THERMAL Engg 4024 (1)

PART-A (2 Marks each) PART-A

1 Intrinsic – does not depend on mass
eg: specific volume, pressure, temperature, density etc.

2 Extrinsic → depend on mass
eg: volume, internal energy, enthalpy

2. Air standard efficiency: Ratio of net workdone per cycle to the heat taken from the source if air is the working medium:

$$\eta_{air} = \frac{\oint \omega}{Q_H} = \frac{Q_H - Q_L}{Q_H}$$

3. Heat energy of steam is converted to kinetic energy. It is used as injector for pumping feed water to boiler

4. A BLACK Body completely absorbs the incident radiation irrespective of its wave length. It does not reflect any radiation.

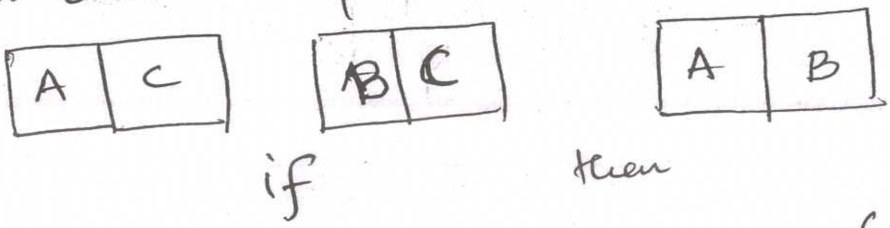
5. Breake power useful power available at the output shaft for doing the external work.

PART-B (Q#1 is on Page #4)

Q#2 Zeroth low

If 2 systems A & B are seprately in

in thermal equillibrium with 'C', then system A & system B are in thermal equillibrium



(Mark-2)

FIRST LAW

Law of conservation of energy

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

Since $\Delta U = 0$ for cyclic process

$\Delta Q = \Delta W$

or

(Mark-2)

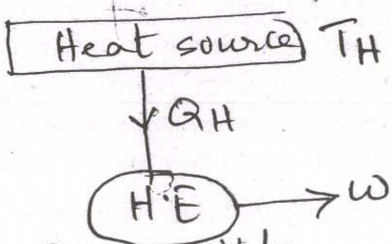
$\oint dQ = \oint dW$

where ΔQ = change in heat transfer
ΔW = change in workdone
ΔU = change in internal energy

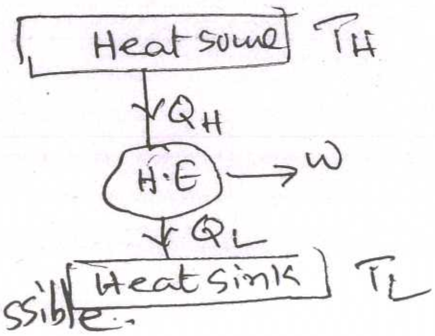
SECOND LAW

KELVIN PLANK'S : impossible to construct an engine working on cyclic process whose sole effect is conversion of all heat supplied to it into an equivalent amount of work.

(Marks-2)



impossible

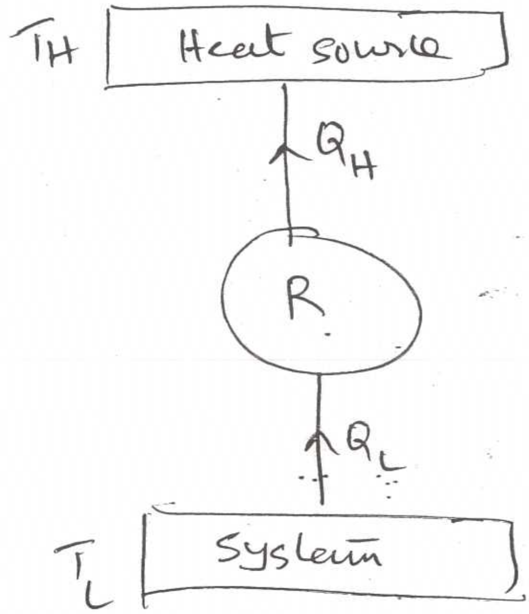


Possible.

OR

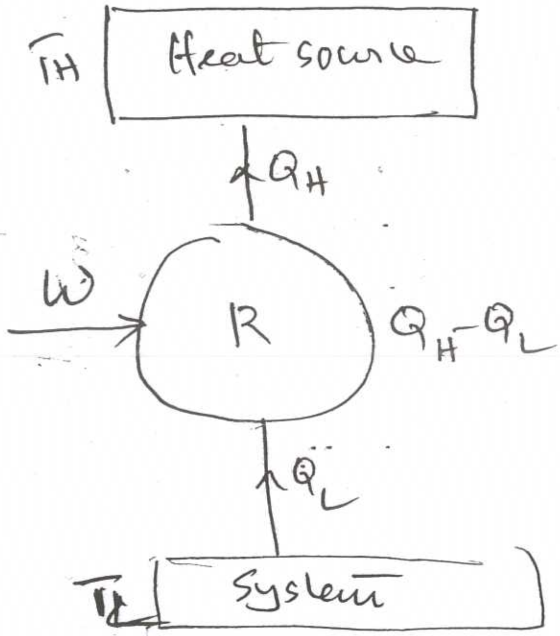
CLAUSIS STATEMENT

It is impossible to construct an engine working in a cyclic process whose effect is the transfer of heat from a body at lower temperature to another body at higher temperature without expenditure of Mechanical work.



Impossible

$Q_H = Q_L$



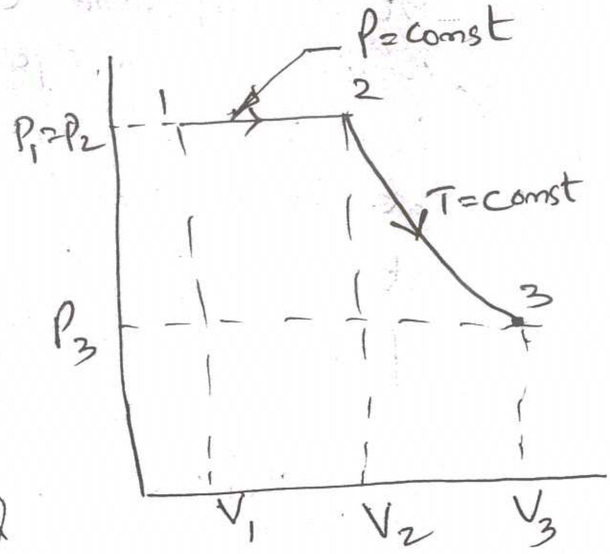
Possible

$Q_H > Q_L$

PART-B

II

1) (a) For Process (1-2)
charle's law



$$V \propto T$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \qquad V_2 = V_1 \times \frac{T_2}{T_1}$$

(b) For Process (2-3)
Boyel's law, isothermal

$$P \propto \frac{1}{V} \qquad PV = \text{Constant}$$

$$T_2 = T_3 \text{ (isothermal)}$$

$$P_3V_3 = P_2V_2$$

$$V_3 = \frac{P_2}{P_3} \times V_2$$

From (a) substitute in (b)

$$V_3 = \frac{P_2}{P_3} \times V_1 \times \frac{T_2}{T_1}$$

$$\Rightarrow \frac{P_3V_3}{P_2} = V_1 \frac{T_2}{T_1}$$

$$\frac{P_3V_3}{P_1} = \frac{V_1 \times T_3}{T_1} \qquad \left[\because P_2 = P_1,\ T_2 = T_3\right]$$

$$\Rightarrow \frac{P_3V_3}{T_3} = \frac{P_1V_1}{T_1}$$

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

(6 Marks)

Page #5

II (3)

WORKING PRINCIPLE OF FOUR STROKE PETROL ENGINE

The various strokes of four stroke petrol engine are explained below

i) Suction stroke

The inlet valve is opened and air-fuel mixture is sucked into the cylinder during the downward movement of the piston. The exhaust valve remains closed during this stroke. This is represented by 5-1 in pV diagram

ii) Compression stroke

The air-fuel mixture is compressed by the upward motion of the piston. The inlet valve and exhaust valve remains closed during this stroke. This is represented by 1-2 in pV diagram

iii) Expansion stroke or power stroke

At the end of compression stroke, spark plug initiates a spark and it ignites the air-fuel mixture. The combustion takes place at constant volume (2-3 in pV diagram).

3 Marks Explanation

The burnt gases drives the piston downwards, which is known as power stroke. Thus work is done on the piston. The inlet valve and exhaust valve remain closed during this stroke. This is represented by 3-4 in pV diagram.

iv) Exhaust stroke

Exhaust valve is opened and inlet valve remains closed during this stroke. The piston moves upwards and the exhaust gas is completely drained out of cylinder through exhaust valve. This is represented by 1-5 in pV diagram. One cycle is completed and the process repeats.

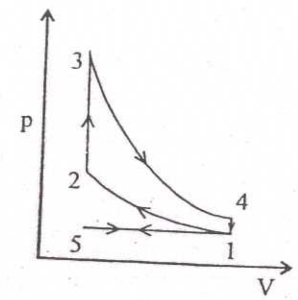
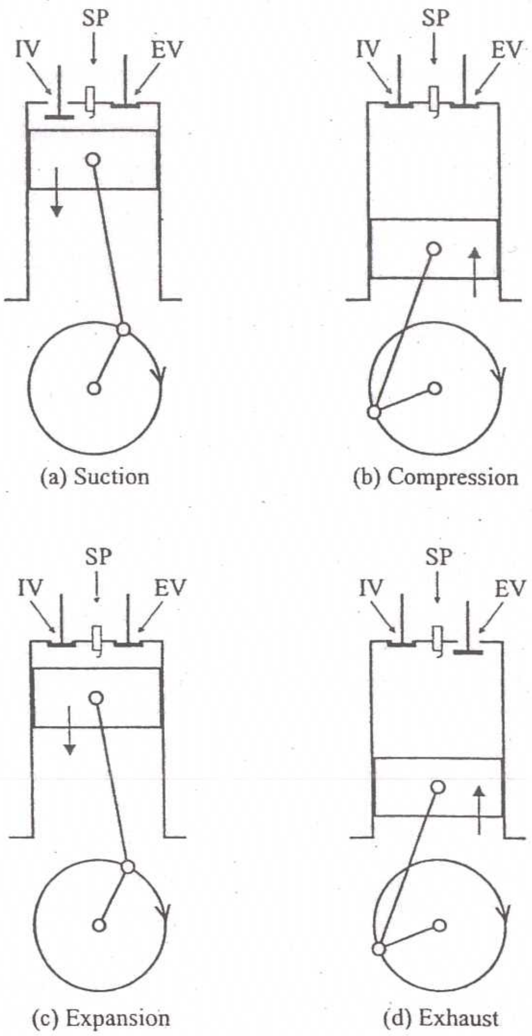


Fig. (5.7) Ideal P-V diagram of a four stroke petrol engine

Page #6

II 3 cont'd



3 Marks for fig

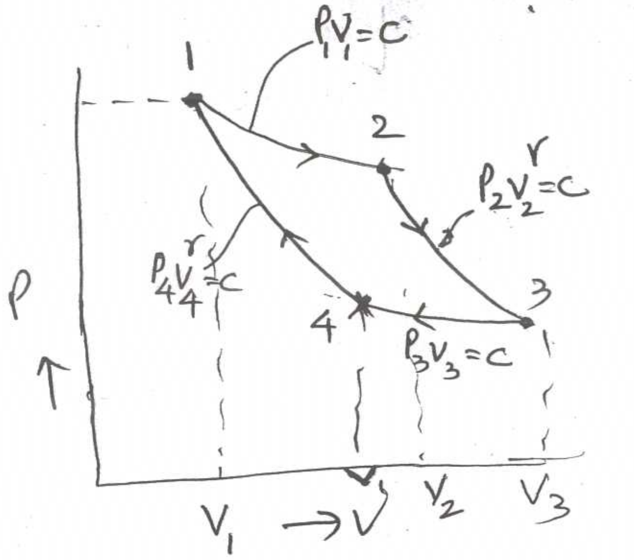
IV - Inlet Valve, EV - Exhaust Valve, SP - Spark Plug

Fig. (5.6) Working of four stroke petrol engine

Page # 7

Part-B

4. carnot cycle



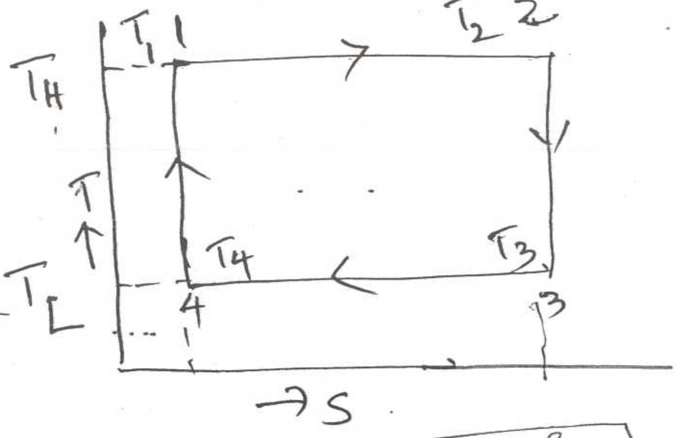
Heat supplied

$$Q_H = Q_{12} + Q_{23}$$
$$= Q_{12} + 0$$
$$= mRT_H \ln 'r'$$

Heat rejected

$$r = \frac{V_2}{V_1} = \frac{V_3}{V_4} \Rightarrow \frac{V_3}{V_2} = \frac{V_4}{V_1} = r_a$$

$$Q_R = Q_{34} + Q_{41}$$
$$= Q_{34} + 0$$
$$= mRT_L$$



$$\eta = \frac{\text{Heat supplied} - \text{Heat rej}}{\text{Heat supplied}}$$

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

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

2 Marks for diagram
2-Marks for Formulae
2-Marks for final answer

From ② → ③ Process ②-3 $\quad \frac{T_2}{T_3} = \left(\frac{V_3}{V_2}\right)^{\gamma-1} \quad \frac{T_H}{T_L} = r_a^{\gamma-1}$

From ④ - ① Process $\quad \frac{T_1}{T_4} = \left(\frac{V_4}{V_1}\right)^{\gamma-1} \Rightarrow \frac{T_H}{T_L} = r_a^{\gamma-1}$

r_a → Adiabatic Ratio

$$\eta_{carnot} = 1 - \frac{1}{r_a^{\gamma-1}}$$

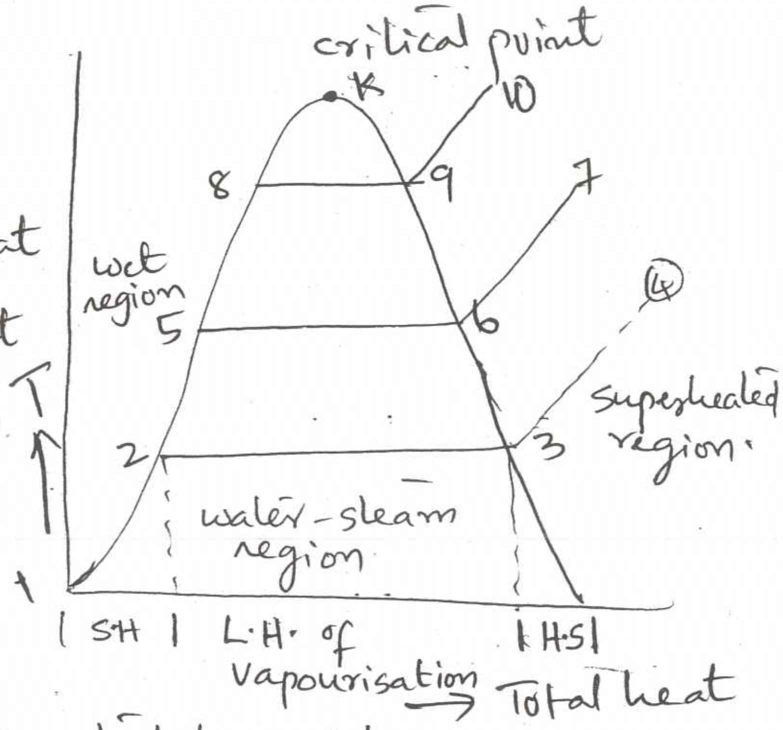
$$= 1 - \frac{1}{\text{Adiabatic index (Adiabatic ratio)}}$$

5.)

S.H → sensible heat

L.H – Latent heat

H.S → super heat



1-2-5-8 → saturated Liquid line

3-6-9 → saturated dry steam line

K → critical point
critical temp

Graph – 3 Marks
Explanation – 3 Marks.

(Q# 6) Thermal Convection refers to heat exchanged between a surface and a fluid moving over the surface.

$Q = hA(t_1 - t_2)$

[3 marks for equation]

h → ~~overall~~ heat transfer coefficient or convection co-efficient ($W/m^2 \cdot {}^\circ C$)

A → Surface area

$(t_1 - t_2)$ → Temp difference between fluid and substance.

$\frac{Q}{A}$ = Heat flux.

[3 Mark for explanation]

(Q# 7) $A = 10 \times 5 = 50 m^2$; $t_1 = 30^\circ C$ $t_2 = 50^\circ C$

$x_1 = 0.25 m$ $x_2 = 0.05 m$

$K_1 = 0.69$ $K_2 = 0.93$

$$Q = \frac{A(t_1 - t_2)}{\frac{x_1}{K_1} + \frac{x_2}{K_2}}$$

$$= \frac{50 \times 250}{\frac{0.25}{0.69} + \frac{0.05}{0.93}} = 30,000 \text{ Watts}$$

$= 30 \text{ KW} = 30 \frac{kJ}{sec}$

Heat lost per hour $= 30 \times 3600 = 108,000 \frac{kJ}{sec}$.

(3 Marks)

Interface temp

For brick wall $Q = k_1 A \frac{(t_1 - t_{inter})}{x_1}$

$$t_1 - t_{inter} = \frac{Q}{A} \cdot \frac{x_1}{K_1}$$

$$= \frac{30000}{50} \times \frac{0.25}{0.69}$$

$$= 217^\circ C$$

$$t_{inter} = 300 - 217^\circ C$$

$$= \underline{\underline{83^\circ C}}$$

or OR (3 marks)

For concrete layer

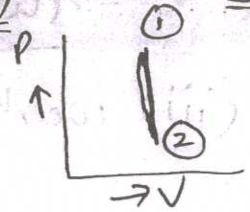
$$t_{inter} - t_2 = \frac{Q}{A} \frac{x_2}{K_2}$$

$$= \frac{30000}{50} \times \frac{0.05}{0.93}$$

$$= 33$$

$$t_{inter} = t_2 + 33$$

$$= 50 + 33 = \underline{\underline{83^\circ C}}$$



Part-C III (a)

(i) $dw = P\,dV \quad dV = 0 \Rightarrow dW = 0$

(ii) $du = mc_v\,dT$

$$\int_1^2 du = mc_v \int_1^2 dT \Rightarrow [u]_1^2 = mc_v [T]_1^2$$

$$u_2 - u_1 = mc_v [T_2 - T_1]$$

(iii) $dQ = du + dw$

$$dQ = du + 0$$

$$= mc_v (T_2 - T_1)$$

(iv) $dH = du + d(PV)$

$$\int_1^2 dH = \int_1^2 du + \int_1^2 d(P.V)$$

$P_2V_2 = mRT_2$

$P_1V_1 = mRT_1$

$$H_2 - H_1 = (u_2 - u_1) + (P_2V_2 - P_1V_1)$$

$$= mc_v(T_2 - T_1) + mR(T_2 - T_1)$$

$$= m(c_v + R)(T_2 - T_1)$$

$$= mC_p (T_2 - T_1)$$

2x4 = 8 Marks

Part-C III (b)

(i) $R = C_p - C_v$

$= 0.98 - 0.73 = 0.25 \frac{kJ}{kg\,K}$ (Answer) — (1 mark)

(ii) Heat added $= mC_p (T_2 - T_1)$

$= 1 \times 0.98 (473 - 298)$
(200 − 25)

$= 171.5$ KJ (Answ) (2 marks)

(iii) work done $= mR(T_2 - T_1)$

$= 1 \times 0.25(473-298)$

$= 43.75$ KJ (Answer) (2 Marks)

(iv) change in internal energy $= Q - W$

$= 171.5 - 43.75$

$= 127.75$

OR

Part-C

IV (a)

(i) $m = \frac{P_1 V_1}{RT_1} = \frac{1000 \times \cdot 0001}{0.297 \times (273+25)}$

$= 1.13 \times 10^{-3}$ kg (Answer) 2 marks

(ii) $P_1 V_1 = P_2 V_2$

$P_2 = \frac{P_1 V_1}{V_2} = \frac{1000 \times 0.0001}{\cdot 001}$

$= 100$[redacted] $\frac{KN}{m^2}$

OR

$P_2 = mRT_2 \qquad T_2 = T_1$

$= 1.13 \times 10^{-3} \times 0.29 \times 298$

$= 100 \frac{KN}{m^2}$

(iii) $W = P_1 V_1 \ln \frac{V_2}{V_1}$

$= 1000 \times 0.0001 \ln \left(\frac{\cdot 001}{\cdot 0001}\right)$

$= 0.2303$ KJ

(iv) $\Delta Q = \Delta U + \Delta W$

$\Delta Q = 0 + \Delta W$

$= 0.2303$ KJ

IV (b) Universal Gas const

If the characteristic gas constant of a gas is multiplied by their corresponding molecular mass then it is found that for all gases, the product is a constant. Its value is $8314 \frac{\text{Joule}}{\text{kg mole K}}$

ie If M_1, M_2, M_3 are molecular mass with R_1, R_2, R_3 as corresponding characteristic gas constant then

$$M_1R_1 = M_2R_2 = M_3R_3 \cdots = 8314 \frac{\text{Joule}}{\text{kg mole K}}$$

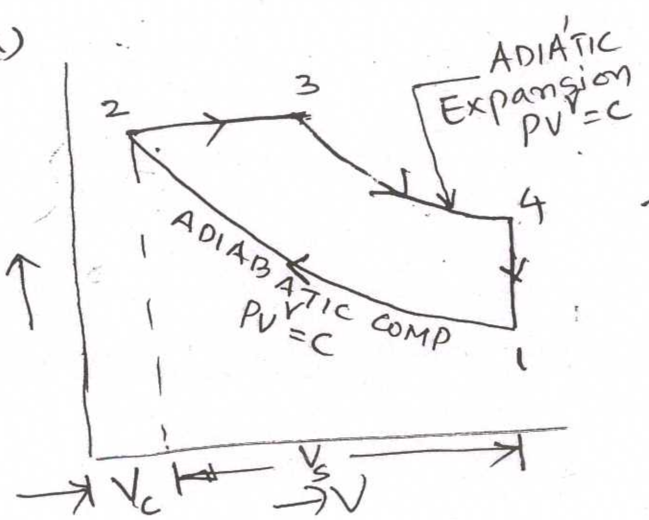
In general

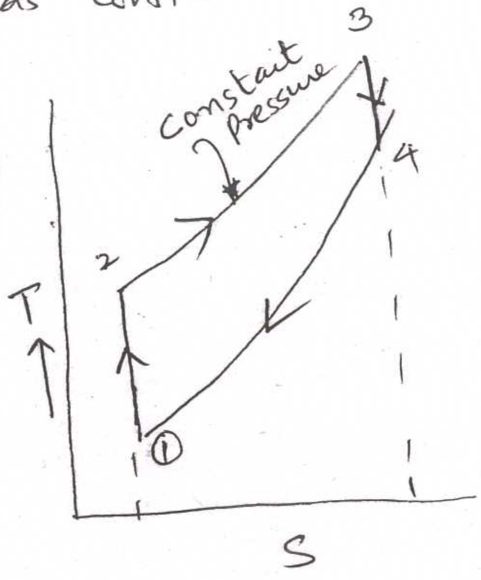
$$R_u = MR$$

(7 Marks)

where R_u is universal gas constant
M – Molecular Mass
R → characteristic gas const.

V (a)





V_c = clearance volume
V_s = swept volume.

4 marks for PV & TS dia

Process

① - ② | Adiabatic (isentropic) compression W_{12} is done on the air at the expense of internal energy
compression ratio $r_c = \frac{V_1}{V_2}$

② - ③ | constant process heat addition
$P_2 = P_3$ $\frac{V_3}{V_2}$ = cut-off ratio

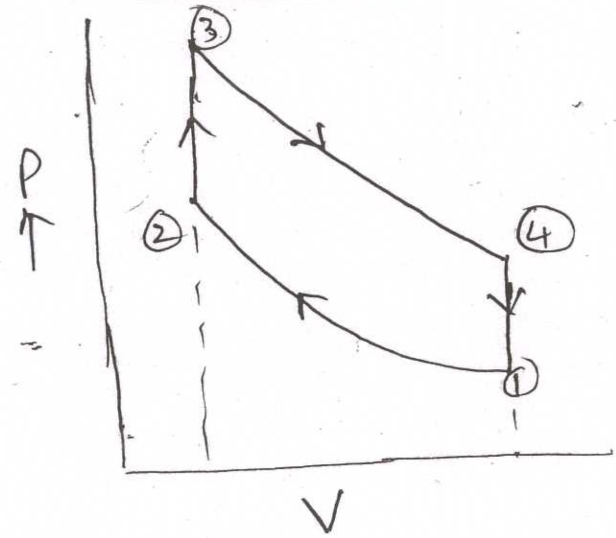
③ - ④ | Adiabatic expansion work is by the air
Expansion ratio $= \frac{V_4}{V_3}$

4 Marks expl'tion

④ - ① | Constant volume heat rejection
$V_4 = V_1$

Thus process complete the cycle and returns to its original state.

$\overline{V}_{(h)}$



$T_3 = 2000 + 273 = 2273\,K$

$T_4 = 800 + 273 = 1073\,K$

V (b) Cont'd

$$\eta_{otto} = 1 - \frac{T_4}{T_3} = 1 - \frac{1073}{2273}$$

$= 52.8\%$ (3 marks) Answer

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

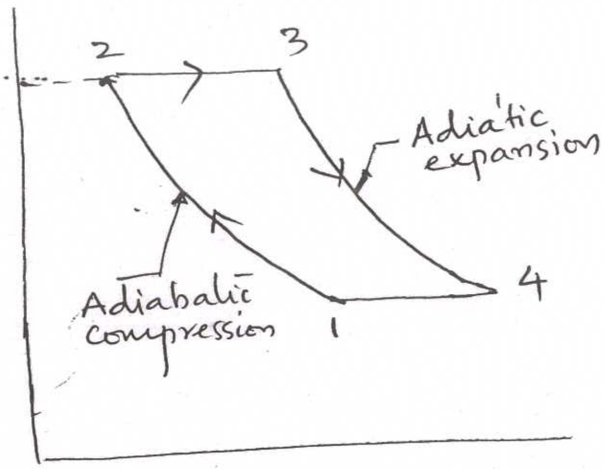
$$\left(\frac{T_3}{T_4}\right)^{1/r-1} = r \qquad r = \text{ratio of expansion}$$

$$r = \left(\frac{2273}{1073}\right)^{1.4-1}$$

$= 6.53$ (Answer) 4 marks

For otto cycle ratio of compression and expansion is same

VI (a)



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

Heat supplied $= mC_p(T_3 - T_2)$

Heat rejected $= mC_p(T_4 - T_1)$

upto here 3 Marks

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

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

we have
compression ratio = expansion ratio

$$\frac{V_1}{V_2} = \frac{V_4}{V_3} = r$$

For Process ① - ②

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

$$T_1 = \frac{T_2}{r^{\gamma - 1}}$$

For Process ③ - ④

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

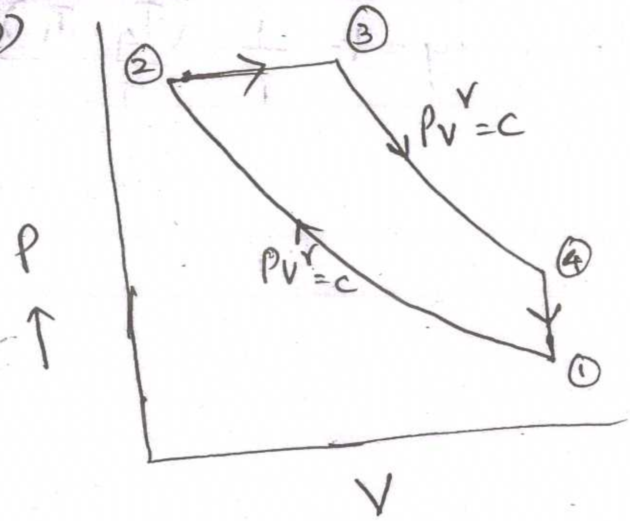
$$T_4 = \frac{T_3}{r^{\gamma - 1}}$$

$$\eta = 1 - \frac{1}{r^{\gamma - 1}} \left[\frac{T_3 - T_2}{T_3 - T_2}\right]$$

$$= 1 - \frac{1}{r^{\gamma - 1}}$$

Balance
4 Marks

VI (b)



$P_1 = 98 \frac{kN}{m^2}$

$T_1 = 44 + 273$
$= 317\ K$

$P_4 = 258 \frac{kN}{m^2}$

(i) $r_c = \frac{V_1}{V_2} = 15$

(ii) $r_e = \frac{V_4}{V_3} = 7.5$

For constant volume process ④ – ①

$\frac{P_4}{T_4} = \frac{P_1}{T_1}$ $\therefore T_4 = T_1 \times \frac{P_4}{P_1}$

$= 317 \times \frac{258}{98}$

$= 835\ K$

(2 Marks)

For adiabatic expansion ③ – ④

$\frac{T_3}{T_4} = \frac{V_4}{V_3}$ $T_3 = T_4\, r_e^{\gamma - 1}$

$= 835 \times 7.5^{0.4}$

$= 1870\ K$

$\therefore$ Maximum Temp attained $= 1870 - 273$
$= 1597^{\circ}C$ Answer 3 Marks

4024 Page 18

$$\text{Thermal efficiency} = 1 - \frac{1}{r}\frac{(T_4 - T_1)}{T_3 - T_2}$$

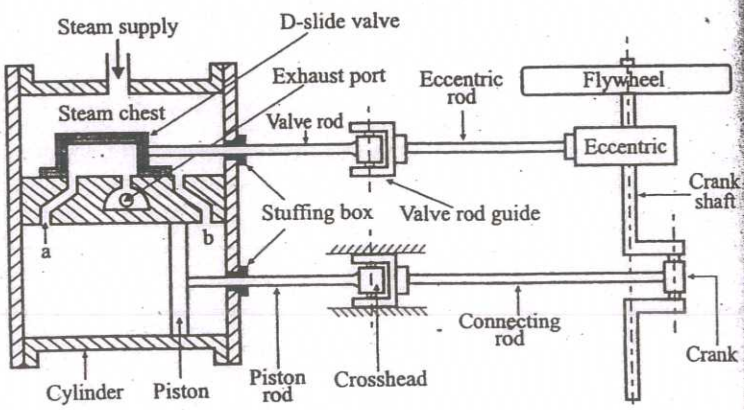
$$= 1 - \frac{1}{1.4}\frac{(835-317)}{(1870-936)}$$

$$= 60.5\%$$

(2 Marks)

VII (a)

Cylinder Double Acting Steam Engine



Single Cylinder Double Acting Steam Engine

4 Marks

Working of steam engine

The working of a simple, horizontal, double acting steam engine is explained below. Refer fig. (4.16).

The high pressure superheated steam from the boiler is supplied to the steam chest. This steam is first admitted to the cover end (left hand side) of the cylinder when the steam admission port (a) is uncovered by the D-slide valve, while the steam is exhausted through the steam port (b) at the crank end and exhaust port (which has done work on the right side of the piston). Now, the steam admitted on the cover end, exerts pressure on the surface of the piston and pushes it to the crank end (right hand side) of the cylinder.

4 Marks

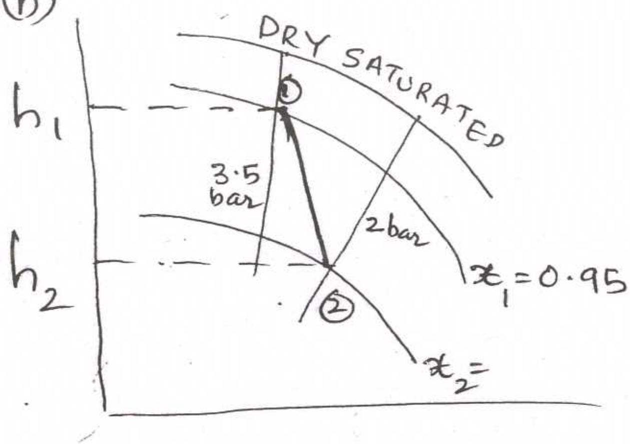
Page # 19 4024

At the end of this stroke, fresh steam from the steam chest is again admitted by the D-slide valve to the crank end of the cylinder (when steam admission port 'b' is opened) while the exhaust steam on the cover end is exhausted through the steam port 'a' and exhaust port. Now the steam at the crank end pushes the piston back to its original position ie; towards left hand side/cover end of the cylinder.

The D-Slide valve gets to and fro motion from the eccentric fitted to the crankshaft.

Thus, two working strokes are completed and the crankshaft turns by one revolution, ie; the engine is double acting. The operations are repeated.

VII (b)



From chart

$h_1 = 2624$

$h_2 = 2534$

$h_1 - h_2 = 2624 - 2534$

$= 90 \frac{kJ}{kg}$ (Answer) (3 Marks)

$x_2 = 0.92$ (2 Marks)

$$V_{exit} = \sqrt{V_1^2 + 2000(h_1 - h_2)}$$

$$= \sqrt{250^2 + 2000 \times 90} = 492.4 \frac{m}{se}$$ Ans (2 marks)

VIII

(a) The complete record of the heat supplied and rejected or carried away by cooling water, exhaust gases and unaccounted gas along with heat equivalent of break power is entered in a tabular form is known as Heat balance sheet

① Heat supplied $= m_f \times C_f$ — 2 Marks

where m_f = mass of fuel consumed in kg/sec

C_f = Lower calorific value of fuel in KJ/kg

Heat supplied in $= \frac{KJ}{sec}$

② Useful work $BP = \frac{KJ}{sec}$ — 2 Marks

③ Heat carried away by cooling water $= m_w C_w (T_1 - T_2)$ $\frac{KJ}{sec}$ — 2 Marks

m_w = mass of water in $\frac{kg}{sec}$

C_w = Sp. heat of water

T_1 & T_2 = Inlet & out temp in K

④ Heat carried away by exhaust gases — 2 Marks

$$Q_g = m_g C_g (T_g - T_a)$$

m_g is mass of exhaust gas in kg/sec

C_g sp. heat of exhaust gas

$T_g - T_a$ → Exhaust gas Temp and Room Temp

VIII

(b) $IP = \frac{BP}{\eta_{mech}} = \frac{30}{0.85} = 35.294 kW$ – 1 mark

$\frac{P_{mi} L A n k}{60} = 35.294$ – 3 marks

$\frac{900 \times 1.5 d \times \frac{\pi}{4} \times d^2 \times \left(\frac{5000}{2}\right) \times 4}{60} = 35.294$

$d^3 = \frac{35.294 \times 60}{900 \times 1.5 \times \frac{\pi}{4} \times 2500 \times 4}$

$d = 0.0585 m = 58.5 mm$

$\therefore L = 1.5 \times 0.0585$

$= 0.0878 m = 87.8 mm$ } 3 Marks

IX

(a) 1. For operating pneumatic equipments

2. For pumping water from deep well

3. For all types of spray works (painting)

4. For driving Air motors & compressed engines

5. Air for Air blast furnace

6. To operate pneumatic controls & cylinders.

7. For scavenging & supercharging IC Engines

8. In gas turbines, jet engines

9. For Air Blast injection

Any 4 → 4 Marks

IX 4024 Page # 22.

(a) (ii)

(1) Improves $\eta_{volumetric}$

(2) savings in work for the same delivery pressure.

(3) strength and size of cylinder can be adjusted.

(4) cheaper materials may be used as the operating temp is lower

(5) Effective lubrication

(6) Leakage loss reduction.

(7) Cost & Maintenance reduced

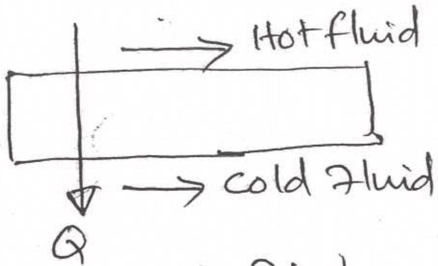
(8) Better Mechanical Balance.

Any 4 - 4 marks

IX

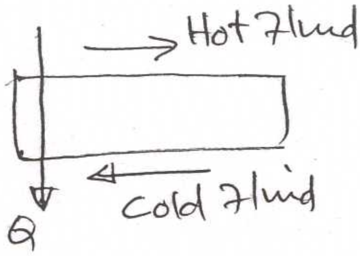
(b) Heat exchangers according to arrangement of flow

(i)



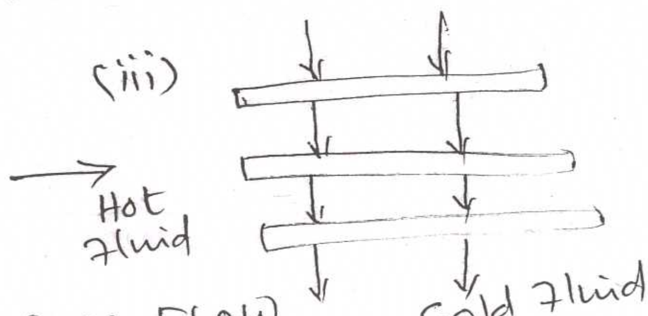
Parallel flow

(ii)



Counter flow

(iii)



CROSS FLOW

3 for fig
4 for exp'ion

X

(a) Fourier law states that the rate of thermal conduction heat flow is directly propotional to surface Area 'A' at right angles to heat flow and change of temparature with respect to length of the path.

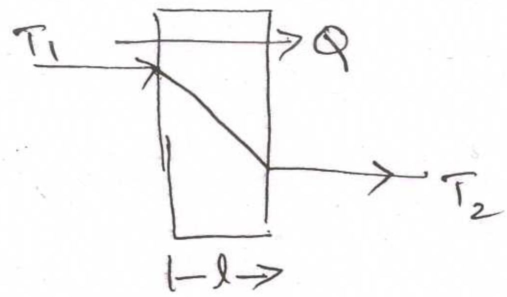
Mathematically

$$Q \propto \frac{A(T_2 - T_1)}{l} \quad \text{OR} \quad Q \propto A\frac{dT}{dx}$$

$$Q = -kA\frac{dT}{dx}$$

k - thermal conductivity

Negative sign indicates that heat flow in the decreaing temparature direction.

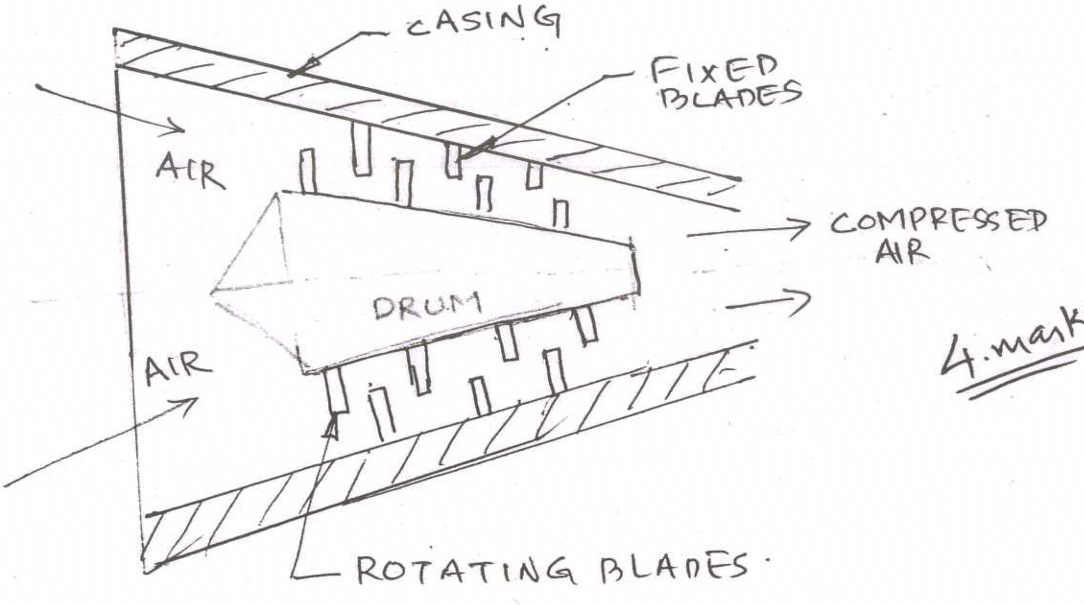


$T_1 > T_2$

(b) The working fluid flows parallel to axis of rotation.

Axial flow compressor consists of rotating and stationary components

A shaft drives a central drum, retained by



4.marks

bearings, which has a number of annual blade rows attached to it. These rotate between a similar number of stationary blade rows attached to stationary casing. Rotors imparts K.E and stators converts increased rotational K.E to static pressure thru diffusion

(3 Marks)