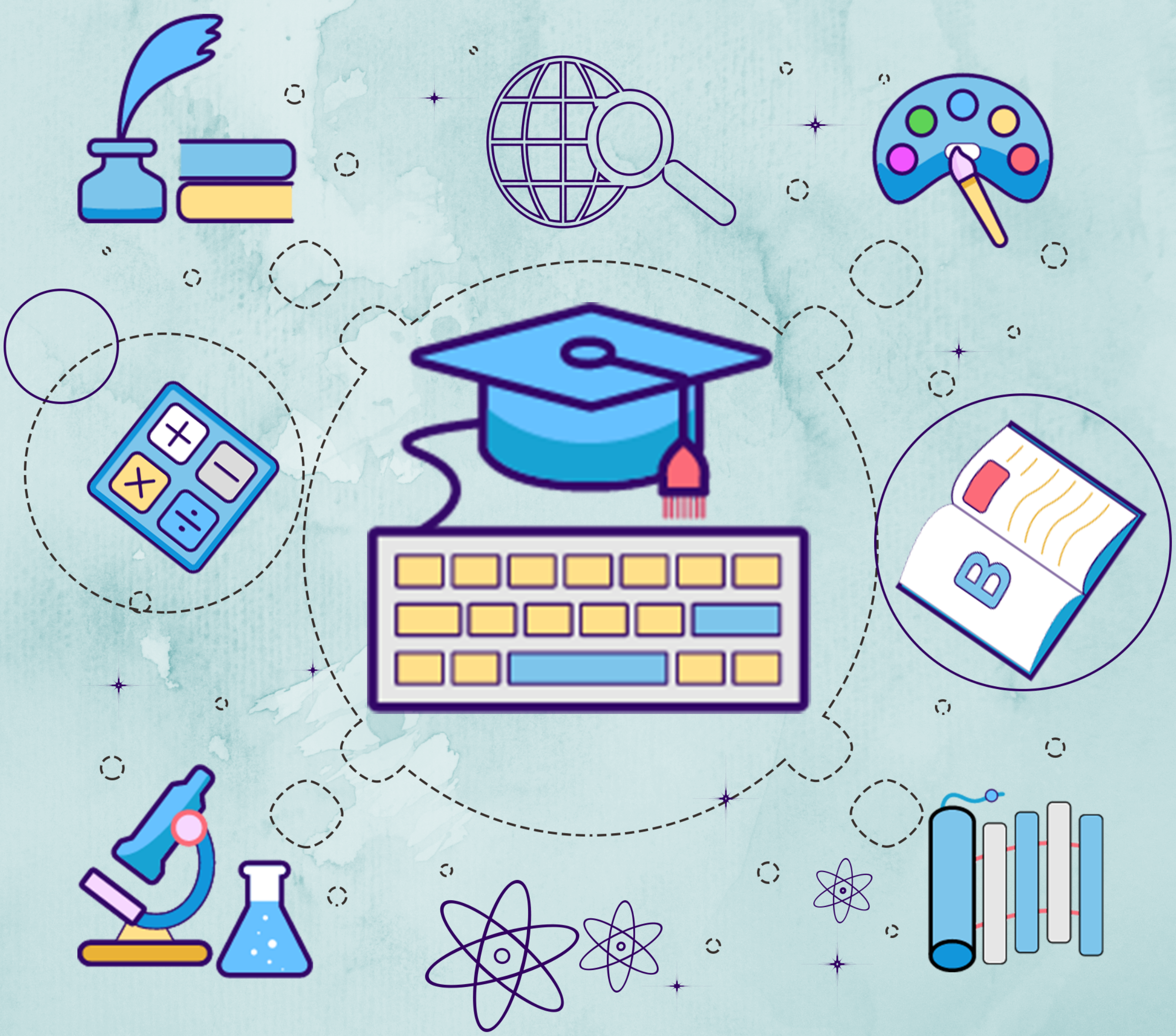
APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

KeralaNotes



SYLLABUS | STUDY MATERIALS | TEXTBOOK

PDF | SOLVED QUESTION PAPERS

EST 120: BASIC CIVIL & MECHANICAL ENGINEERING

MODULE 4

Syllabus: *Analysis of thermodynamic cycles: Carnot, Otto, Diesel cycles, Derivation of efficiency of these cycles, Problems to calculate heat added, heat rejected, net work and efficiency. IC Engines: CI, SI, 2- Stroke, 4-Stroke engines. Listing the parts of different types of IC Engines. Efficiencies of IC Engines (Definitions only), Air, Fuel, cooling and lubricating systems in SI and CI Engines, CRDI, MPFI. Concept of hybrid engines*

Important Questions and Answers

Expected University Question for PART A (4 Marks)

1. **"No engine can be made to work on Carnot cycle" Justify the statement?**
   - The expansion and compression processes are adiabatic and hence the two operations should be carried out as quickly as possible so that there is hardly any time for the heat exchange to take place.
   - On other hand, heat supply and heat rejection takes place isothermally which means the operations must be slow to maintain the constant temperature.

   It is obvious that sudden changes in the speed of an engine in one cycle are not possible in actual practice.

2. **What will happen, when diesel fuel is accidentally filled to a petrol car?**

   In case a petrol car is topped up with diesel, the chances of damage are quite minute.

   - Petrol is much more refined than diesel and thus, it is ignited by the spark created by spark plugs.
   - If a petrol car is cranked with diesel in its tank, the spark plugs and fuel system will be clogged by the diesel.
   - The fuel filter is one of the first parts to be affected because fuel filters in petrol engines are not used to the greasy property of diesel.

   These will lead to misfiring of the engine, heavy smoke from the exhaust, and car simply won't start.

3. **Carburettor engines are now being replaced by MPFI engines. Comment?**

   - A Multi Point fuel injection (MPFI) is a method of injecting fuel into internal combustion engine through multi ports situated on intake valve of each cylinder.

- The MPFI system precisely delivers fuel in the right amount and can improve it according to several parameters resulting is less fuel wastage and better fuel efficiency.
- A carburettor is unable to adjust the fuel ratio according to the engine conditions.

4. Why compression ratio of petrol engine is low compared to diesel engines?

Due to high volatile nature of petrol, the compression ratio of petrol engines is typically lower in the range of 8 to 12. The petrol engine mixes petrol with air & compresses this mixture in the combustion chamber. The better mixing of air and fuel with each other makes it homogeneous. An electric spark-plug then ignites the compressed air-fuel mixture with a spark. Thus, it causes the fuel to burn completely and instantly.

In diesel engine, diesel can be ignited only after by the heat generated during the compression of air inside a cylinder; therefore it requires higher compression ratio (16 to 22) whereas a petrol engine uses spark ignition and hence has lower compression ratio.

5. Bring out the concept of hybrid vehicles?

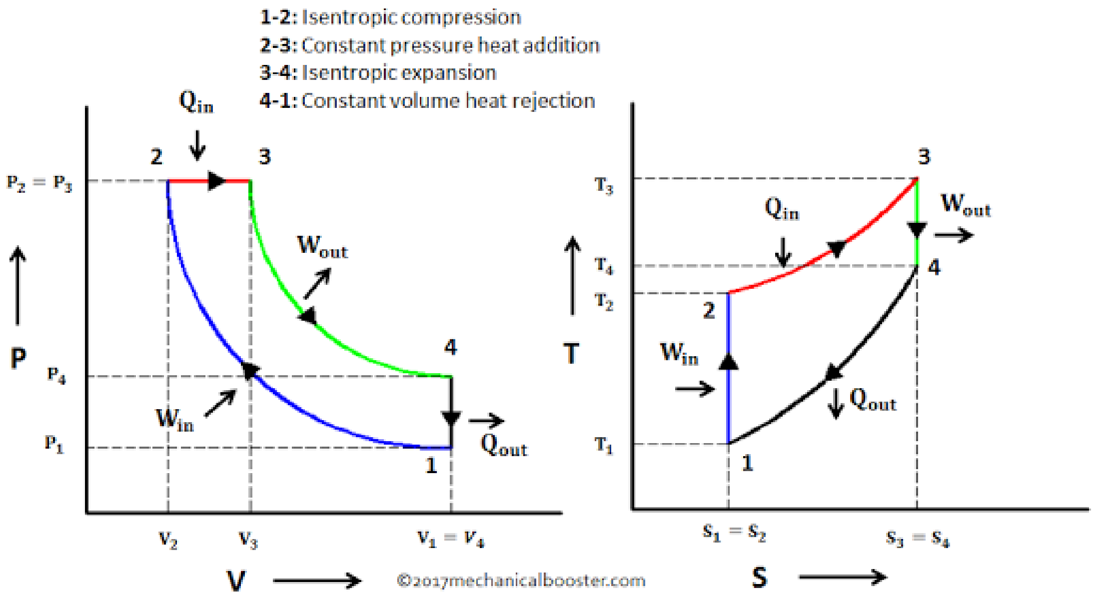
- Hybrid electric vehicles are powered by an internal combustion engine and an electric motor, which uses energy stored in batteries.
- A hybrid electric vehicle cannot be plugged in to charge the battery. Instead, the battery is charged through regenerative braking and by the internal combustion engine.
- The extra power provided by the electric motor can potentially allow for a smaller engine. The battery can also power auxiliary loads and reduce engine idling when stopped.
- Together, these features result in better fuel economy without sacrificing performance.

6. Name few hybrid vehicles in India & mention its importance?

- Maruti Suzuki Ertiga SHVS,
- Maruti Suzuki Ciaz SHVS,
- Mahindra Scorpio Intelli-Hybrid,
- Toyota Camry Hybrid,
- Honda Accord Hybrid,
- Volvo XC90 Hybrid,
- BMW i8

Hybrid electric vehicles are powered by an internal combustion engine and an electric motor, which uses energy stored in batteries. A hybrid electric vehicle cannot be plugged in to charge the battery. Instead, the battery is charged through regenerative braking and by the internal combustion engine. Together, these features result in better fuel economy without sacrificing performance.

7. Draw the P-V diagram of a diesel cycle and define the terms (i) Compression ratio, (ii) Expansion ratio, (iii) Cut-off ratio related to Diesel cycle?



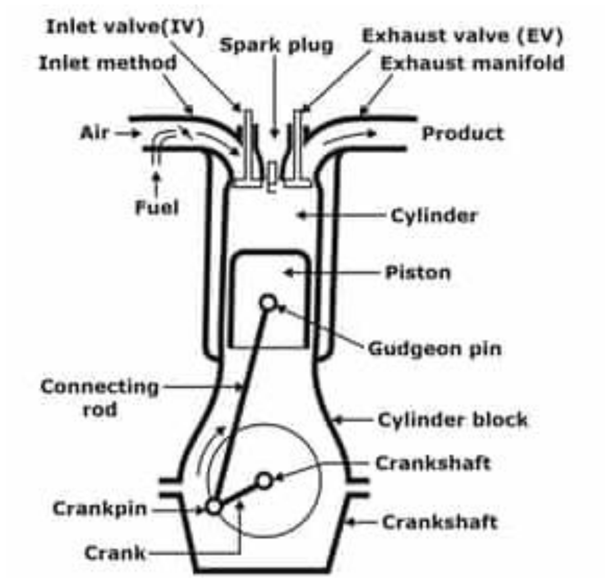
P-V and T-S Diagram of Diesel Cycle

(i) Compression Ratio (r) = V_1/V_2

(ii) Expansion Ratio (r_1) = V_4/V_3

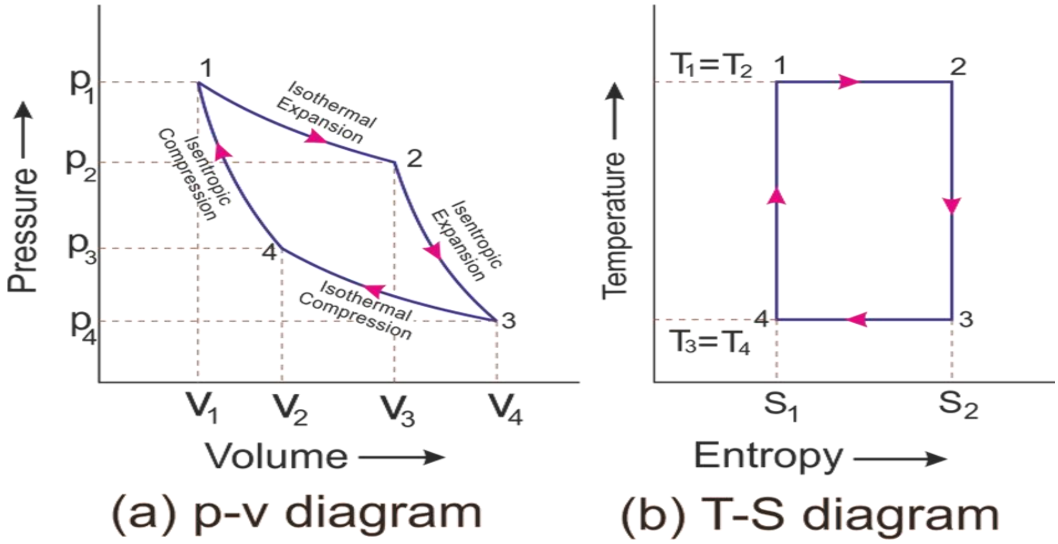
(iii) Cut-off Ratio (ρ) = V_3/V_2

8. With the help of a neat sketch show the important parts of an IC Engine?



Expected University Question for PART B (6/10 Marks)

9. Draw the P-V & T-S Diagram of a Carnot Cycle and explain the processes?



The Carnot cycle consists of the following four processes:

Process 1 -2: ***A reversible isothermal gas expansion process***: In this process, the ideal gas in the system absorbs q_{in} amount heat from a heat source at a high temperature T_{high}, expands and does work on surroundings.

Process 2-3: ***A reversible adiabatic/Isentropic gas expansion process***: In this process, the system is thermally insulated. The gas continues to expand and do work on surroundings, which causes the system to cool to a lower temperature, T_{low}.

Process 3-4: ***A reversible isothermal gas compression process***: In this process, surroundings do work to the gas at T_{low}, and causes a loss of heat, q_{out}.

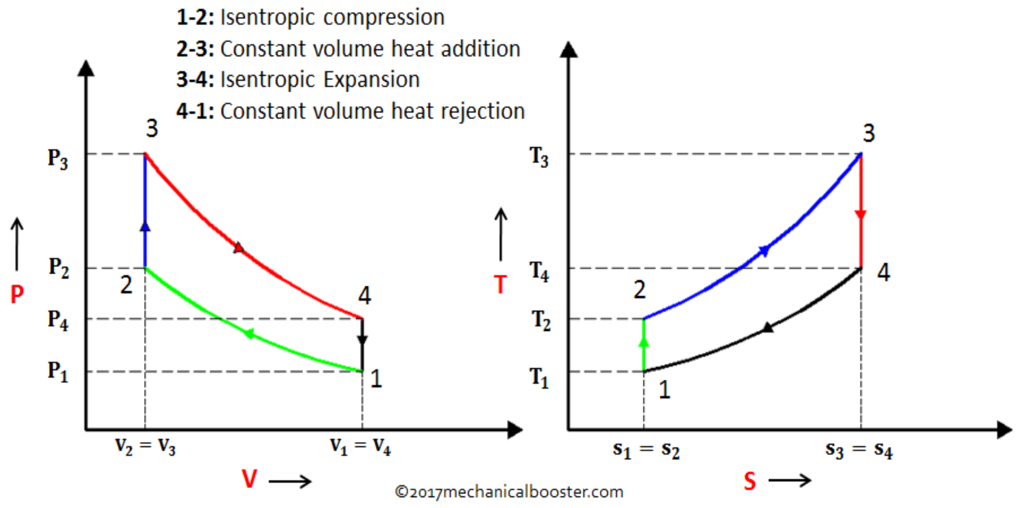
Process 4-1: ***A reversible adiabatic/Isentropic gas compression process***: In this process, the system is thermally insulated. Surroundings continue to do work to the gas, which causes the temperature to rise back to T_{high}.

10. Compare the working of Two Stroke (2S) or Four Stroke (4S) IC engines?

TWO STROKE ENGINE	FOUR STROKE ENGINE
Cycle completed in 2 strokes or 1 revolution of crankshaft	Cycle completed in 4 strokes or 2 revolution of crankshaft
More power developed	Less power developed
Smaller flywheel	Heavier flywheel
Easier design	Complicated design
Ports are used	Valves are used
Easier to start	Not easier to start
Compression ratio is lower	Higher compression ratio
Less thermal efficiency	Higher thermal efficiency

Operating temperature is more	Less operating temperature
Less weight	Heavier engine
More noisy engine	Less noisy

11. Sketch and Explain the ideal cycle for Petrol Engines?

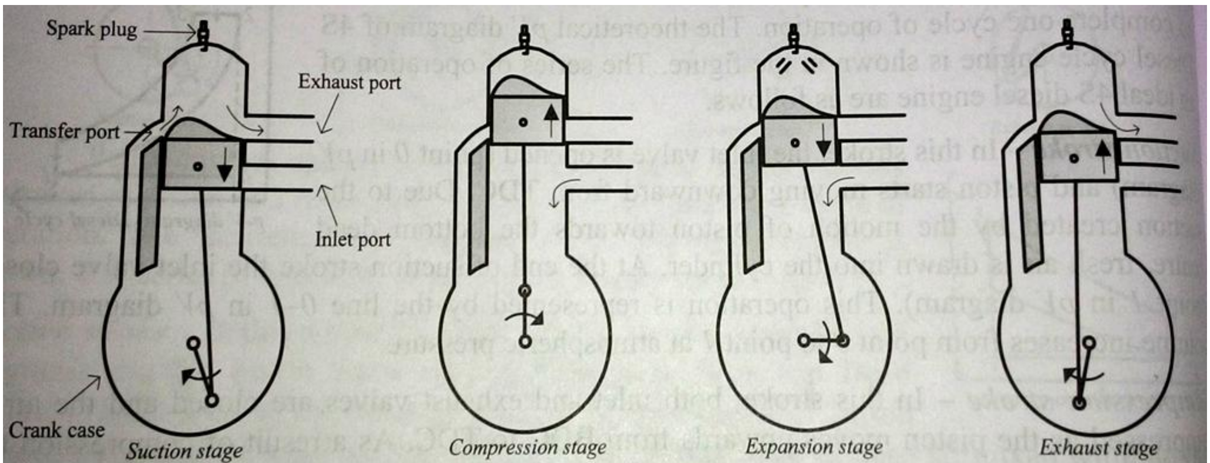


P-V and T-S Diagram of Otto Cycle

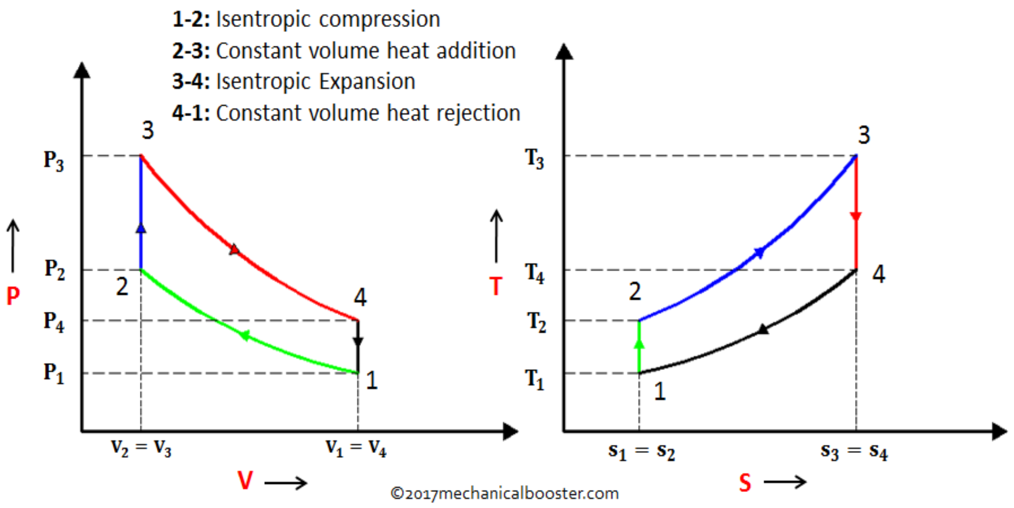
12. Explain with neat sketch the working of a petrol engine that produces power in a single revolution?

Or

Discuss the working of a two stroke (2S) petrol/SI engine?



Working of two stroke petrol engine



P-V and T-S Diagram of Otto Cycle

SUCTION STAGE:

Piston going toward BDC, uncovers both the transfer port and the exhaust port while the inlet port remains closed. Fresh air-fuel mixture flows into the cylinder from the crank case due to the compression of charge by the lower side of the piston. Introduction of fresh charge pushes the burned gases out of the cylinder

COMPRESSION STAGE

Upward movement of piston first covers the transfer port and then the exhaust port. Air – fuel mixture is compressed due to the upward motion of piston. Also, in this stage, the inlet port opens and the fresh air –fuel mixture enters into the crank case through inlet port

EXPANSION STAGE

When piston reaches TDC, the charge is ignited with the help of a spark plug. Due to combustion, piston is pushed down, piston moves from TDC to BDC

EXHAUST STAGE

Movement of piston toward BDC, the exhaust port is opened. The products of combustion are exhausted through the exhaust port into atmosphere. This completes the cycle and the engine is ready to suck the charge again.

13. Discuss the classification of IC Engines?

Based on the ignition system

- ***Spark ignition engines:*** in which an electric spark is used for igniting the air-fuel mixture. Most of the engines using petrol or gaseous fuel belong to this category

- ***Compression ignition engines*:** in which air is compressed to a very high temperature and pressure and fuel is injected to it in the form of a spray. The fuel gets ignited due to the high temperature of the compressed air. Most of the engines using diesel as fuel belong to this category.

Based on the type of fuel used

- ***Petrol engines:*** in which highly volatile liquid fuel such as petrol is used.
- ***Diesel engines:*** in which less volatile liquid fuel such as petrol is used.
- ***Gas engines:*** in which gaseous fuel such as methane is used as the main fuel.
- ***Dual- fuel engines:*** in which a gaseous fuel or a highly volatile liquid fuel is supplied along with air during the suction stroke and a viscous liquid fuel is injected into the combustion space near the end of the compression stroke.

Based on the working cycle

- ***Otto cycle engine:*** in which the engine works based on the Otto cycle (constant volume cycle). Most of the petrol engines and gas engines work on the cycle.
- ***Diesel cycle engine:*** in which the engine works based on the diesel cycle. Most of the low speed oil engines work on this cycle.

Based on the number of strokes per cycle

- ***Four stroke engines:*** in which one cycle of operation is completed in four strokes of the piston
- ***Two stroke engines:*** in which one cycle of operation is completed in two strokes of the piston

Based on the application of the engine

- ***Stationary engines:*** which are used in power plants
- ***Mobile engines:*** which are used in automobiles, aircrafts, etc

Based on the cooling system

- ***Air cooled engines:*** in which heat is directly dissipated into the air around the cylinder
- ***Water cooled engines:*** in which excess heat is removed from the engine cylinder and cylinder head by circulating water through the jackets provided in the engine cylinder and cylinder head

Based on the speed of the engine

- ***Low speed engines:*** up to 350rpm
- ***Medium speed engines:*** 350-1000rpm

- ***High speed engines:*** above 1000rpm

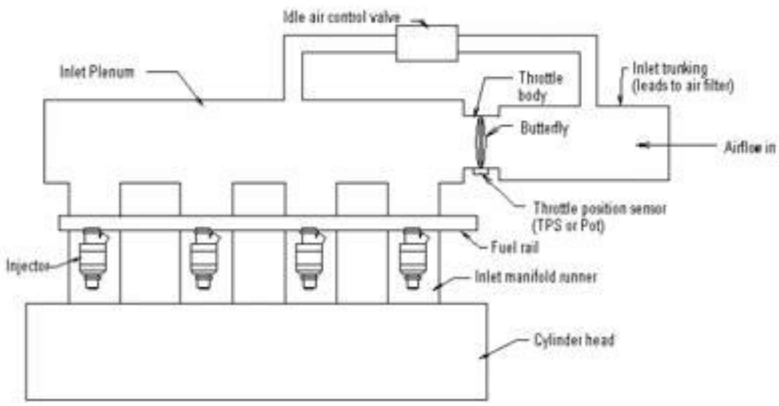
Based on the number of cylinders

- ***Single cylinder engine:*** in which there is only one cylinder in an engine.
- ***Multi cylinder engine:*** in which there are more than one cylinder in an engine.

14. Explain about MPFI, CRDI and Hybrid Engines?

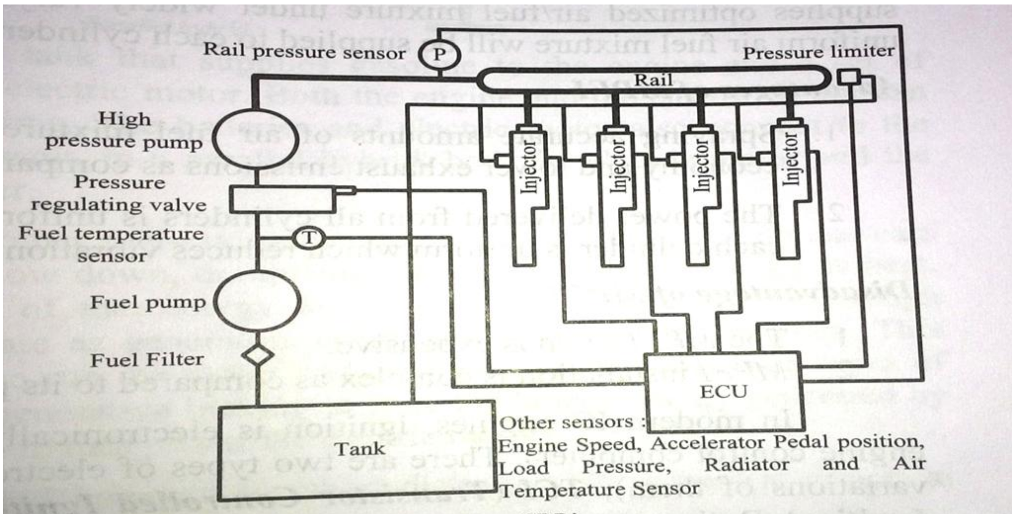
MPFI: Some fuel injectors, like carburettors, mix in fuel at a single point in the throttle body. Whereas, Multi-Point Fuel Injection (**MPFI**) systems inject fuel at each cylinder, allowing much greater control over how much fuel the **engine** burns. In **MPFI** systems, the injection generally takes place directly inside the cylinder's intake valve.

Multiple point injection with plenum



CRDI (Common Rail Direct Injection): Common rail distributes the fuel to the computer controlled injectors at a constantpressure of up to 1600 bar

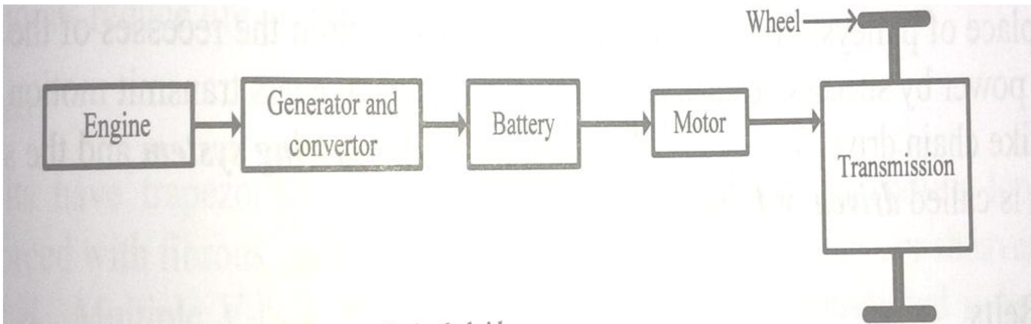
- Electronic control unit(ECU) receives signals from various sensors and uses those signals to operate injection
- Common rail engines maintain a constant pressure regardless of the injection sequence
- More accurately measured and timed fuel spray in the combustion chamber significantly reduces unburned fuel and increases the fuel efficiency.



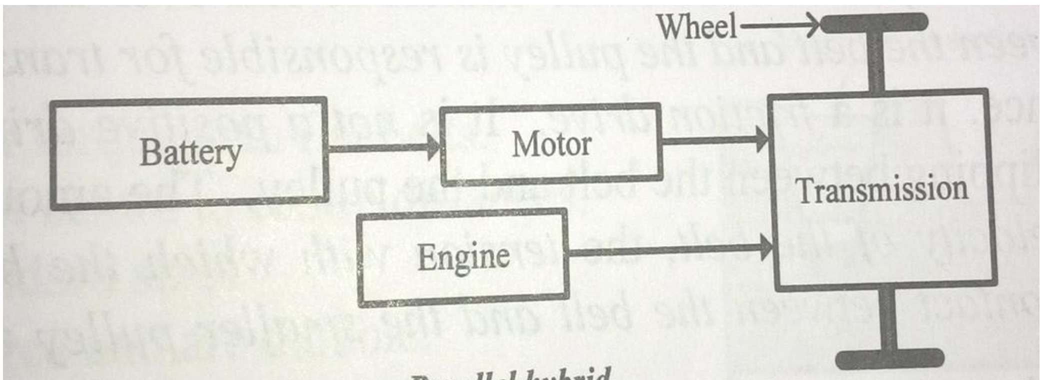
CRDi

Hybrid Engine:

- Hybrid electric vehicles are powered by an internal combustion engine and an electric motor, which uses energy stored in batteries.
- A hybrid electric vehicle cannot be plugged in to charge the battery. Instead, the battery is charged through regenerative braking and by the internal combustion engine.
- The extra power provided by the electric motor can potentially allow for a smaller engine. The battery can also power auxiliary loads and reduce engine idling when stopped.
- Together, these features result in better fuel economy without sacrificing performance.



Series hybrid

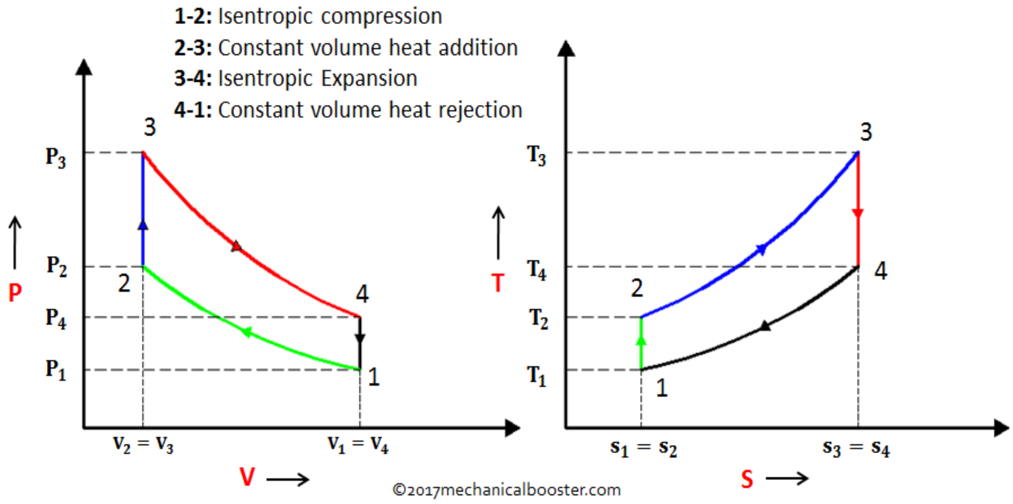


Parallel hybrid

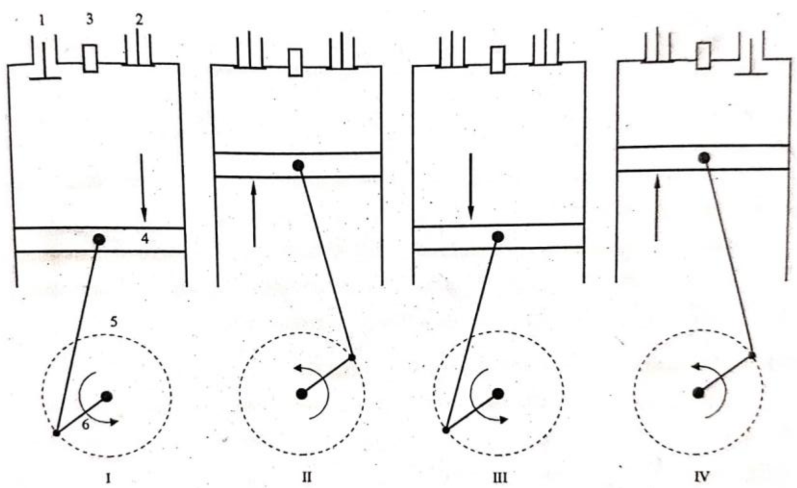
15. Discuss the working of a Four Stroke SI Engines?

Or

With the help of a neat diagram, explain the working of an SI engine which develops one power stroke during two crank rotations?



P-V and T-S Diagram of Otto Cycle



I. Suction stroke II. Compression stroke III. Working stroke IV. Exhaust stroke

1. Inlet valve 2. Exhaust valve 3. Spark plug 4. Piston 5. Connecting rod 6. Crank

Fig. 1.26. Working of four stroke petrol engine

Suction Stroke: During this stroke the piston moves from Top Dead Centre (TDC) to Bottom Dead Centre (BDC). The Inlet valve opens and the fuel air mixture is sucked into the engine cylinder. The exhaust valve remains closed throughout this stroke.

Compression Stroke: The air fuel mixture is compressed as the piston moves from BDC to TDC. Just before the end of this stroke, the spark plug initiates a spark which ignites the mixture and combustion takes place at constant volume (line 2-3 in P-V Diagram). Both inlet and exhaust valves remains closed throughout this stroke.

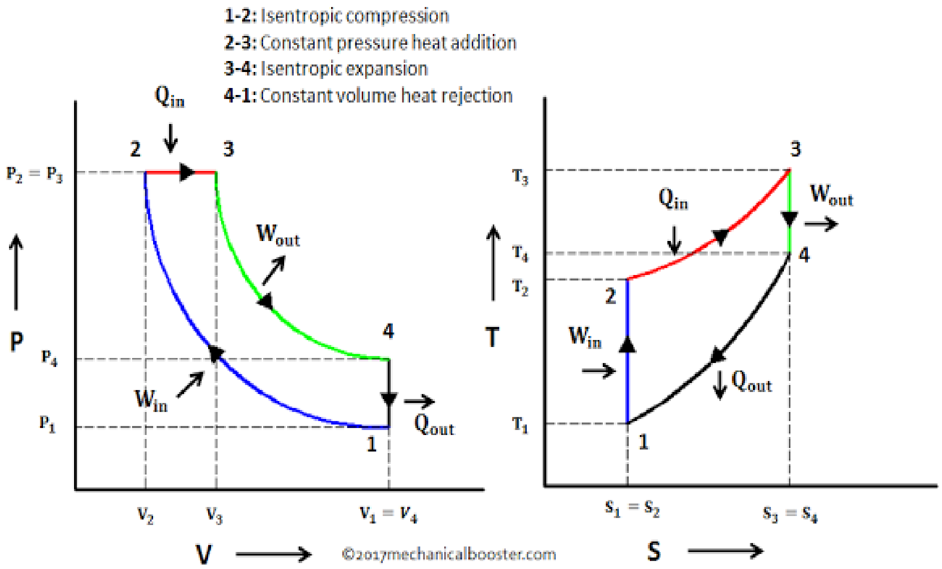
Expansion/Working Stroke: As the fuel air mixture burns, hot gases are produced which drive the piston towards BDC and thus work is done. This expansion process is shown by the line 3-4 in P-V Diagram. Both the valves remain closed during this stroke.

Exhaust Stroke: The removal of burnt gases is accomplished during this stroke. The piston moves from BDC to TDC and the exhaust gases are driven out of the engine cylinder. During this stroke the exhaust valve remains opened and the inlet valve remains closed. By this one cycle is completed.

16. Compare the working of SI & CI engines

PETROL ENGINE (SI)	**DIESEL ENGINE** (CI)
Petrol air mixture flows through the inlet valve	Air flows through the inlet valve
Carburettor is used	Fuel injector is used
Maximum pressure 10 bar	Maximum pressure 35-40 bar
Spark plug is used	No spark plug
Otto cycle	Diesel cycle
Compression ratio 6 to 10	Compression ratio 16 to 22
Easier to start	Not easier to start
Less vibration	Vibration is more
Less weight	Heavier engine
High speed engines	Low speed engines
Maintenance cost is less	Maintenance cost is more

17. Sketch a Diesel Cycle on P-V & T-S diagram & Explain?



P-V and T-S Diagram of Diesel Cycle

First Stage (Reversible adiabatic or isentropic compression):

Consider a cylinder containing 'm' kg of air. Let P1, V1 and T1 the pressure, volume and temperature of air inside the cylinder at state 1. The air is compressed adiabatically to state 2, doing work on the air. Curve 1-2 in the P-V diagram and line 1-2 in T-S diagram represent this process

Second Stage (Constant pressure heating):

During this stage, the air is heated at constant pressure from temperature T2 to T3 by an external hot body represented by straight line 2-3 in the P-V diagram and curve 2-3 in the T-S diagram. Supply of heat is cut off at point 3. Therefore it is called as **cut-off point.**

Third Stage (Reversible adiabatic or isentropic expansion):

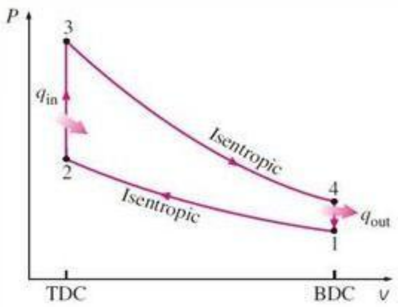
At state 3, the hot body is removed and the air is allowed to expand adiabatically to state 4, doing external work. This process is represented by curve 3-4 in the P-V diagram and a straight line 2-3 in T-S diagram. In this process no heat is absorbed or rejected by the air.

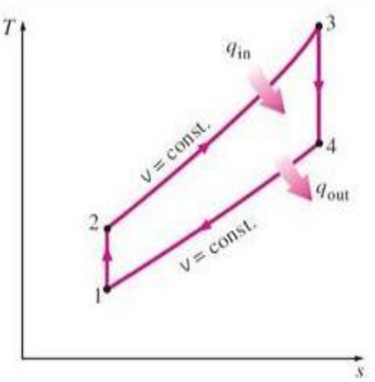
Fourth Stage (Constant volume cooling):

During this stage heat is rejected at constant volume to an external cold body till state 1 is reached. This process is represented by the line 4-1 in the P-V diagram and by the curve 4-1 in the T-S diagram.

18. Derive an expression for the air standard efficiency of Otto cycle?

Otto Cycle:





Q_s @ $V = C$ · $2 \to 3 = mC_v(T_3 - T_2)$.

Q_R @ $V = C$ · $4 \to 1 = mC_v(T_4 - T_1)$.

$$\eta = 1 - \frac{Q_R}{Q_s}$$

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

$$= 1 - \frac{(T_4 - T_1)}{(T_3 - T_2)} \quad \text{———— } (i).$$

$1 \to 2$ · Adiabatic Compression·

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

$\frac{V_1}{V_2}$ = Compression Ratio, r

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

$$\boxed{T_2 = T_1 \cdot r^{\gamma - 1}} \quad \text{———— } (ii)$$

3→4: Adiabatic Expansion.

$$\frac{T_3}{T_4} = \left(\frac{V_4}{V_3}\right)^{\gamma-1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}.$$

$\because$ $V_4 = V_1$
$V_3 = V_2$.

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

$$\boxed{T_3 = T_4 \cdot r^{\gamma-1}.} \quad \text{———} \quad (iii).$$

Substituting (ii) and (iii) in (i).

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

$$\Rightarrow 1 - \frac{(T_4 - T_1)}{\left(T_4 \cdot r^{\gamma-1} - T_1 \cdot r^{\gamma-1}\right)}$$

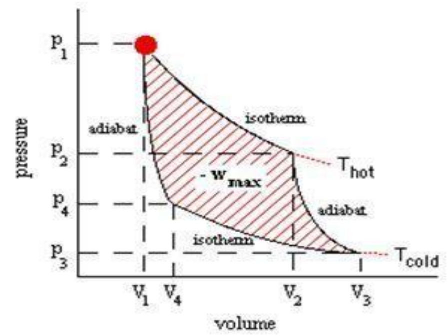
$$\Rightarrow 1 - \frac{(T_4 - T_1)}{(T_4 - T_1) \cdot r^{\gamma-1}}.$$

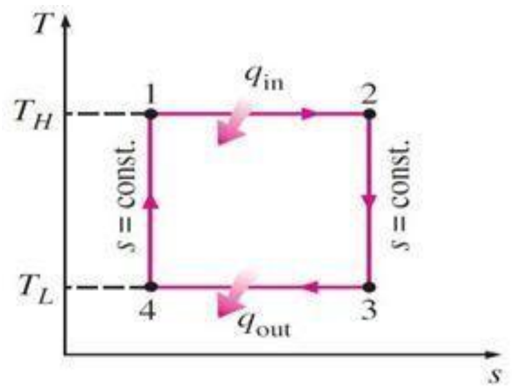
$$= 1 - \frac{1}{r^{\gamma-1}}.$$

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

19. Explain the air standard Carnot cycle with neat sketches and derive the expression for efficiency?

CARNOT CYCLE :





1 → 2 Isothermal Expansion
2 → 3 Adiabatic Expansion
3 → 4 Isothermal Compression
4 → 1 Adiabatic Compression.

From TS diagram:

Heat supplied $Q_s = T_1 (S_2 - S_1)$.

Heat Rejected $Q_R = T_3 (S_3 - S_4)$.

Air standard efficiency,

$$\eta = \frac{Q_s - Q_R}{Q_s}$$

$$= 1 - \frac{Q_R}{Q_s}$$

$$= 1 - \frac{T_3 (S_3 - S_4)}{T_1 (S_2 - S_1)}$$

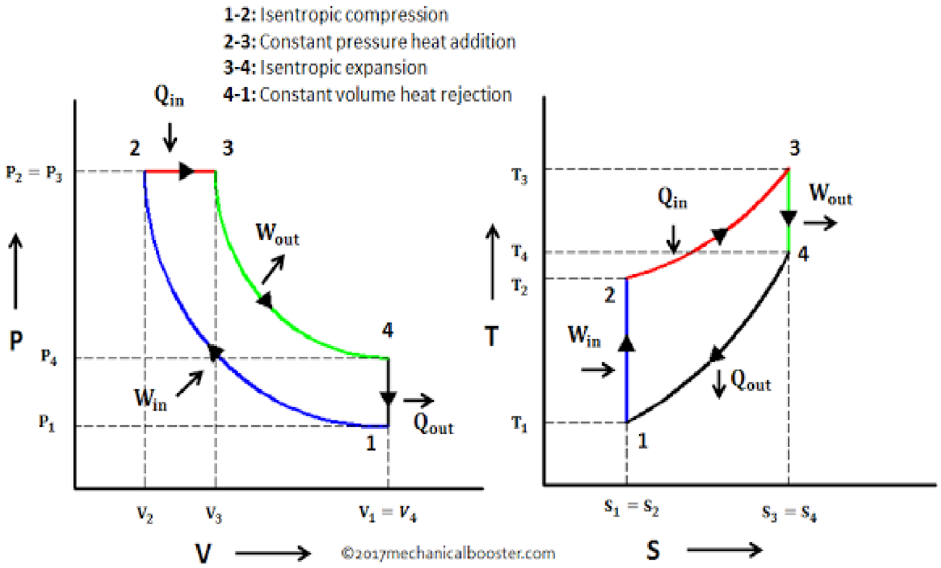
From TS diagram

$S_3 = S_2$
$S_4 = S_1$

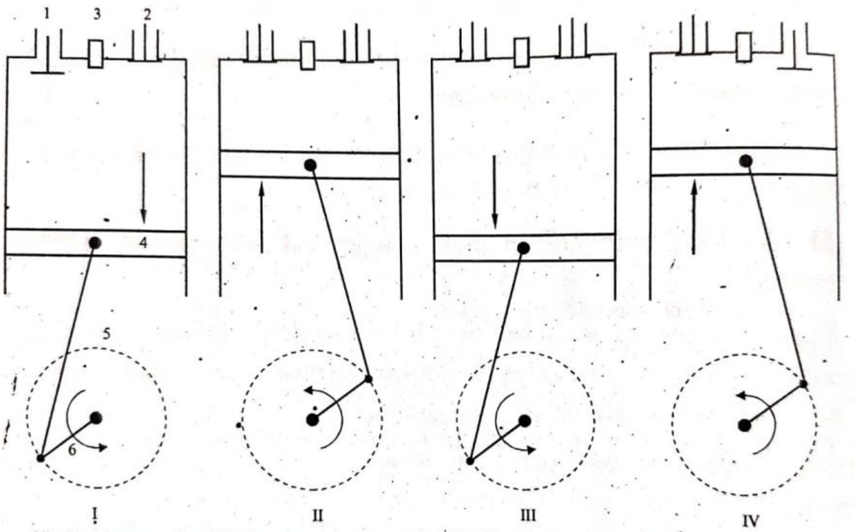
$$= 1 - \frac{T_3 (S_2 - S_1)}{T_1 (S_2 - S_1)}$$

$$\boxed{\eta = 1 - \frac{T_3}{T_1}}$$

20. With the help of a neat diagram explain the working of Four Stroke Diesel Cycle?



P-V and T-S Diagram of Diesel Cycle



I. Suction stroke II. Compression stroke III. Working stroke IV. Exhaust stroke

1. Inlet valve 2. Exhaust valve 3. Fuel Injector 4. Piston 5. Connecting rod 6. Crank

Fig. 1.23. Working of four stroke diesel engine

SUCTION STROKE

- Piston moves from TDC to BDC. Inlet valve opens and the Fresh –Air is drawn into the engine cylinder. Exhaust valve remains closed

COMPRESSION STROKE

- Piston moves from BDC to TDC and compresses the air. Both valves remain closed. Just before the end of the stroke, the fuel is injected in the form of fine spray through fuel injection valve, the temperature of the compressed air is sufficiently high to ignite the fuel and combustion takes place. The injection of fuel is continued for some time and is cut off at a point. Both the valves remains closed

EXPANSION/ WORKING STROKE

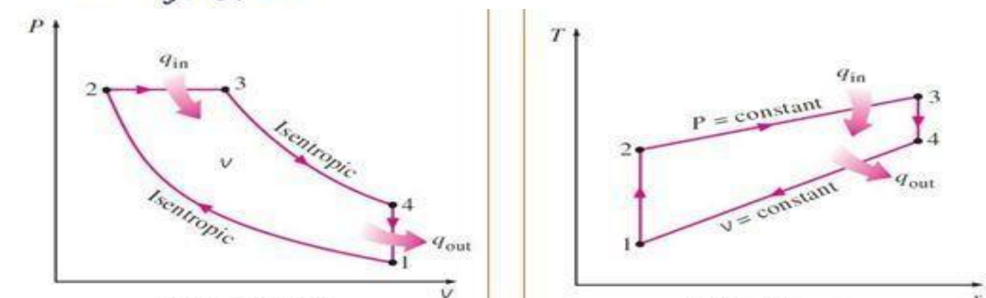
- Piston moves from TDC to BDC and thus work is done. Both valves remain closed.
- At the end of stroke exhaust valve opens and exhaust gas flow outside through exhaust valve

EXHAUST STOKE

- Piston moves from BDC to TDC for the removal of the burnt gases. Inlet valve remains closed and exhaust opens. This completes the cycle and the engine is ready to suck air again.

21. Derive an expression for the air standard efficiency of Diesel cycle?

DIESEL CYCLE: —



(a) P- v diagram (b) T-s diagram

1→2 · Adiabatic compression

2→3 Constant pressure $(p=c)$

3→4 Adiabatic Expansion.

4→1. Constant Volume $(v=c)$.

$$\eta = 1 - \frac{Q_R}{Q_s}.$$

Q_R @ $v=c \Rightarrow Q_R = mC_v(T_4 - T_1)$.

Q_s @ $p=c \Rightarrow Q_s = mC_p(T_3 - T_2)$.

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

$$\boxed{\eta = 1 - \frac{1}{\gamma}\left(\frac{T_4 - T_1}{T_3 - T_2}\right)} \quad \text{— (i)} \quad \because \frac{C_p}{C_v} = \gamma$$

Assume. $\frac{V_3}{V_2} = \rho$, cut off Ratio.

$\frac{V_1}{V_2} = r$, Compression Ratio

$\frac{V_4}{V_3} = r_1$, Expansion Ratio.

Relationship between r_1, r & ρ

$$\frac{V_4}{V_3} = \frac{V_4}{V_2} \times \frac{V_2}{V_3}.$$

$$\frac{V_4}{V_3} = \frac{V_1}{V_2} \times \frac{V_2}{V_3}$$ [∵ $V_4 = V_1$ from pv diagram]

$$r_1 = r \times \frac{1}{\rho}$$

$$\boxed{r_1 = \frac{r}{\rho}}$$

$1 \to 2$ :: Adiabatic process.

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

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

$$\boxed{T_2 = T_1 \cdot r^{\gamma-1}.} \text{ ——— (ii)}$$

$2 \to 3$:- $p = C$

$$\frac{T_3}{T_2} = \frac{V_3}{V_2}.$$

$$\frac{T_3}{T_2} = \rho.$$

$$T_3 = T_2 \cdot \rho$$

$$\boxed{T_3 = T_1 \cdot r^{\gamma-1} \cdot \rho} \text{ ——— (iii)}$$

3-4 Adiabatic

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

$$= r_1^{\gamma-1}$$

we know $r_1 = \frac{r}{\rho}$

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

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

$$T_4 = T_1 \cdot \rho r^{\gamma-1} \times \frac{\rho^{\gamma-1}}{r^{\gamma-1}}$$

$$= T_1 \cdot \rho \times \rho^{\gamma-1}$$

$$\boxed{T_4 = T_1 \cdot \rho^{\gamma}} \text{ --- (iv)}$$

Substituting (ii), (iii) and (iv) in Equation (i).

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

$$= 1 - \frac{1}{\gamma}\left(\frac{T_1 \cdot \rho^{\gamma} - T_1}{T_1 \cdot \rho \cdot r^{\gamma-1} - T_1 \cdot r^{\gamma-1}}\right)$$

$$= 1 - \frac{1}{\gamma} \times \frac{T_1(\rho^{\gamma} - 1)}{T_1(\rho r^{\gamma-1} - r^{\gamma-1})}$$

$$\Rightarrow 1 - \frac{1}{\gamma} \times \frac{(\rho^{\gamma} - 1)}{r^{\gamma-1}(\rho - 1)}$$

$$\boxed{\eta_{Diesel} = 1 - \frac{1}{\gamma} \times \frac{1}{r^{\gamma-1}} \times \frac{(\rho^{\gamma} - 1)}{(\rho - 1)}}$$

References:

1. "Basics of Mechanical Engineering", J. Benjamin, Tenth Edition (2019), Pentex Publications
2. "Basics of Civil and Mechanical Engineering", P. Binu, R. Rajesh Kumar, First Edition (2019), Jyothis Pubishers.