ME 268: Fundamentals of Mechanical Engineering
(Model Lab)

LECTURE 1
INTERNAL COMBUSTION ENGINES

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INTRODUCTION OF HEAT ENGINES

- **Heat Engines: A machine or device which derives heat from the combustion of fuel and converts part of this energy into mechanical work is called a *heat engine*.**

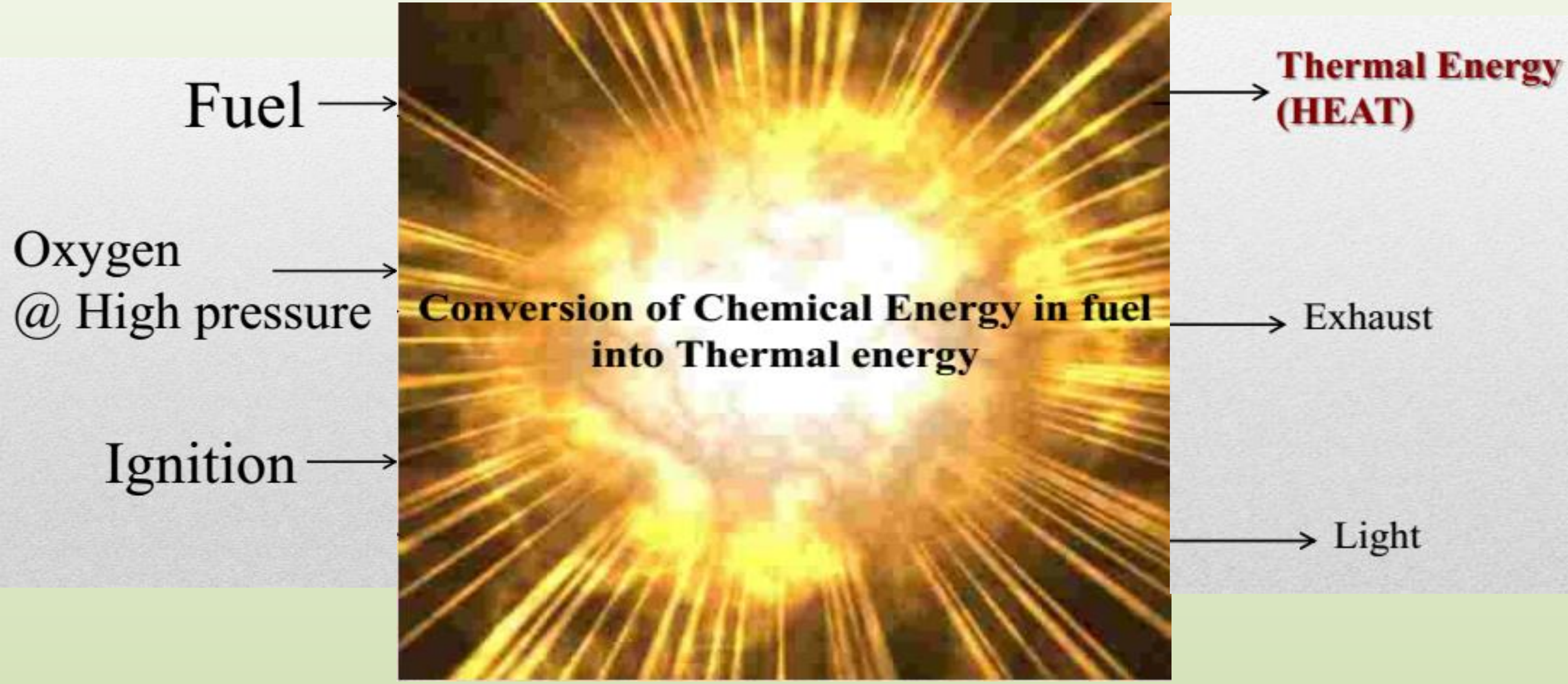
- **Heat engines may be classified into two main classes as follows:**

  1. **Internal combustion engines (e.g. Automobile engines)**
  2. **External combustion engines (e.g. Steam engines)**

INTRODUCTION OF I.C. ENGINES

- **Internal Combustion Engines :** An internal combustion engine (ICE) is a heat engine where the combustion of a fuel occurs with an oxidizer (usually air) in a confined space named combustion chamber.
- This exothermic reaction creates gases at a very high temperature and pressure, which are permitted to expand inside that confined chamber.
- The high pressure gas expands against the mechanical mechanisms (linkage) of the engine.
- Thrust produced by this expanding gas drives the engine creating useful work.

INTRODUCTION OF I.C. ENGINES

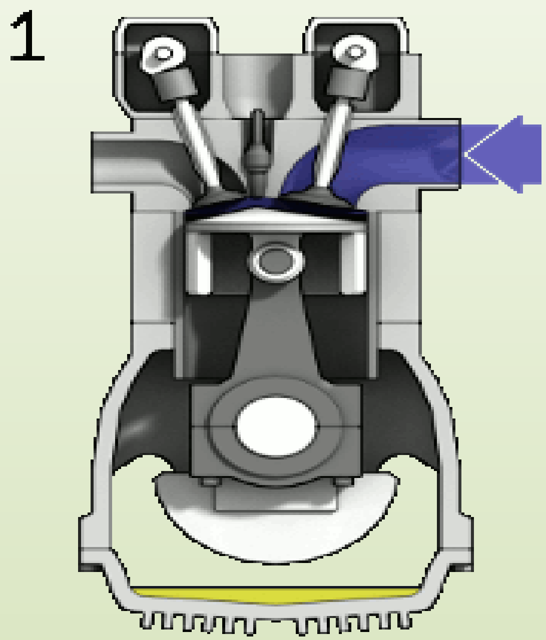


CLASSIFICATION OF I.C. ENGINES

The internal combustion engines may be classified in the following ways:

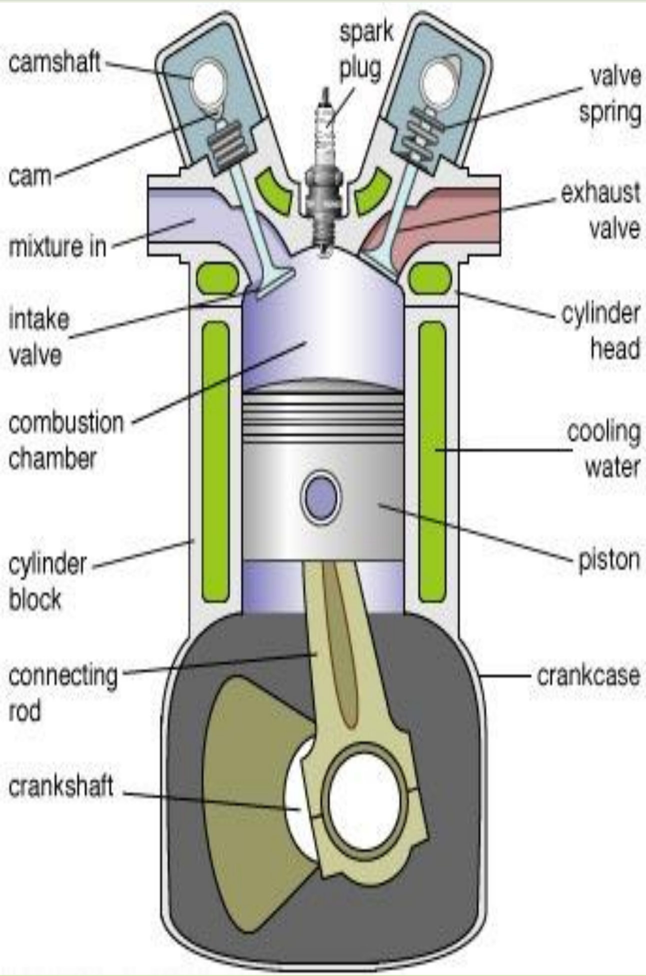
1. According to the *type of fuel* used
   a) Petrol engines, b) Diesel engines, and c) Gas engines.
2. According to the *method of igniting* the fuel
   a) Spark ignition engines, and b) Compression ignition engines.
3. According to the *number of strokes* per cycle
   a) Four stroke cycle engines, and b) Two stroke cycle engines.
4. According to the *cycle of operation*
   a) Otto cycle engines, b) Diesel cycle engines, and c) Dual cycle engines.

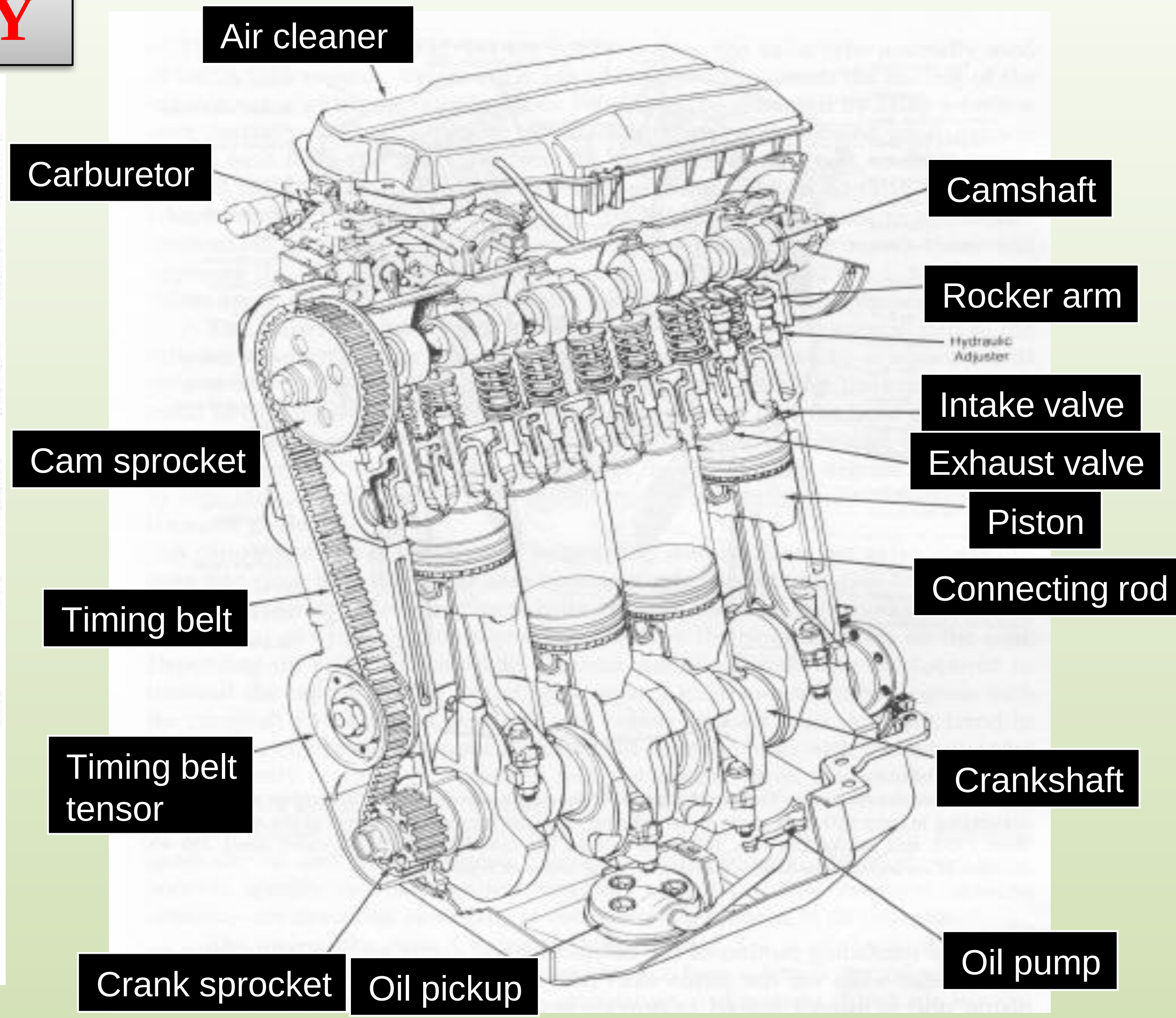
MECHANISM OF I.C. ENGINES



- **All Internal combustion engines must carry out five events:**
  - **Air-fuel mixture must be brought into the combustion chamber.**
  - **Mixture must be compressed.**
  - **Mixture must be ignited.**
  - **Burning mixture must expand into increasing combustion chamber volume.**
  - **Exhaust gases must be removed.**

ENGINE ANATOMY



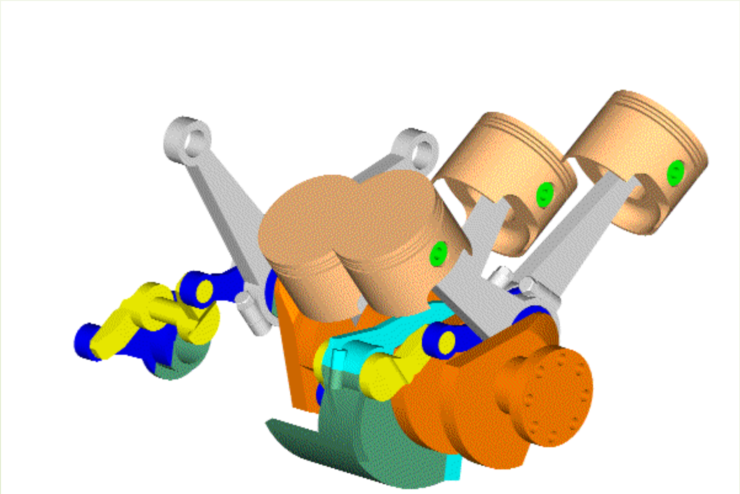


CONSTRUCTIONAL DETAILS OF I.C. ENGINE

PISTON

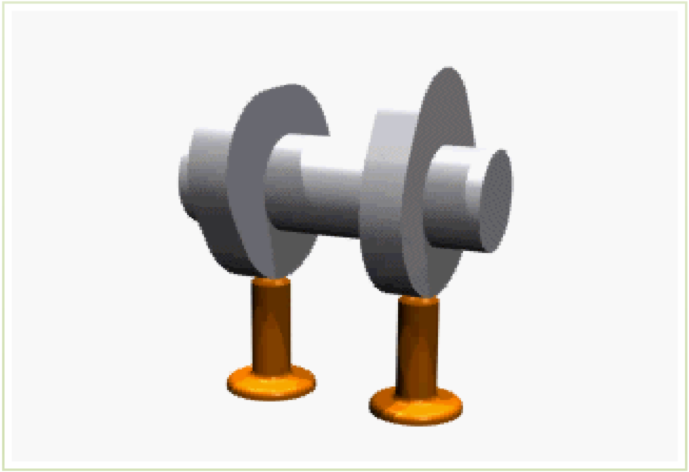
CYLINDER BLOCK

CRANK and CRANKSHAFT

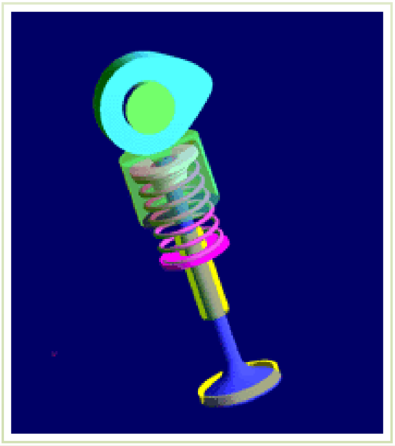


SPARK PLUG

CAM and CAMSHAFT



VALVE



CONSTRUCTIONAL DETAILS OF I.C. ENGINE

- **Cylinder :** It is one of the most important part of the engine, in which the piston moves to and fro in order to develop power. The engine cylinder has to withstand a high pressure.
- **Cylinder head :** It is fitted on one end of the cylinder, and act as a cover to close the cylinder bore. Generally, the cylinder head contains inlet and exit valves for admitting fresh charge and exhausting the burnt gases.
- **Piston :** It is considered as the heart of an I.C. engine, whose main function is to transmit the force exerted by the burning of charge to the connecting rod.
- **Crankshaft :** It is considered as the backbone of an I.C. engine whose function is to convert the reciprocating motion of the piston into the rotary motion with the help of connecting rod.

CONSTRUCTIONAL DETAILS OF I.C. ENGINE

- **Connecting rod :** It is a link between the piston and crankshaft, whose main function is to transmit force from the piston to the crankshaft.
- **Cam and Camshaft :** Camshaft opens the intake and exhaust valves at correct time and for correct duration. Cam changes rotary motion into reciprocating motion.
- **Intake valve :** Intake valve lets the air or air-fuel mixture to enter the combustion chamber.
- **Exhaust valve :** Exhaust gases lets the exhaust gases escape the combustion chamber.
- **Spark Plug :** It initiates the ignition after the compression stroke.

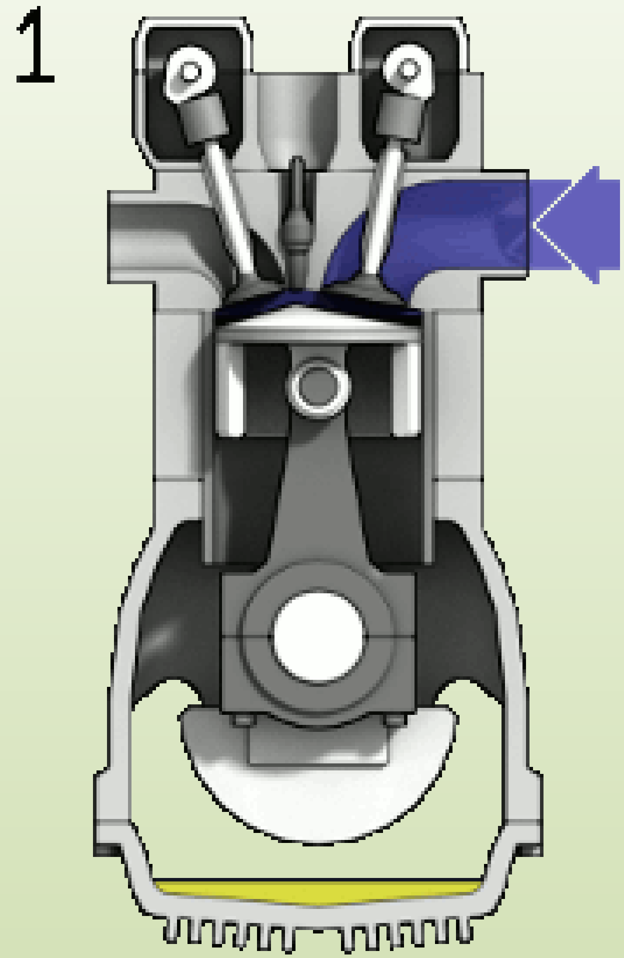
S.I. AND C.I. ENGINES

- **Spark Ignition engines (S.I. engines) : Air and fuel mixture is compressed in the compression chamber and the combustion is initiated by spark.**
- **Compression Ignition engines (C.I. engines) : Air alone is compressed in the engine and fuel is injected into the cylinder towards the end of the combustion stroke. Combustion starts when the air-fuel mixture self ignites due to high temperature in the combustion chamber caused by high compression.**

  - ✓ **Both S.I. and C.I. engine operate on either a four stroke (4-stroke) cycle or a two stroke (2-stroke) cycle.**

4-STROKE ENGINE OPERATION

STEPS INVOLVED:
1-SUCTION
2-COMPRESSION
3-EXPANSION
4-EXHAUST



4-STROKE ENGINE OPERATION

- **Intake Stroke**
  - Intake valve open.
  - Piston moves down (TDC to BDC) in cylinder.
  - Low pressure is created in cylinder.
  - Air is brought into the combustion chamber due to pressure differences.

- **Compression Stroke**
  - Both valves closed.
  - Piston moves from BDC to TDC
  - Air in combustion chamber is compressed, raising its temperature.
  - Near TDC of Compression stroke, fuel is injected into the combustion chamber.

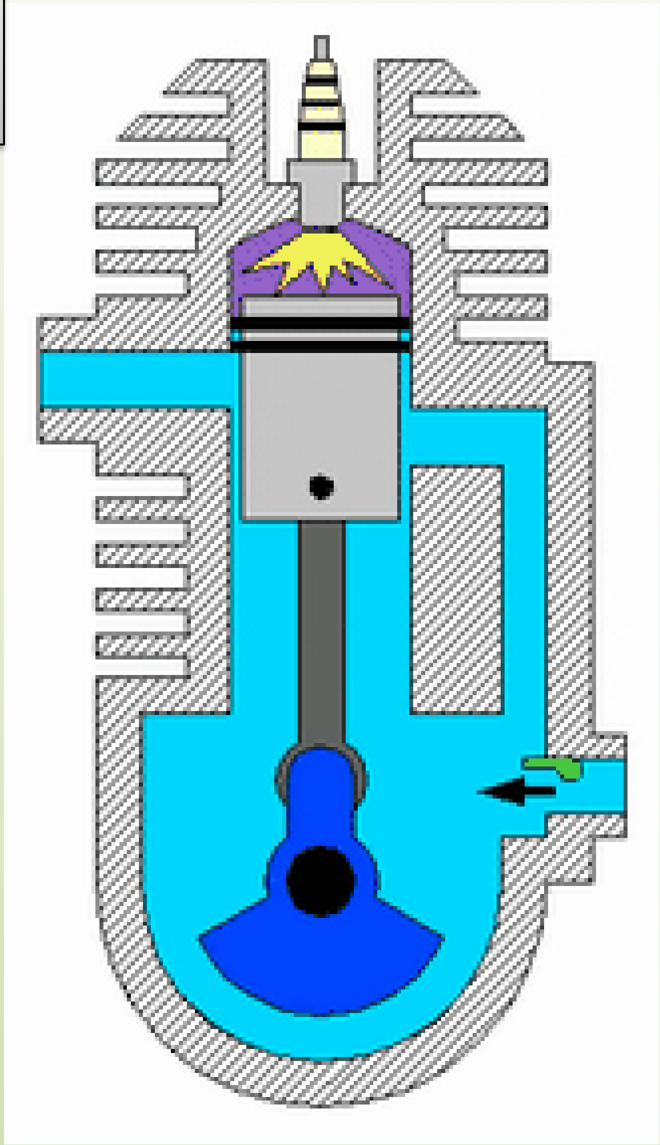
4-STROKE ENGINE OPERATION

- **Power Stroke**
  - Both valves are closed
  - Air-fuel mixture burns rapidly
  - Expansion of the burning air-fuel mix applies force to the head of the piston
  - Piston is driven down in the cylinder.

- **Exhaust Stroke**
  - Piston moves from BDC to TDC.
  - Exhaust valve is open.
  - Burnt air-fuel mixture is scavenged from combustion chamber.

2-STROKE ENGINE OPERATION

- **Suction and compression during upward stroke of the piston**
- **Expansion and exhaust during downward stroke of the piston**
- **There is one power stroke for every revolution of the crankshaft.**



COMPARISON OF 4-STROKE AND 2-STROKE ENGINE

Advantages :

1. **A two stroke cycle engine gives twice the number of power strokes than the four stroke cycle engine at the same engine speed.**
2. **For the same power developed, a two-stroke cycle engine is lighter, less bulky and occupies less floor area.**
3. **As the number of working strokes in a two-stroke cycle engine are twice than the four-stroke cycle engine, so the turning moment of a two-stroke cycle engine is more uniform. Thus it makes a two-stroke cycle engine to have a lighter flywheel and foundations. This also leads to a higher mechanical efficiency of a two-stroke cycle engine.**

COMPARISON OF 4-STROKE AND 2-STROKE ENGINE

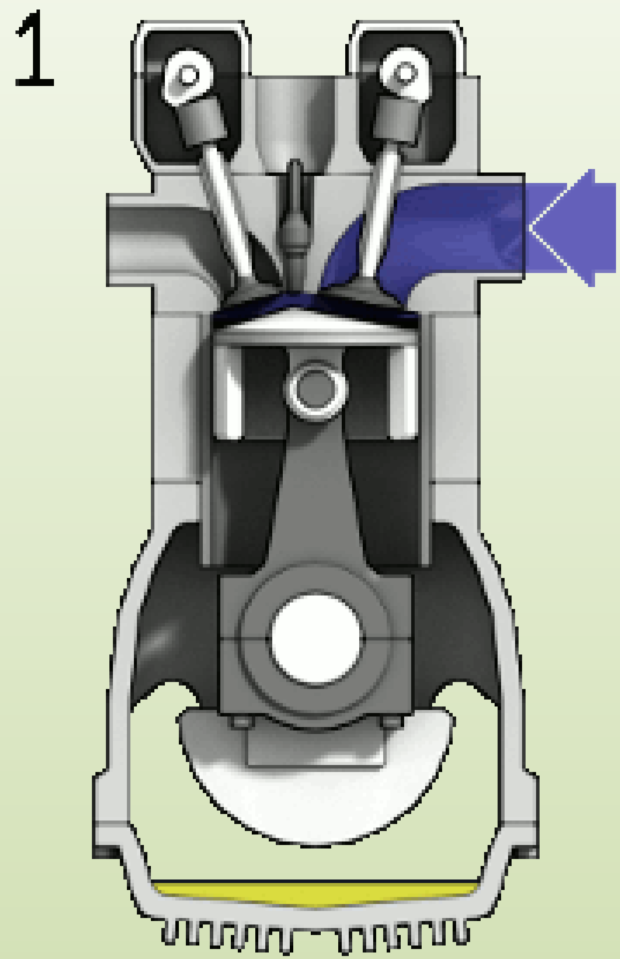
Disadvantages

1. Thermal efficiency of a two-stroke cycle engine is less than that a four-stroke cycle engine.
2. Overall efficiency of a two-stroke cycle engine is also less than that of a four-stroke cycle engine because in a two-stroke cycle, inlet and exhaust ports remain open simultaneously for sometime. A small quantity of charge is lost from the engine cylinder.
3. In case of a two-stroke cycle engine, the number of power strokes are twice as those of a four-stroke cycle engine. Thus the capacity of the cooling system must be higher. There is a greater wear and tear in a two-stroke cycle engine.
4. The consumption of lubricating oil is large in a two-stroke cycle engine because of high operating temperature.

S.I. ENGINE (PETROL ENGINE) OPERATION

Stroke 1 (intake) Air fuel mixture enters cylinder.

Stroke 2 (compression) Air fuel mixture is then compressed



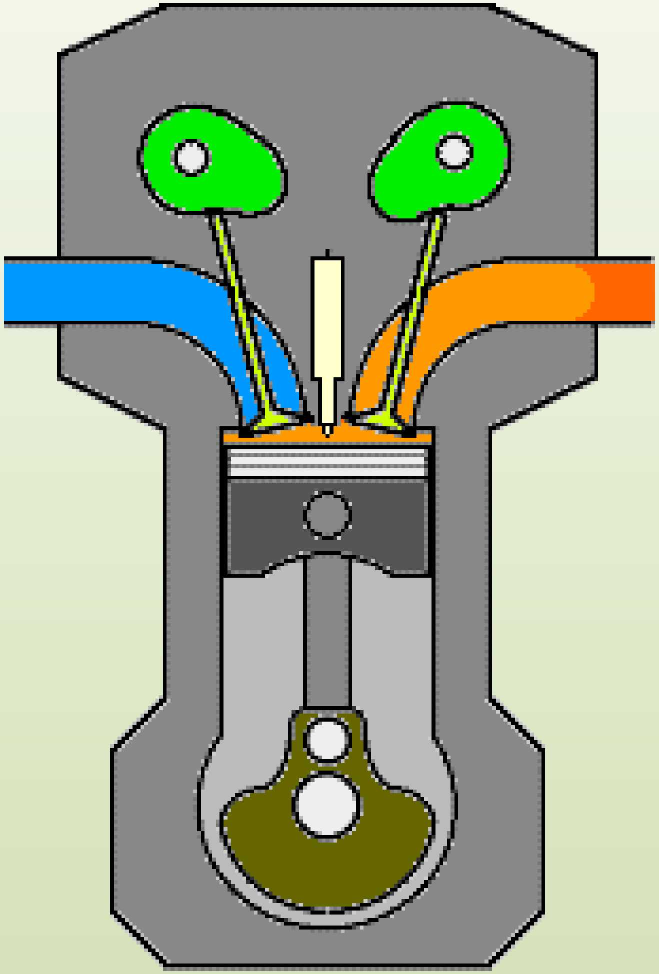
Stroke 3 (power) Combustion is initiated by spark

Stroke 4 (exhaust) burnt gases are expelled from the engine.

C.I. ENGINE (DIESEL ENGINE) OPERATION

Stroke 1 (intake) only air enters cylinder.

Stroke 2 (compression) air is compressed to high extent, raising its temperature.



Stroke 3 (power) diesel is injected, high air temperature ignites diesel.

Stroke 4 (exhaust) burnt gases are expelled from the engine.

COMPARISON OF PETROL AND DIESEL ENGINES

Petrol Engines	Diesel Engines
1. A petrol engine draws a mixture of petrol and air during suction stroke.	A diesel engine draws only air during suction stroke.
2. The carburettor is employed to mix air and petrol in the required proportion and to supply it to the engine during suction stroke.	The injector or atomiser is employed to inject the fuel at the end of combustion stroke.
3. Pressure at the end of compression is about 10 bar.	Pressure at the end of compression is about 35 bar.
4. The charge (i.e. petrol and air mixture) is ignited with the help of spark plug.	The fuel is injected in the form of fine spray. The temperature of the compressed air is sufficiently high to ignite the fuel.

COMPARISON OF PETROL AND DIESEL ENGINES

Petrol Engines	Diesel Engines
5. The combustion of the fuel takes place at constant volume. It works on Otto cycle.	The combustion of the fuel takes place at constant pressure. It works on Diesel cycle.
6. A petrol engine has compression ratio from 6 to 10.	A diesel engine has compression ratio from 15 to 25.
7. The starting is easy due to low compression ratio.	The starting is difficult due to high compression ratio.
8. As the compression ratio is low, the petrol engines are lighter and cheaper.	As the compression ratio is high, the diesel engines are heavier and costlier.
9. The running cost of a petrol engine is high because of the higher cost of petrol.	The running cost of diesel engine is low because of the lower cost of diesel.

COMPARISON OF PETROL AND DIESEL ENGINES

	Petrol Engines	Diesel Engines
10.	The maintenance cost is less.	The maintenance cost is more.
11.	The thermal efficiency is about 26%.	The thermal efficiency is about 40%.
12.	Overheating trouble is more due to low thermal efficiency.	Overheating trouble is less due to high thermal efficiency.
13.	These are high speed engines.	These are relatively low speed engines.
14.	The petrol engines are generally employed in light duty vehicle such as scooters, motorcycles and cars. These are also used in aeroplanes.	The diesel engines are generally employed in heavy duty vehicles like buses, trucks, and earth moving machines.

Mechanical Supercharging:

- ❖ Supercharging can easily produce 50% more power than a normally aspirated engine of the same size.
- ❖ The supercharger is powered directly by the engine, which usually drives it at a fixed transmission ratio.

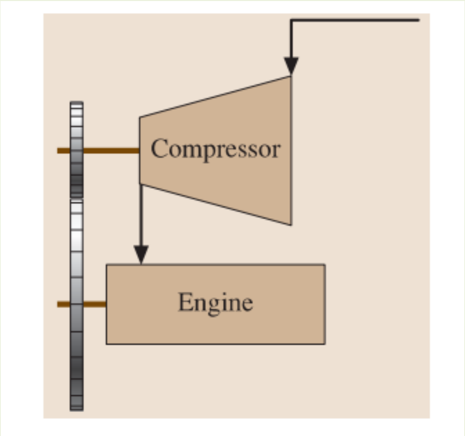


Fig: Supercharger

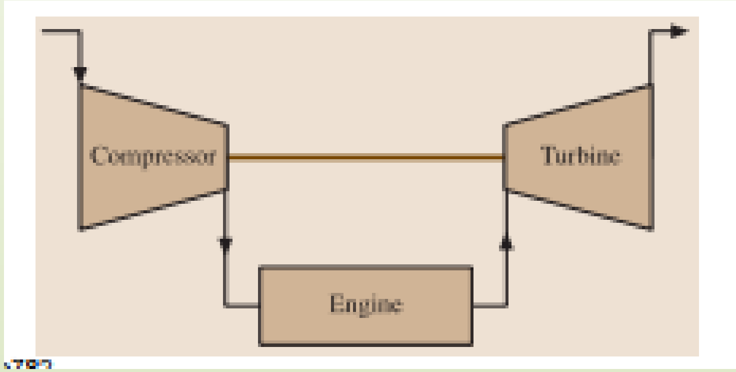
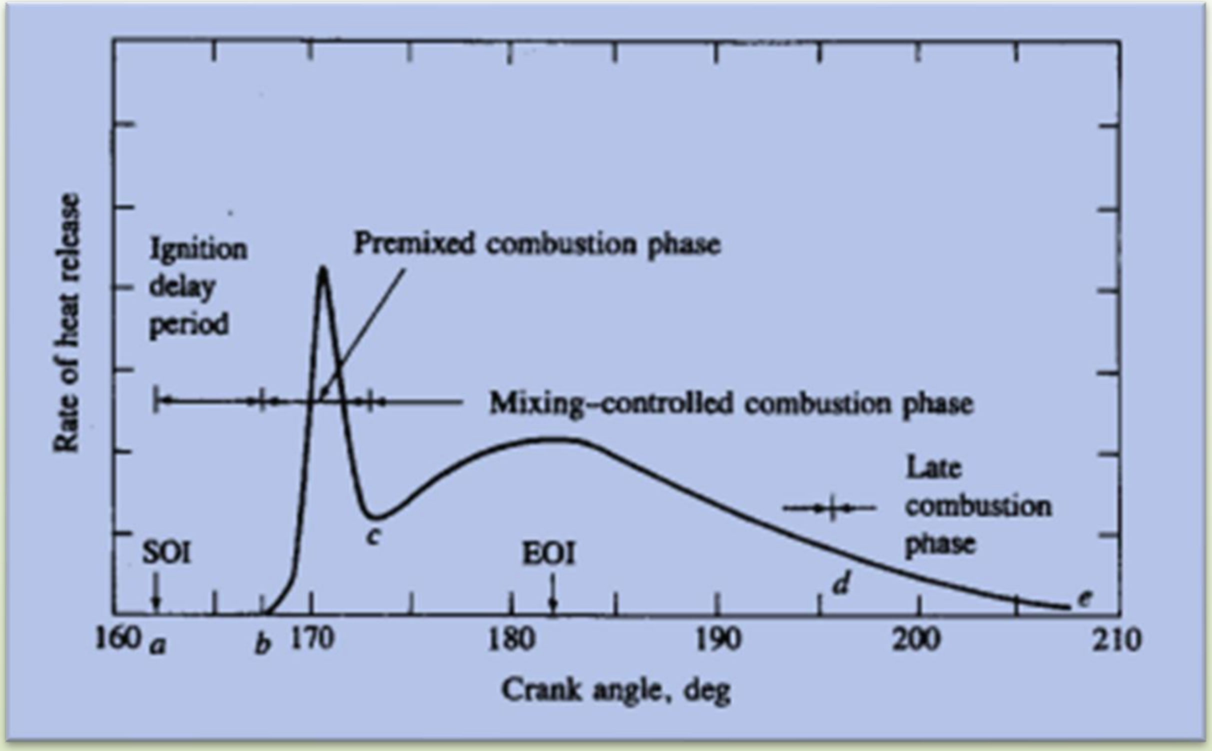


Fig: Turbocharger

Exhaust-gas Turbocharging:

- ❖ In turbocharging, exhaust-driven turbine is employed to convert the energy in the exhaust gases into mechanical energy, making it possible for the turbocharger to compress the induction gas.

Phases of a DI Engine Combustion:



- Ignition Delay (ab)
  - Ignition Delay = Physical Delay + Chemical Delay
- Premixed or Rapid Burning Phase (bc)
- Mixing Controlled Combustion Phase (cd)
- Late Combustion Phase (de)

Combustion Stoichiometry:

$$\underbrace{C_\alpha H_\beta O_\gamma N_\delta}_{fuel} + \underbrace{a_s\,(O_2 + 3.76N_2)}_{air} \longrightarrow \underbrace{n_1 CO_2 + n_2 H_2 O + n_3 N_2}_{complete\ combustion\ product}$$

- $a_s \equiv$ stoichiometric molar air-fuel ratio
- $(A/F)_s \equiv$ stoichiometric air-fuel ratio

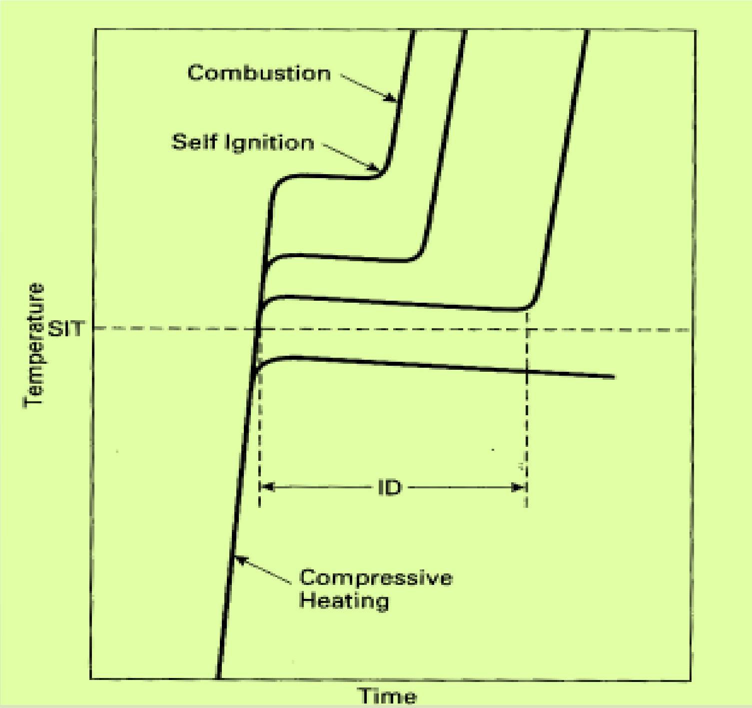
$$a_s = \alpha + \frac{\beta}{4} - \frac{\gamma}{2} \Longrightarrow \left(\frac{A}{F}\right)_s = \left(\frac{F}{A}\right)_s^{-1} = \frac{28.85(4.76a_s)}{12\alpha+\beta+16\gamma+14\delta}$$

- $\phi \equiv$ fuel-air equivalence ratio, simply equivalence ratio
- $\lambda \equiv$ relative air-fuel ratio or excess-air factor

$$\phi = \lambda^{-1} = \frac{(A/F)_s}{(A/F)_a} = \frac{(F/A)_a}{(F/A)_s} : \quad \phi \begin{cases} < 1 & : \text{lean mixture} \\ = 1 & : \text{stoichiometric mixture} \\ > 1 & : \text{rich mixture} \end{cases}$$

Auto-ignition & Self-ignition Temperature (SIT):

- If the temperature of an air-fuel mixture is raised high enough, the mixture will self ignite without the need of an external igniter. The temperature above which this occurs is called the **SIT**.



- If mixture temperature is above SIT, self-ignition will occur after a short time delay called **ignition delay (ID).**

Engine Cycles:

Otto Cycle:

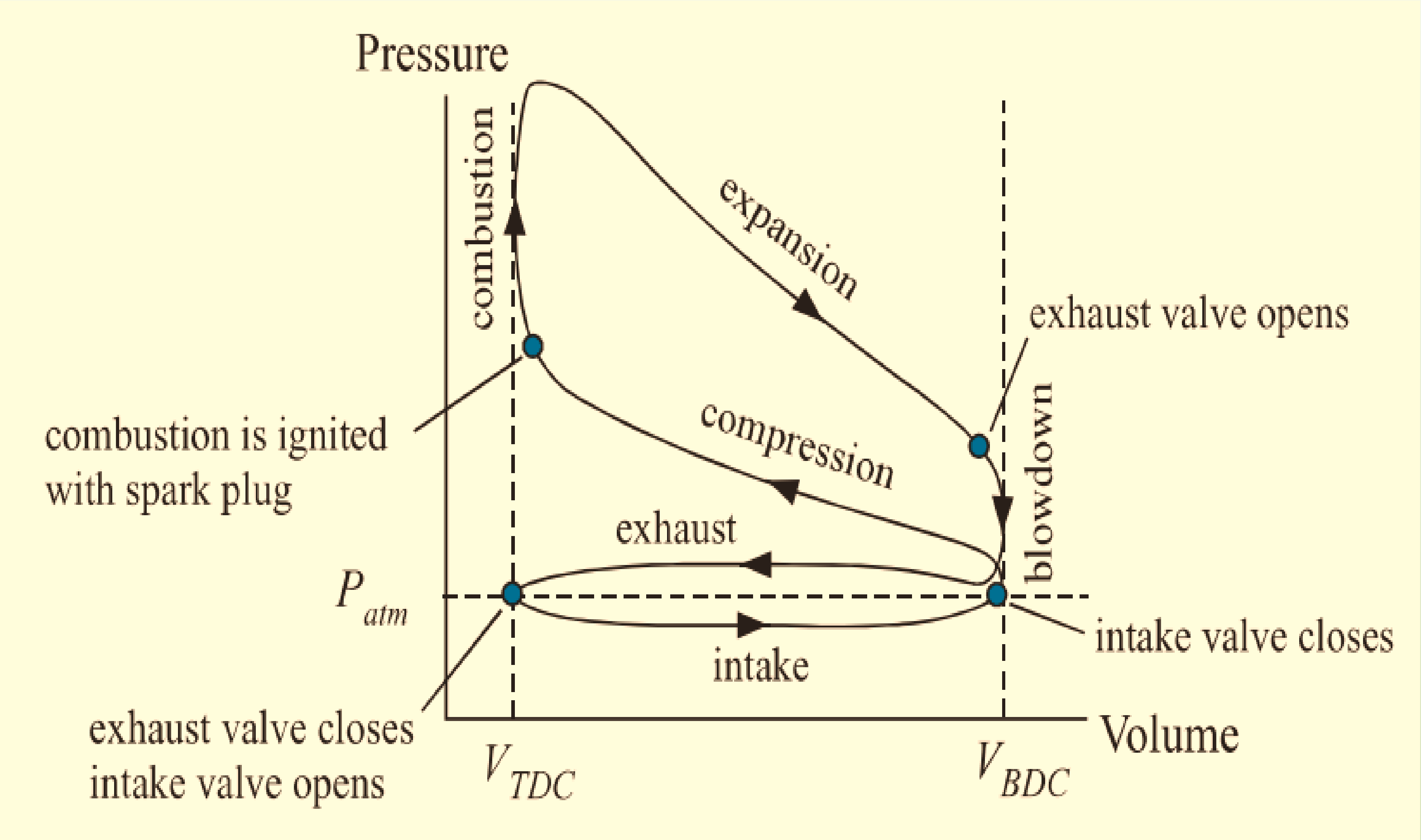


Fig: P-V diagram of actual Otto Cycle

Diesel Cycle:

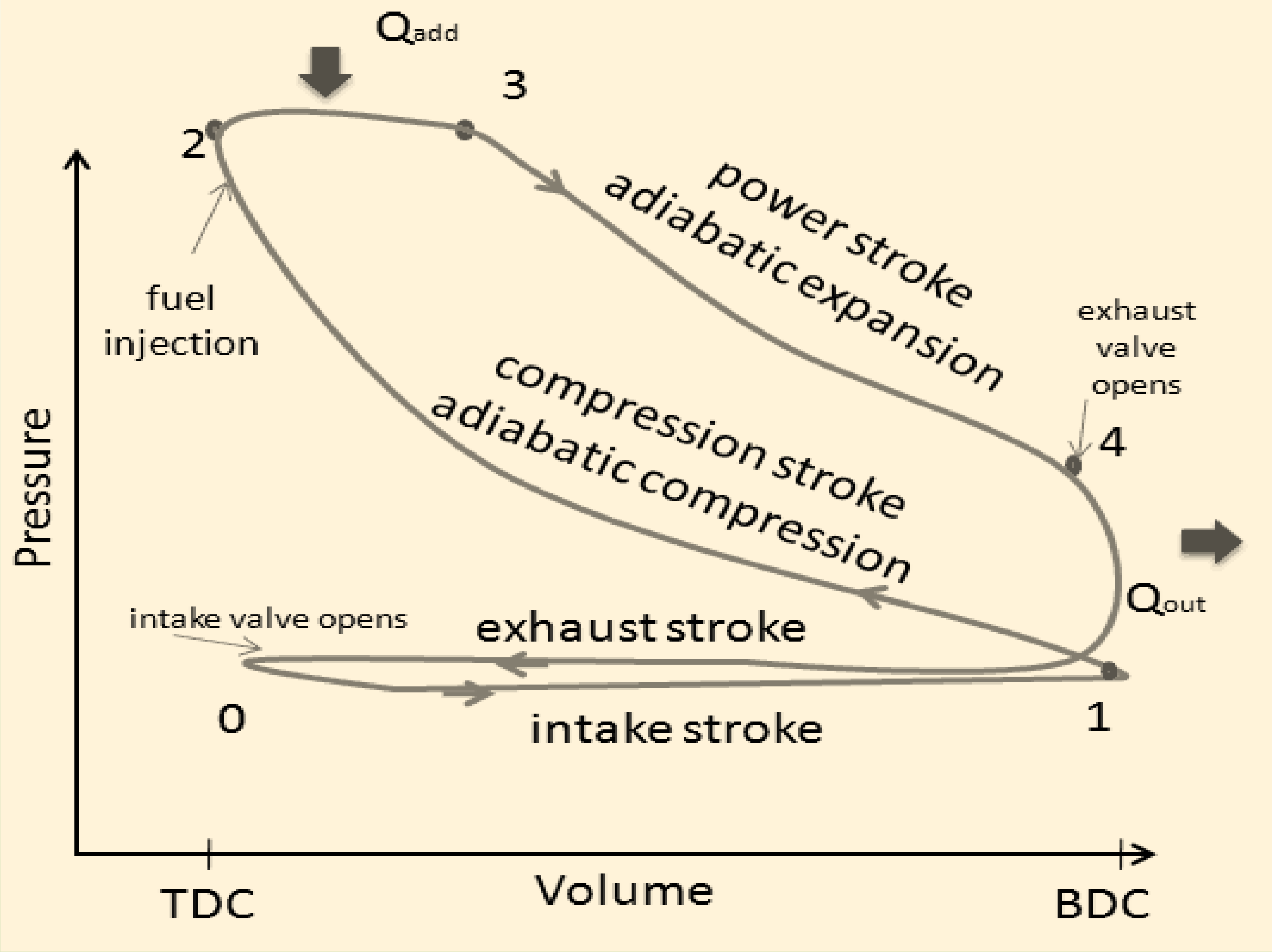
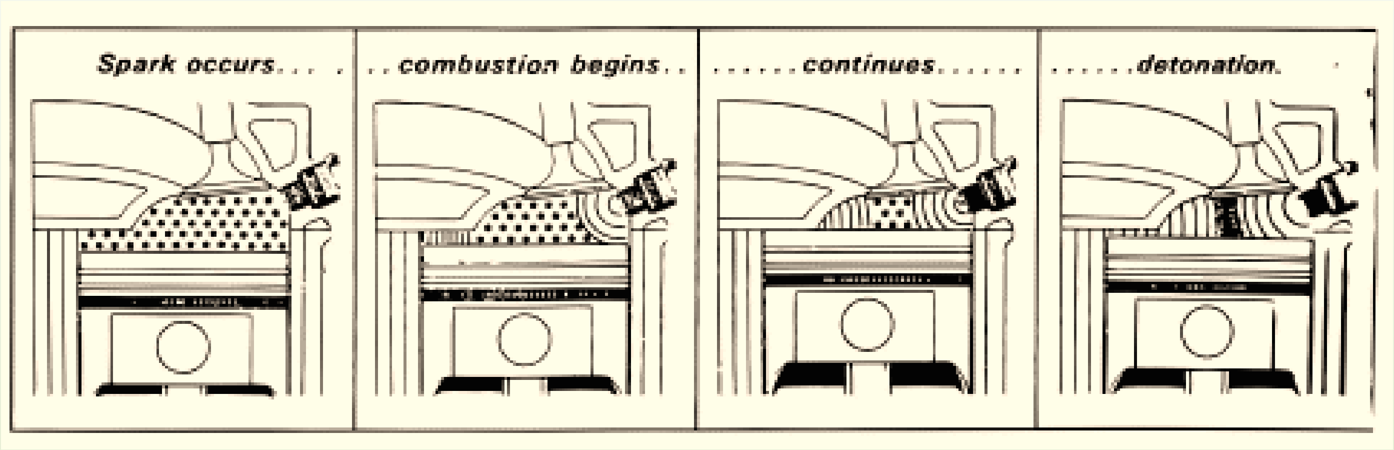


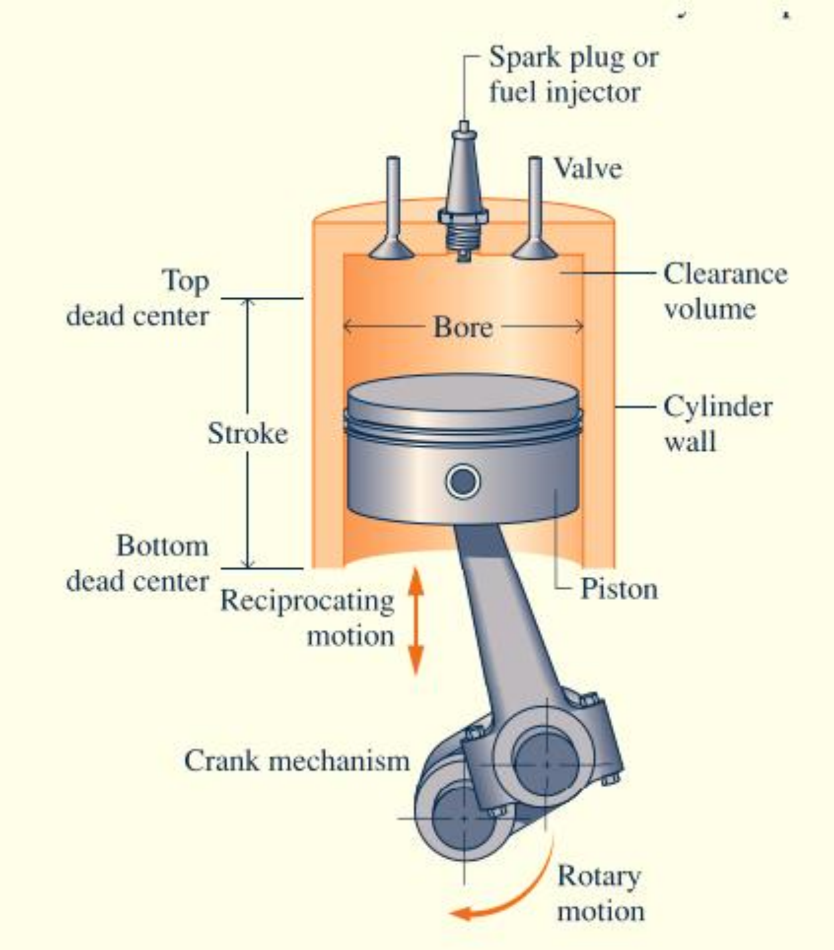
Fig: P-V diagram of actual Diesel Cycle

Engine Knock:



Knock is the name of the noise transmitted through the engine structure when essentially spontaneous ignition of a portion of end-gas, the fuel, air, residual gas, mixture ahead of the flame front – occurs

ICE Nomenclature:



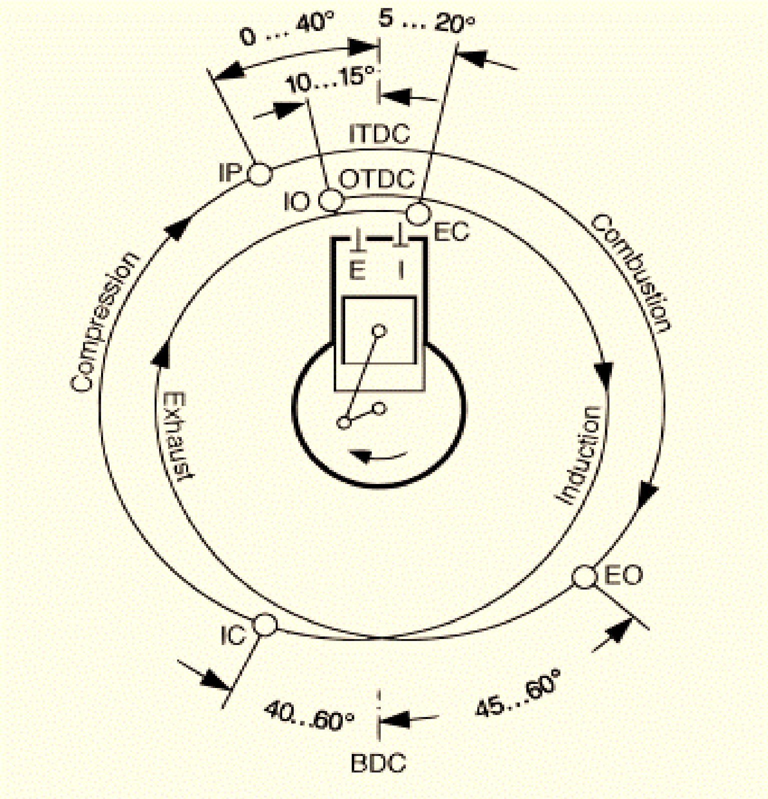
$$V_d = Displacement\ Volume$$

$$V_d = V_{BDC} - V_{TDC} = \frac{\pi}{4} b^2 S$$

Where, $b = bore, s = stroke$

Compression Ratio, $r_c = \frac{V_{BDC}}{V_{TDC}}$

Valve Timing Diagram:



Valve timing - and thus gas exchange - are regulated by a camshaft which opens the valves by depressing them against the valve springs to discharge the exhaust gas and to draw in the fresh gas.

E-Exhaust
EO-Exhaust opens
EC-Exhaust closes
I-Intake
IO-Intake opens
IC-Intake closes

TDC-Top dead center,
OTDC-Overlap TDC,
ITDC-Ignition TDC

BDC-Bottom dead center
IP-Ignition point

Feeling Sleepy!!!

Enough for today.

Thank You