Chapter 4 – Prime Movers

Session 1 – IC Engines
Introduction and Working of
4 Stroke Petrol and Diesel Engines

Topic Learning Outcomes:

1. Discuss Steam as a working medium in prime movers and heat engines and its characteristic properties

2. Explain the working principle of impulse and reaction steam turbine

3. **Outline the basic operating principles behind two-stroke and four-stroke internal combustion engines.**

Lesson Schedule

1.1. Introduction, Classification and Parts of an IC Engine
1.2. Working Principle of 4 Stroke Petrol and Diesel Engine
2.1. Working Principle of 2 Stroke Petrol and Diesel Engine
2.2. Comparison of 2 stroke and 4 stroke engines, And Comparison of diesel and petrol engines
3.1. Formulae for IC Engine Calculations
3.2. Numerical Problems on Engine Performance
4.1. Steam- Formation of steam, Properties of steam
4.2. Applications of steam, Steam turbines: Working Principle of Impulse and Reaction Steam Turbines

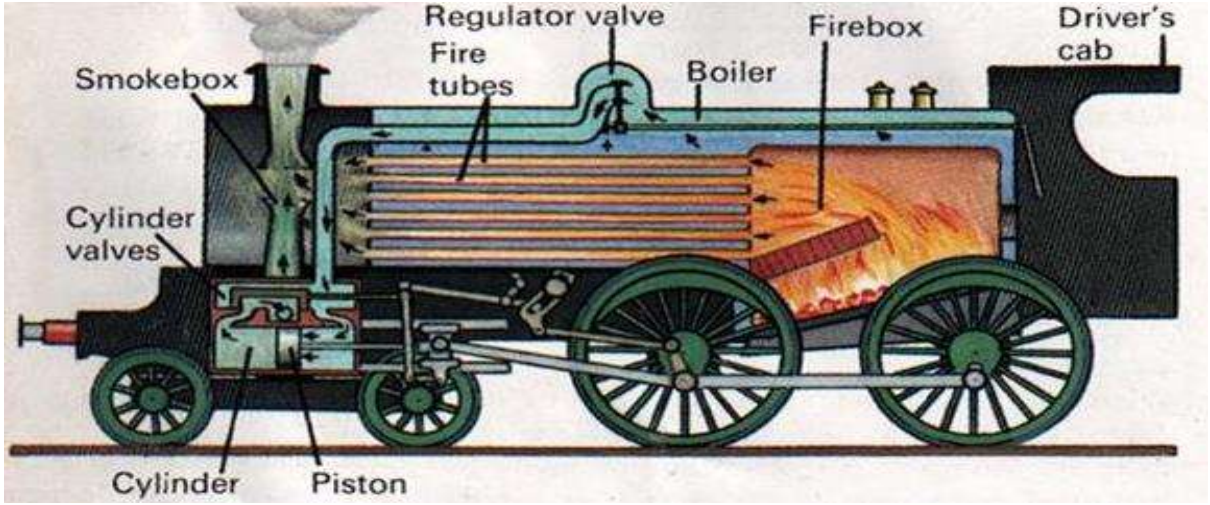
Internal Combustion Engines

Heat Engines

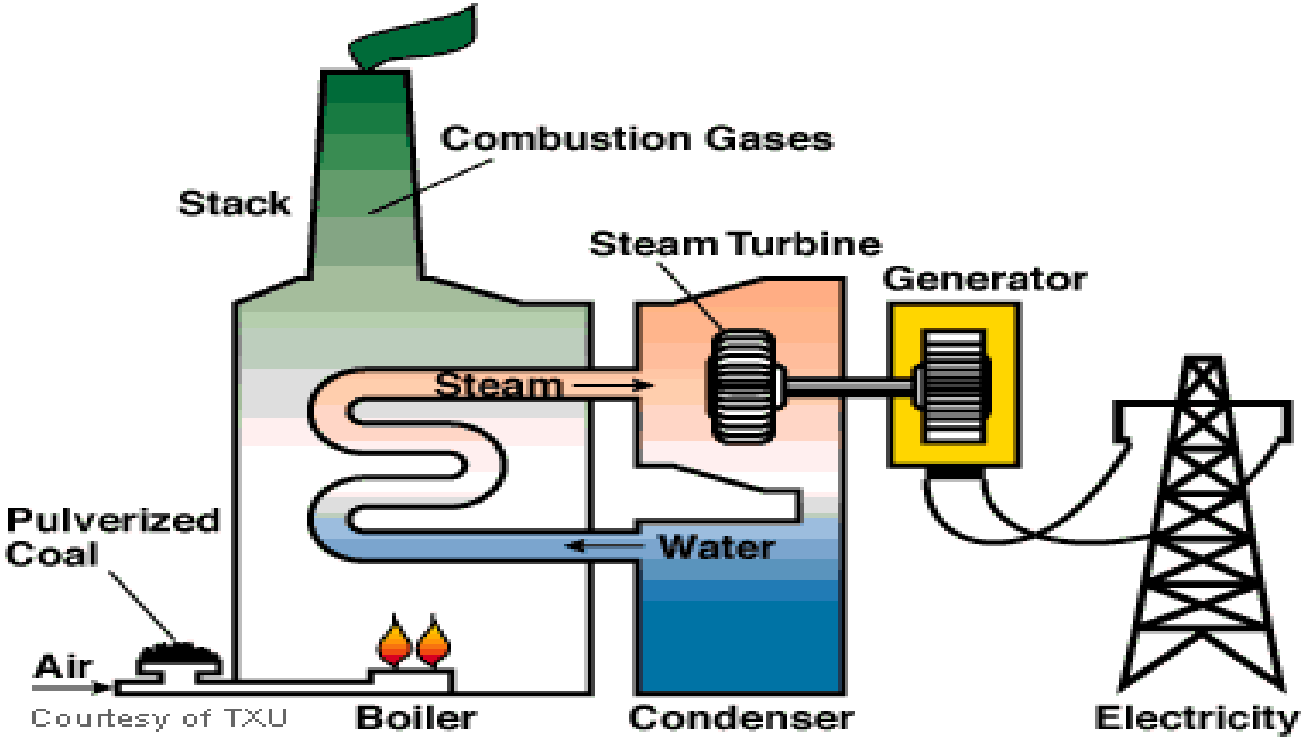
- An engine which converts heat energy into mechanical energy which can be used for doing mechanical work is known as Heat Engine.

- There are two types:
  - *External Combustion Engines (EC Engines)*
    - *Steam Engines, Steam Turbines*
  - **Internal Combustion Engines (IC Engines)**
    - **Automotive Engines, Locomotive Engines,**
    - **Jet Engines, Rockets.**

External Combustion Engines



External Combustion Engines

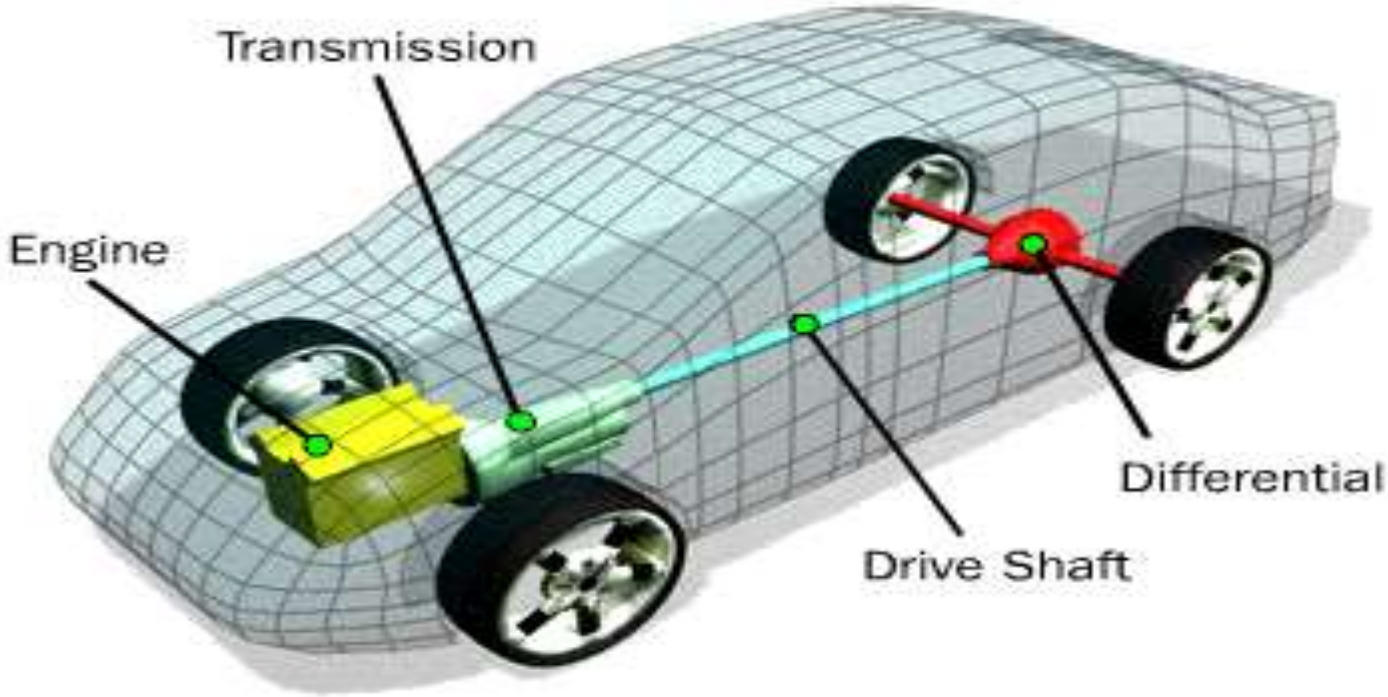


Steam Turbine Power Plant

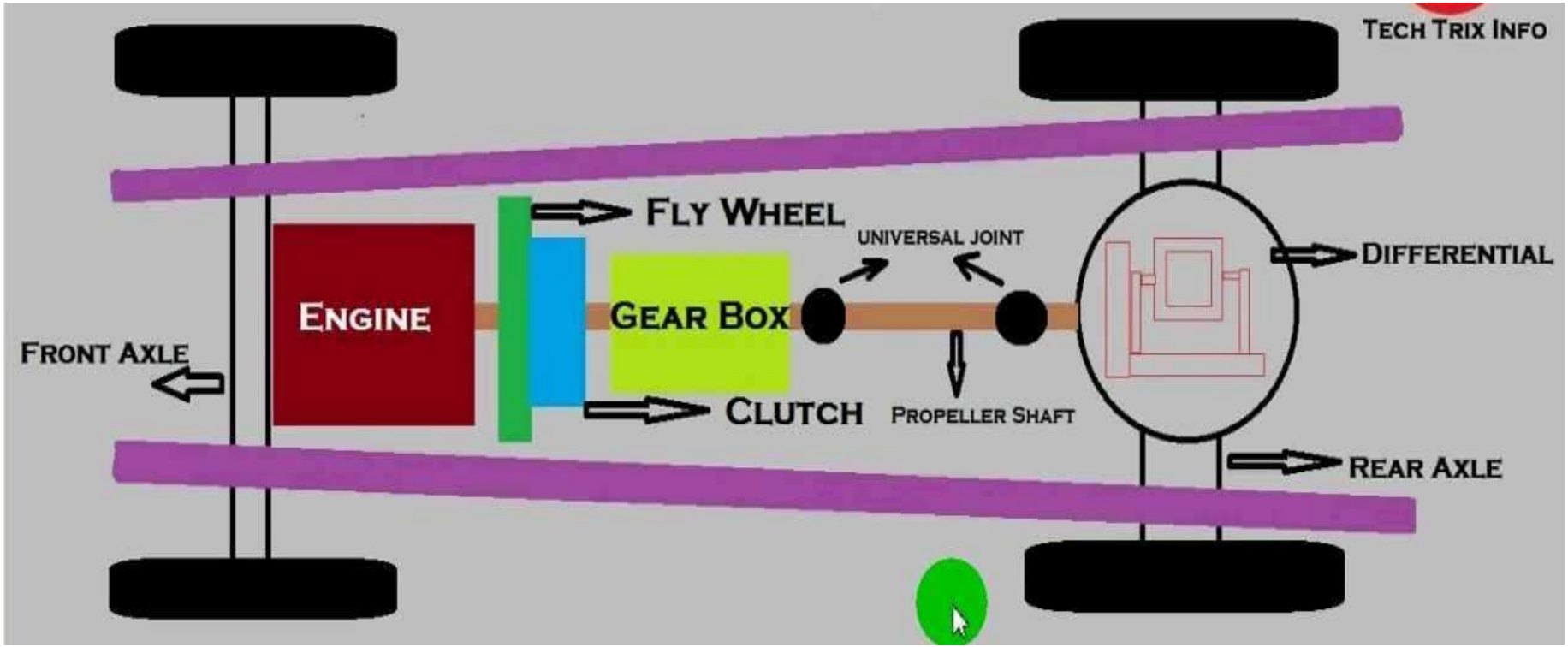
Internal Combustion Engine

- Internal Combustion engine, popularly known as **IC Engine** is a heat engine which converts **heat energy** produced by the combustion of fuels taking place inside the engine cylinder to **mechanical energy**.

Layout of an Automobile



Layout of an Automobile



Internal Combustion Engines

Small Engines

Internal Combustion Engines

Automotive Engine

Internal Combustion Engines

Locomotive Engines

Internal Combustion Engines

Marine Engine

Classification of IC Engines

I. Based on the nature of Thermodynamic Cycle:

1. Otto Cycle Engine
2. Diesel Cycle Engine
3. Dual Combustion Cycle Engine

Classification of IC Engines…

II. Based on the type of Fuel used:

1. Petrol Engine
2. Diesel Engine
3. Gas Engine
4. Bi-Fuel Engine

Classification of IC Engines…

III. Based on the Number of Strokes:

1. Four Stroke Engine
2. Two Stroke Engine

Classification of IC Engines…

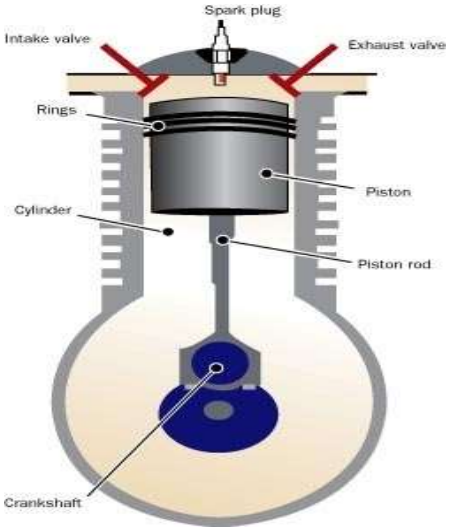
IV. Based on the method of Ignition:

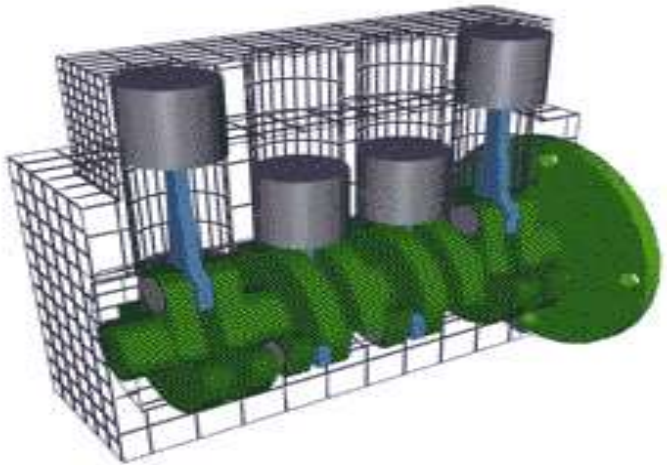
1. Spark Ignition Engine
2. Compression Ignition Engine

Classification of IC Engines…

V. Based on the number of Cylinders:

1. Single Cylinder Engine
2. Multi-cylinder Engine



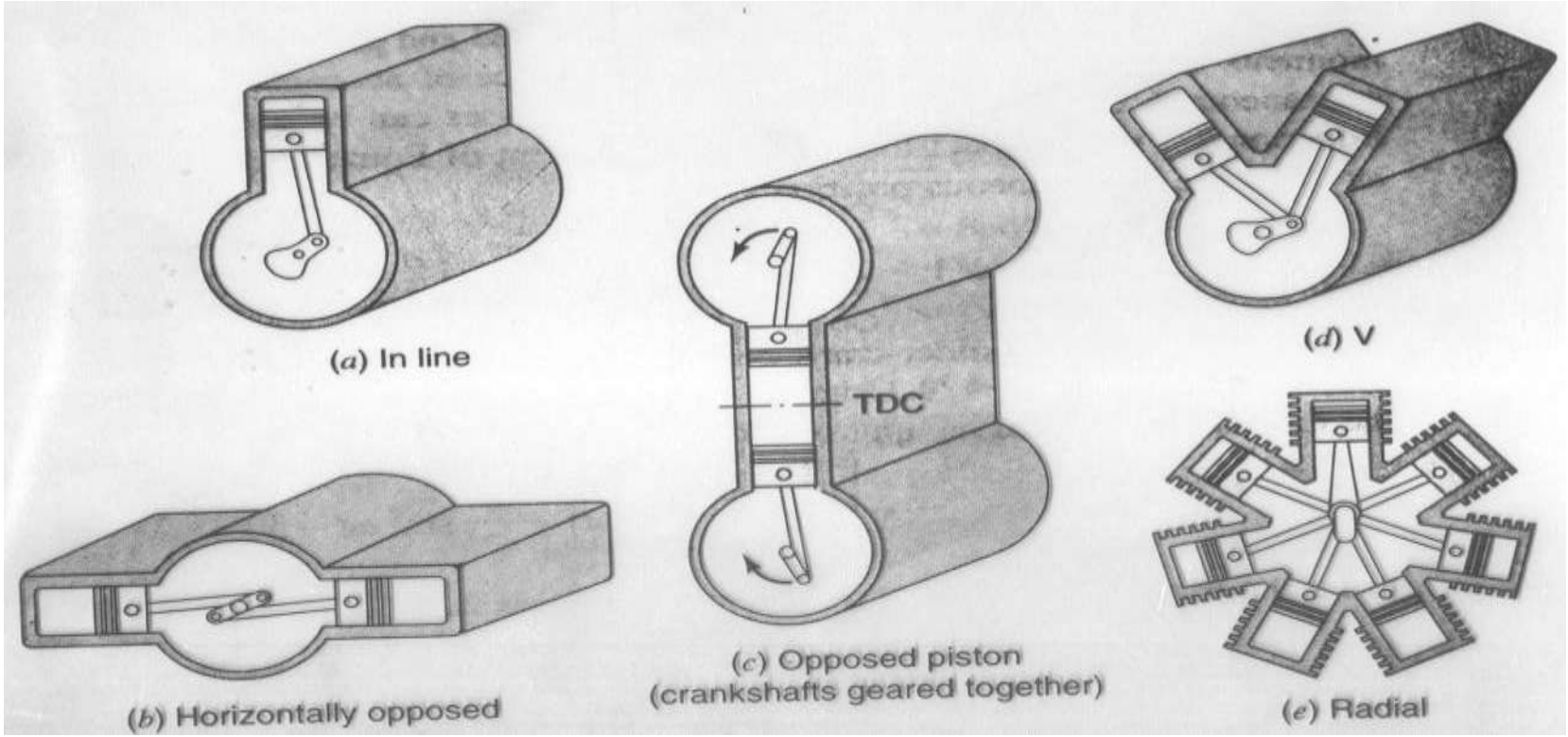


Classification of IC Engines…

VI. Based on the Position of the cylinder:

1. Horizontal Engine
2. Vertical Engine
3. V Engine (Vee)
4. Opposed Cylinder Engine
5. Radial Engine

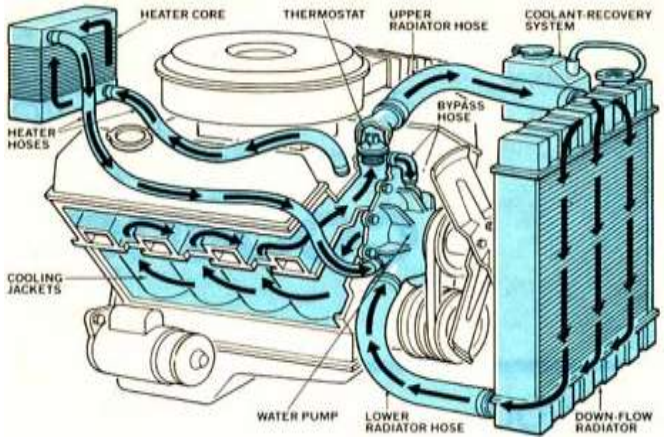
Arrangement of cylinders



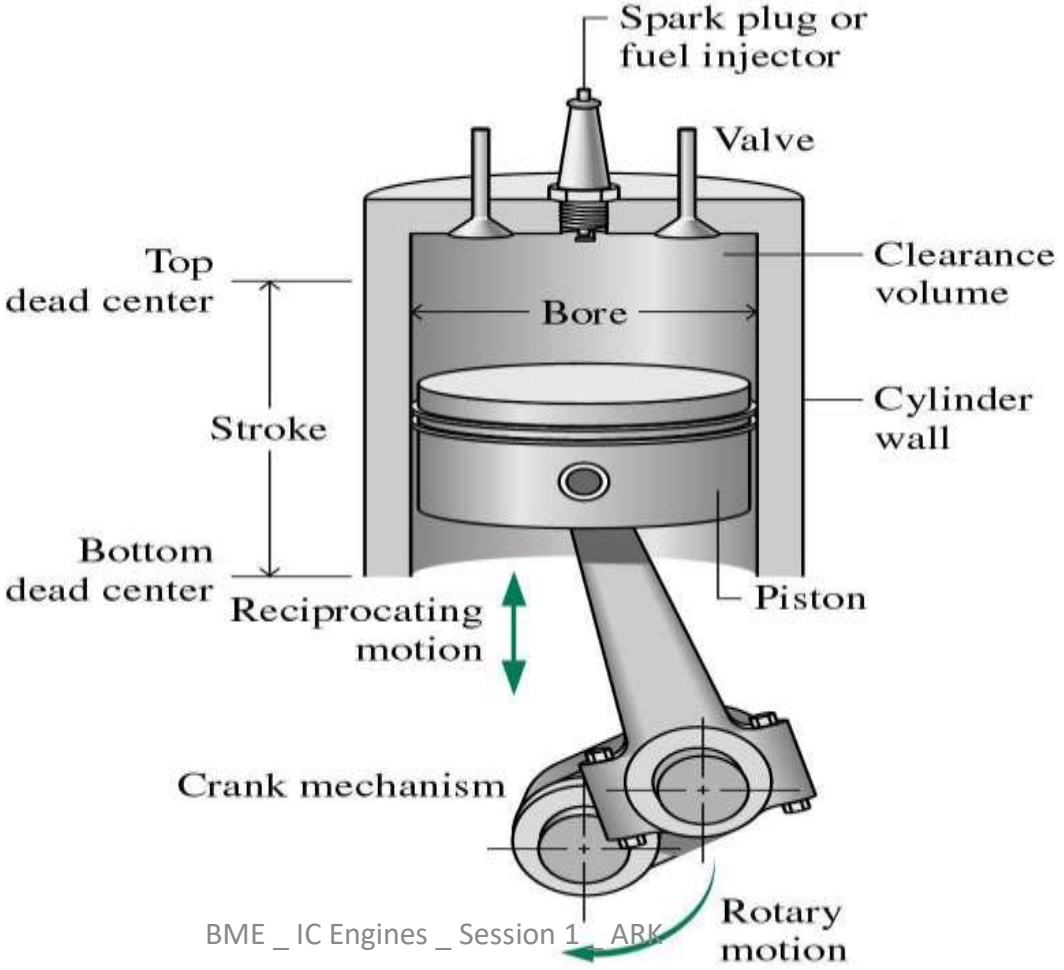
Classification of IC Engines…

VII. *Based on the method of cooling:*

1. Air cooled Engines
2. Water cooled Engines

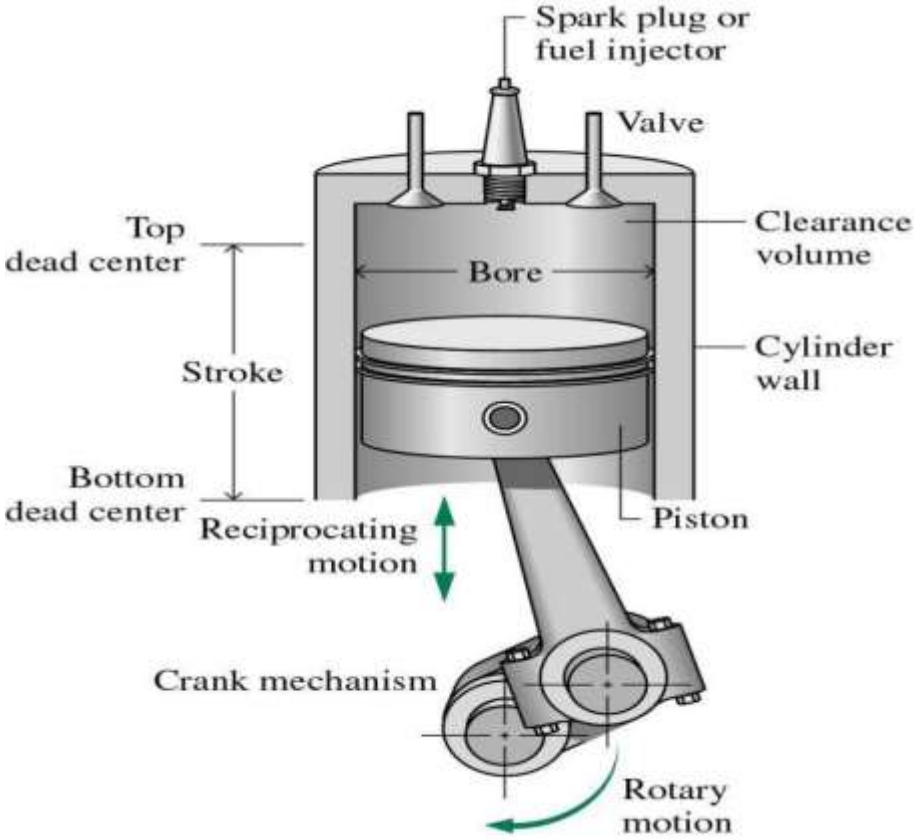


IC Engine Terminologies



IC Engine Terminologies

- Cylinder Bore (D)
- Top Dead Center (TDC)
- Bottom Dead Center (BDC)
- Stroke (L)



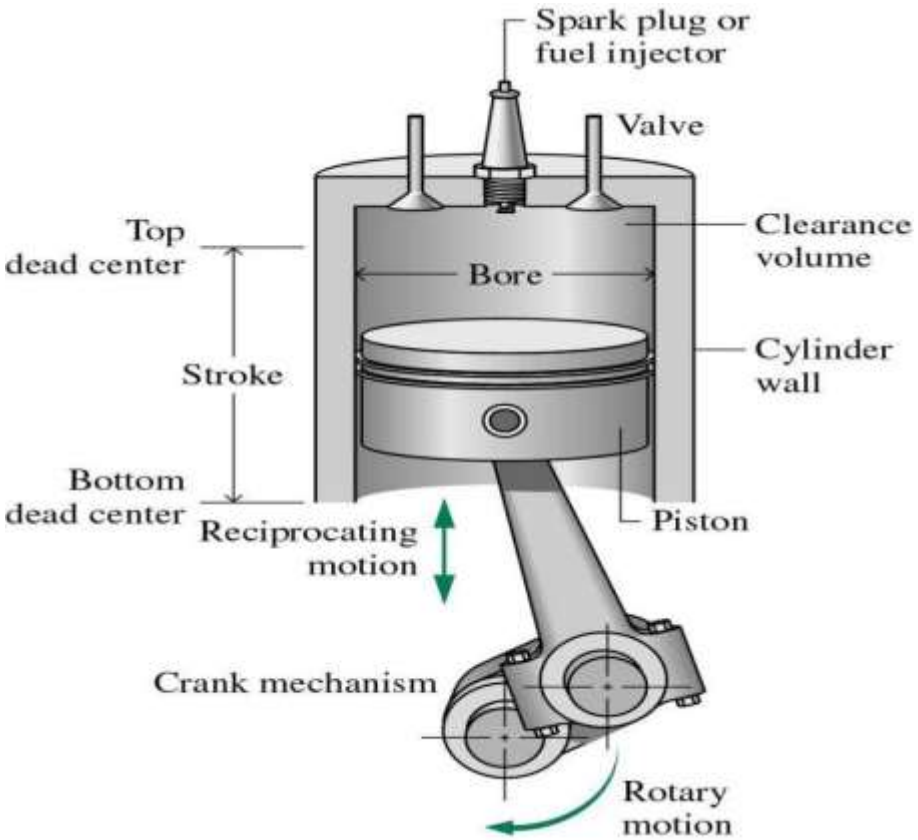
IC Engine Terminologies

- Swept Volume (Vs = A x L)
- Clearance Volume (Vc)
- Cylinder Volume

  (V = Vs +Vc)

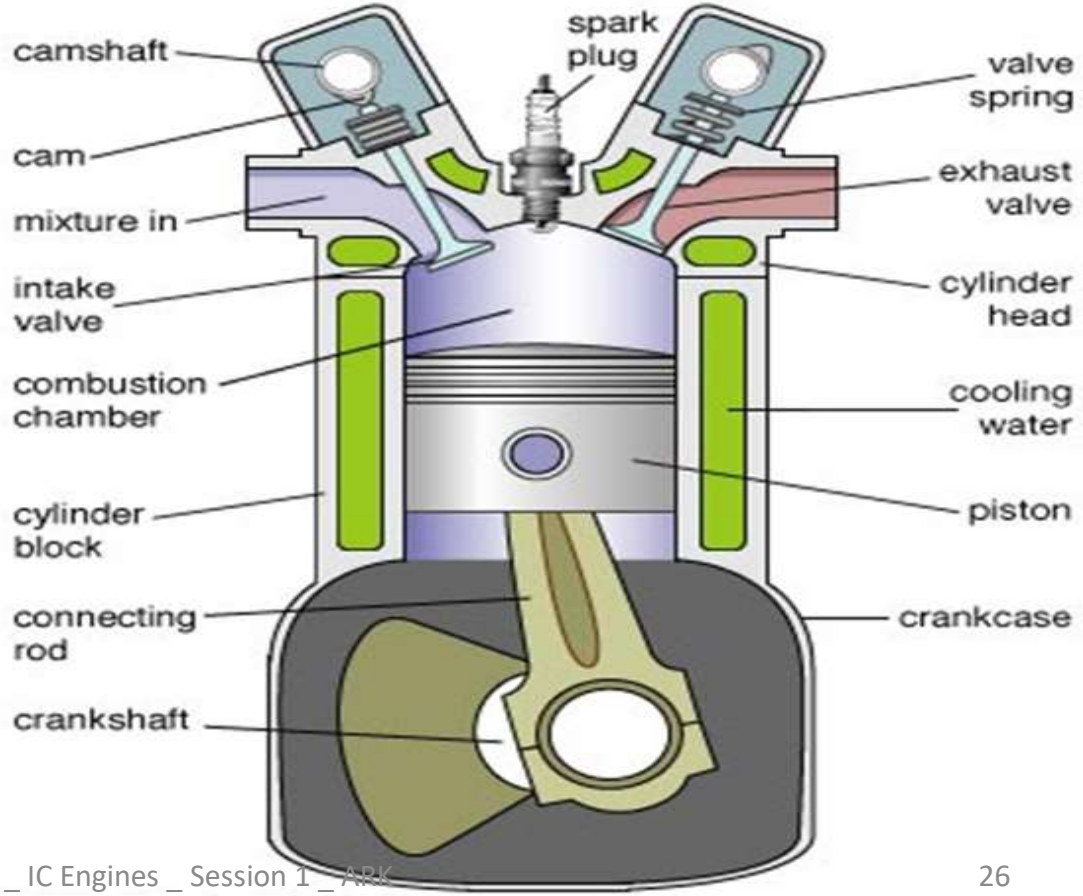
- Compression Ratio,

$$CR = \frac{Vs + Vc}{Vc}$$



Major Components of IC Engine:

- Engine block
- Cylinder head
- Piston
- Connecting rod
- Crank shaft
- Cam shaft
- Valves



Engine Block

Contains:

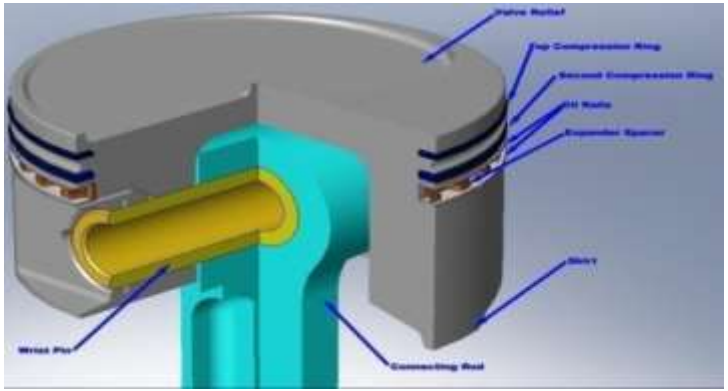
- Cylinder bores
- Pistons and rings
- Connecting rods
- Crankshaft
- Bearings
- Timing gears
- Oil pan and filter
- Camshaft
- Flywheel

Cylinder Head

- Covers cylinders.
- Forms top of combustion chamber.
- Contains intake and exhaust valves and springs.
- Contains spark plugs/ Injectors.
- Bolted to engine block with bolts.
- Head gasket is placed between block and cylinder head.

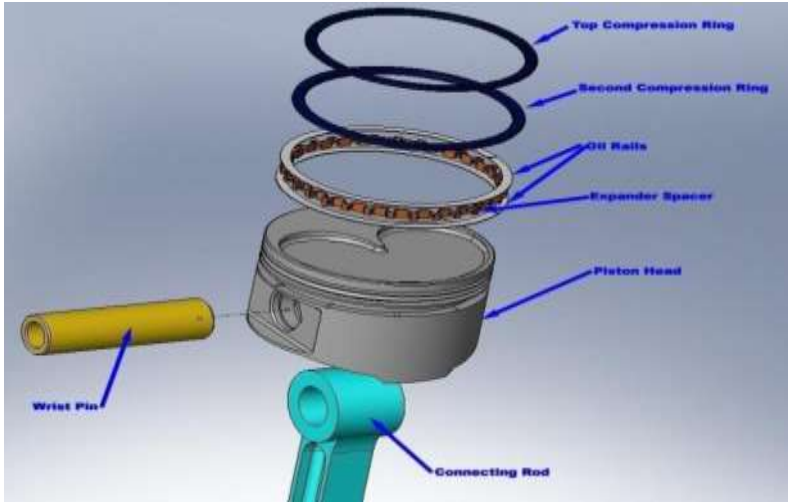
Pistons

- Moves up and down in cylinders.
- Creates low pressure to draw in mixture.
- Compresses mixture for ignition.
- Transmits forces of combustion to rotate crankshaft.
- Pushes exhaust gases out of cylinder.



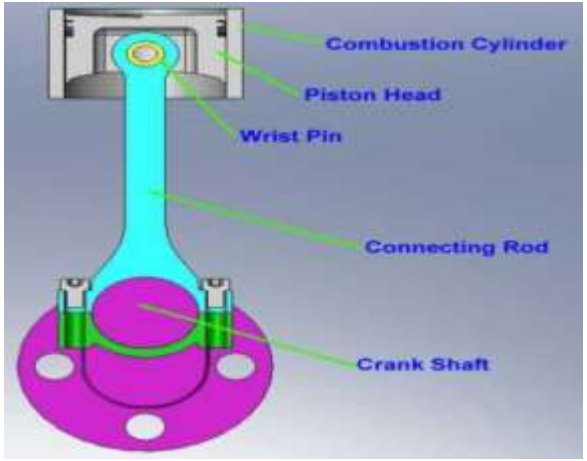
Piston Rings

- Mounted in grooves on piston.
- Takes up clearance in cylinder required for piston expansion



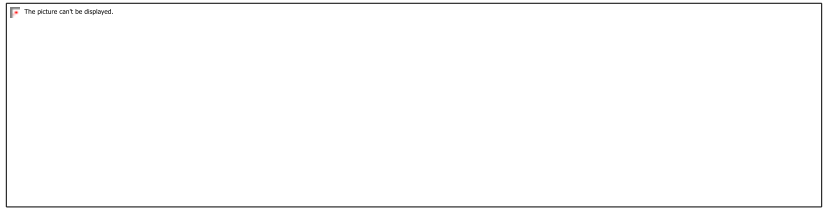
Connecting rods

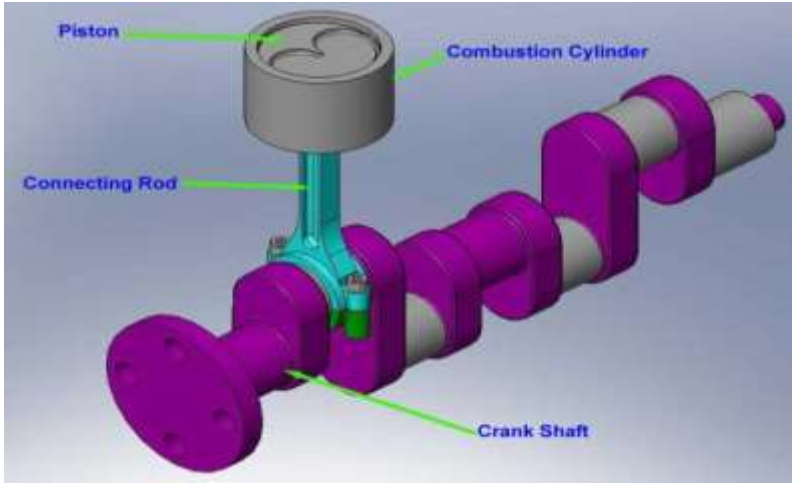
- Connect pistons & crankshaft.
- Upper end is connected to piston pin
  - Uses bushing to allow movement on pin.
- Lower end is split to allow installation on crankshaft journal.
  - Uses precision insert (bearing) to allow rotation on crankshaft journal.
  - Bearing requires oil film at all times to prevent metal to metal contact with journal.



Crankshaft

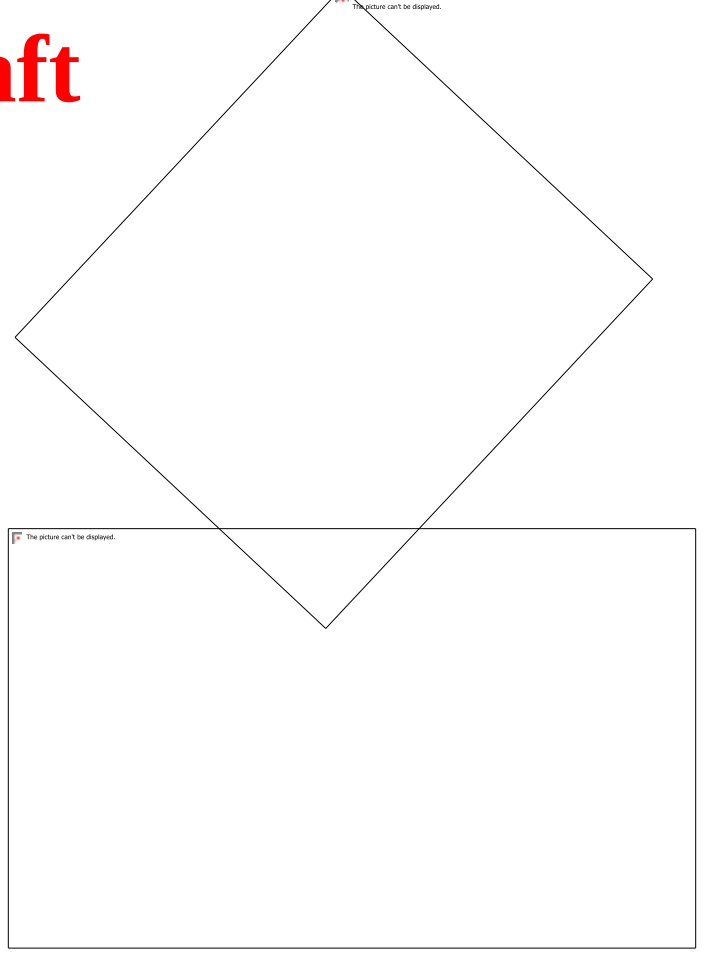
- Changes reciprocating motion to rotary motion
- Provides turning force to wheels
- Flywheel is mounted on rear of crank and transfers power to transmission
- Pulleys mounted on front of crank drive accessories such as alternator or A/C compressor





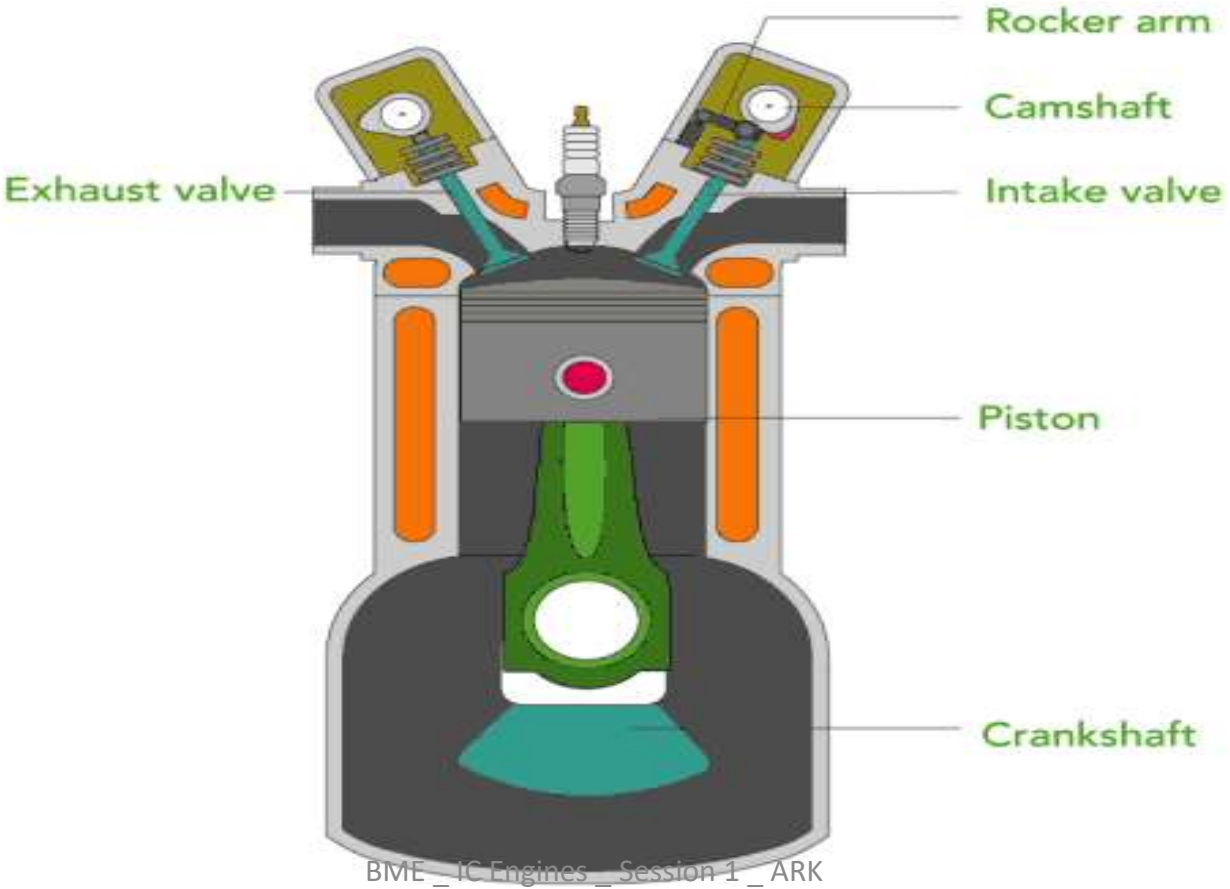
Camshaft

- Camshaft lobes, open valves
- Lifters sit on top of lobes and transmit motion to pushrods.
- Pushrods transmit motion to cylinder head rocker arms to open valves.
- Camshaft must be timed to crankshaft.

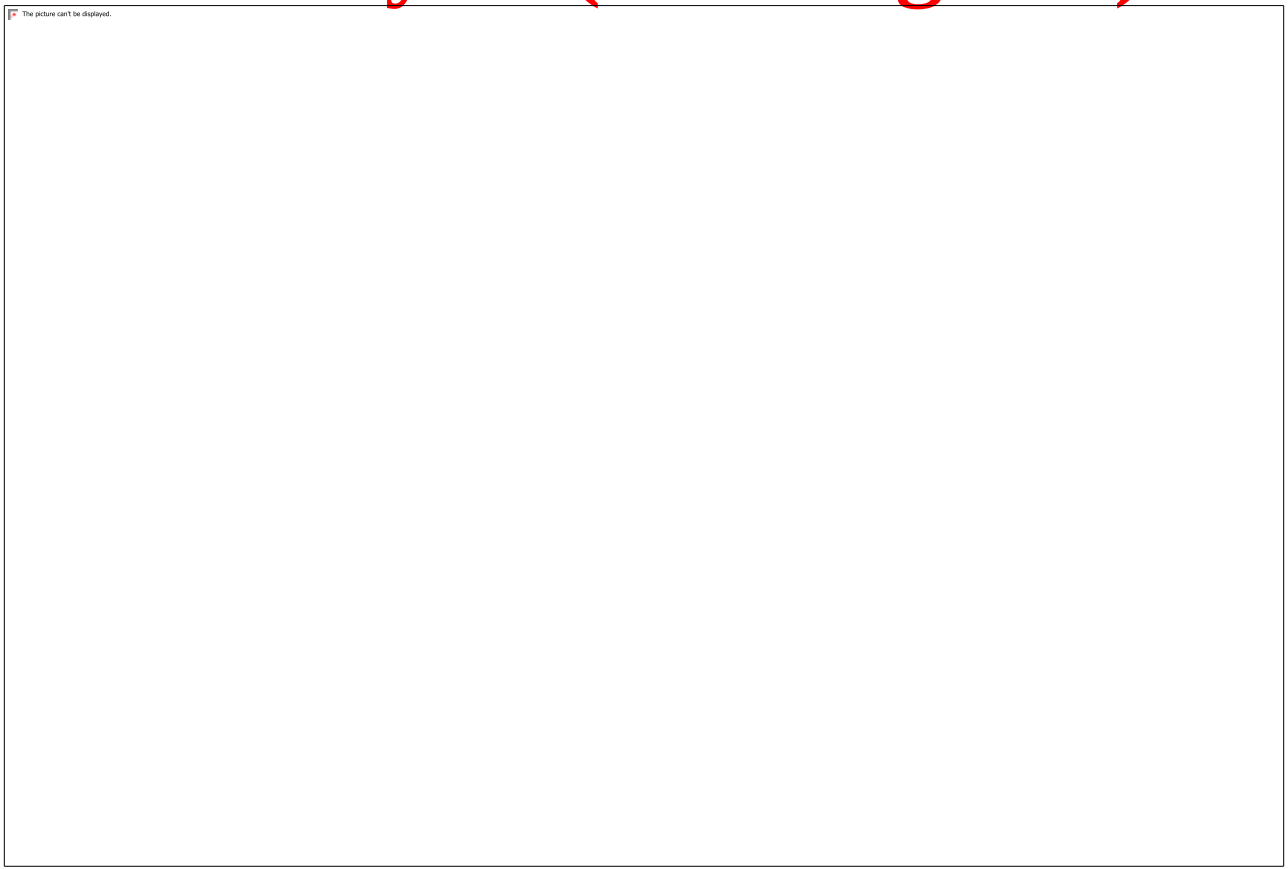


FOUR STROKE PETROL ENGINE

4 Stroke Petrol Engine



Otto Cycle (PV Diagram)



Otto Cycle (PV Diagram)

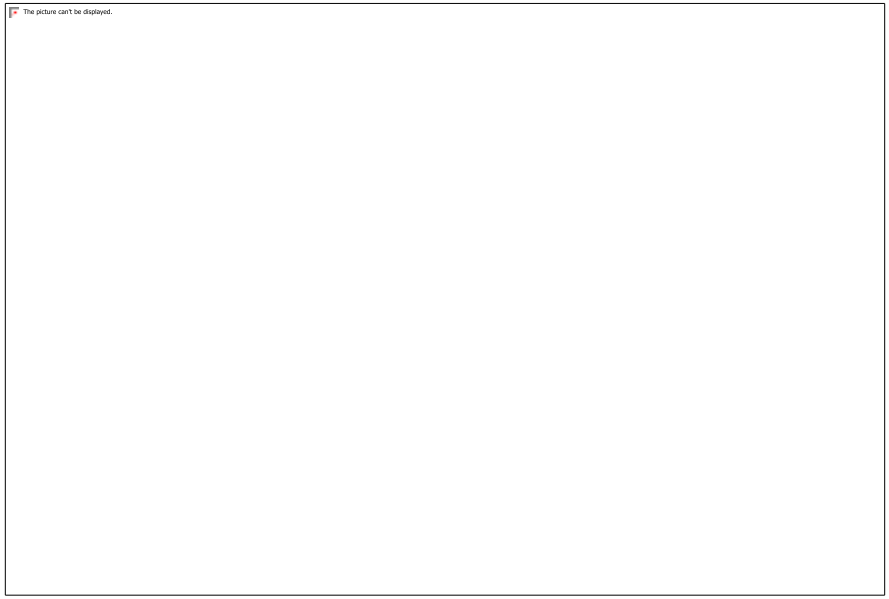
It has four processes:

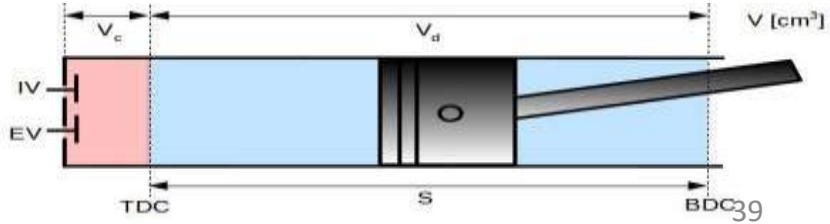
- 1 -2 : Isentropic Compression
- 2 -3 : Constant Volume Heat Addition
- 3 -4 : Isentropic Expansion
- 4 -1 : Constant Volume Heat Rejection

Note:

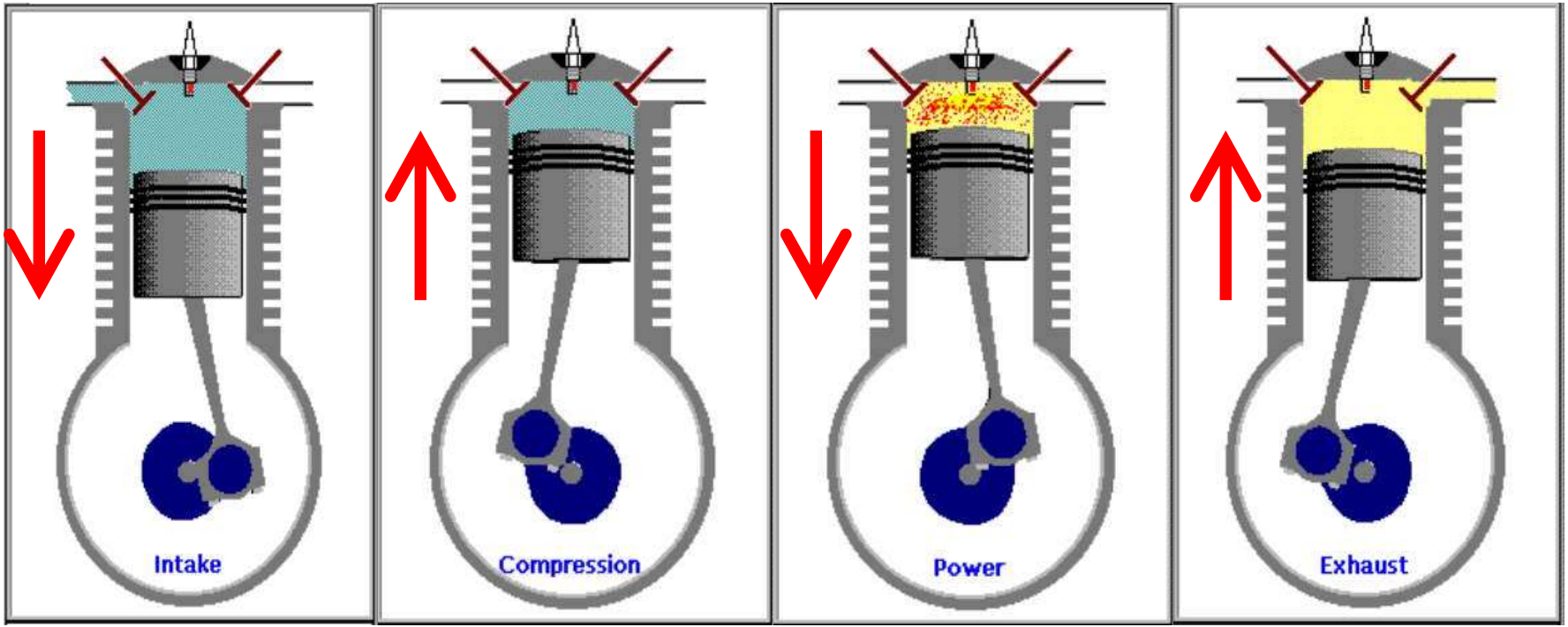
- 0-1 : Suction Stroke
- 1-0 : Exhaust Stroke

All Petrol Engines operate on basis of Thermodynamic Otto Cycle

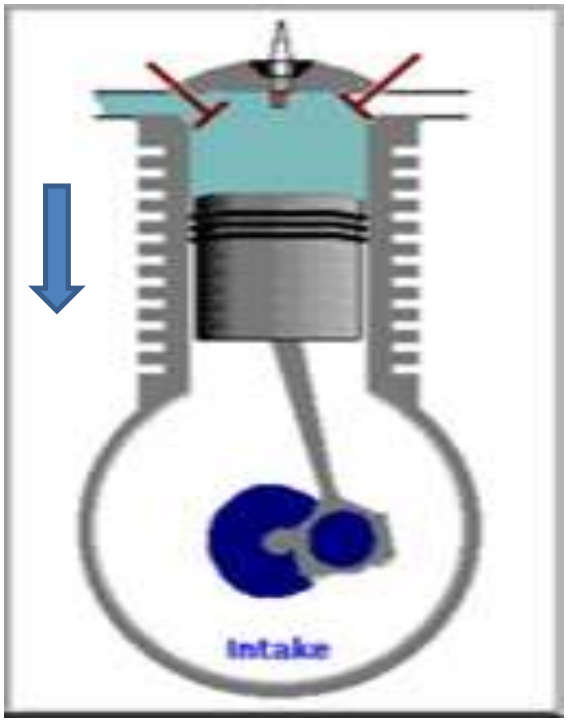




Overview of 4S Petrol Engine

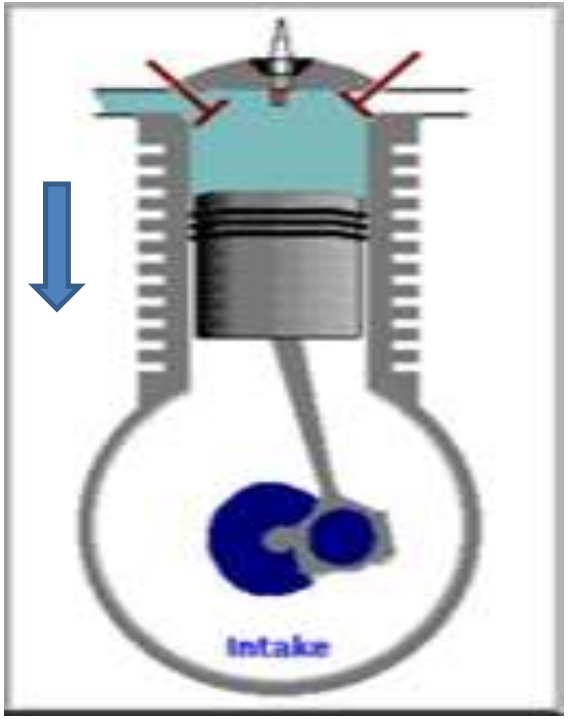


Intake Stroke of 4S Petrol Engine



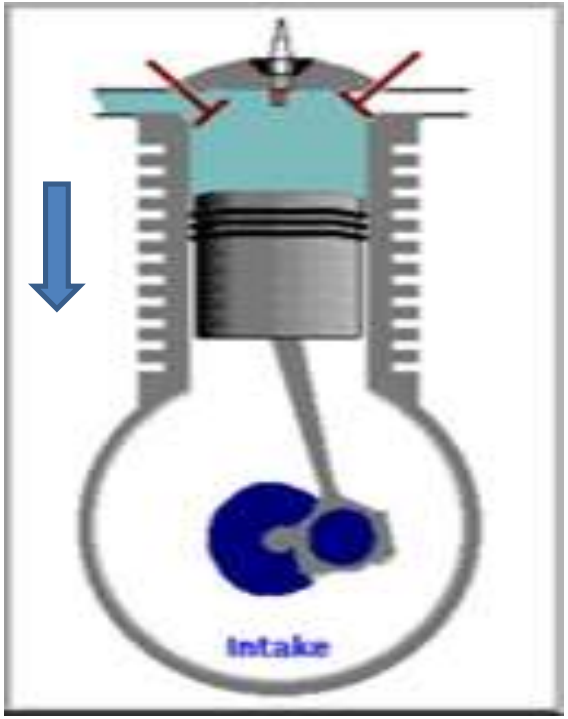
- In this stroke, the piston begins at top dead center.
- The inlet valve will be open and exhaust valve closed.
- The piston descends from the top of the cylinder(TDC) to the bottom of the cylinder(BDC), increasing the volume of the cylinder. This creates partial vacuum in the cylinder.

Intake Stroke …*(Continued)*



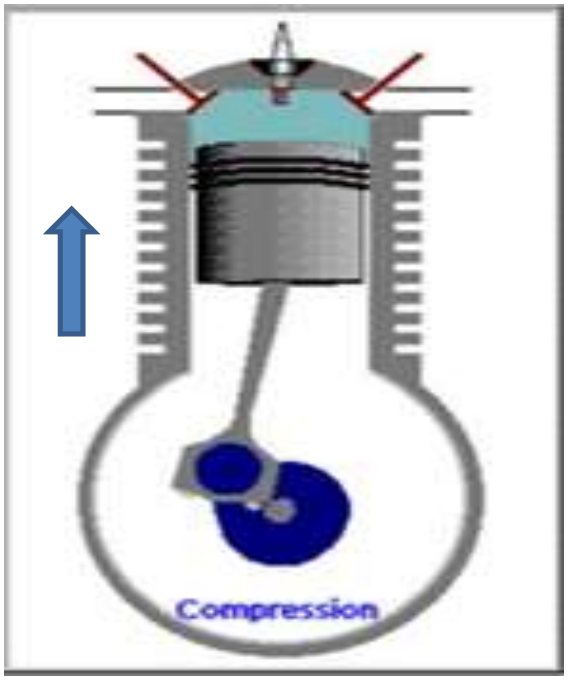
- A mixture of Petrol and air is sucked into the cylinder through the intake port.
- The crankshaft completes half revolution during this process.

Intake Stroke …*(Continued)*



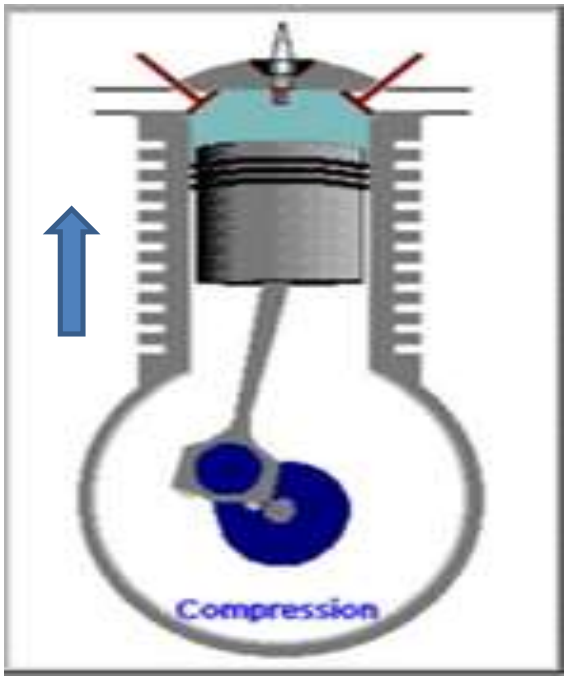
- Suction process is represented by 0-1 in the PV Diagram of Otto Cycle

Compression Stroke of 4S Petrol Engine



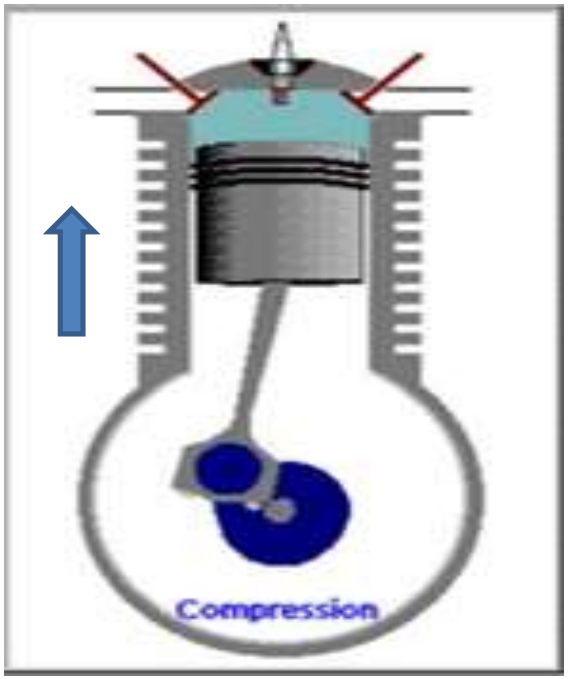
- In this stroke, both intake and exhaust valves are closed.
- The piston moves from bottom dead center (BDC) to the top dead center (TDC) of the cylinder.
- Due to this movement, the piston compresses the petrol and air mixture inside the cylinder.

Compression Stroke …*(Continued)*



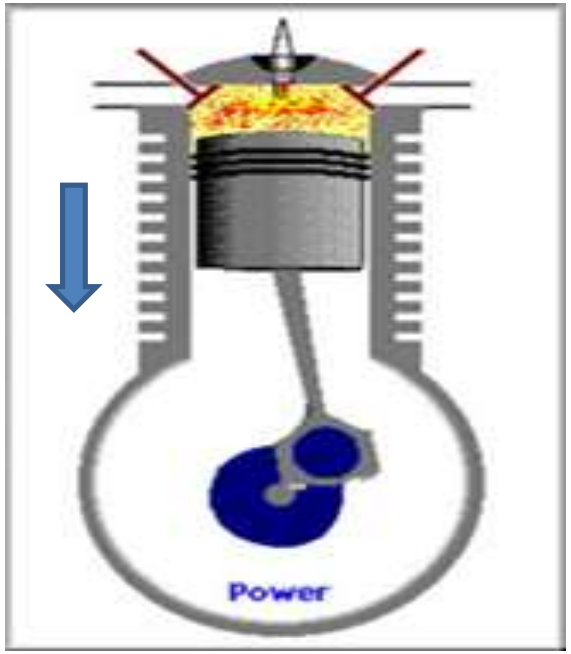
- The compression ratio of a petrol engine is about 7:1 to 11:1.
- The crankshaft completes another half revolution during this process. (One full revolution by the end of compression stroke).

Compression Stroke …*(Continued)*



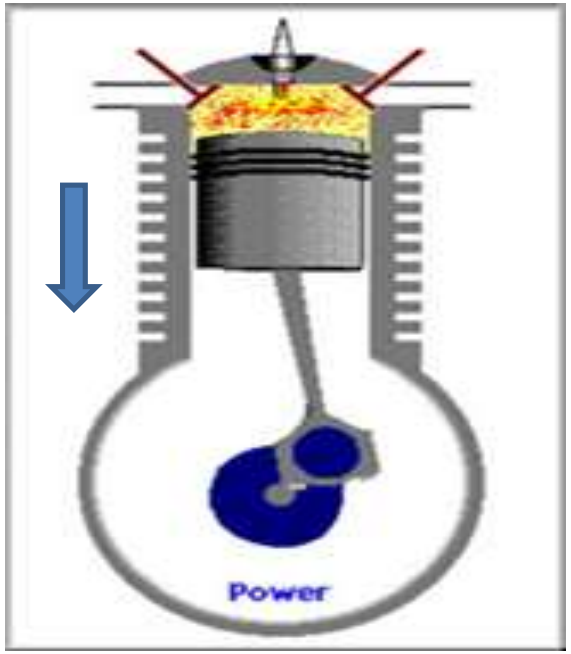
- Compression process is represented by 1-2 in the PV Diagram of Otto Cycle.

Power Stroke of 4S Petrol Engine



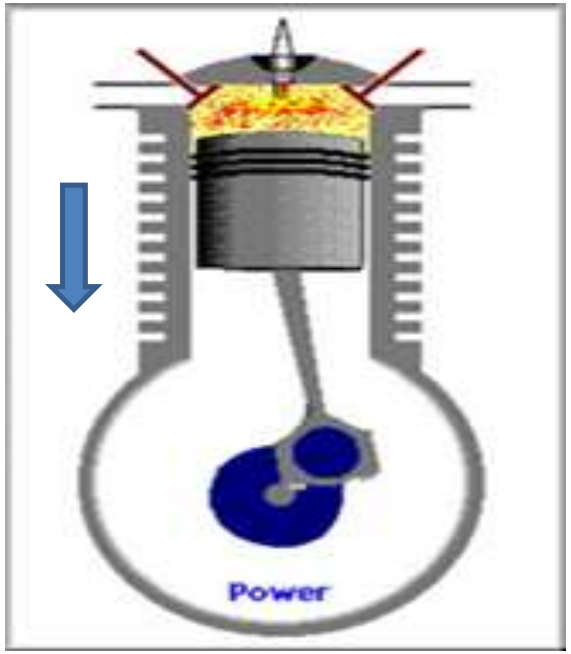
- This is the start of the second revolution of the crankshaft.
- During this stroke, both valves are closed.
- While the piston is close to Top Dead Centre(TDC), the compressed petrol-air mixture is ignited, by a spark-plug in petrol engines.

Power Stroke …*(Continued)*



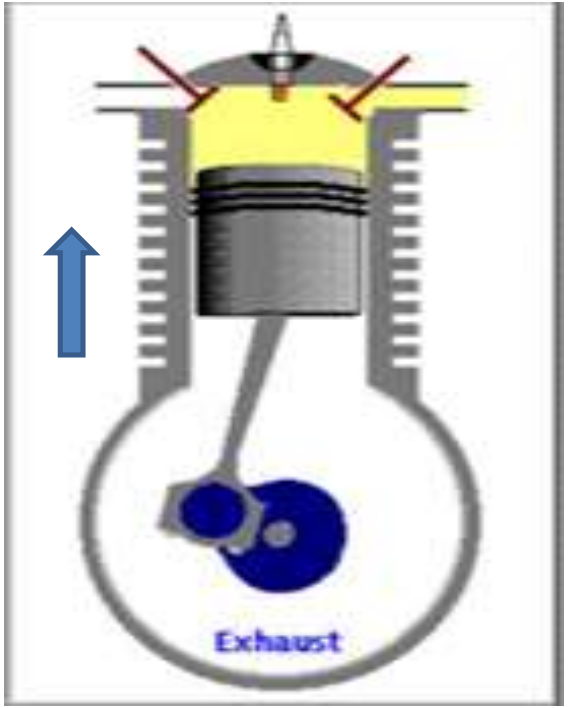
- Heat addition process is represented by 2-3 in the PV Diagram of Otto Cycle
- The resulting pressure due to the combustion, forces the piston to move down towards bottom dead center (BDC).

Power Stroke …*(Continued)*



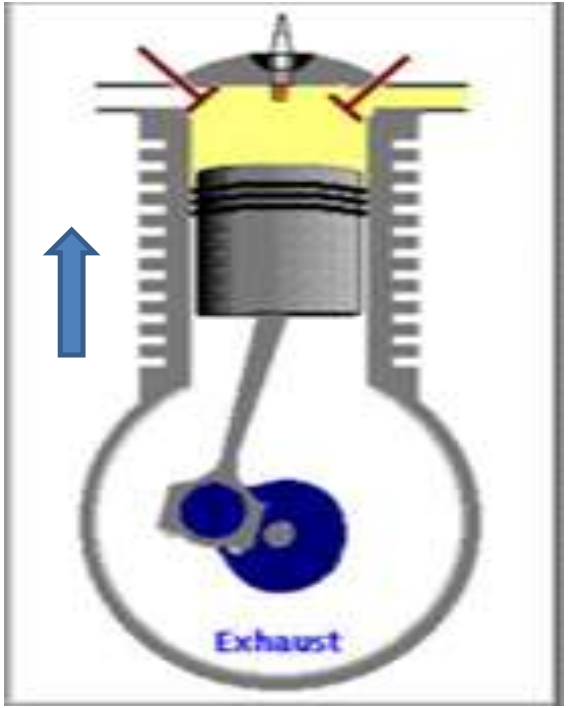
- Expansion process is represented by 3-4 in the PV Diagram of Otto Cycle

Exhaust Stroke of 4S Petrol Engine



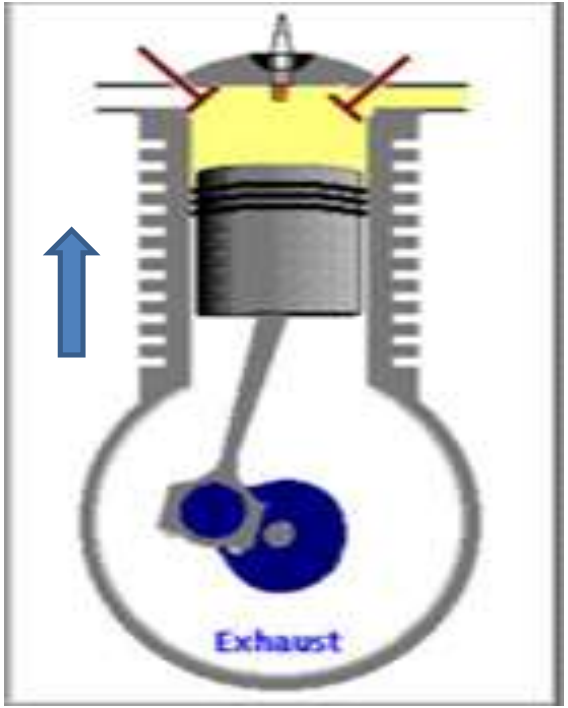
- During the *exhaust* stroke, the piston once again returns to top dead center (TDC) from bottom dead center (BDC).
- The exhaust valve is open.
- Heat rejection process is represented by 4-1 in the PV Diagram of Otto Cycle

Exhaust Stroke …*(Continued)*

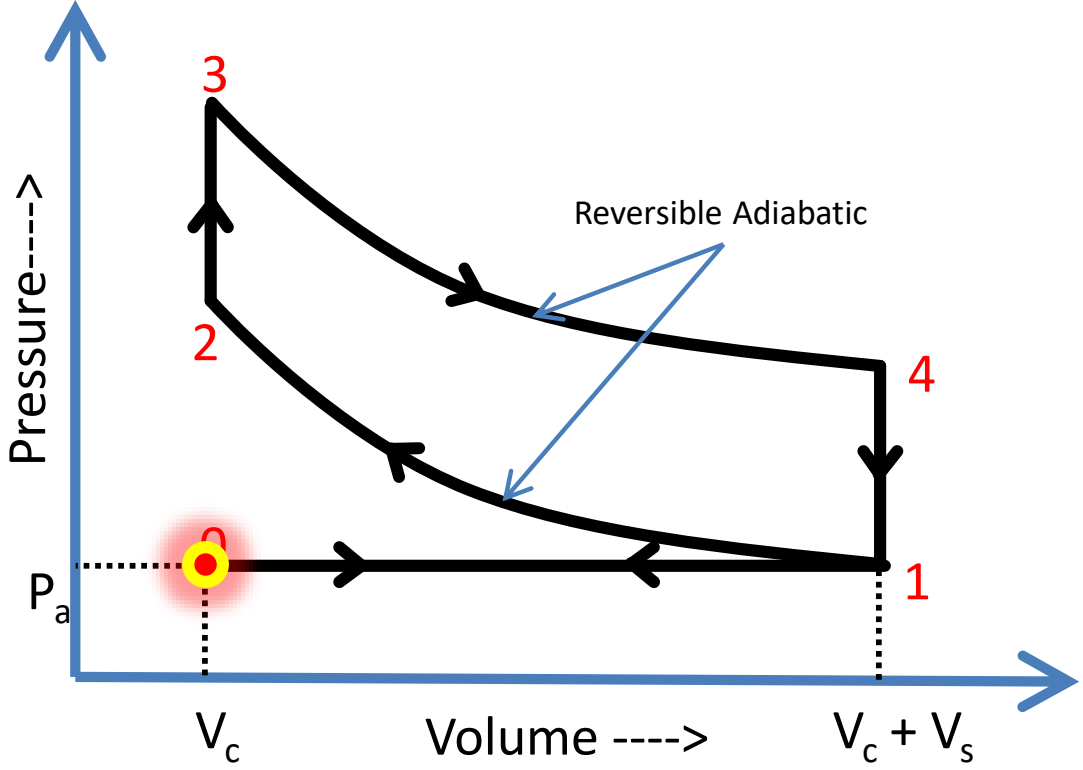


- This action expels the combusted petrol-air mixture through the exhaust valve(s)
- This completes two full revolution of the crankshaft

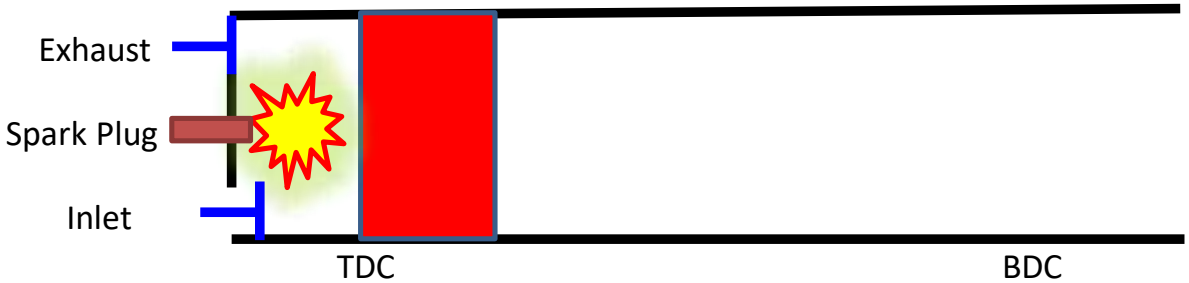
Exhaust Stroke …*(Continued)*

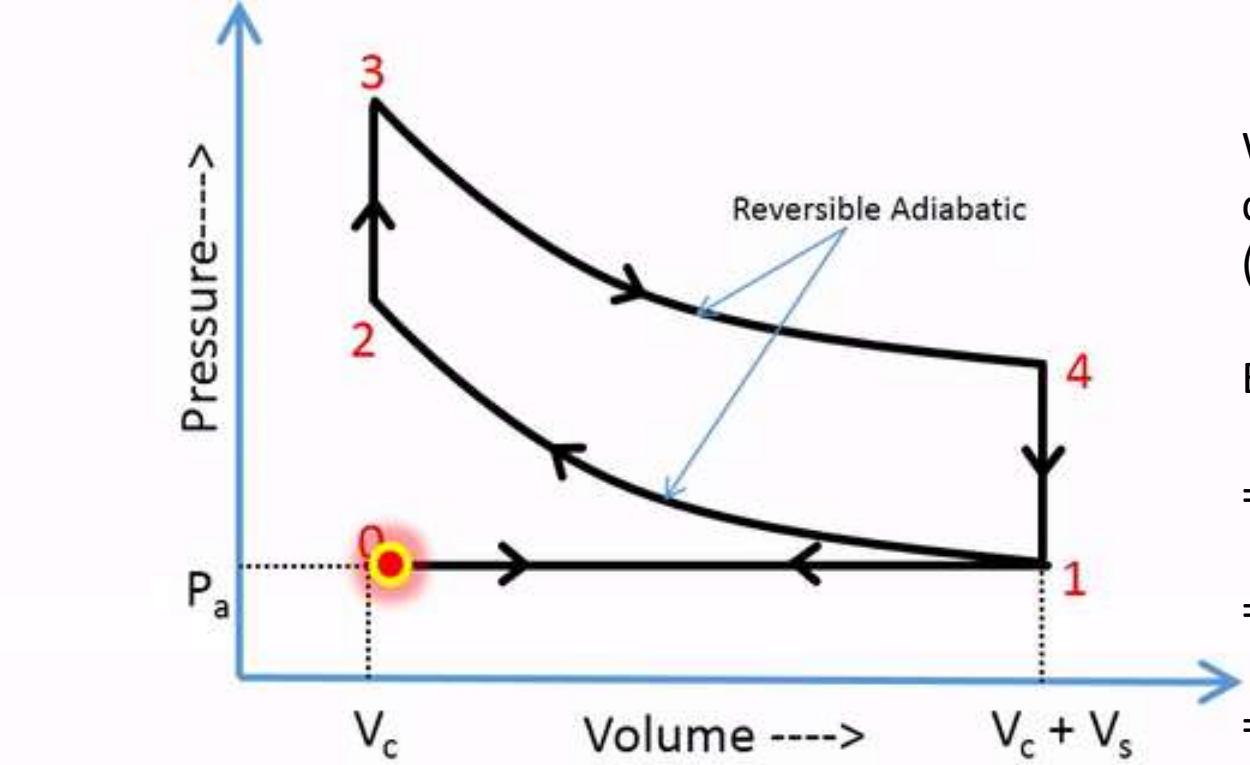


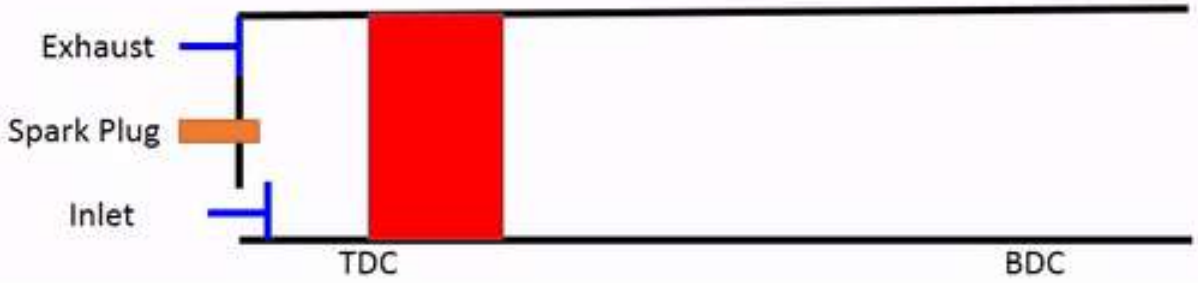
- Exhaust process is represented by 1-0 in the PV Diagram of Otto Cycle



Constant Volume Combustion Cycle







Why are processes 1-2 and 3-4 considered reversible adiabatic (isentropic)?

Engine speed: 1800 rpm

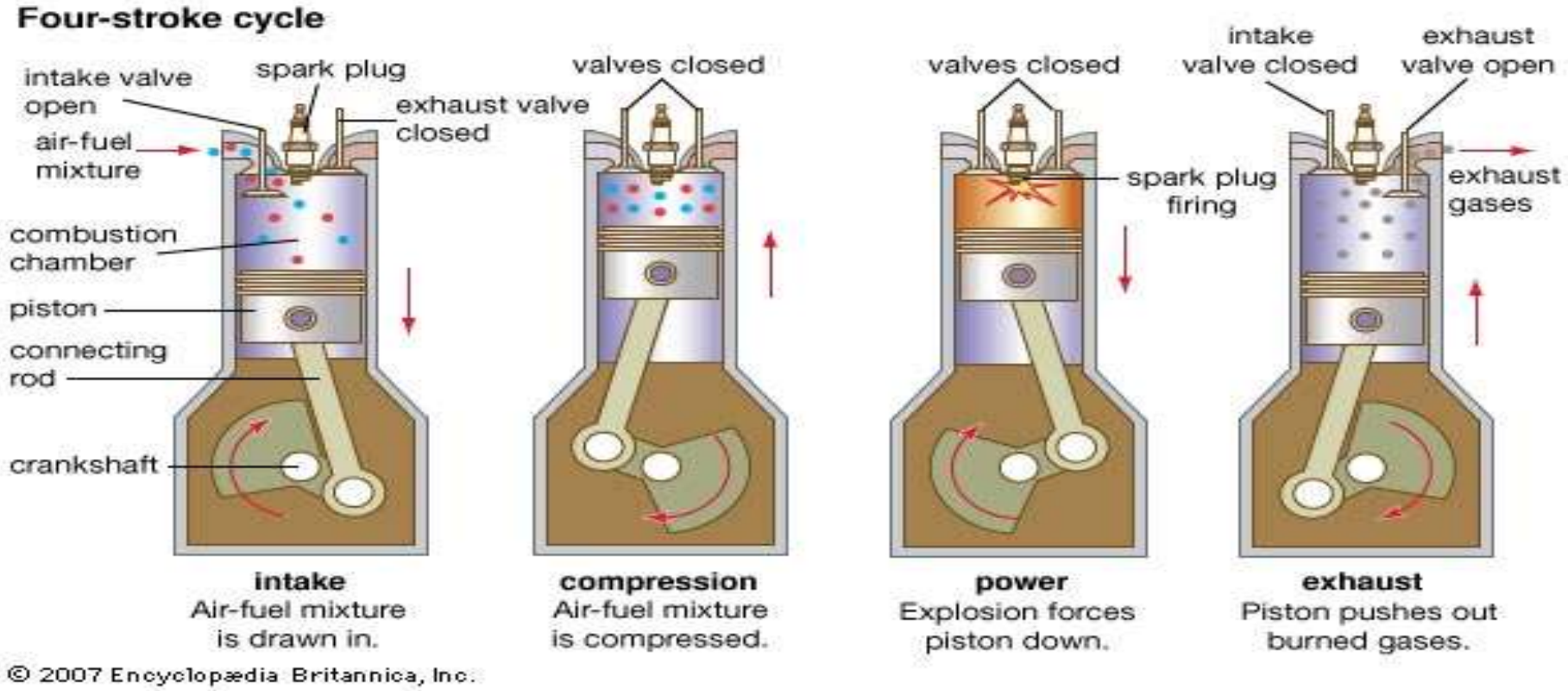
= 1800/60 cycles per second

= 30 cycles per second

= 60 strokes of piston per second

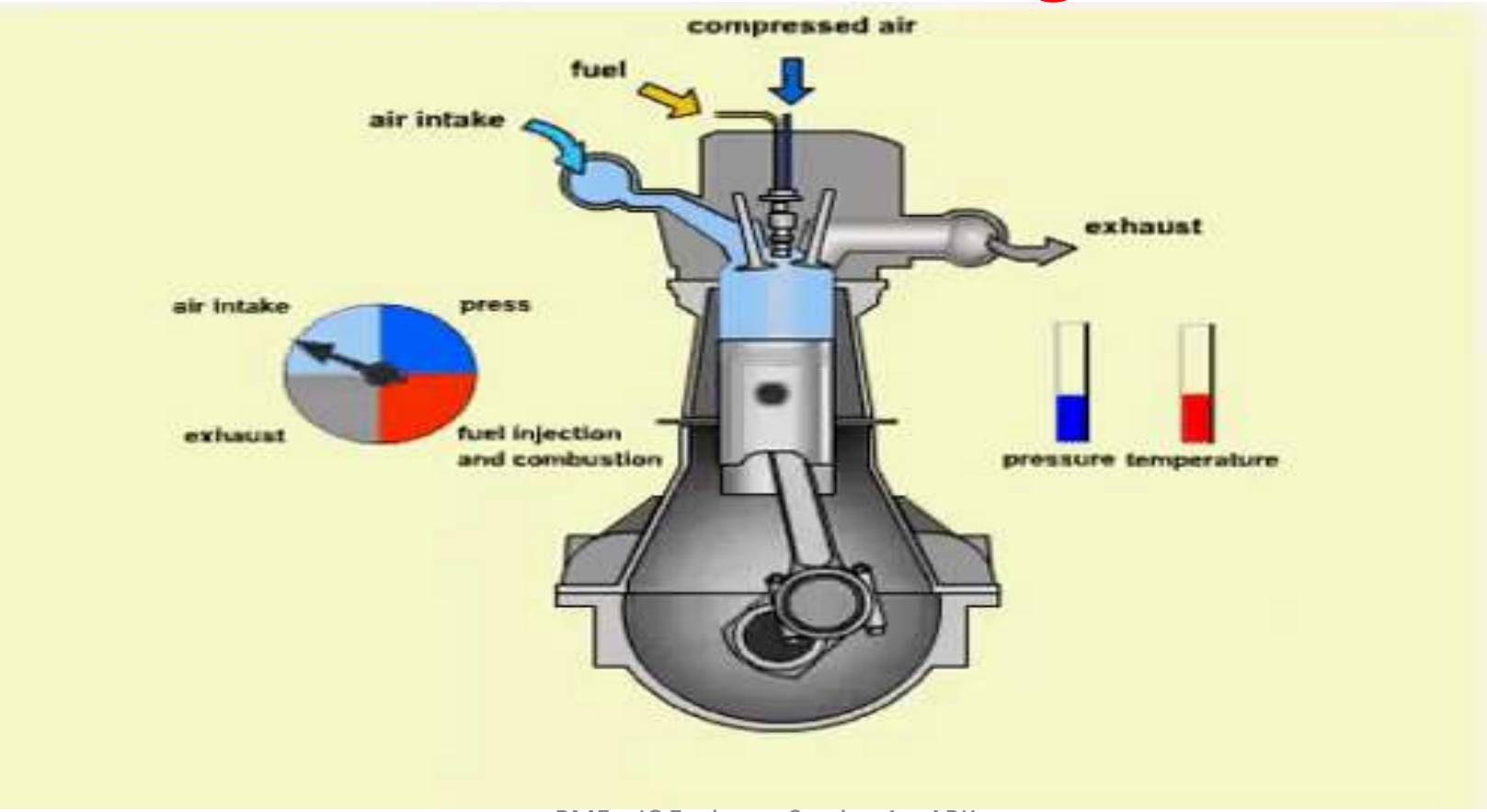
Instantaneous processes are adiabatic.

Summary of 4 Stroke Petrol Engine

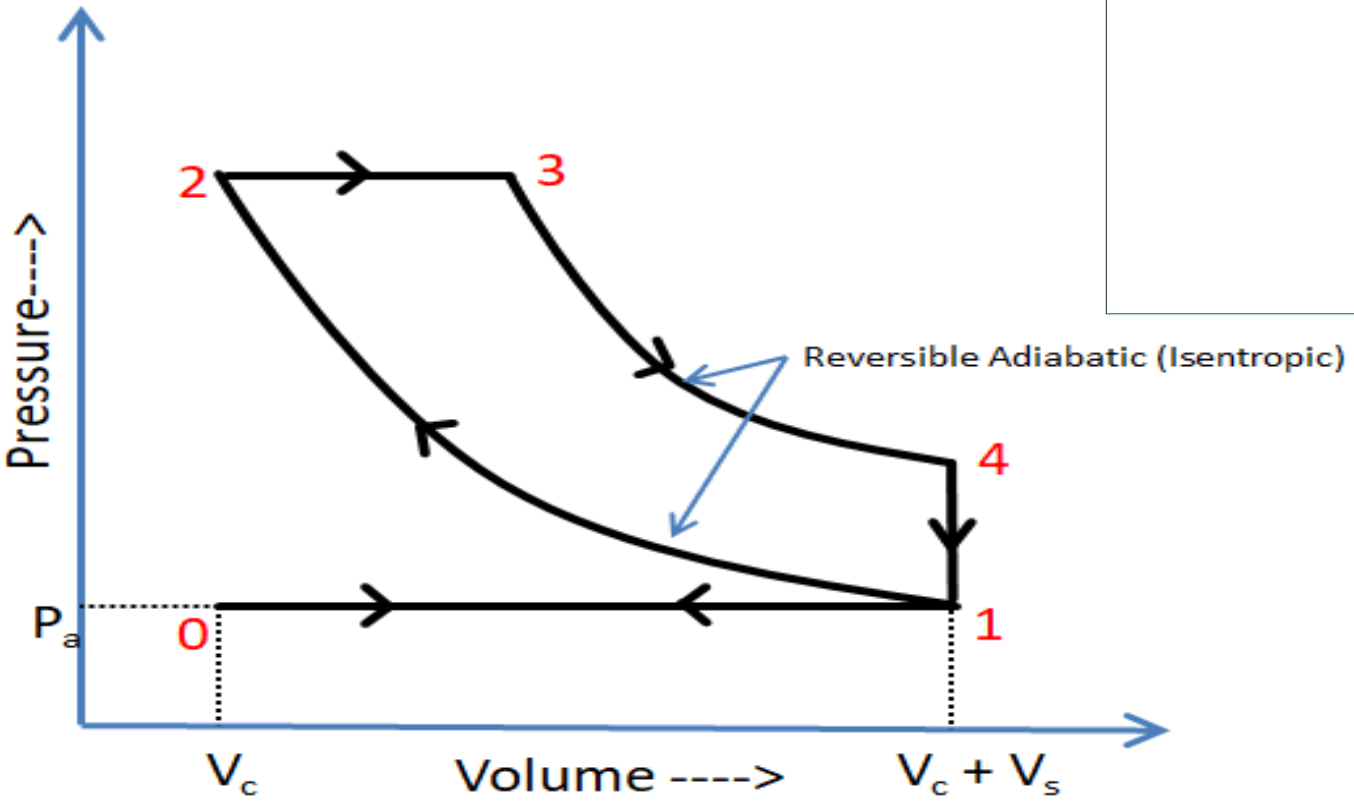


FOUR STROKE DIESEL ENGINE

4 Stroke Diesel Engine



Diesel Cycle (PV diagram)



Theoretical Diesel Cycle for 4-Stroke Diesel Engine

Diesel Cycle (PV diagram)

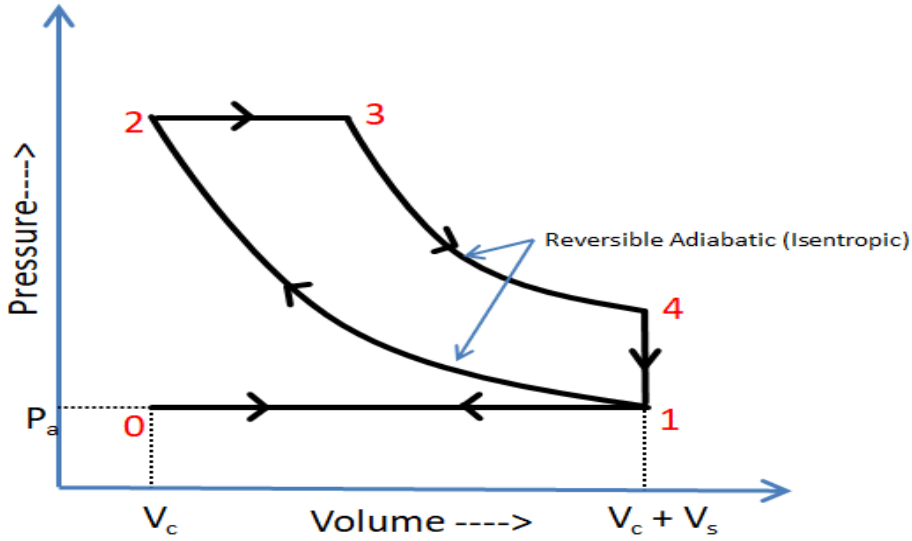
It has four processes:

- 1 -2 : Isentropic Compression
- 2 -3 : Constant Pressure Heat Addition
- 3 -4 : Isentropic Expansion
- 4 -1 : Constant Volume Heat Rejection

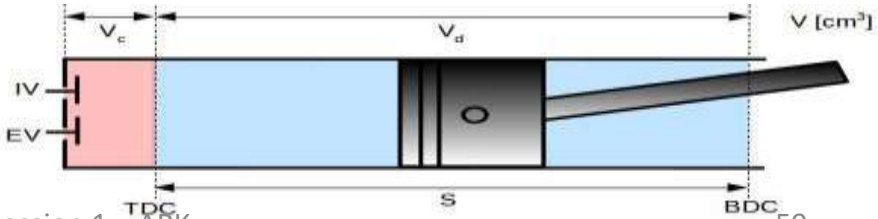
Note:

- 0-1 : Suction Stroke
- 1-0 : Exhaust Stroke

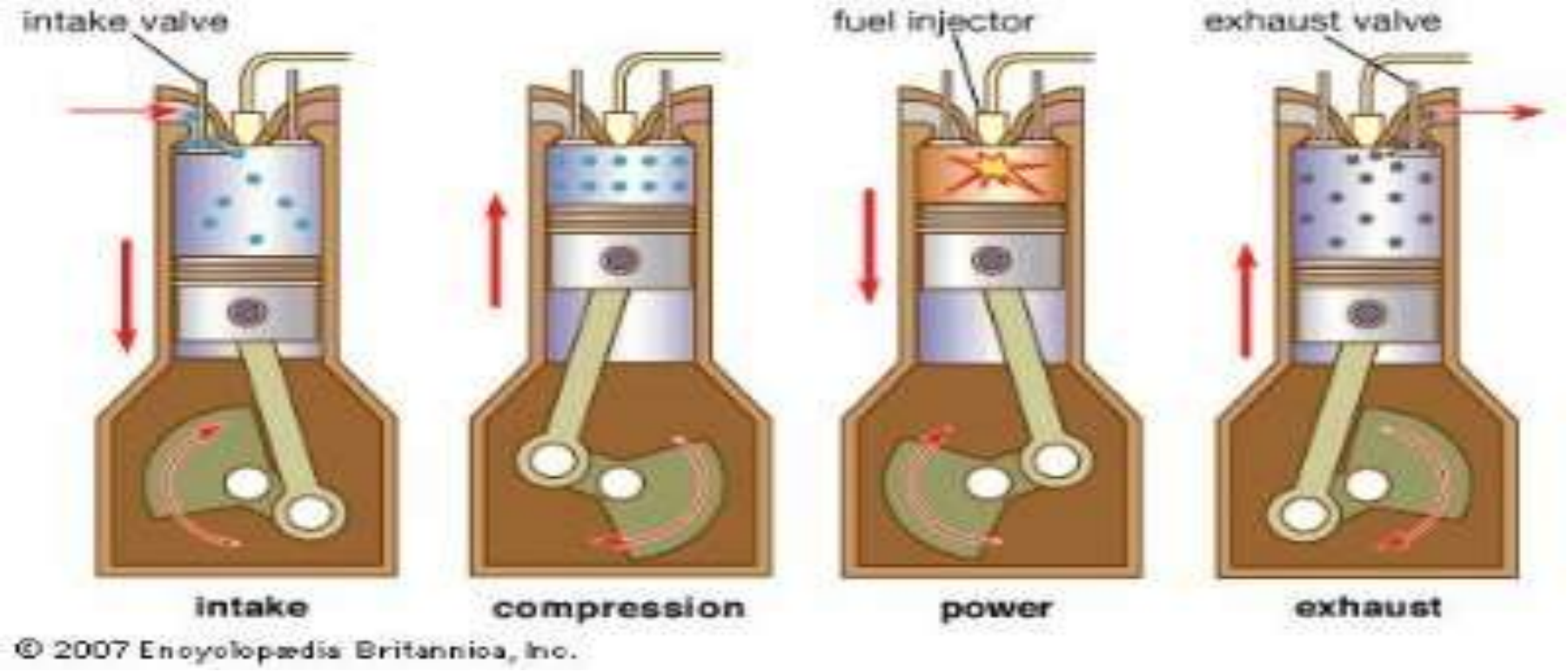
All Diesel Engines operate on basis of Thermodynamic Diesel Cycle



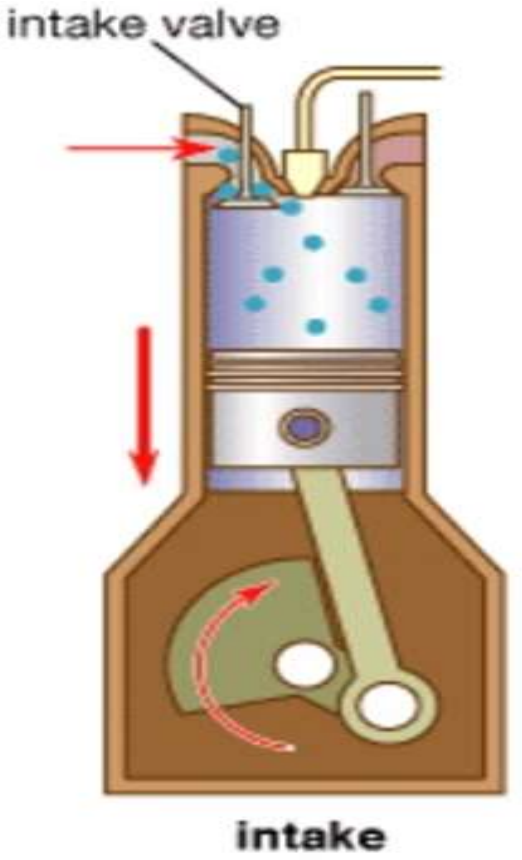
Theoretical Diesel Cycle for 4 Stroke Diesel Engine



4 Stroke Diesel Engine

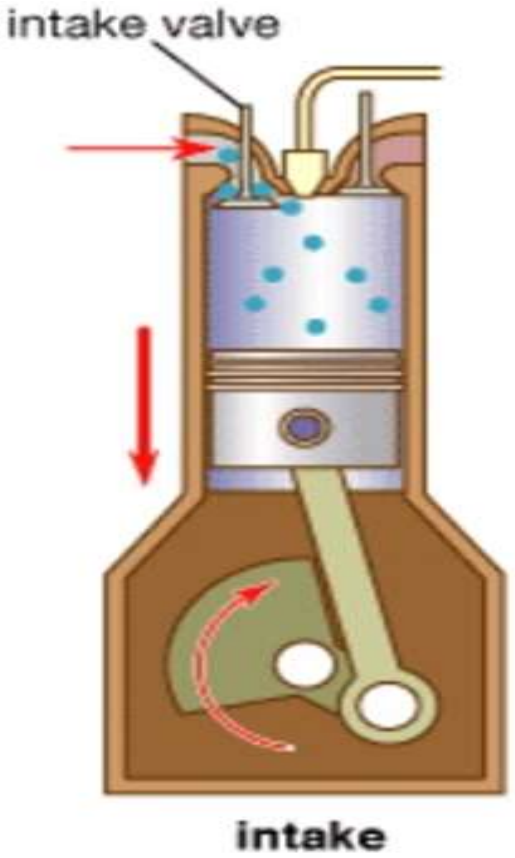


Intake Stroke of 4S Diesel Engine



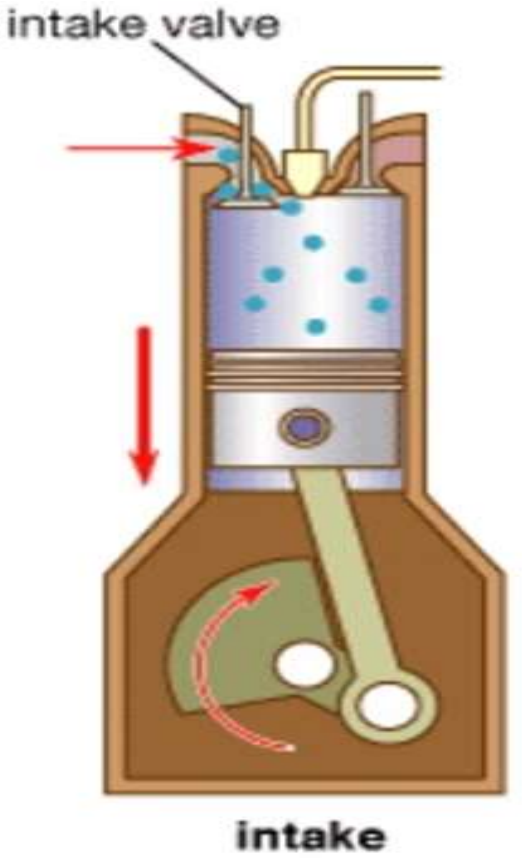
- In this stroke, the piston begins at TDC.
- The piston descends from the top of the cylinder(TDC) to the bottom of the cylinder(BDC), increasing the volume of the cylinder. This creates partial vacuum in the cylinder.
- During this stroke, the inlet valve will be open and exhaust valve closed.

Intake Stroke …*(Continued)*

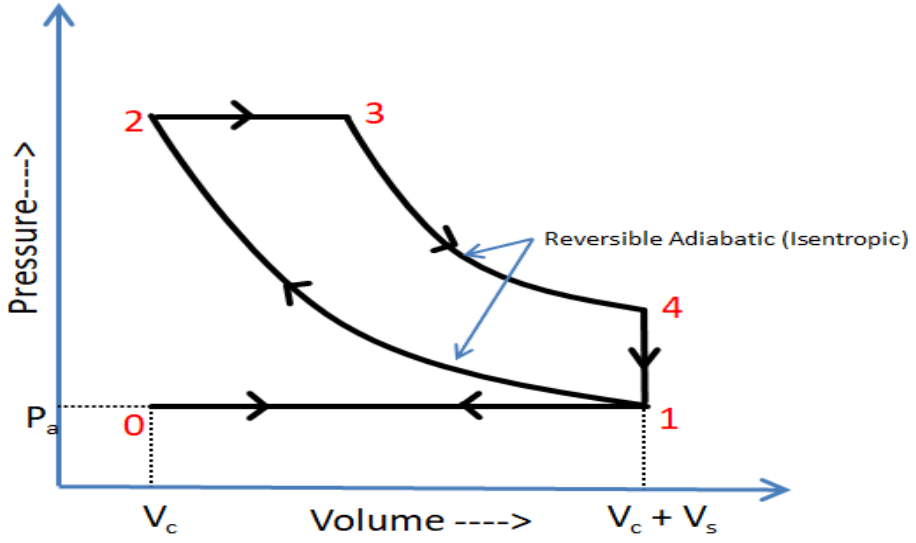


- Air is sucked into the cylinder through the intake port.
- The crankshaft completes half revolution during this process.

Intake Stroke …*(Continued)*

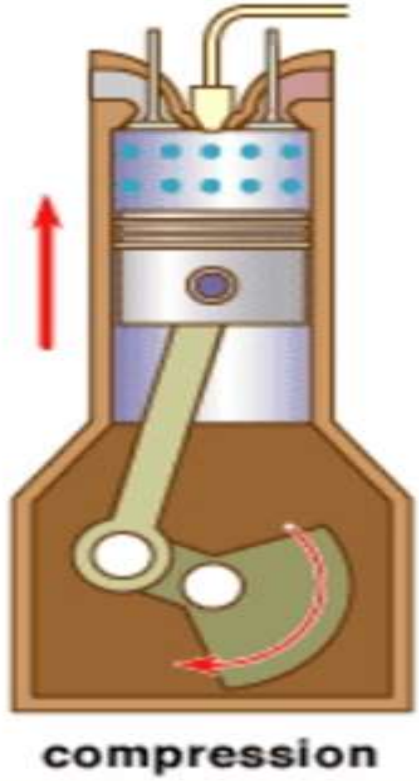


- Suction process is represented by 0-1 in the PV Diagram of Diesel Cycle



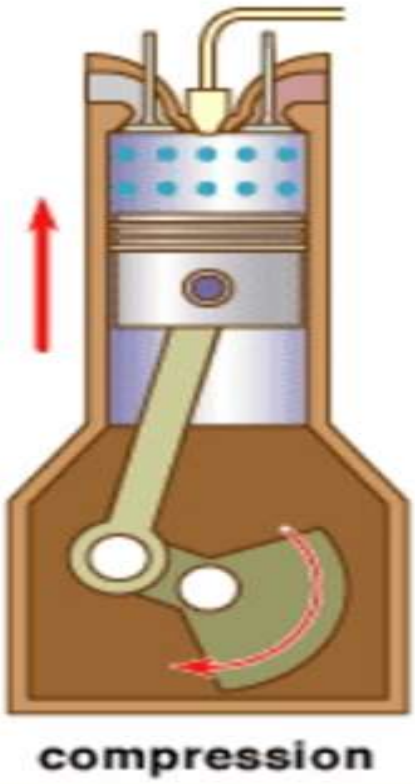
Theoretical Diesel Cycle for 4 Stroke Diesel Engine

Compression Stroke of 4S Diesel Engine



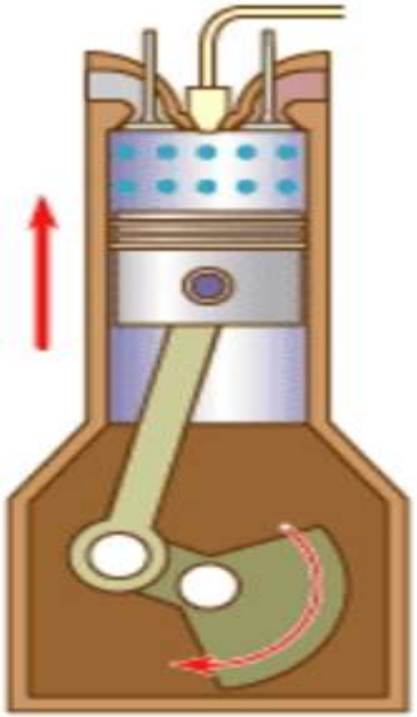
- In this stroke, both intake and exhaust valves are closed.
- The piston moves from bottom dead center(BDC) to the top dead center(TDC) of the cylinder.
- Due to this movement, the piston compresses the air inside the cylinder.
- The compression ratio of a diesel engine is about 14:1 to 22:1

Compression Stroke …*(Continued)*

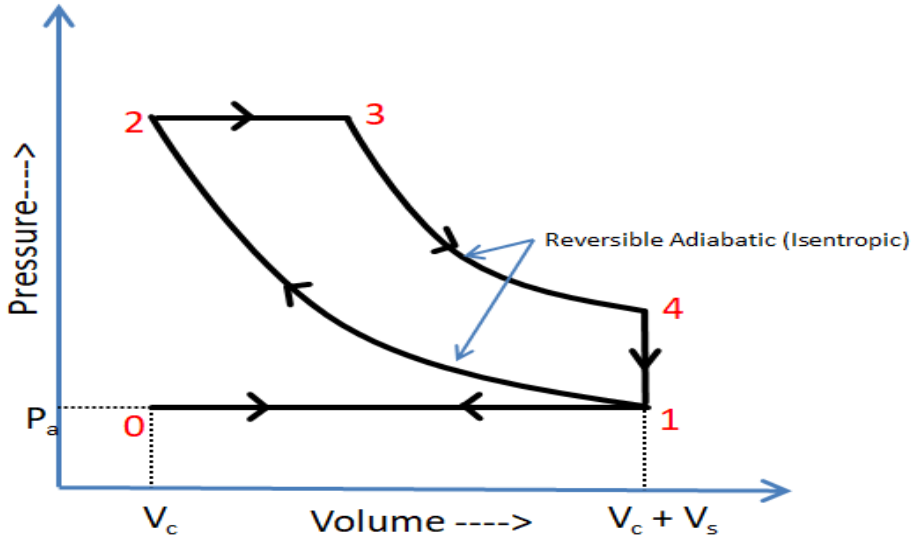


- While the piston is close to Top Dead Centre(TDC), Diesel is injected into the cylinder using Fuel Injector.
- The crankshaft completes another half revolution during this process. (One full revolution by the end of compression stroke)

Compression Stroke …*(Continued)*

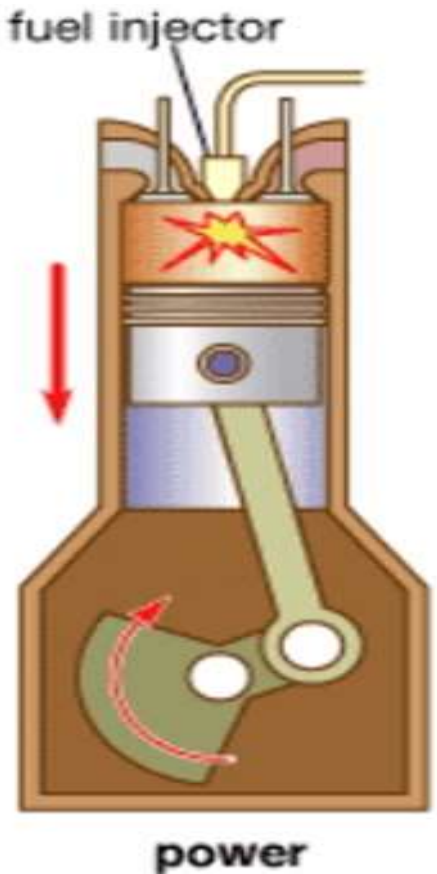


- Compression process is represented by 1-2 in the PV Diagram of Diesel Cycle



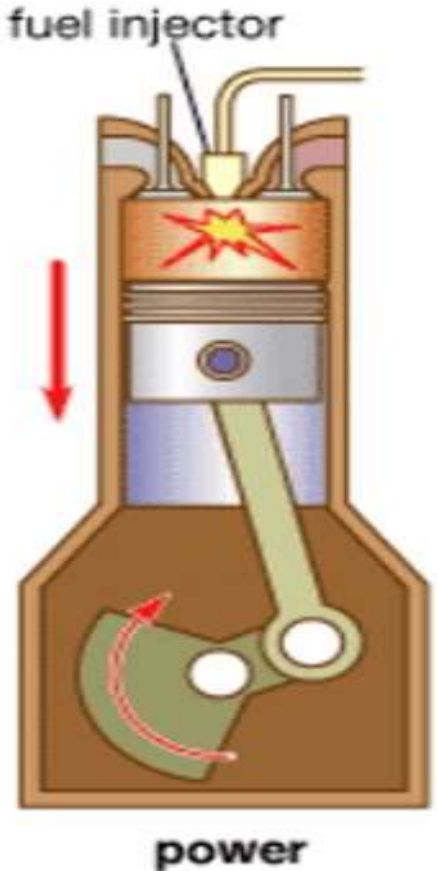
Theoretical Diesel Cycle for 4 Stroke Diesel Engine

Power Stroke of 4S Diesel Engine



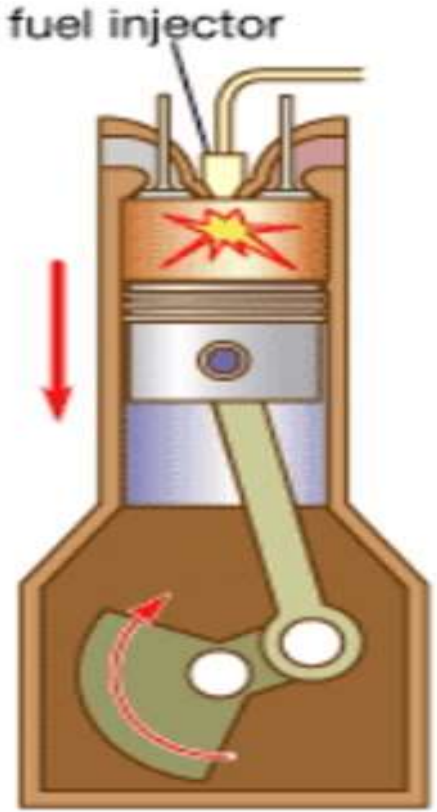
- This is the start of the second revolution of the crankshaft.
- During this stroke, both valves are closed.
- Due to high compression ratio, the temperature inside the cylinder would be around 700^{o}C and is sufficient to ignite diesel fuel. Diesel combusts in the presence of air and high temperature.
- Heat addition process is represented by 2-3 in the PV Diagram of Diesel Cycle

Power Stroke …*(Continued)*

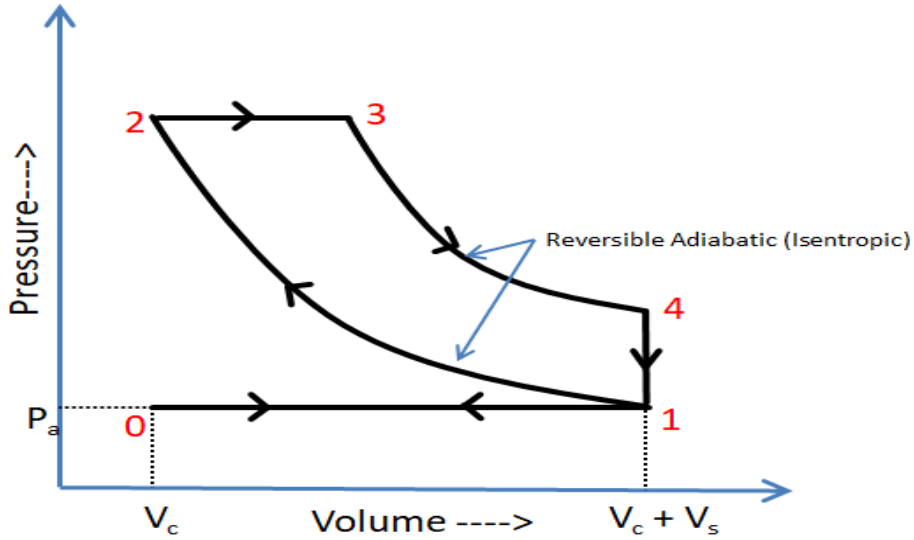


- The resulting pressure due to the combustion, forces the piston to move down towards bottom dead center(BDC).
- Expansion process is represented by 3-4 in the PV Diagram of Diesel Cycle

Power Stroke …*(Continued)*

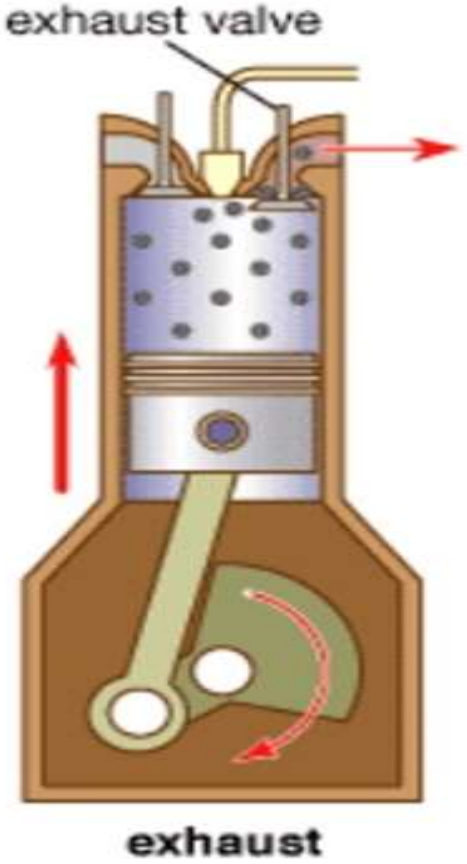


- Expansion process is represented by 3-4 in the PV Diagram of Diesel Cycle



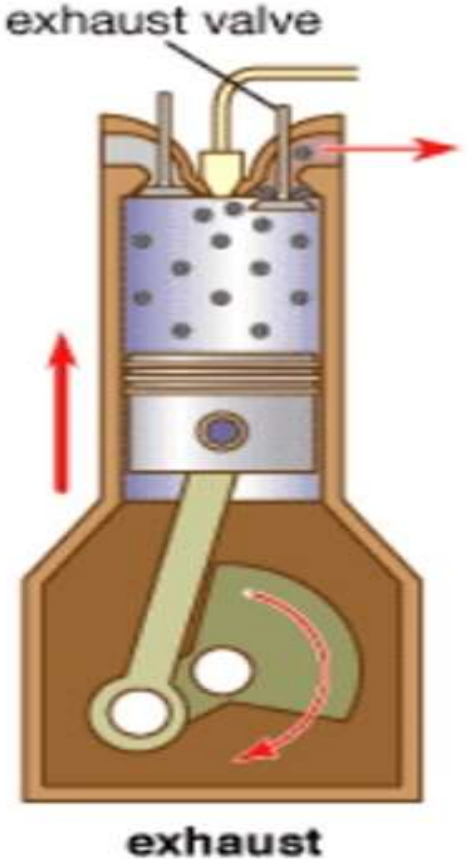
Theoretical Diesel Cycle for 4 Stroke Diesel Engine

Exhaust Stroke of 4S Diesel Engine



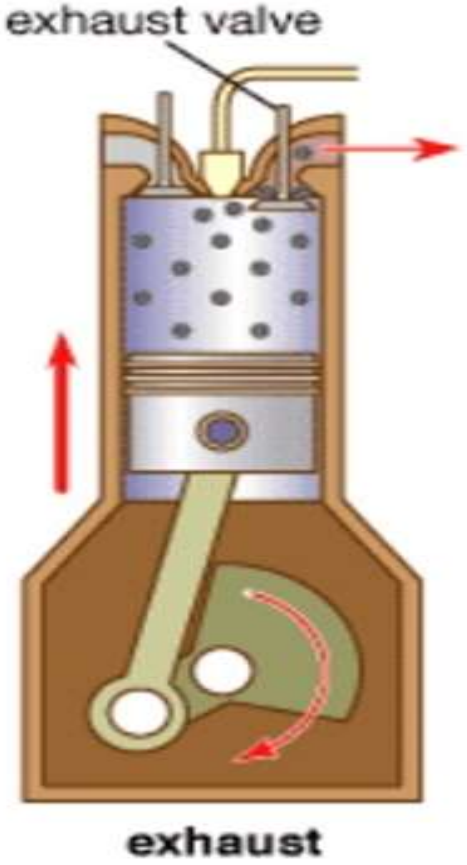
- During the *exhaust* stroke, the piston once again returns to top dead center(TDC) from bottom dead center(BDC).
- The exhaust valve is open.
- The heat rejection process is represented by 4-1 in the PV diagram of Diesel cycle.

Exhaust Stroke …*(Continued)*

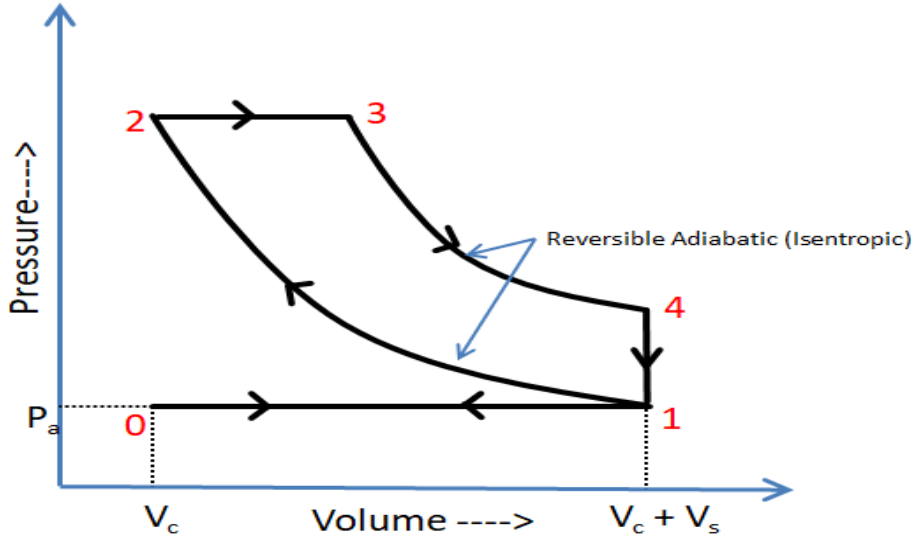


- This action expels the combusted gases through the exhaust valve(s)
- This completes two full revolution of the crankshaft

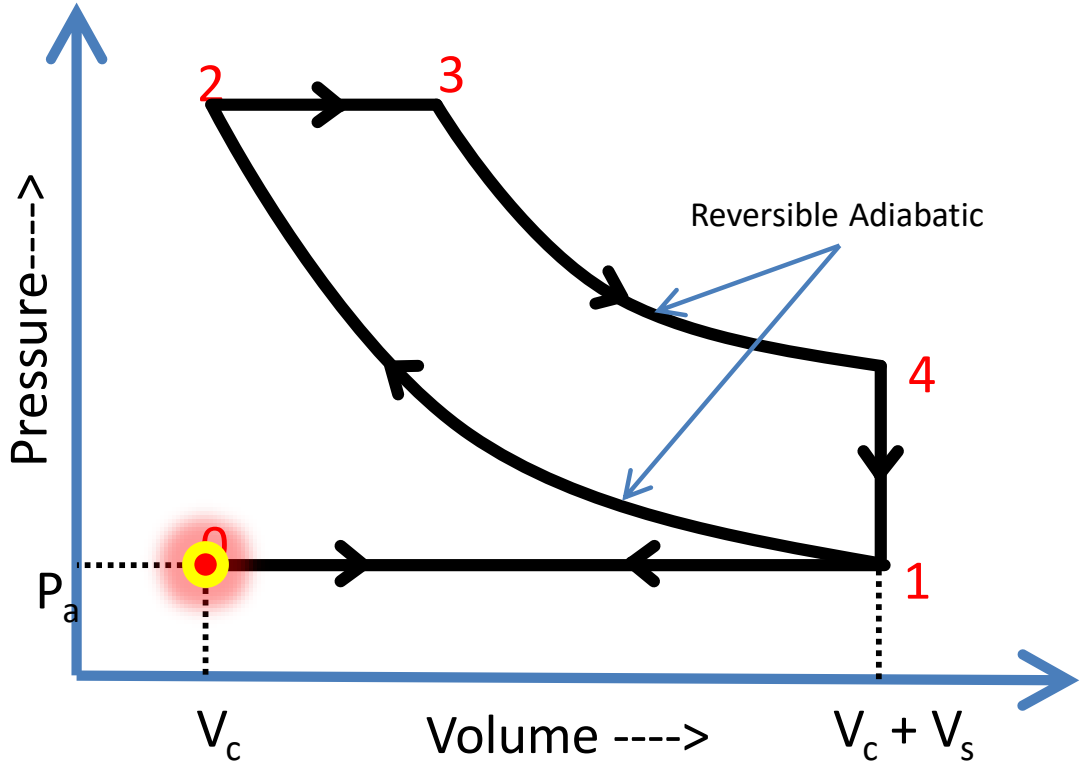
Exhaust Stroke …*(Continued)*



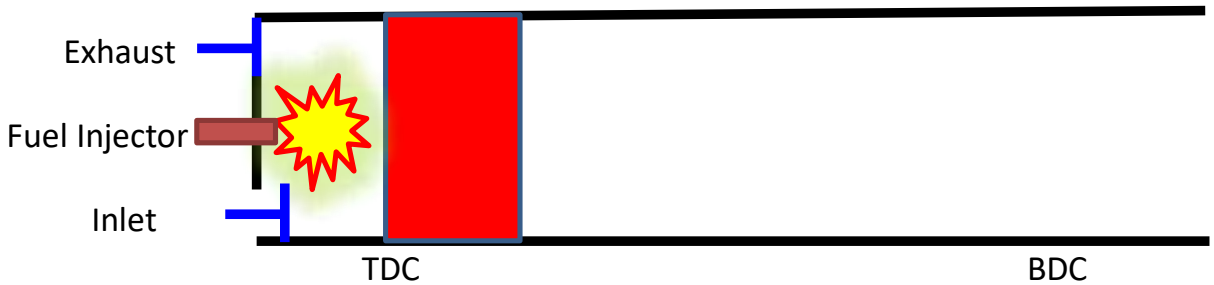
- Exhaust process is represented by 1-0 in the PV Diagram of Diesel Cycle

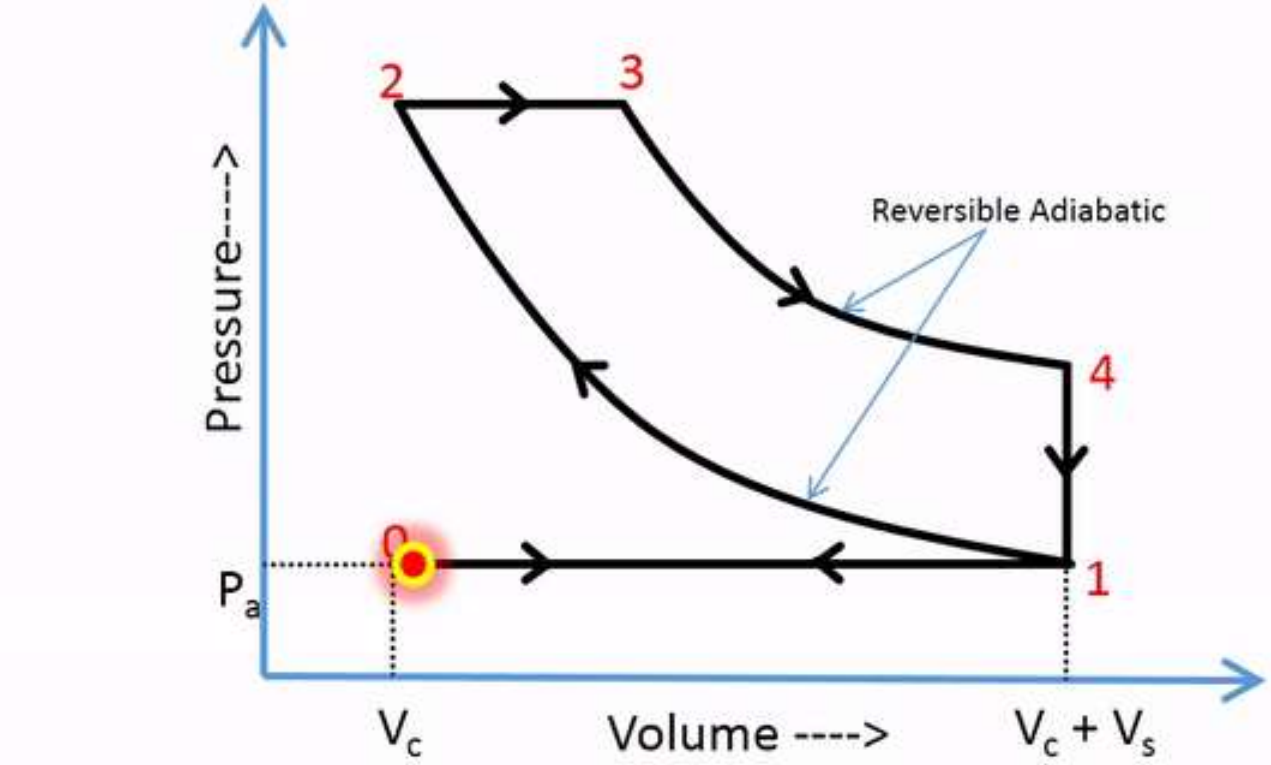


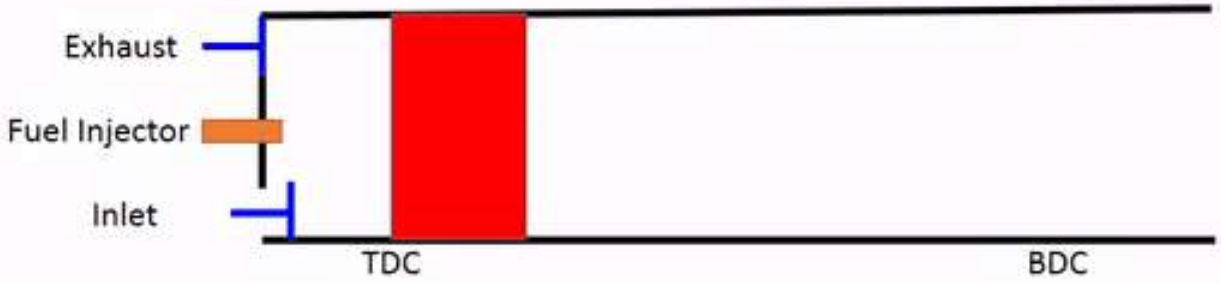
Theoretical Diesel Cycle for 4 Stroke Diesel Engine



Constant Pressure Combustion Cycle

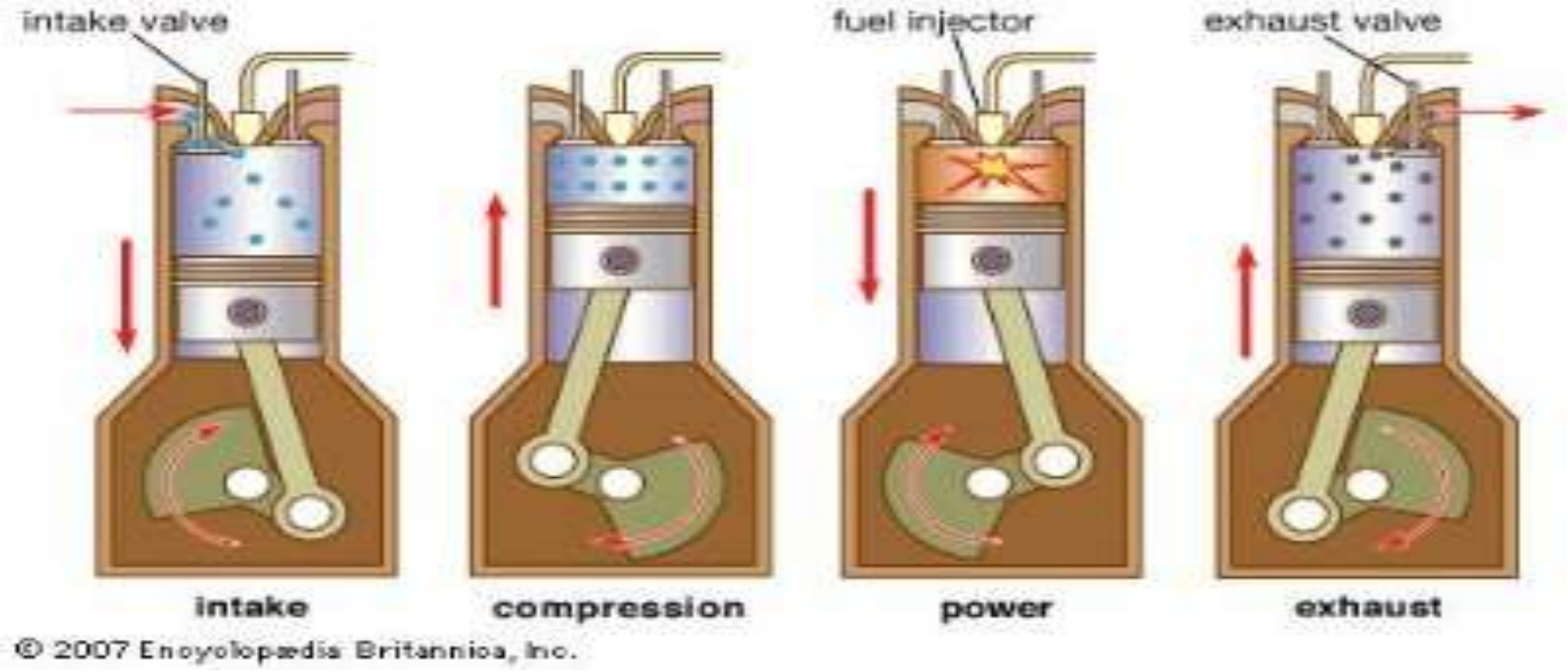






Constant Pressure Combustion Cycle

Summary of 4 Stroke Diesel Engine



COMPARISON BETWEEN PETROL ENGINE AND DIESEL ENGINE

Comparison between SI and CI Engines

Description	SI Engine (Petrol Engine)	CI Engine (Diesel Engine)
Cycle of operation	Otto Cycle	Diesel Cycle
Fuel used	Petrol	Diesel
Fuel Supply	Using carburetor	Using Fuel Injection Pump
Charge drawn during suction stroke	Mixture of Petrol & Air	Only Air is drawn in.
Ignition of charge	Using Spark plug	Self ignition

Comparison between SI and CI Engines

Description	SI Engine (Petrol Engine)	CI Engine (Diesel Engine)
Compression Ratio	7:1 to 11:1	14:1 to 22:1
Power output	Less (low CR)	High
Thermal Efficiency	Less (low CR)	High
Starting of Engine in cold condition	Easy to start	Difficult to start

Comparison between SI and CI Engines

Description	SI Engine (Petrol Engine)	CI Engine (Diesel Engine)
Exhaust gas pollution	**More** (Incomplete Combustion due to limited air availability)	**Less** (Excess air available for complete Combustion)
Operating cost	**High** (fuel is costlier)	**Low**
Initial cost	**Less** (light weight)	**More**
Noise and Vibration	**Less** (Low working pressure)	**More** (High working pressure)

Today's Learnings

- Introduction
- Classification of IC Engines
- Major Parts of IC Engines
- Terminologies used
- Principle of working of a 4 Stroke Petrol Engine
  - *Otto cycle PV Diagram and working of each stroke*
- Principle of working of a 4 Stroke Diesel Engine
  - *Diesel cycle PV Diagram and working of each stroke*
- Comparison between Petrol and Diesel engines

Q & A

- If you have any queries, post them in the chat box of MS Teams.

Thank You