# Internal Combustion Engine

By

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AP/MECH

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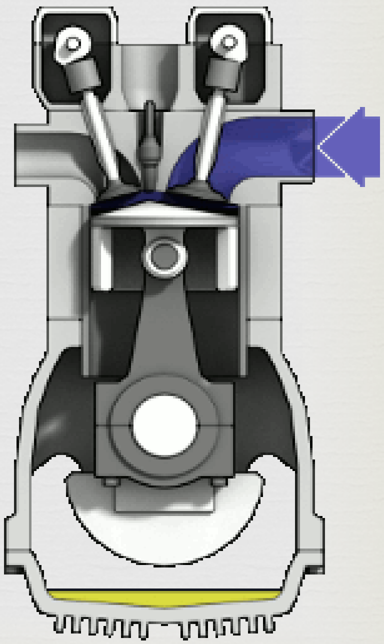

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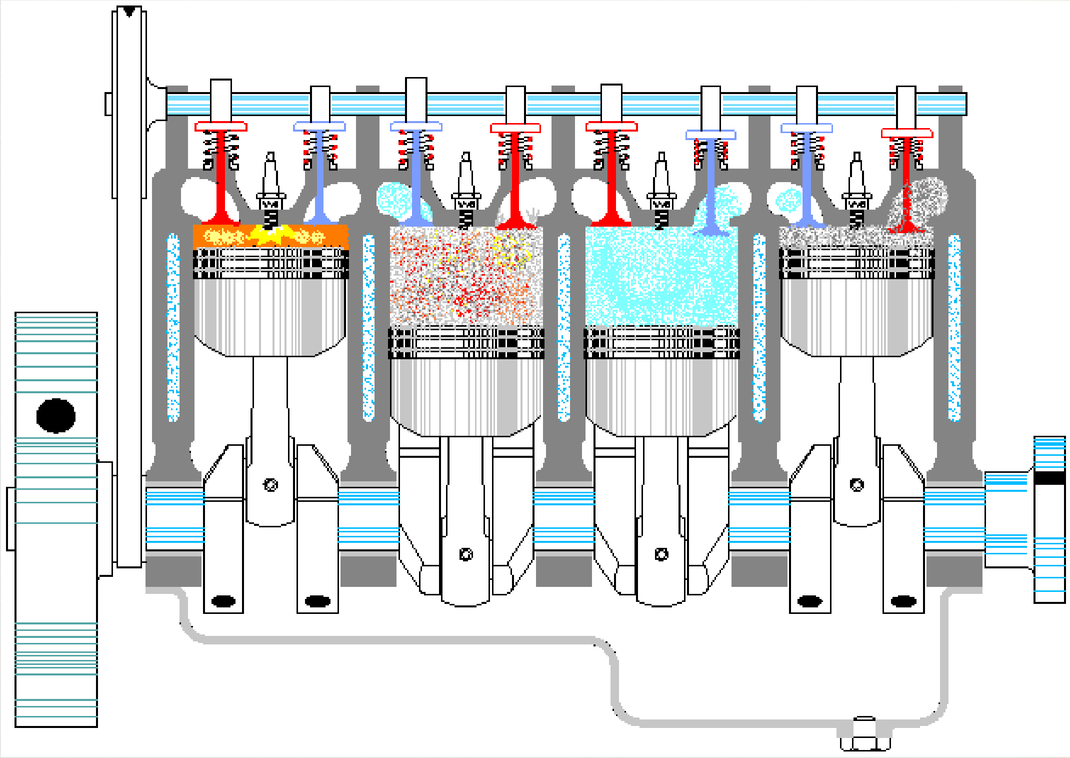
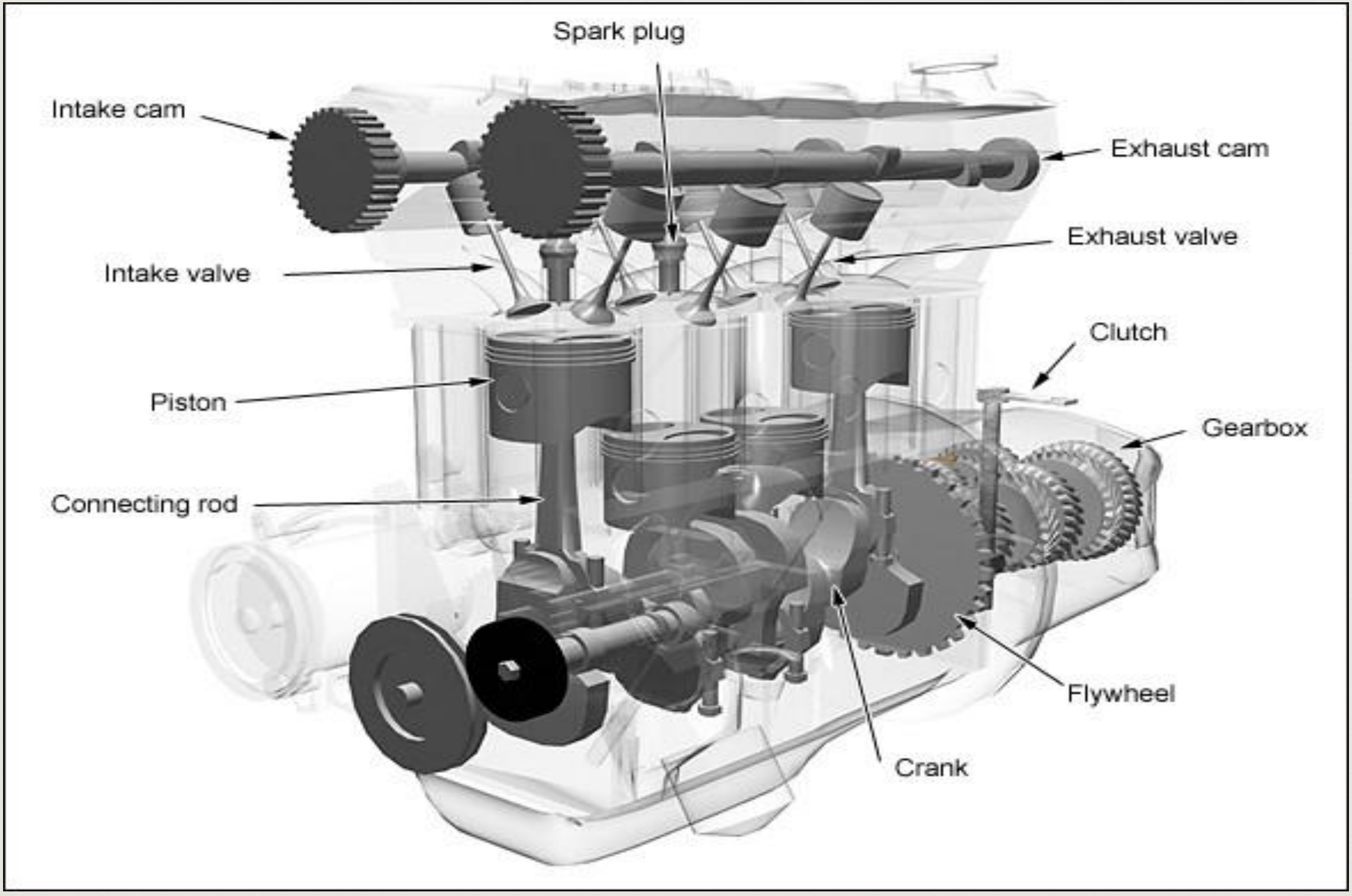
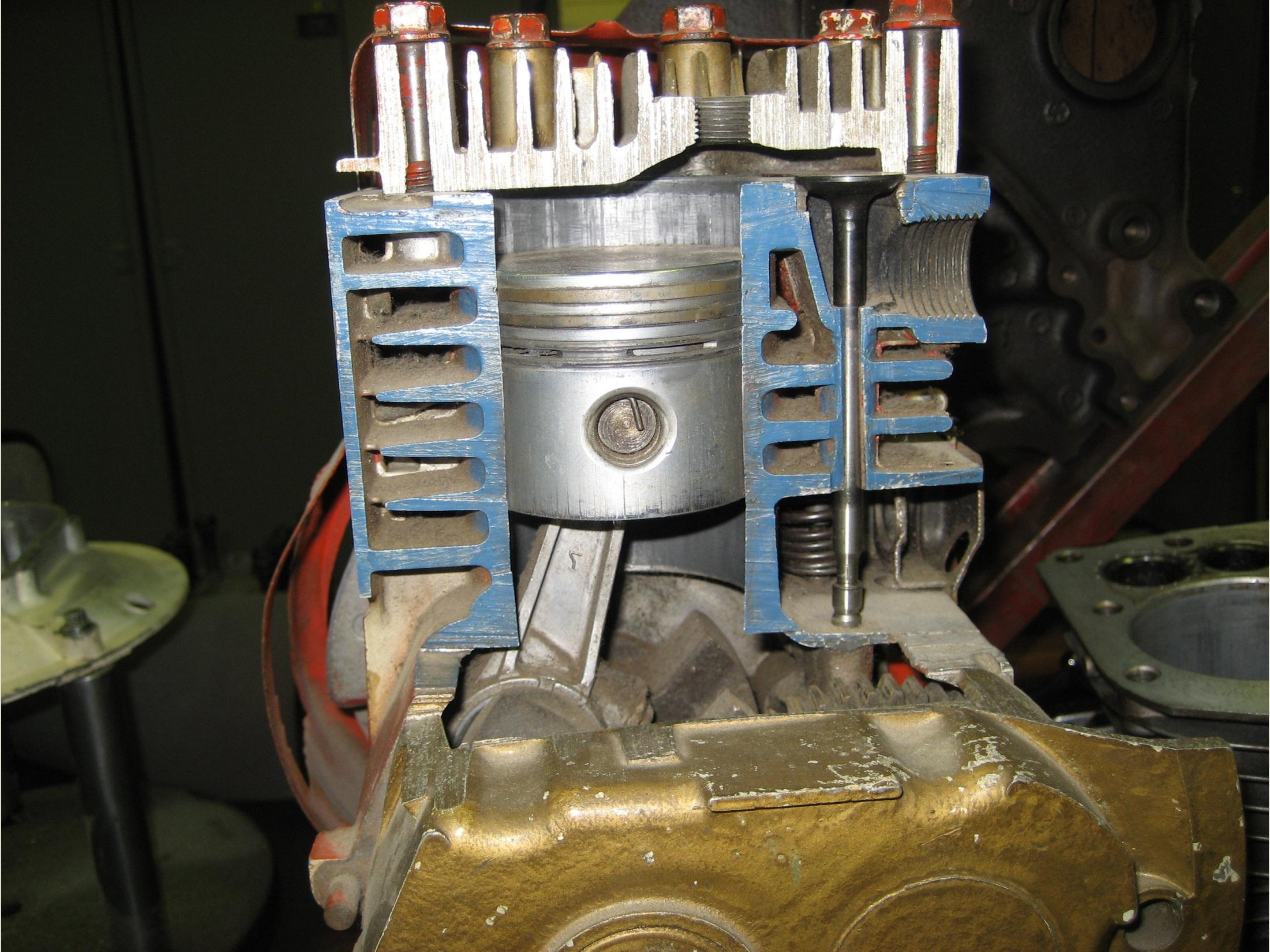


# Internal Combustion Engines





- In an **Internal combustion engine**, combustion takes place within working fluid of the engine, thus fluid gets contaminated with combustion products.
  - Petrol engine is an example of internal combustion engine, where the working fluid is a mixture of air and fuel .
- In an **External combustion engine**, working fluid gets energy using boilers by burning fossil fuels or any other fuel, thus the working fluid does not come in contact with combustion products.
  - Steam engine is an example of external combustion engine, where the working fluid is steam.

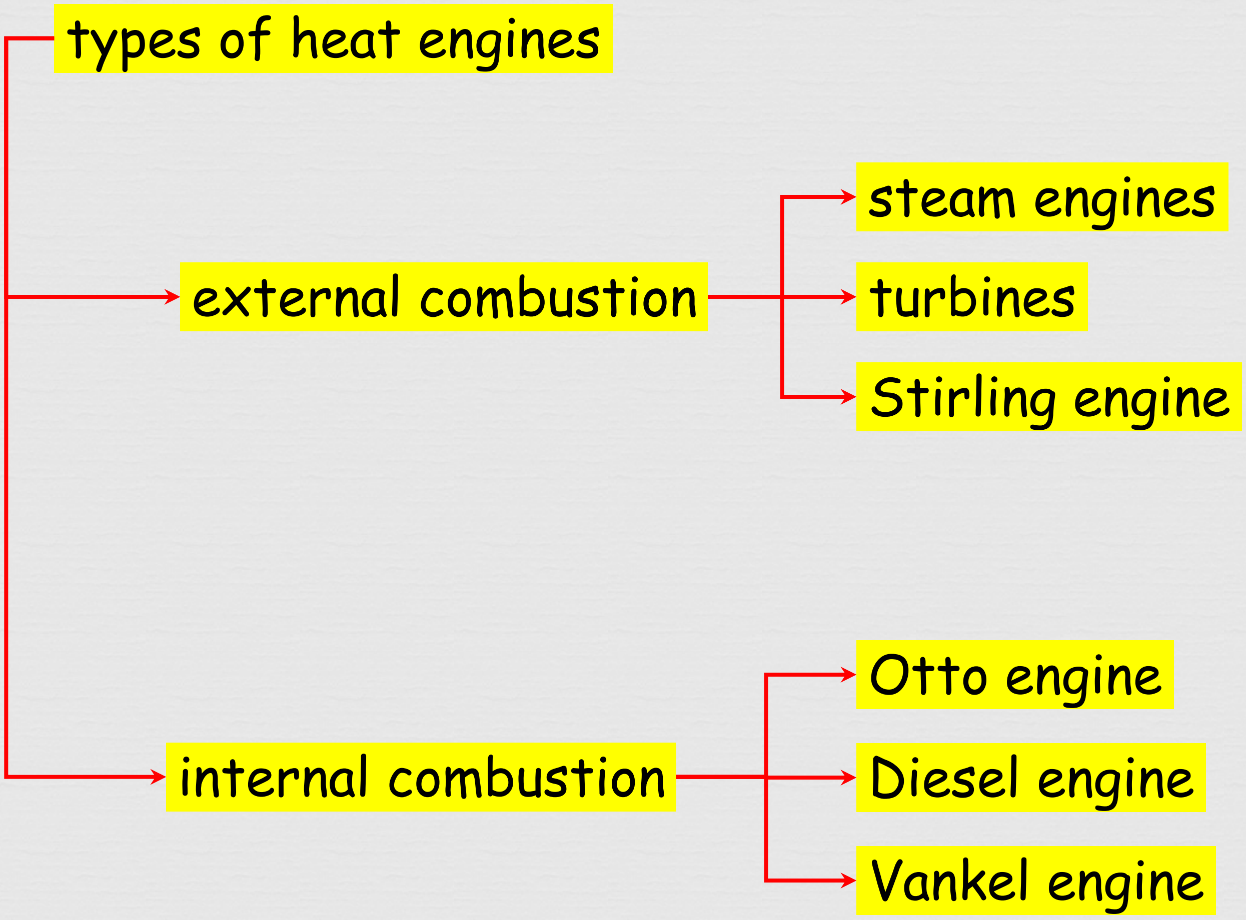
Internal combustion engines may be classified as :

- Spark Ignition engines.
- Compression Ignition engines.

- **Spark ignition engine (SI engine):** An engine in which the combustion process in each cycle is started by use of an external spark.
- **Compression ignition engine (CI engine):** An engine in which the combustion process starts when the air-fuel mixture self ignites due to high temperature in the combustion chamber caused by high compression.
  - Spark ignition and Compression Ignition engine operate on either a four stroke cycle or a two stroke cycle

- Four stroke cycle : It has four piston strokes over two revolutions for each cycle.
- Two stroke cycle : It has two piston strokes over one revolution for each cycle.
- We will be dealing with Spark Ignition engine and Compression Ignition engine operating on a four stroke cycle.

# Internal Combustion Engines

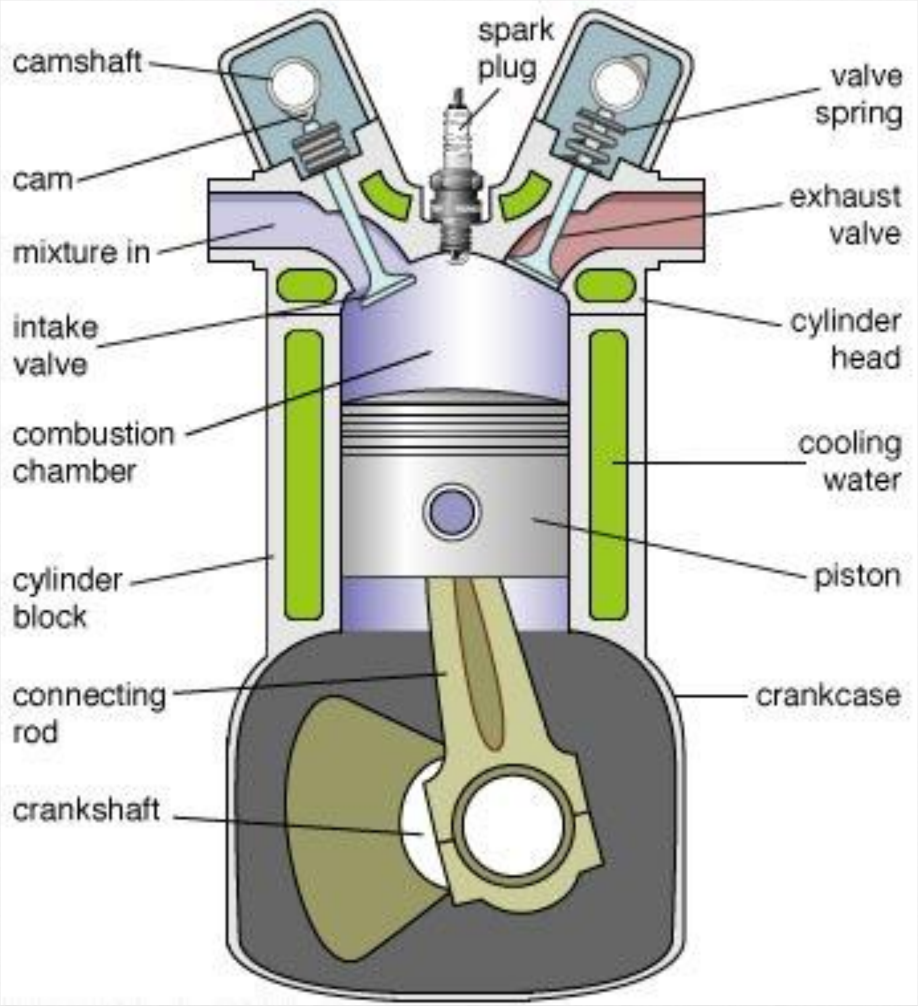


# Applications of I.C. Engines

***The internal combustion engine is an engine in which the combustion of fuel-oxidizer mixture occurs in a confined space***


applied in:
automotive
rail transportation
power generation
ships
aviation
garden appliances

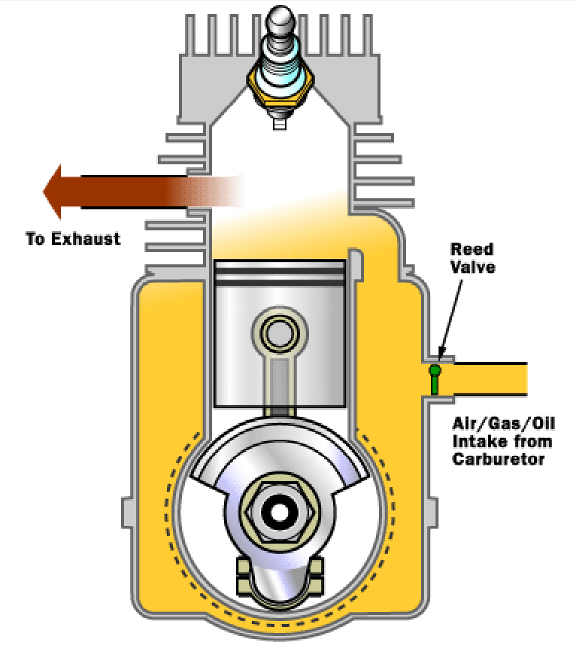
# Internal Combustion Engines



# Internal Combustion Engines
# – two stroke -

## 1. Power / Exhaust

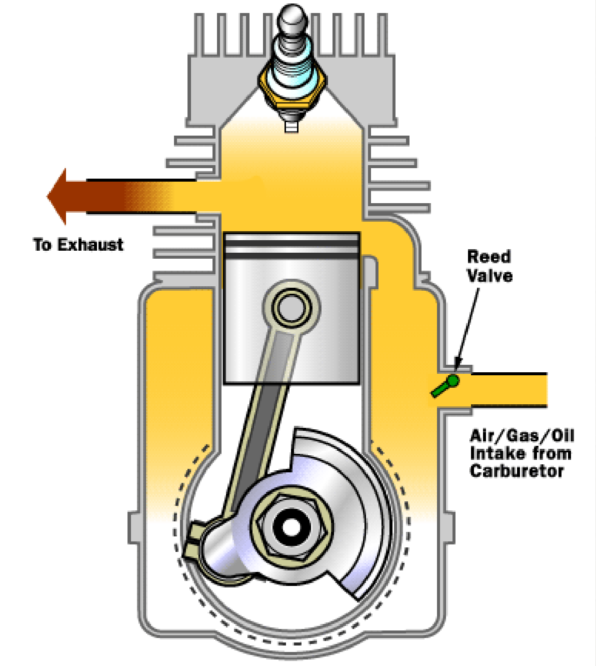
a. ignition
b. piston moves downward compressing fuel-air mixture in the crankcase
c. exhaust port opens



Fuel-intake position of a two-stroke engine

## 2. Intake / Compression

a. inlet port opens
b. compressed fuel-air mixture rushes into the cylinder
c. piston upward movement provides further compression

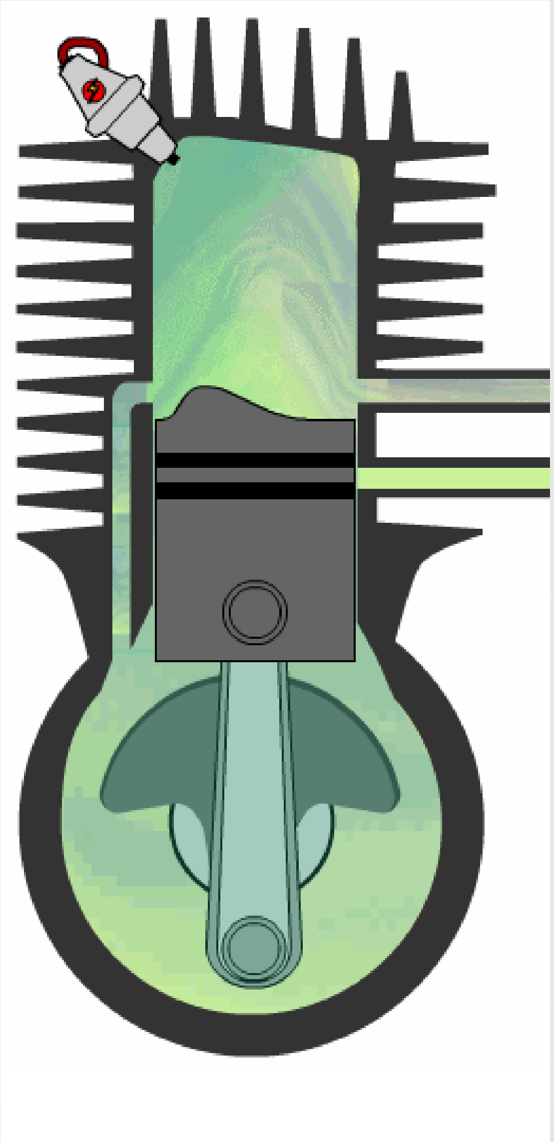


Compression action of a two-stroke engine

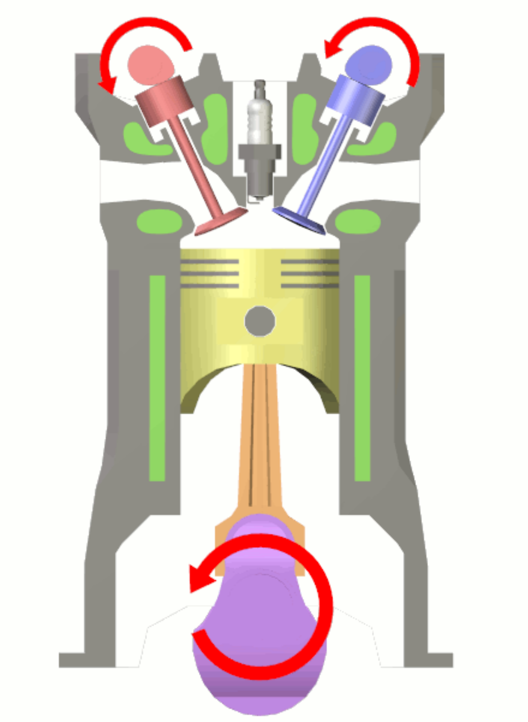
# Internal Combustion Engines – two stroke -

**Advantages**:
•lack of valves, which simplifies construction and lowers weight
•fire once every revolution, which gives a significant power boost
•can work in any orientation
•good power to weight ratio

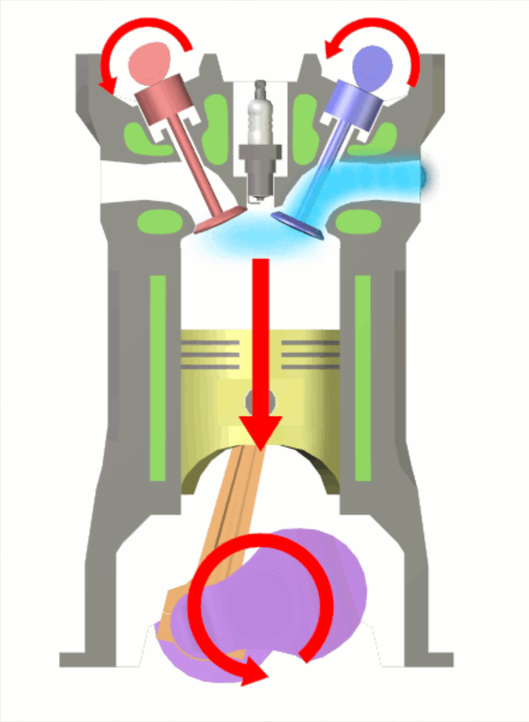
**Drawbacks:**
•lack of a dedicated lubrication system makes the engine to wear faster.
•necessity of oil addition into the fuel
•low efficiency
•produce a lot of pollution



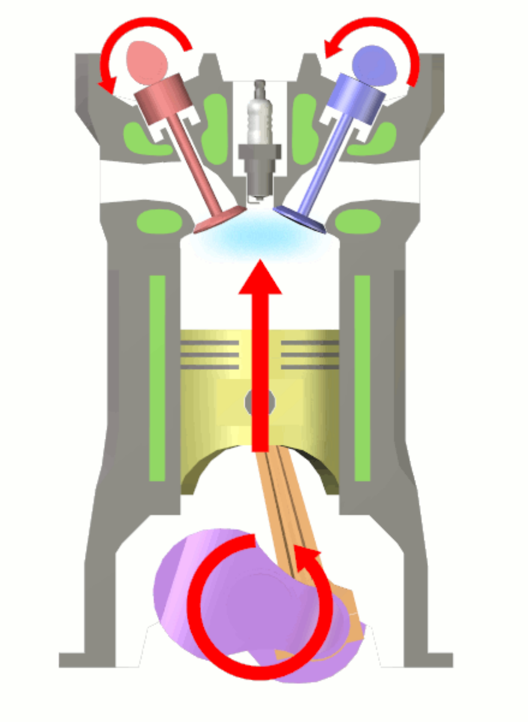
# Internal Combustion Engines
## – four stroke -



starting position



1. intake

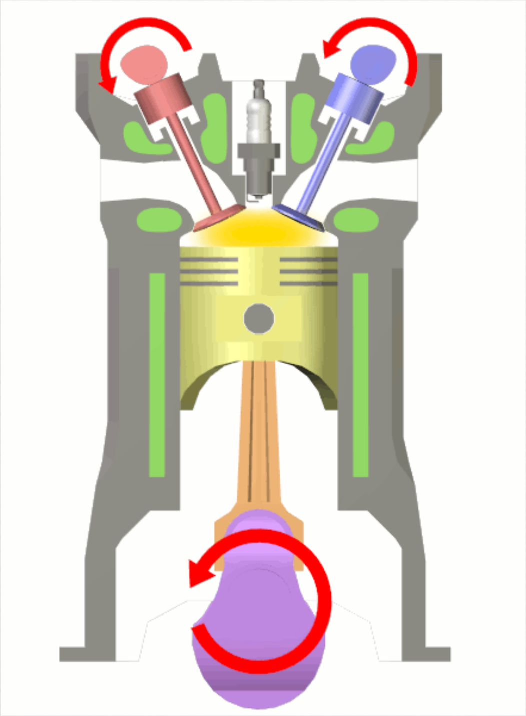


2. compression

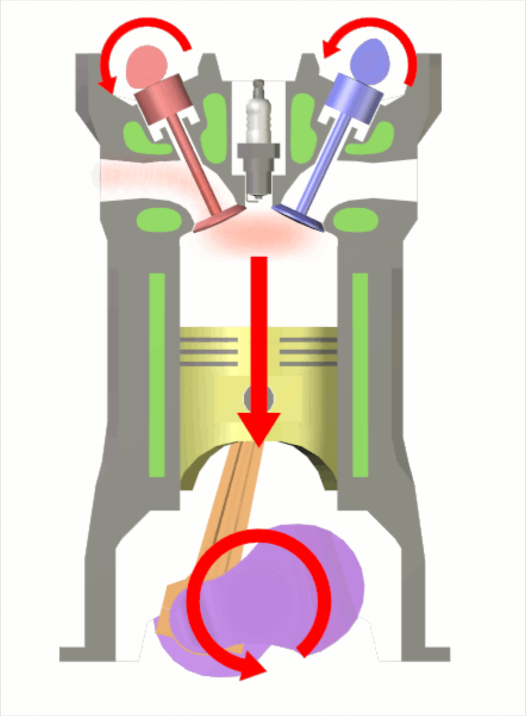
a. piston starts moving down
b. intake valve opens
c. air-fuel mixture gets in

a. piston moves up
b. both valves closed
c. air-fuel mixture gets compressed

# Internal Combustion Engines
# – four stroke -

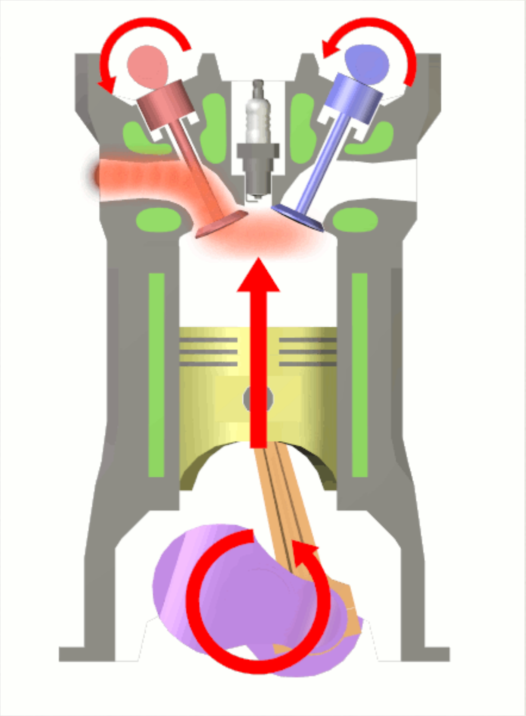


ignition



3. power

a. air-fuel mixture explodes driving the piston down

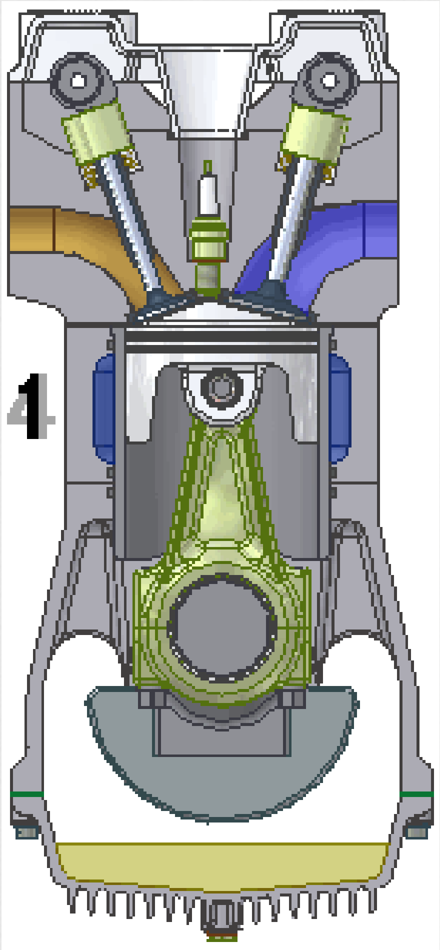


4. exhaust

a. piston moves up
b. exhaust valve opens
c. exhaust leaves the cylinder

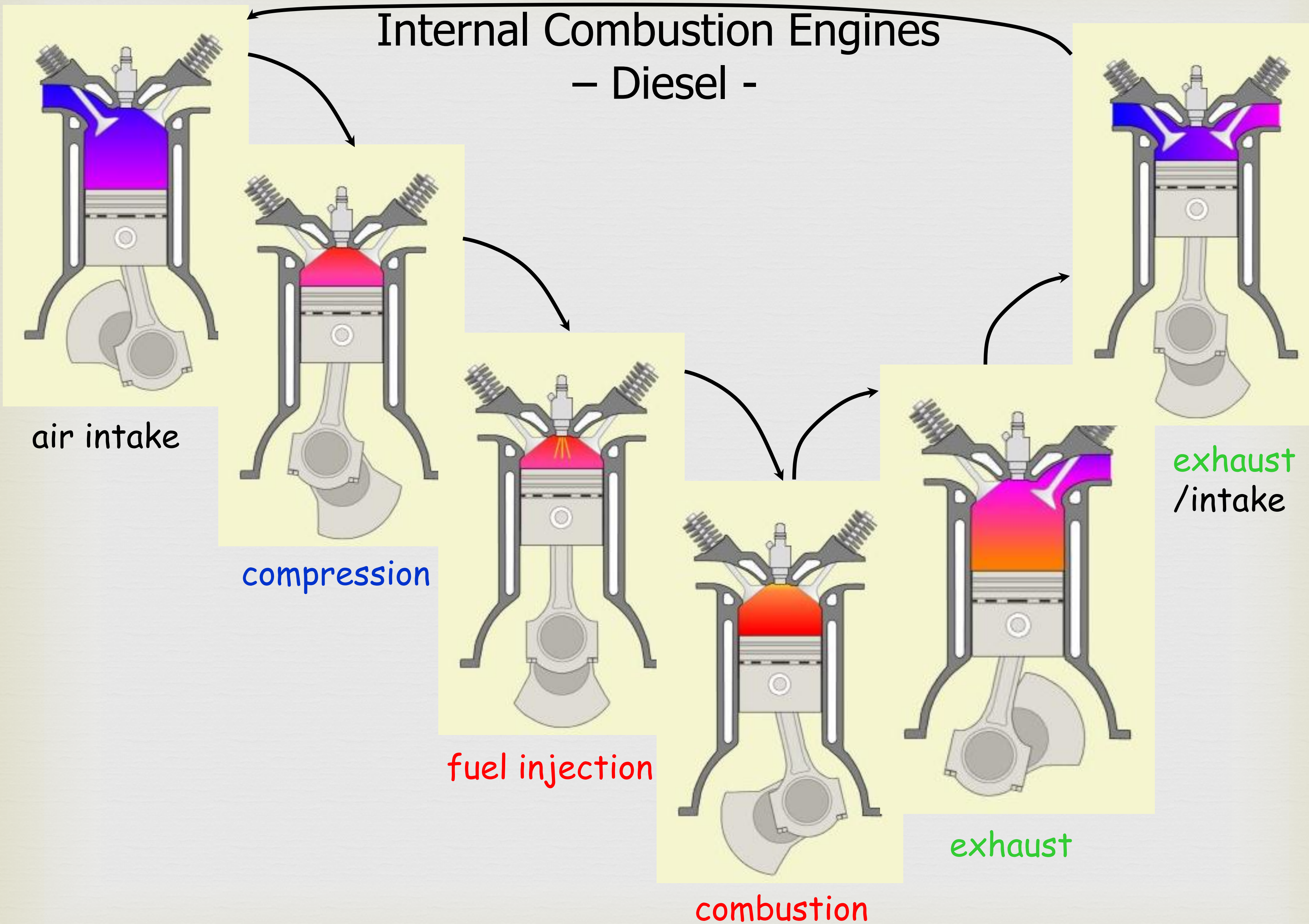
# Internal Combustion Engines
# – four stroke -

**Advantages**:
•dedicated lubrication system makes to engine more wear resistant
•better efficiency that 2-stroke engine
•no oil in the fuel – less pollution



**Drawbacks:**
•complicated constriction
•should work in horizontal position due to lubrication

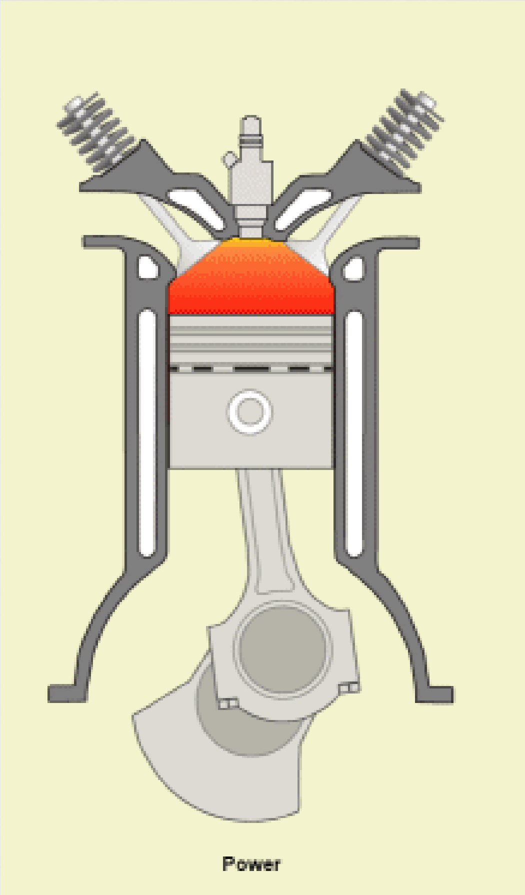
# Internal Combustion Engines
# – Diesel -



# Internal Combustion Engines
# – Diesel -

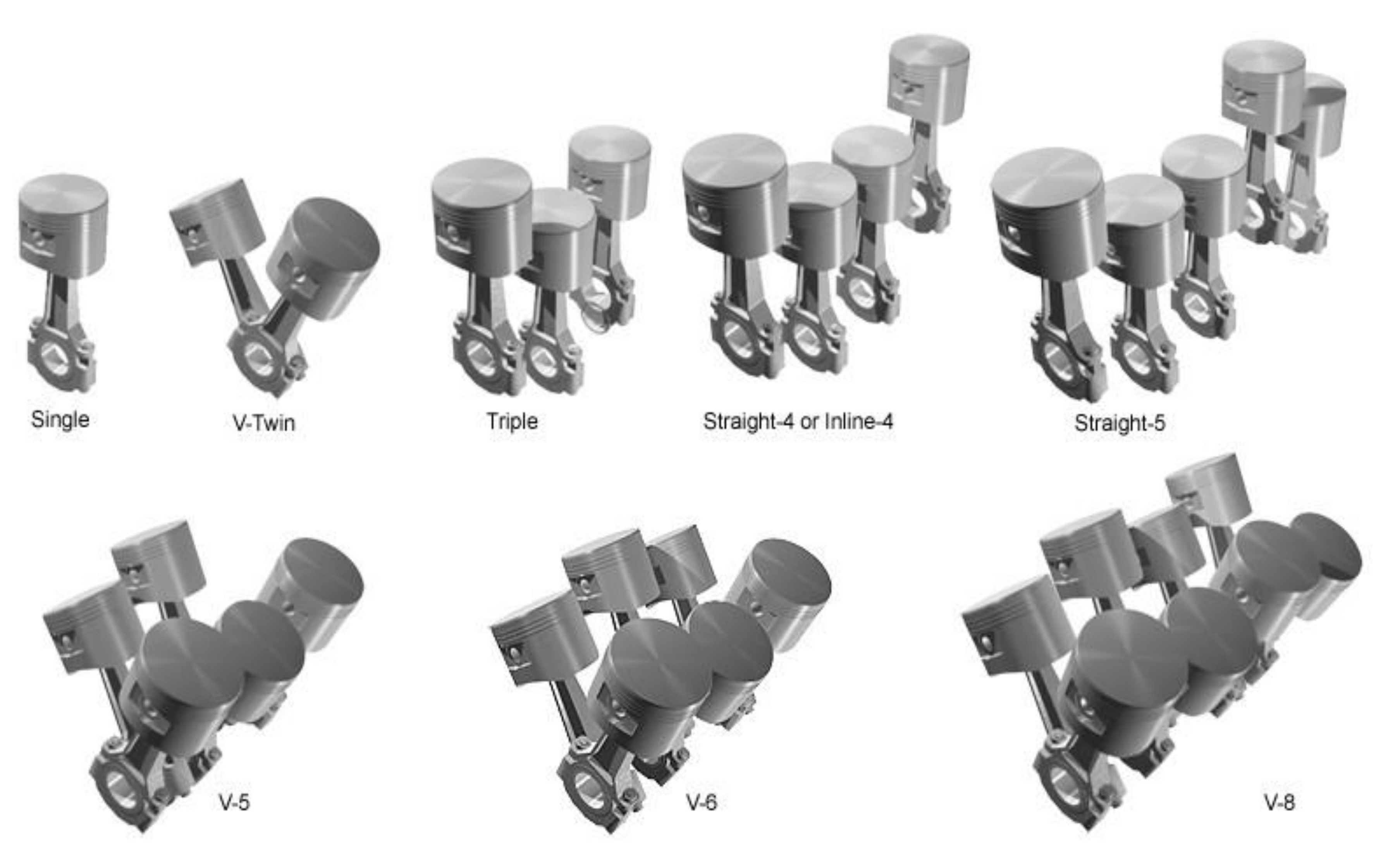
**Advantages**:
•self ignition (without electrical spark plug)
•better efficiency
•reliability
•higher durability
•supplied with worse fuels

**Drawbacks:**
•more $NO_x$ production
•more expensive production
•more weight
•louder
•lower revolutions



# Internal Combustion Engines
# – multi-cylinder -

**Cylinder layouts**



| Two-stroke Cycle Engines | Four-Stroke Cycle Engines |
|---|---|
| •Lighter weight | •Heavier weight |
| •Operates in many positions | •Operates in limited positions |
| •Higher power to weight ratio | •Lower power to weight ratio |
| •Engine oil usually mixed with fuel | •Engine oil in a reservoir |
| •Louder operation | •Quieter operation |
| •Higher Engine speeds | •Slower engine speeds |
| •More vibration | •Smoother operation |
| •Rough idling operation | •Smoother idling operation |

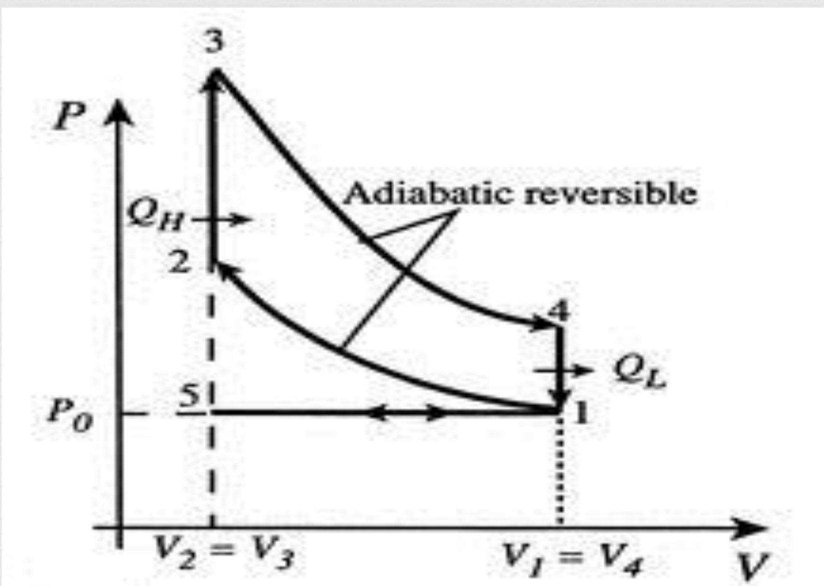
# Assumptions of Air standard cycle

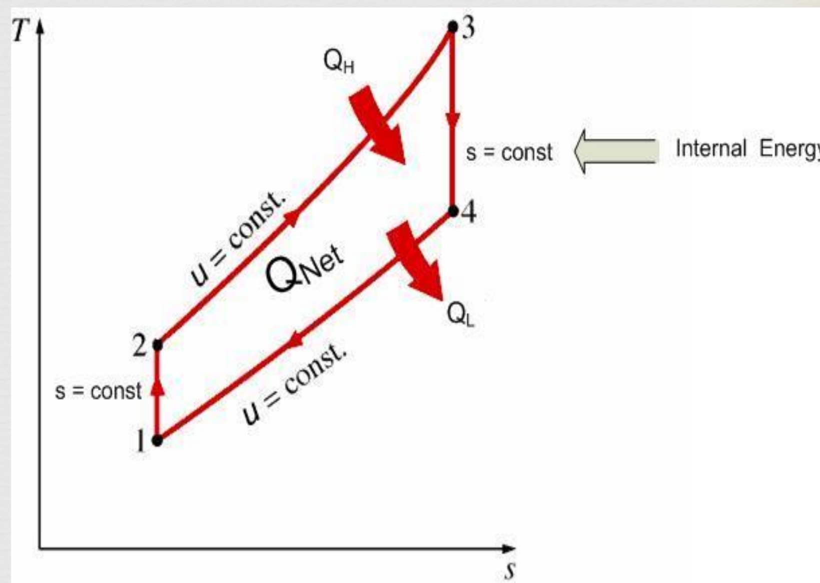
- A perfect gas is used as a working medium
- The transfer of heat that does not affect the temperature of source and sink.
- The wall of piston and cylinder perfectly insulator
- The cylinder head is perfect heat conductor or perfect insulator as requirement.
- The working fluid has a fixed mass
- The working medium does not undergoes any chemical change throughout the cycle
- The specific heat Cp and Cv do not vary with temperature

# Power Cycles

## a) Otto cycle

The air standard Otto Cycle is an ideal cycle that approximates a spark-ignition internal combustion engine. It assumes that the heat addition occurs instantaneously while the piston is at TDC.



# a) Otto cycle

***Process***

(1-2) Isentropic Compression

Compression from $v_1 \Rightarrow v_2$

$\downarrow$ $\downarrow$

BDC(β=180º ) TDC (θ=0º)

(2-3) Constant Volume heat input: $Q_H$

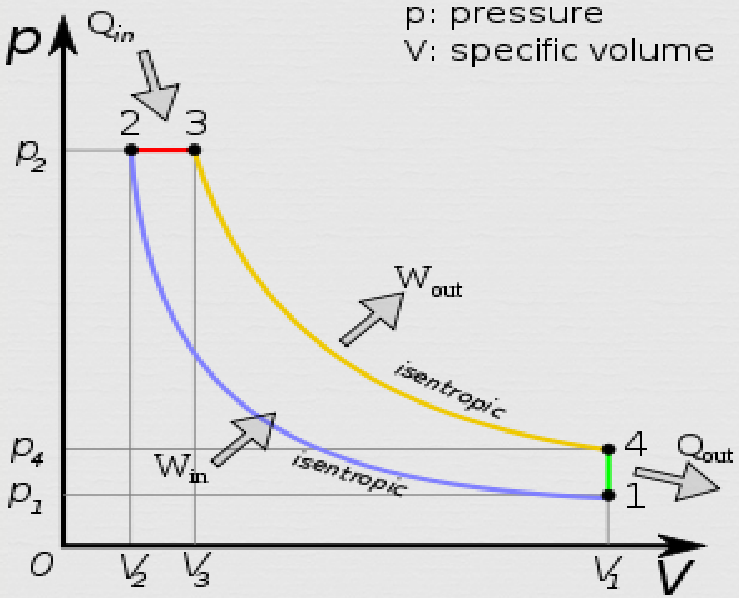
- While at TDC: $u_{min}$
- Ignition of fuel (chemical reaction takes place)

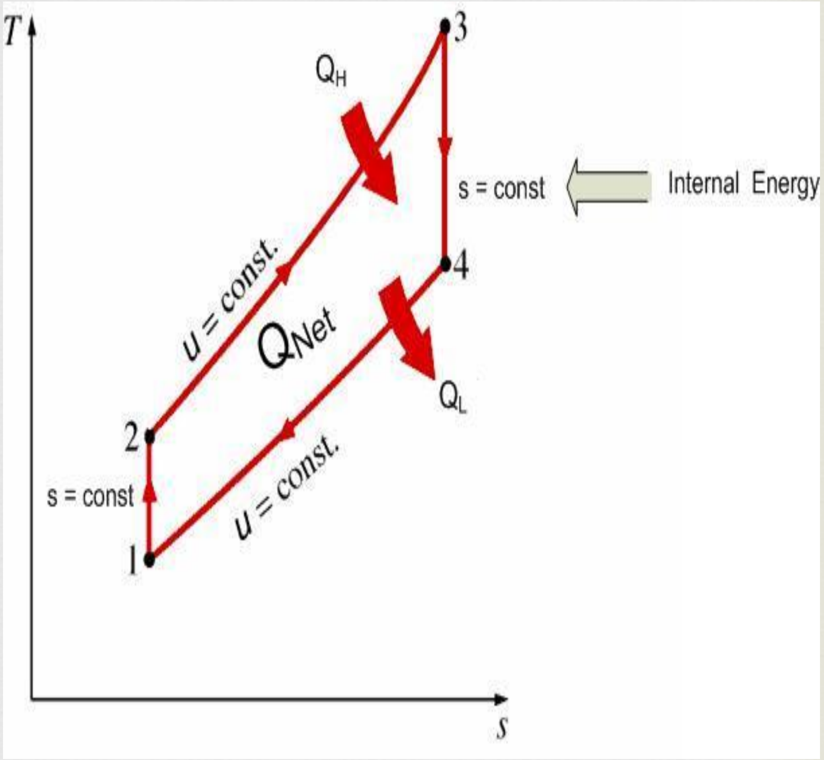
(3-4) Isentropic Expansion

- Power is delivered while s = const.

(4-1) Constant volume heat rejection process

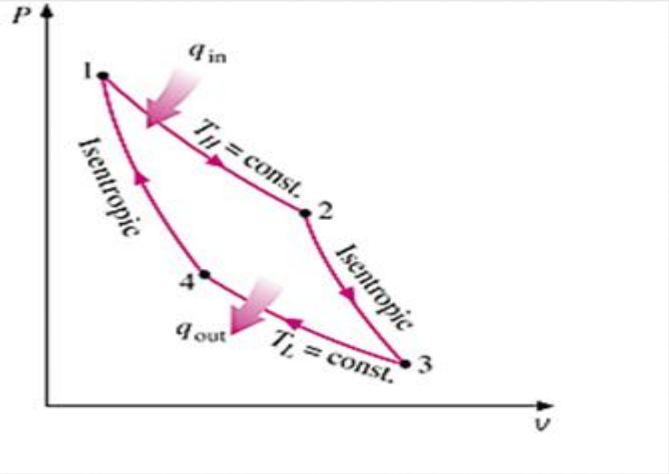
# b) Diesel cycle



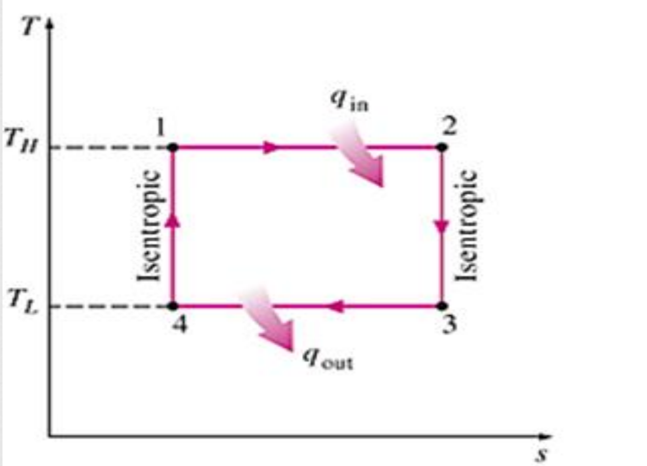




***Process 1-2:*** Isentropic compression
***Process 2-3:*** Constant pressure heat addition
***Process 3-4:*** Isentropic expansion
***Process 4-1:*** Constant volume heat rejection

# c) Carnot cycle




P-V Diagram




T-S Diagram

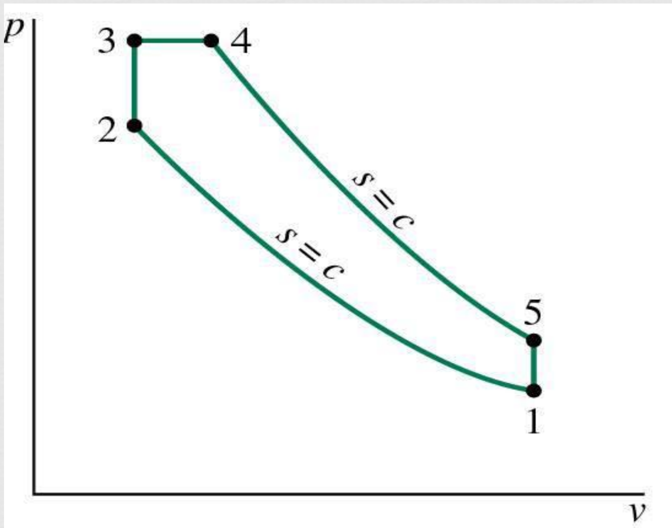
***Process 1-2*:** reversible isothermal during this air expand and heat addition at temperature T1

***Process 2-3:*** Air expand from temperature T2 to T3

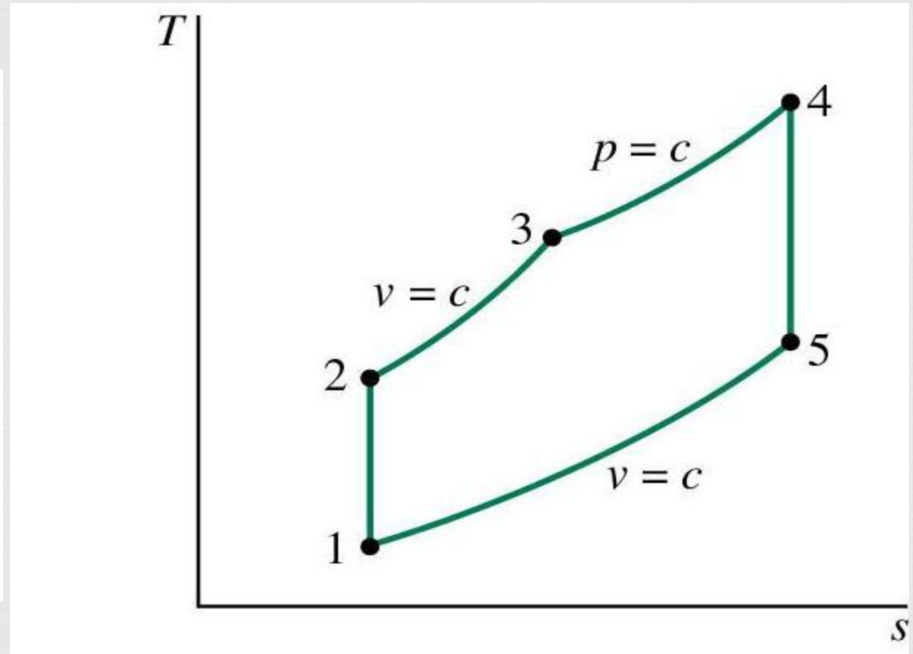
***Process 3-4*:** Air is compressed isothermally. heat is rejected during this process.

***Process 4-1:*** Air is compressed adiabatically from T4 to T1

**Dual cycle:** A more realistic ideal cycle model for modern, high-speed compression ignition engine.



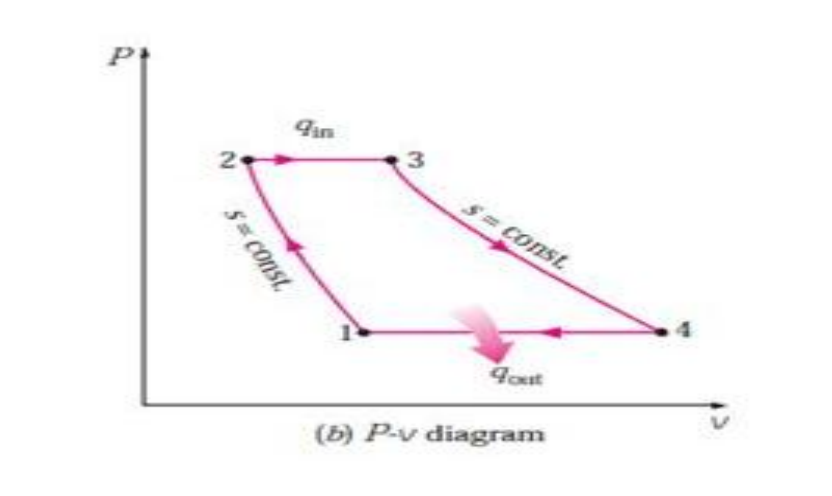

*P-v* diagram of an ideal dual cycle.

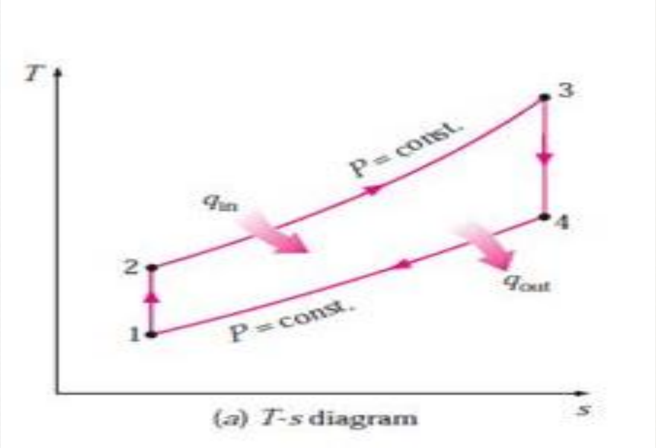



*T-s* diagram of an ideal dual cycle.

***Process 1-2:*** Isentropic compression
***Process 2-3:***Constant pressure heat addition
***Process 3-4:*** Constant volume heat addition
***Process 5-5:***Isentropic expansion
***Process 5-1:*** Constant volume heat rejection

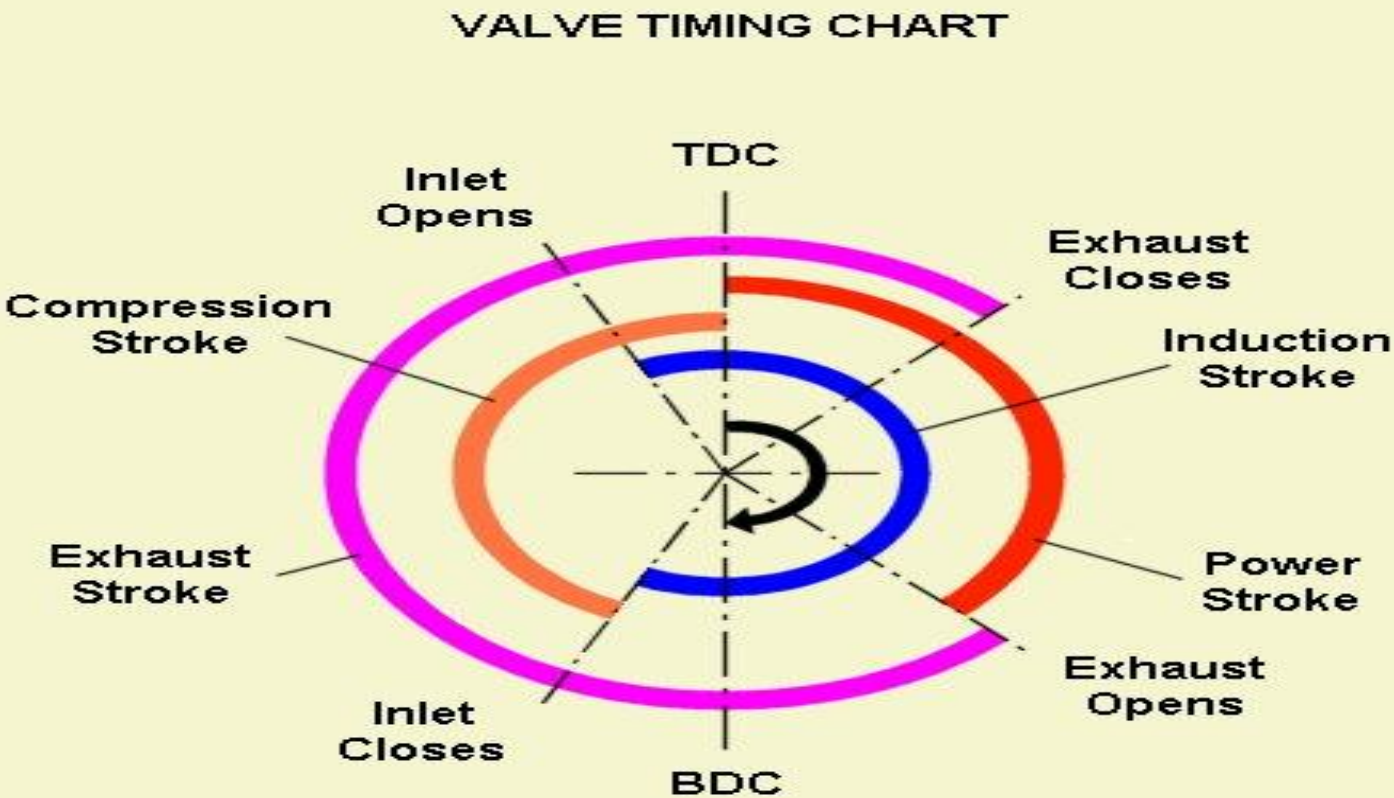
# Brayton cycle



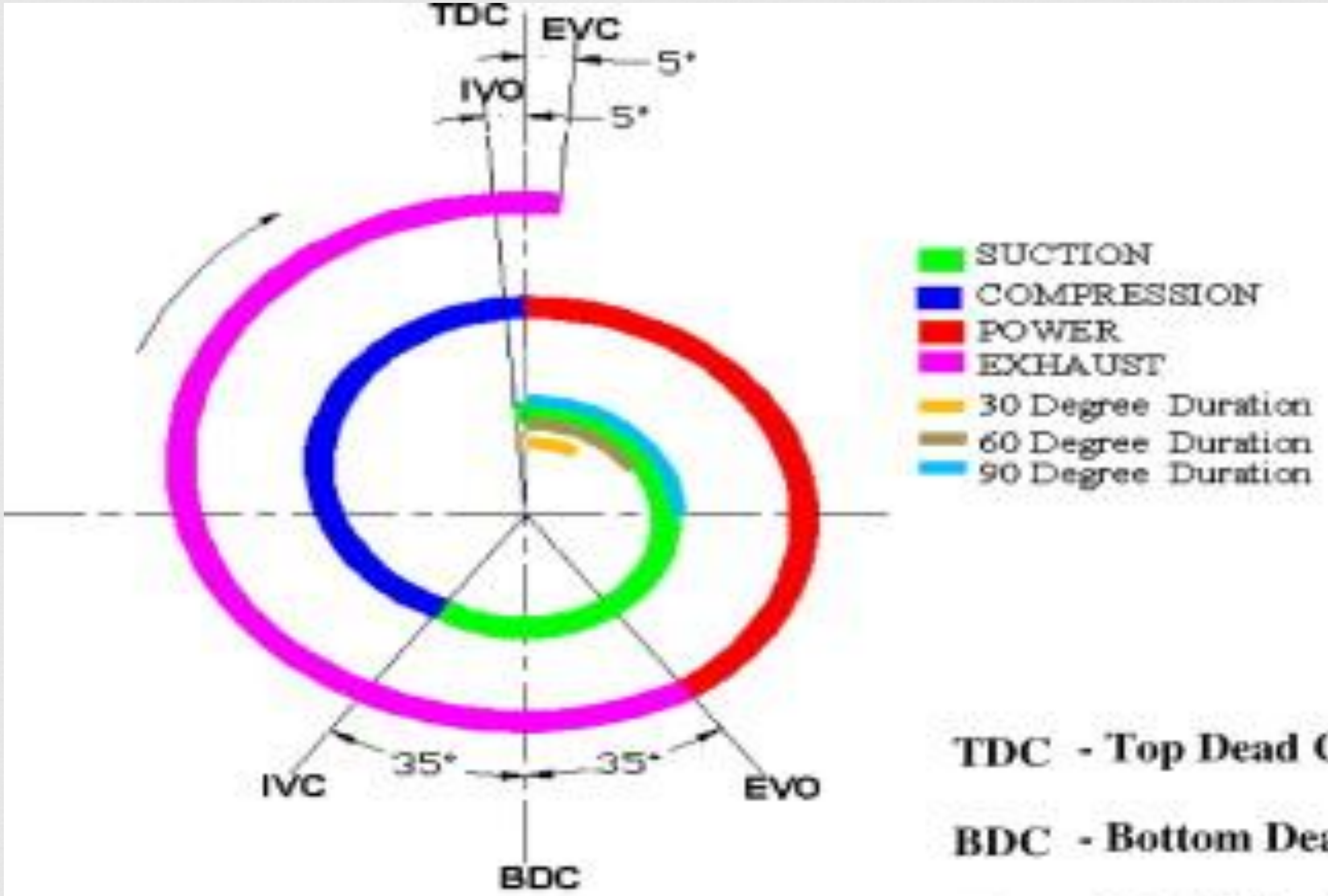




***Process 1-2:*** Isentropic compression
***Process 2-3:*** Constant pressure heat addition
***Process 3-4:*** Isentropic expansion
***Process 4-1:*** Constant pressure heat rejection

# Valve Timing diagram for 4-s SI & CI



# Valve Timing diagram for 4-s SI & CI



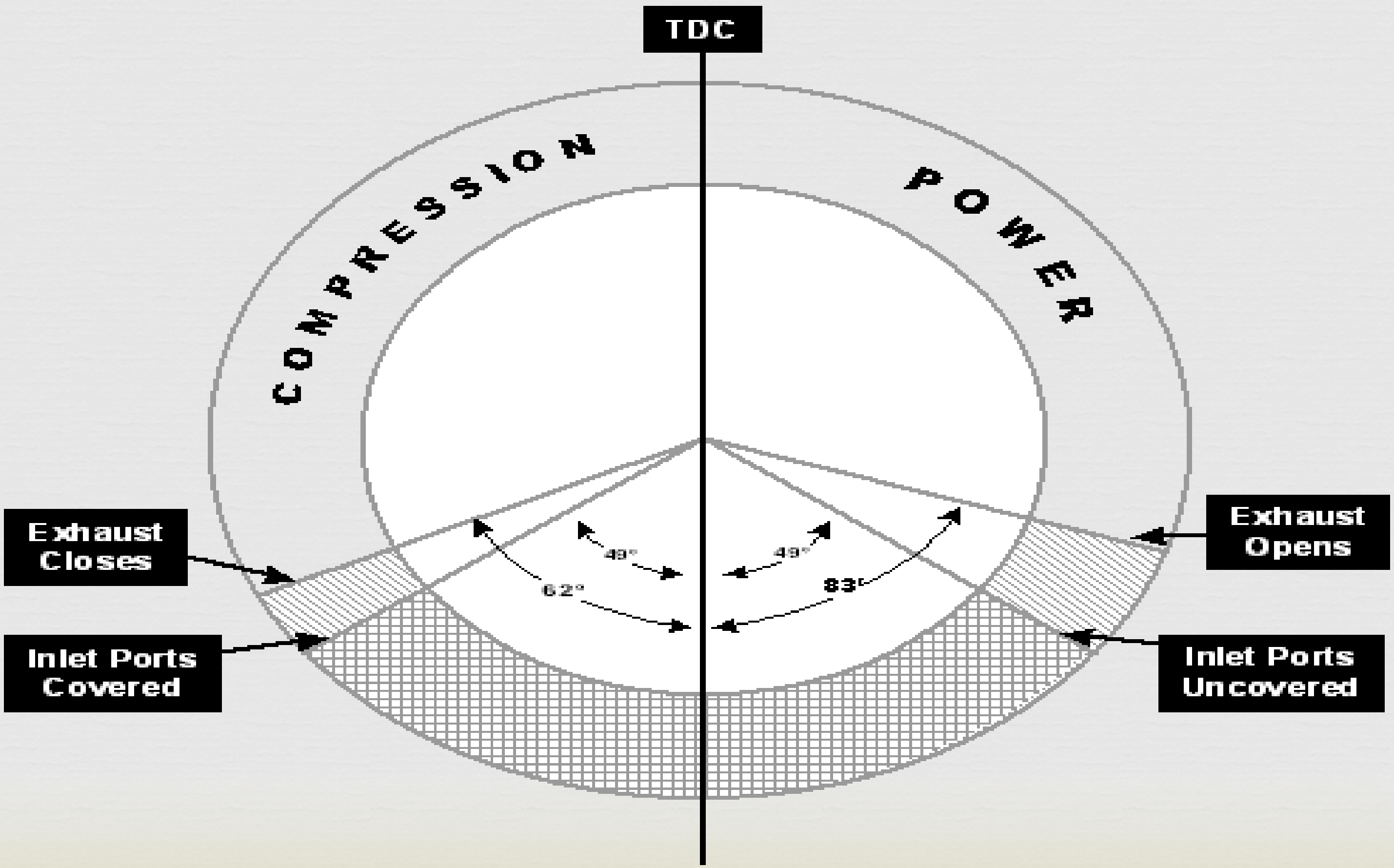

**TDC** - Top Dead Centre

**BDC** - Bottom Dead Centre

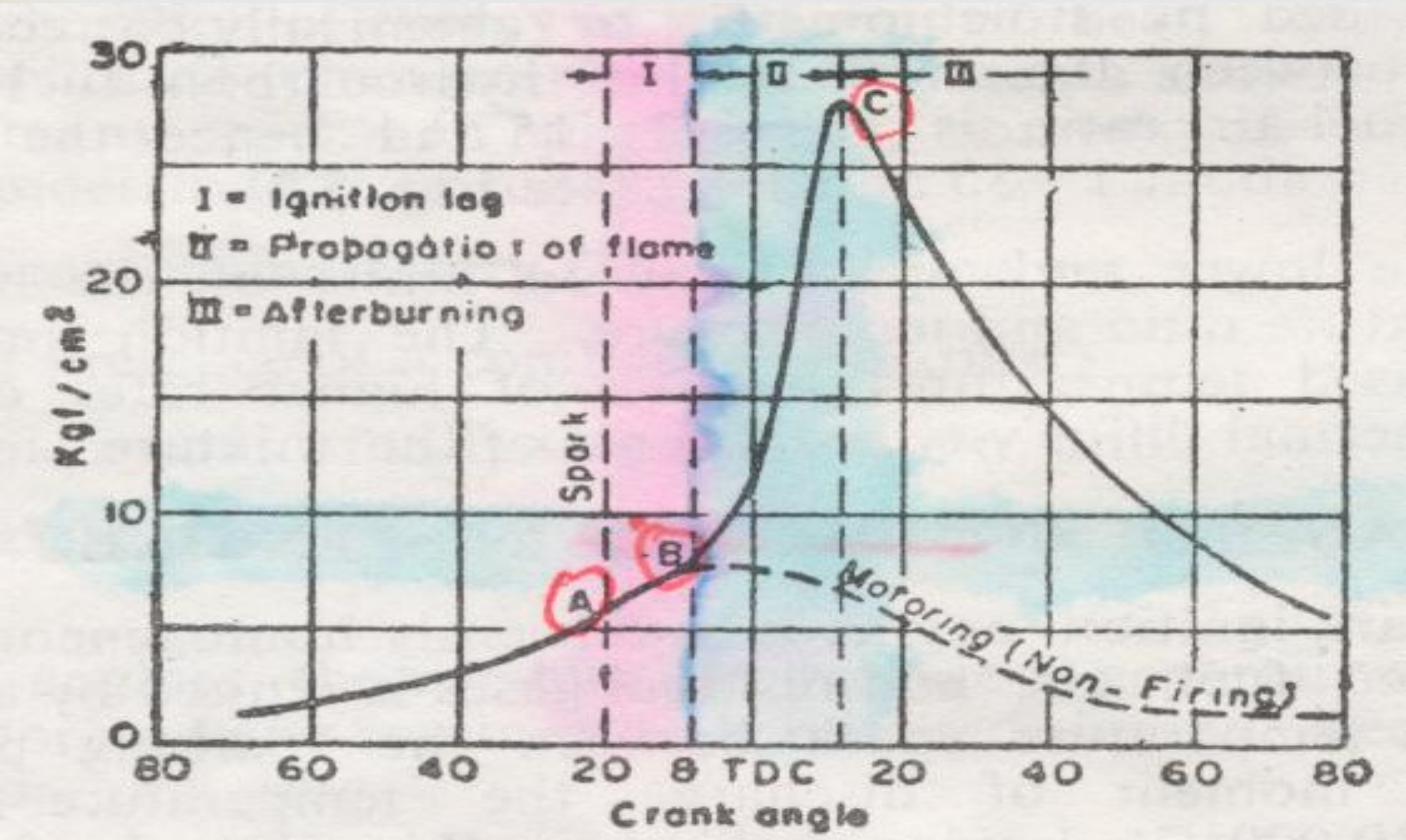
**IVO** - Inlet Valve Open

**IVC** - Inlet Valve Close

# Valve Timing diagram for 2-Stroke engine



# Stages of combustion in SI engine



# Stages of combustion in SI engine

- ***Ignition Lag***

  It is related with growth and development of a left propagating flame.

- ***Flame Propagation***

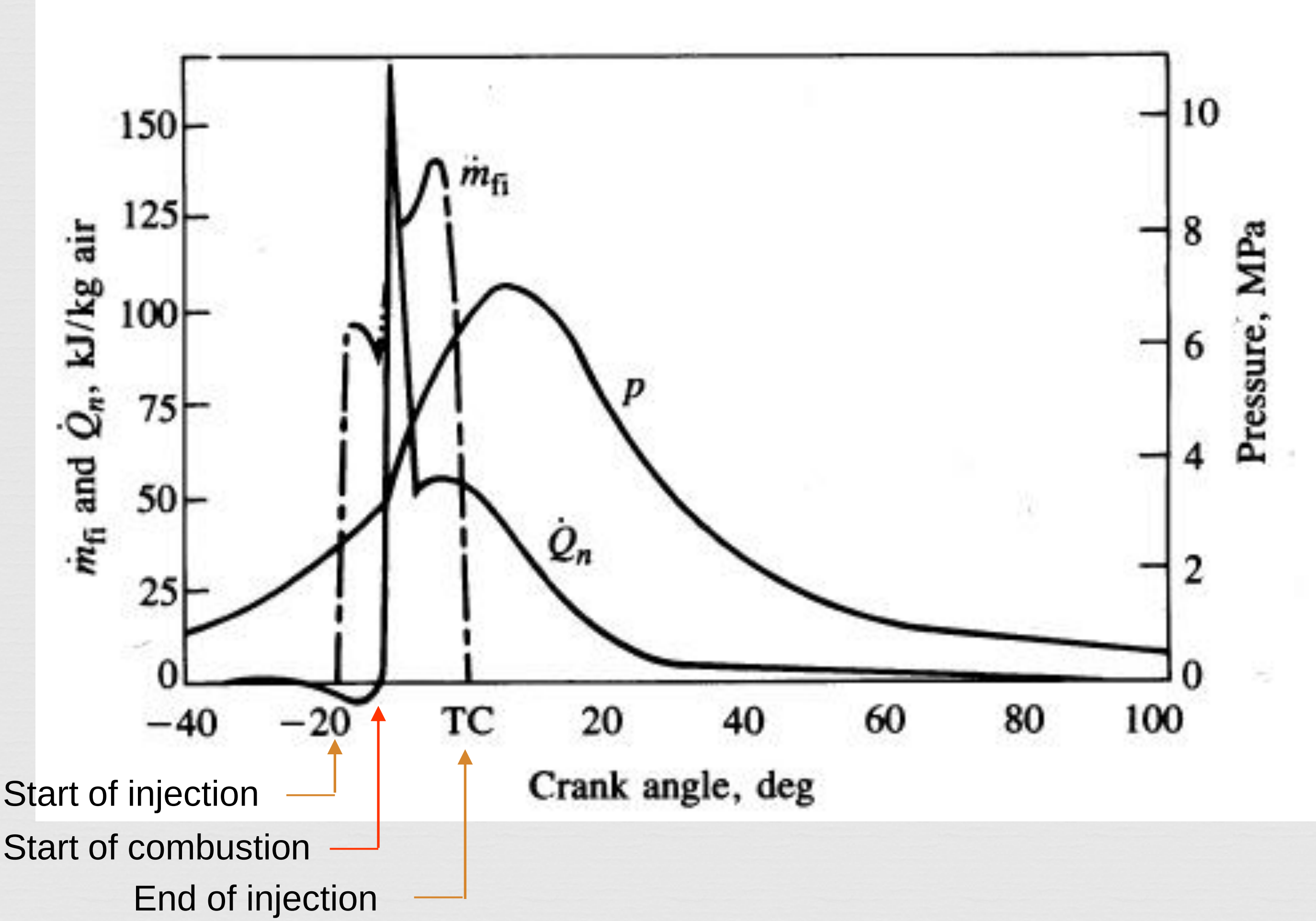
  During this the sudden pressure and temperature rise. The heat released rate is depend on turbulence intensity and reaction rate of charge.

- ***After Burning***

  This is instant at which the pressure is reached on the indicator diagram. The velocity of flame decreases so combustion rate decreases. Since the expansion stroke start before this stage.

# In Cylinder Measurements

This graph shows the fuel injection flow rate, net heat release rate and cylinder pressure for a direct injection CI engine.



# Combustion in CI Engine

The combustion process proceeds by the following stages:

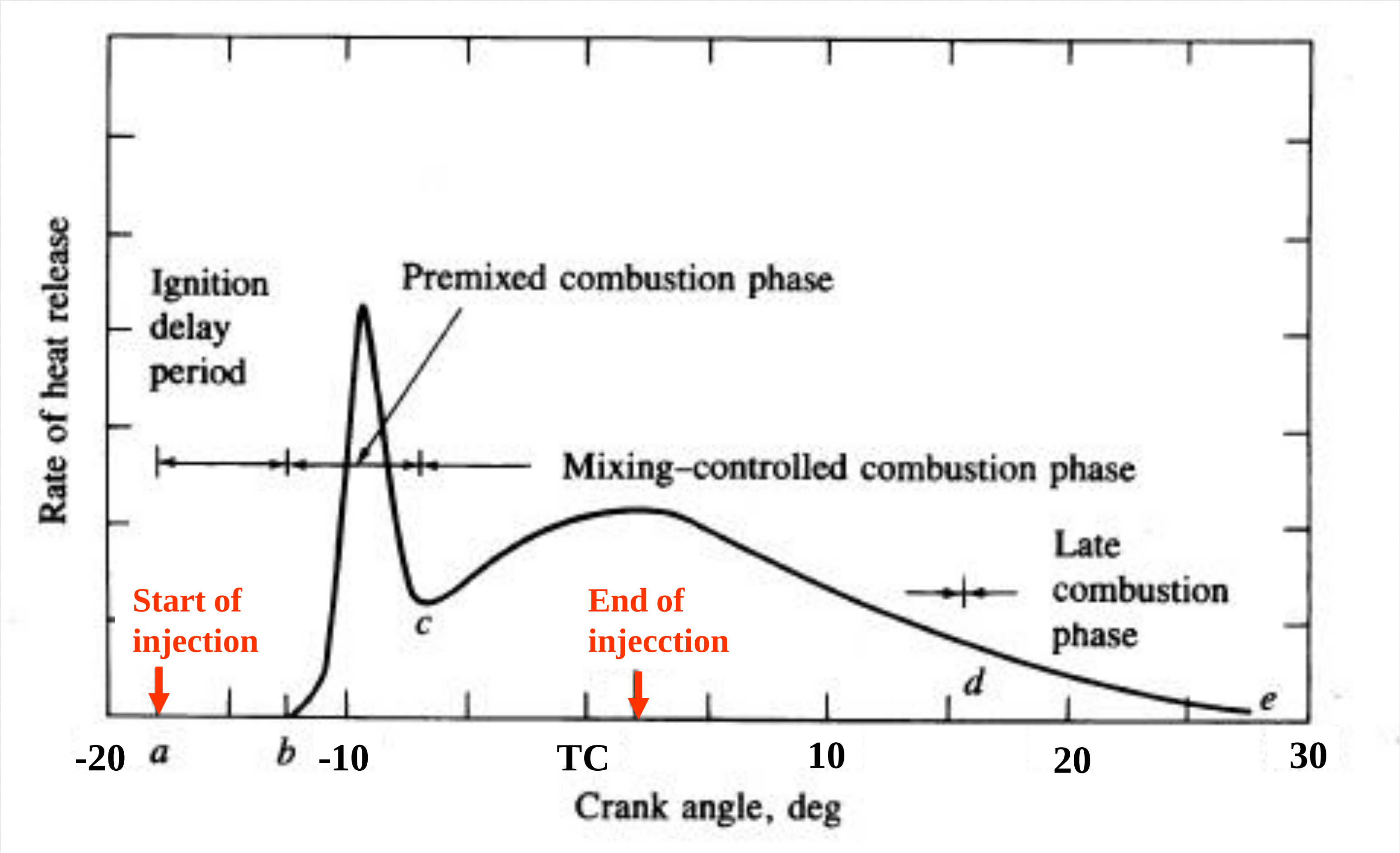
*Ignition delay (ab)* - fuel is injected directly into the cylinder towards the end of the compression stroke. The liquid fuel atomizes into small drops and penetrates into the combustion chamber. The fuel vaporizes and mixes with the high-temperature high-pressure air.

*Premixed combustion phase (bc)* – combustion of the fuel which has mixed with the air to within the flammability limits (air at high-temperature and high-pressure) during the ignition delay period occurs rapidly in a few crank angles.

*Mixing controlled combustion phase (cd)* – after premixed gas consumed, the burning rate is controlled by the rate at which mixture becomes available for burning. The rate of burning is controlled in this phase primarily by the fuel-air mixing process.

*Late combustion phase (de)* – heat release may proceed at a lower rate well into the expansion stroke (no additional fuel injected during this phase). Combustion of any unburned liquid fuel and soot is responsible for this.

# Four Stages of Combustion in CI Engines



# Scavenging

- It is the process of clearing or sweeping out the exhaust gases from the combustion chamber of the cylinder.
- It is necessary that cylinder should not have any burnt gases because they mixed with the fresh incoming charge and reduce its strength.
- Power will loss if the fresh charge is diluted by the exhaust gases.
- The scavenging is necessary only in two stroke engines since piston does not help for clearing the burned gas from the cylinder.

# Types of scavenging

- Cross flow scavenging
- Full loop or back flow scavenging
- Uniform flow scavenging

# Pre- Ignition

- In SI engine the combustion during the normal working is initiated by a electric spark.
- The spark is timed to occur at a definite point just before the end of the compression stroke.
- The ignition of the charge should not occurs before the spark is introduced in the cylinder, if the ignition start due to any other reasons when the piston is still doing its compression stroke is called as pre-ignition

# Pre-ignition occurs due to following reasons

- High compression ratio
- Overheated spark plug point
- Incandescent carbon deposit on cylinder wall.
- Overheated exhaust valve
- It may occur due to faulty timing of spark production.

# Effects of Pre-ignition

- Reduce useful work per cycle
- Increase heat losses from engine
- Reduction in the thermal efficiency
- Subjected the engine components to excessive pressure

# Detonation

- It is the indication of abnormal combustion in the engine cylinder, in normal combustion of SI engine the spark is produce just before the end of compression .
- In abnormal combustion after the combustion produced, there is rise of temperature and pressure due to the combustion of the ignited fuel which leads to propagate the flame to the remote part of the cylinder & the charge present in the remote part reaches to critical temperature

# Effects of detonation

- Noise
- Mechanical damage
- Increase heat transfer
- Pre-ignition
- Decrease in power out put

# Simple carburetor

- A carburetor's primary purpose is to produce a mixture of fuel and air to operate the engine.
- Gasoline engines cannot run on liquid gasoline.  It must be vaporized and mixed with air in the proper proportions for varying conditions.

# Carburetion

- The carburetor must create an air fuel mixture that is correct for different circumstances such as:
- Cold or hot starting
- Idling
- Part throttle
- Acceleration
- High speed operation
- Carburetors work on the principle of air pressure differences. When discussing pressure differences we will talk about

# How does it work?

- Air enters the top of the carburetor and is mixed with liquid fuel.

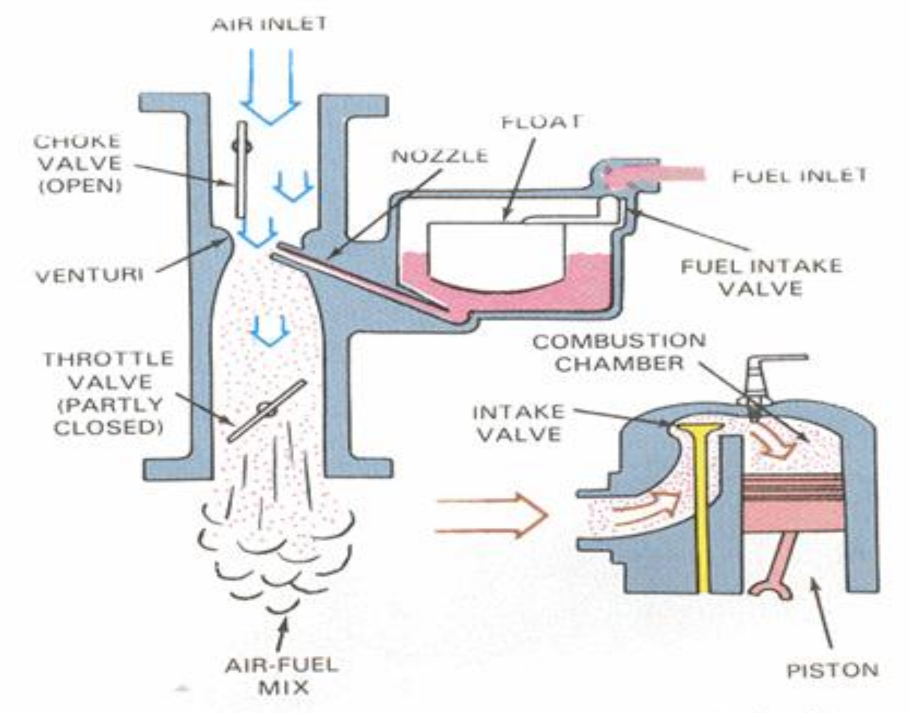


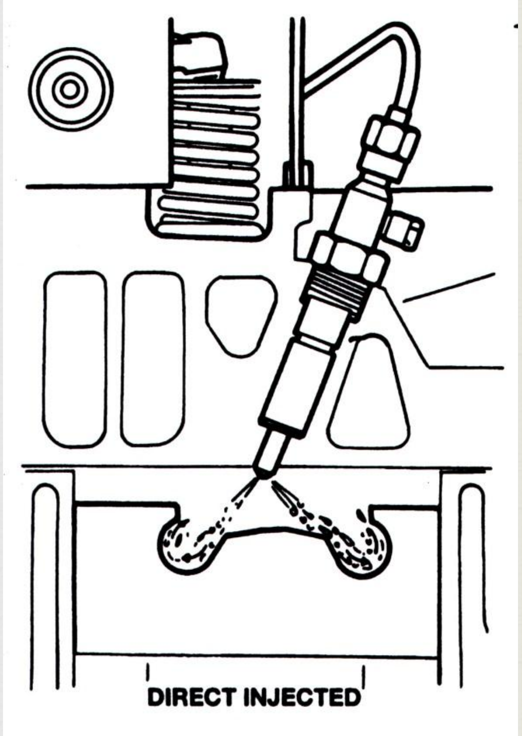

*Fig. 5-1. Air entering carburetor mixes with fuel in proper proportion, and mixture flows into combustion chamber. (Deere & Co.)*

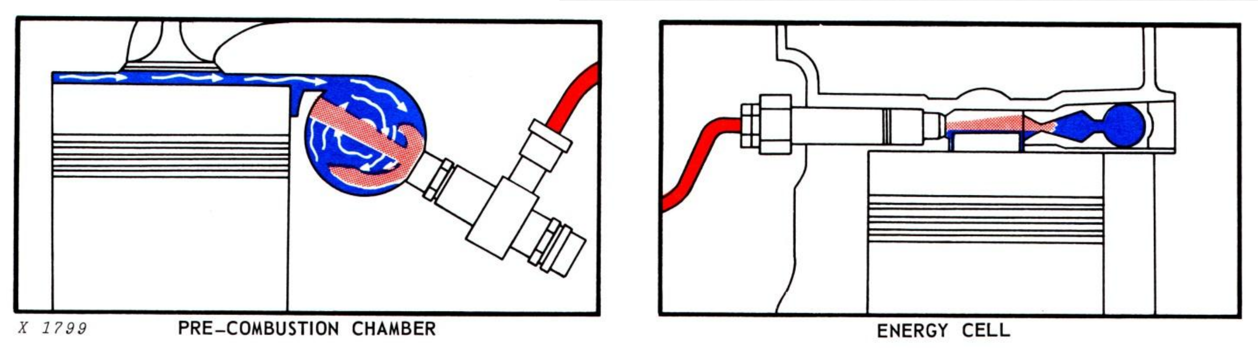
# How does it work?

- This increase in velocity reduces pressure causing fuel to be drawn into the air stream.
- Particles of fuel are vaporized by air rushing through the venturi.
- The air fuel mixture is forced into the intake manifold by atmospheric pressure and burned in the combustion chamber of the engine.
- A venturi is a restriction in an air passage that increases air speed or velocity.

# Direct Fuel Injection

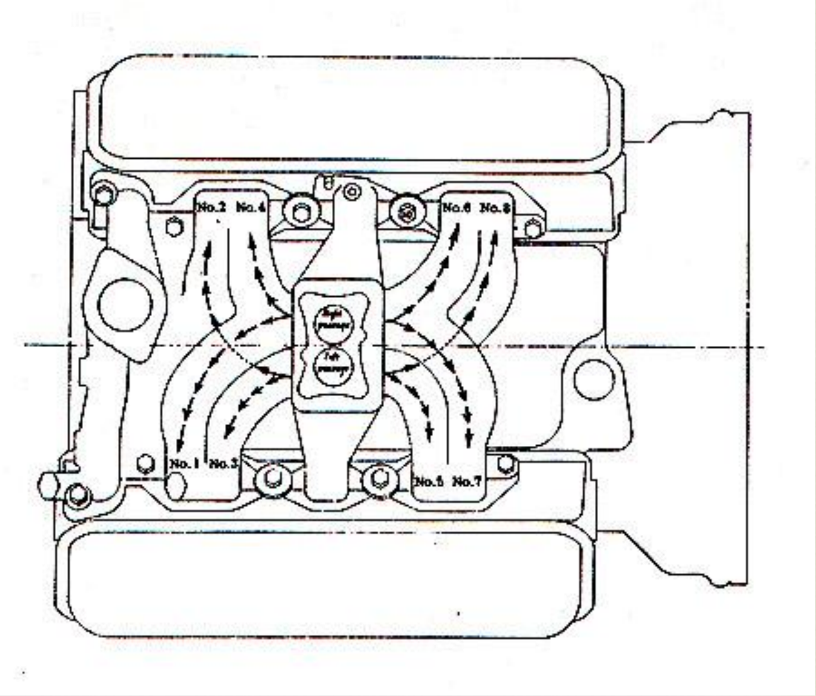
- Fuel injected directly into the combustion chamber.
- Fuel injector nozzle is also located in the combustion chamber.
- Very common in diesel engines.



# Throttle Body Fuel Injection

- Injectors are located in the throttle body.
- Throttle body is the intake cavity or intake manifold.
- The Carburetor is removed from the intake manifold and simply replaced by a fuel injection system.



# Multi-Port (Point) Fuel Injection

- Uses one injector located:
  - At the mouth of the intake valve -or-
  - At the mouth of an individual intake port that is connected to only one intake valve.
- Much more efficient
- Chrysler began this in the late 70's, Ford mid 80's, Chevy Vortex