°C calculate the efficiency of the cycle and ratio of adiabatic expansion Take $\gamma = 1.4$ for air.

Ans

Given, $T_H = 420 + 273 = 693K$
$T_L = 10 + 273 = 283K$

$$\eta = 1 - \frac{T_L}{T_H} = \frac{283}{693} = 0.59 \times 100 = 59\%$$

Ans

(Q3) In a Carnot Cycle operating between Temp. Limits of 87°C and 63°C find the efficiency of the cycle?

Ans

Given $T_H = 87 + 273 = 360\,K$

$T_L = 63 + 273 = 336\,K$

$$\therefore \eta = 1 - \frac{T_L}{T_H}$$

$$= 1 - \frac{336}{360} = 0.06$$

$$= 0.06 \times 100 = 6\%$$

(Q4) In a Carnot cycle working between the temperature limit 317°C and 22°C find Efficiency, the Engine absorbs 2100 KJ/min of Heat Calculate the Net work done.

Ans

Given

$T_H = 317 + 273 = 590\,K$

$T_L = 22 + 273 = 295\,K$

$$\therefore \eta = 1 - \frac{T_L}{T_H} = 1 - \frac{295}{590} = \frac{1}{2}$$

$$= 0.5 \times 100 = 50\%$$

$$\eta = \frac{\text{work done}}{\text{heat supplied}}$$

$w = \eta \times Q_s \Rightarrow w = 0.5 \times 2100$

$w = 1050\ KJ/min$

Ans

(Q5) The temperature limits in carnot cycle are 420°c and 10°c Calculate the efficiency, and value of Expansion Ratio.

Ans

Given

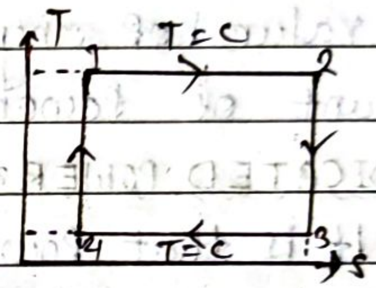
$$T_H = 420 + 273 = 693 K$$

$$T_L = 10 + 273 = 283 K$$

$$\therefore \eta = 1 - \frac{T_L}{T_H} = 1 - \frac{283}{693} = 0.59 \times 100$$

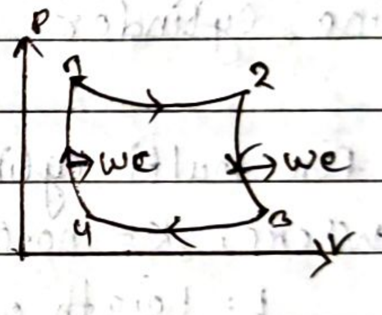
$$= 59\%$$

$$(r_e) = \frac{V_3}{V_2}$$



Process (2-3)

$$\frac{V_2^{\gamma}}{T_2} = \frac{V_3^{\gamma}}{T_3}$$



$$= \left(\frac{V_2}{V_3}\right)^{\gamma-1} = \left(\frac{T_2}{T_3}\right)$$

$$= \frac{V_3}{V_2} = \left(\frac{T_3}{T_2}\right)^{\frac{1}{\gamma-1}}$$

$T_L = 283 K$; $T_H = 693 K$

$(1-2) = T = C$, $(T_1 = T_2)$

$(3-4) = T = C$; $(\because T_3 = T_4)$

$$= \left(\frac{693}{283}\right)^{\frac{1}{1.4-1}} = 9.3$$

Ans