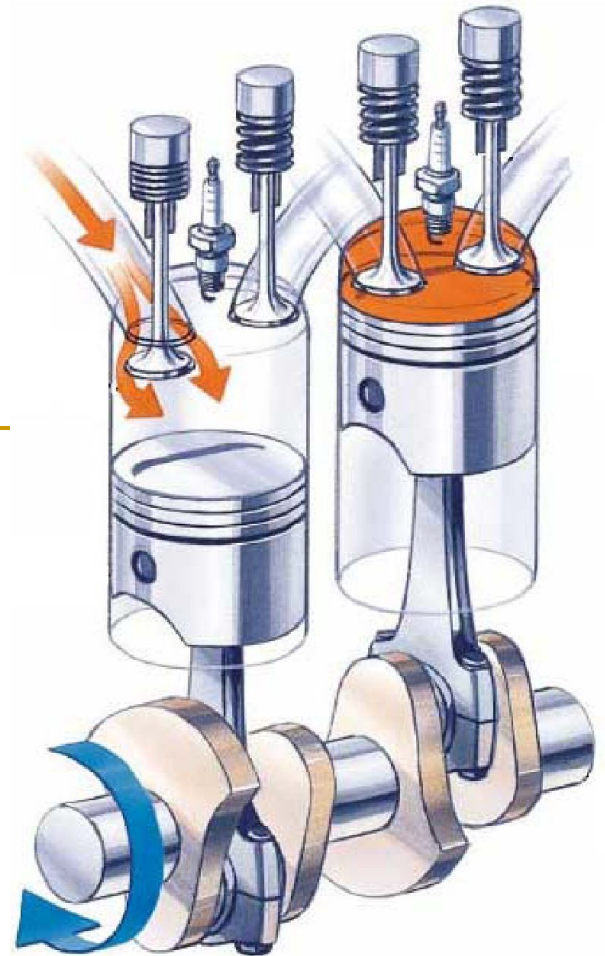


# Internal Combustion Engine

Basics, Components, Systems,  
Construction, Test and Perspectives

Aleksey Terentyev



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Post graduate course at the Izhevsk State Technical University (of ISTU)  
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Outcome: PhD degree in Technique – «Noise and Vibration of the Car»

### Position

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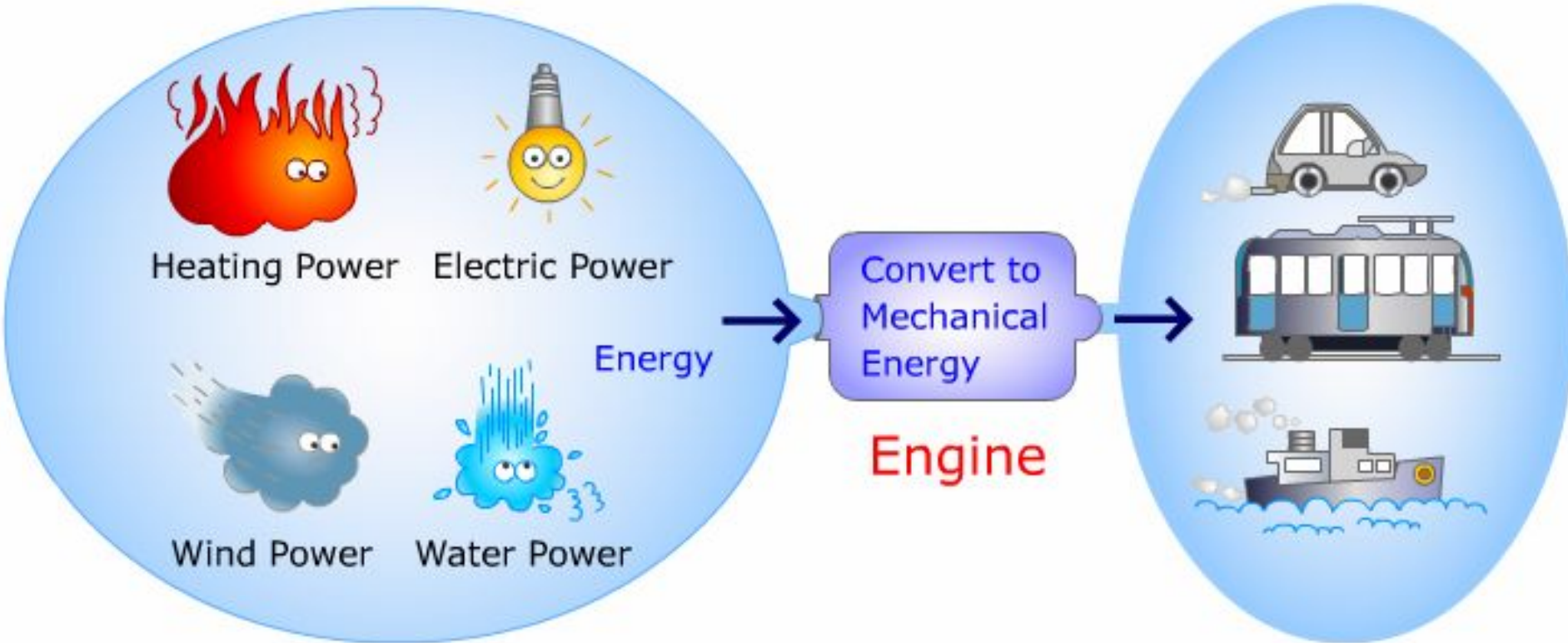
Work experience: from 1999



# What is an Engine?

**In general** An engine is a device which transforms one form of energy into another form

**In automotive** Engine is a device which transforms the chemical energy of a fuel into thermal energy and utilizes this thermal energy to perform useful work



# 1. Types of Power Plants

Heat engine can be broadly classified into two categories:

- (a) Internal Combustion Engines (an abbreviation ICE);
- (b) External Combustion Engines (an abbreviation ECE)

**Table 1.1 Classification of heat engines**

<i>Classification</i>	<i>Name of Engines</i>	<i>Reciprocating or Rotary</i>	<i>Maximum size in kW</i>	<i>Principal Use</i>
(a) Internal combustion engines	1. Gasoline or petrol engine (SI)	Reciprocating	4000	Road vehicles, small, industrial, small marine, (propulsion of ships), small aircrafts
	2. Gas engine (SI)	Reciprocating	4000	Industrial, electric power
	3. Diesel engine (CI)	Reciprocating	40,000	Road vehicles, industrial, locomotives electric power, marine
	4. Wankel engine (SI, CI)	Rotary	400	Road vehicles, small aircrafts
	5. Open cycle gas turbine	Rotary	15,000	Electric power, aircraft
	6. Jet engine	Rotary	8000	Aircraft
	7. Rocket	No mechanism	Very big	Missiles, space travel
(b) External combustion engines	1. Steam engine	Reciprocating	4000	Locomotives, ships
	2. Steam turbine	Rotary	5,00,000	Electric power, large marine
	3. Stirling or hot air engine	Reciprocating	800	Experimental, power in space, vehicles
	4. Closed cycle gas turbine	Rotary	80,000	Electric power, marine

SI = spark ignition

CI = compression ignition

# 1.1. Classification of Heat Engines

Engines whether Internal Combustion or External Combustion are of two types:

(I) Rotary engines

(II) Reciprocating engines

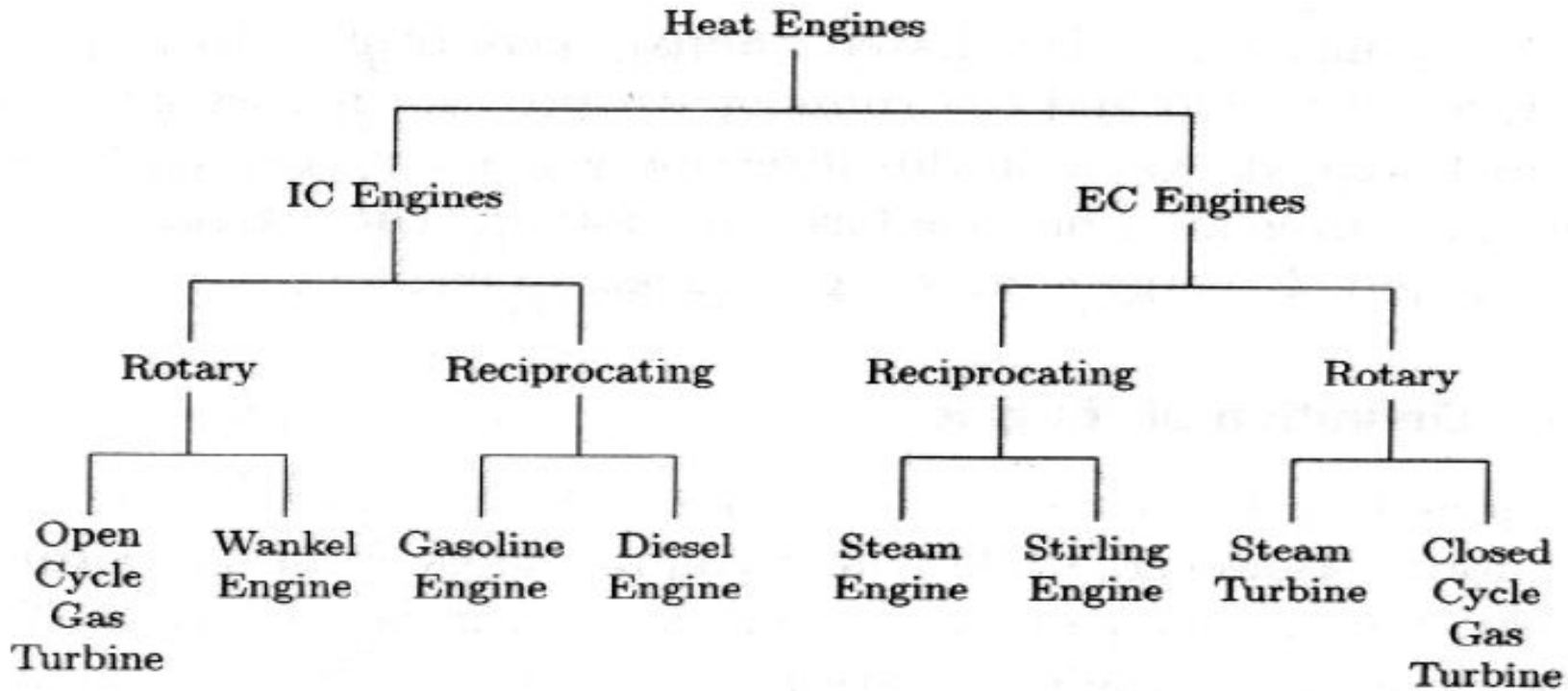


Fig.1.1  
Classification of heat engines

# 1.2. Classification of Internal combustion Engines (an abbreviation ICE)

There are many different types of internal combustion engines. They can be classified by their:

- 1. Application.** Automobile, truck, locomotive, light aircraft, marine, etc.
- 2. Basic engine design.** Reciprocating engines (in-line, V, opposed), rotary engines (Wankel)
- 3. Working cycle.** Four-stroke cycle: naturally aspirated (admitting atmospheric air), supercharged (admitting precompressed fresh mixture), and turbocharged (admitting fresh mixture compressed in a compressor driven by an exhaust turbine), two-stroke cycle: crankcase scavenged, supercharged, and turbocharged
- 4. Valve or port design and location.** Overhead (or I-head) valves, underhead (or L-head) valves, rotary valves, cross-scavenged porting (inlet and exhaust ports on opposite sides of cylinder at one end), loop-scavenged porting (inlet and exhaust ports on same side of cylinder at one end), through- or uniflowscavenged (inlet and exhaust ports or valves at different ends of cylinder)
- 5. Fuel.** Gasoline (or petrol), fuel oil (or diesel fuel), natural gas, liquid petroleum gas, alcohols (methanol, ethanol), hydrogen, dual fuel



## 1.2. Classification of Internal combustion Engines (ICE)

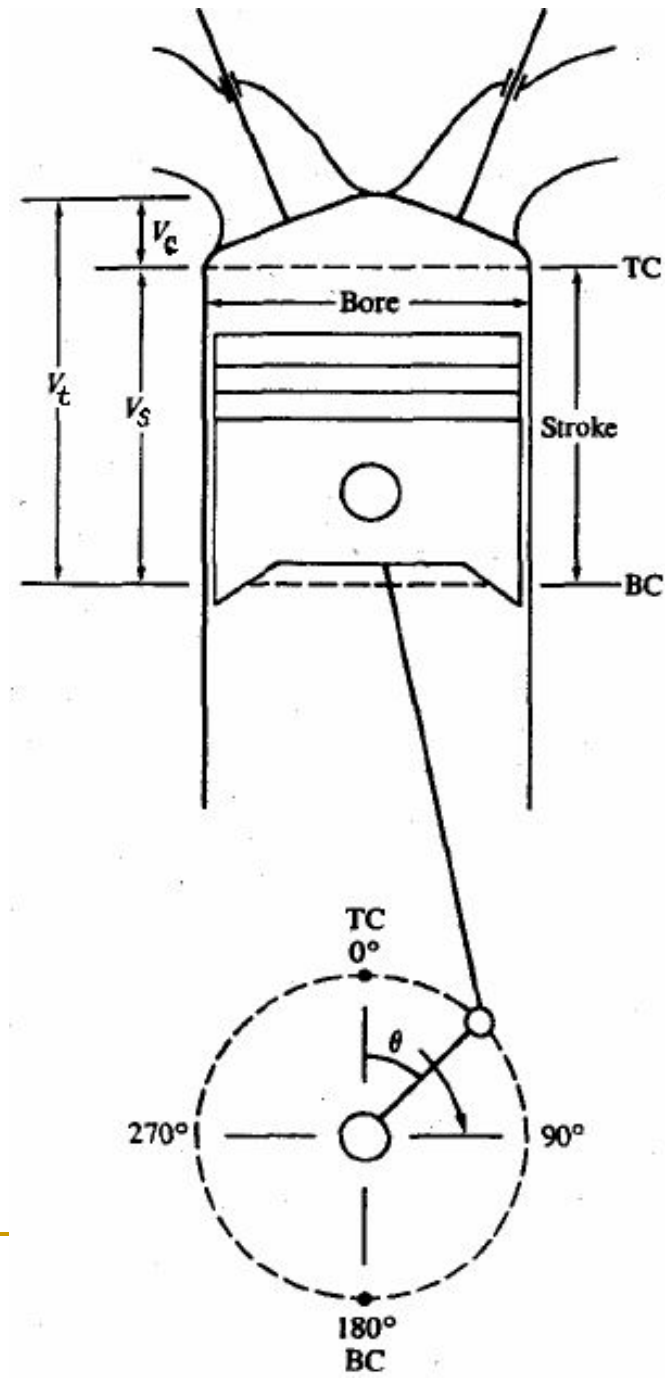
6. **Method of mixture preparation.** Carburetion, fuel injection into the intake ports or intake collector, fuel injection into the engine cylinder
7. **Method of ignition.** Spark ignition (in conventional engines where the mixture is uniform and in stratified-charge engines where the mixture is non-uniform), compression ignition (in conventional diesels, as well as ignition in gas engines by pilot injection of fuel oil)
8. **Combustion chamber design.** Open chamber (many designs: e.g., disc, wedge, hemisphere, bowl-in-piston), divided chamber (small and large auxiliary chambers; many designs: e.g., swirl chambers, prechambers)
9. **Method of load control.** Throttling of fuel and air flow together so mixture composition is essentially unchanged, control of fuel flow alone, a combination of these
10. **Method of cooling.** Water cooled, air cooled, uncooled (other than by natural convection and radiation)

All these distinctions are important and they illustrate the breadth of engine designs available.

## 2. Basic Geometry of the Reciprocating Internal Combustion Engine (an abbreviation RICE)

Bore - engine cylinder diameter,  
TC – top (dead) center,  
BC – bottom (dead) center,  
Stroke - distance between TC and BC,  
 $V_c$  – combustion chamber volume,  
 $V_s$  – swept (or working) volume,  
 $V_t$  - total cylinder volume,  
 $V_t / V_c = \epsilon = r_c$  - compression ratio

Figure 2.1 Basic Geometry of the RICE





# 3. Main Components and Principle of Operation of the Internal Combustion Engine

In reciprocating engines, the piston moves back and forth in a cylinder and transmits power through a connecting rod and crank mechanism to the drive power shaft.

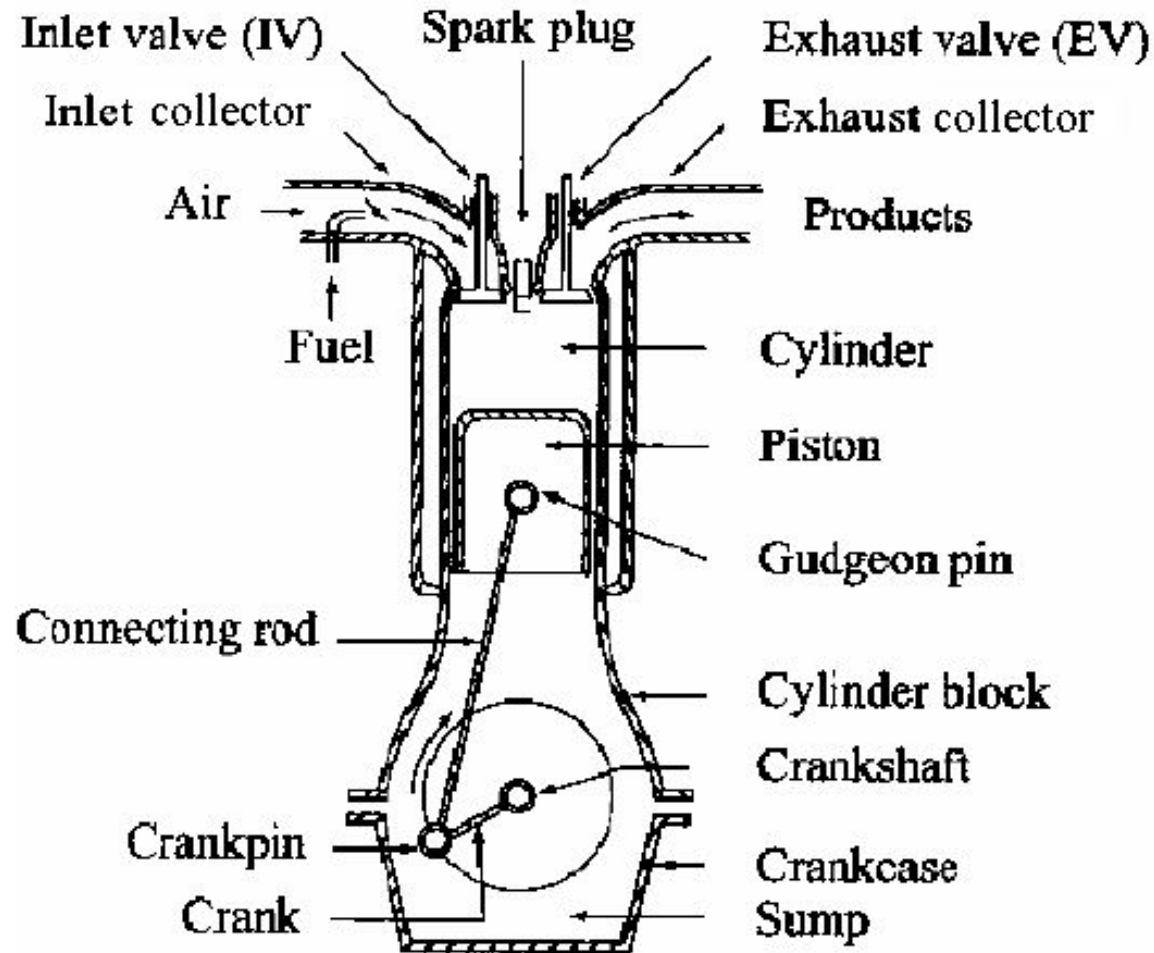
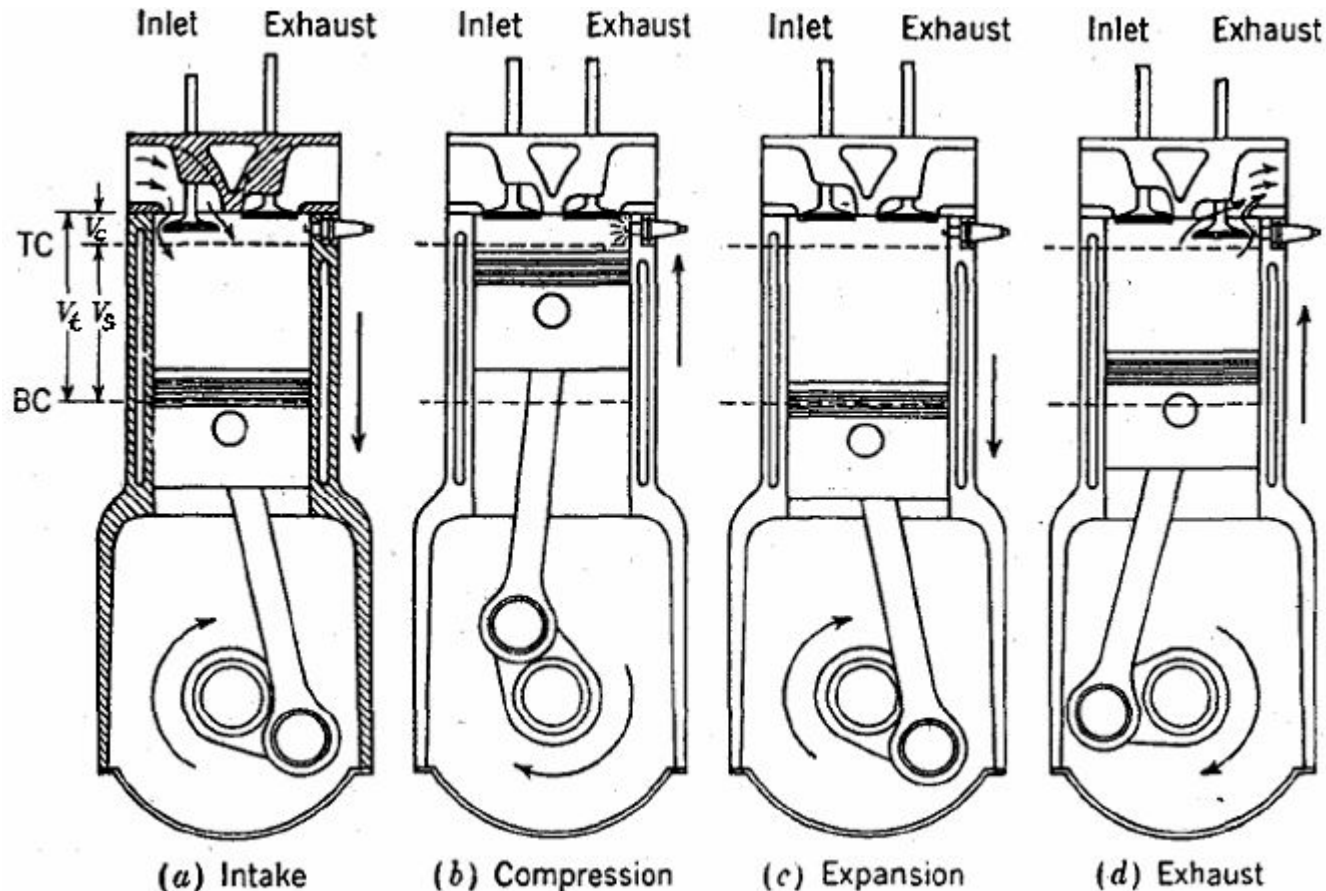


Figure 3.1 Cross section of a RICE

# 4. The Four-Stroke Petrol Engine Cycle

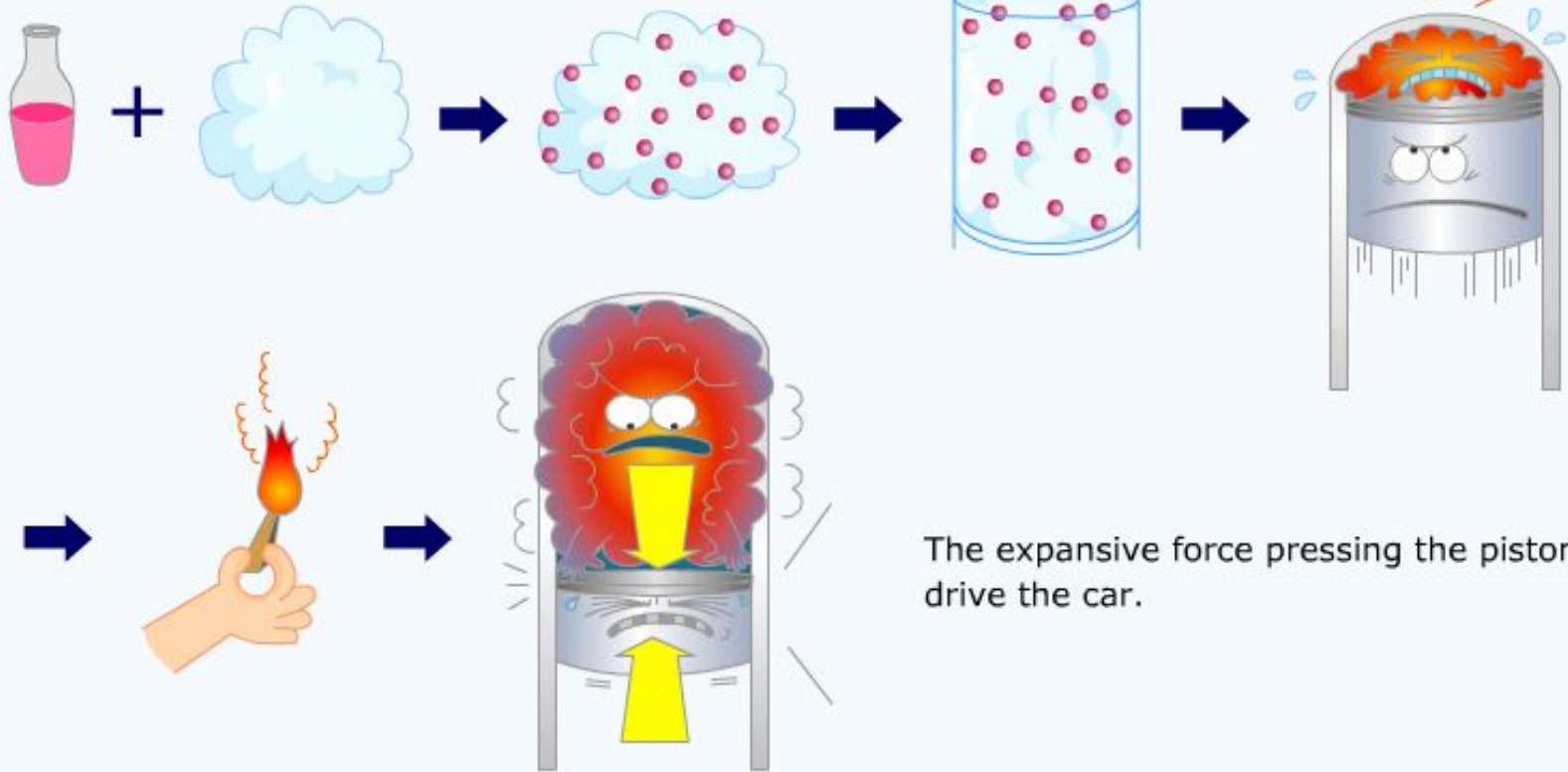
A cycle is one complete sequence of 4 strokes of the piston in the cylinder



The operating cycle of the four-stroke petrol engine includes: inlet stroke, compression stroke, power stroke, exhaust stroke.

# How does this work ?

The process is accompanied by any runtime heat engine are mixing the fuel with the air, suction the mixture into the cylinder, compression the mixture, ignition the mixture and combustion the mixture

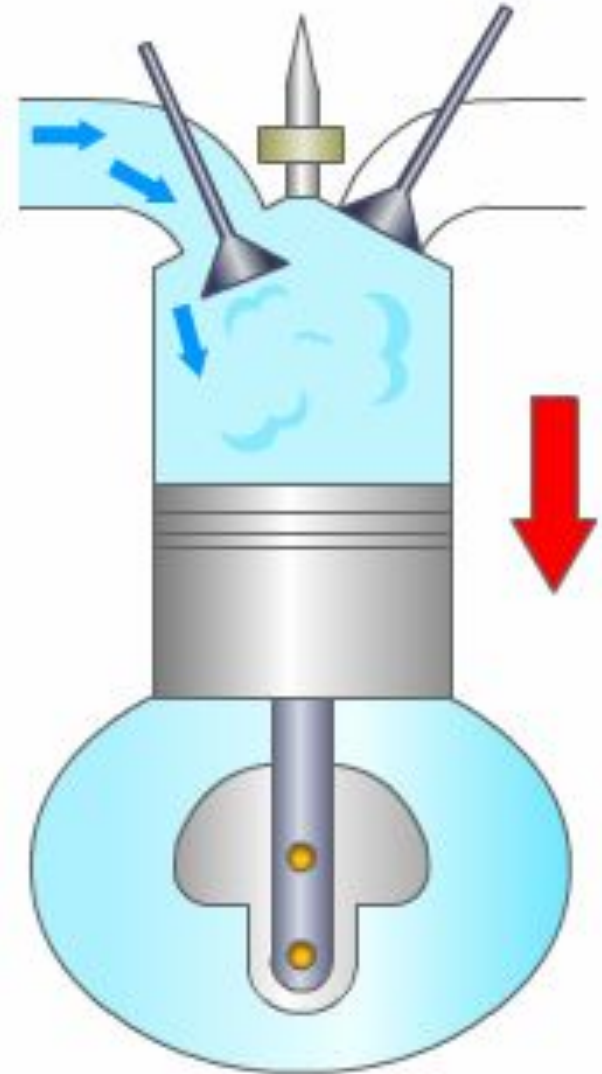


The expansive force pressing the piston shall drive the car.

## 4.1 Inlet Stroke

To describe the complete cycle, let's assume that the piston is at the top of the stroke (top dead center) and the inlet and the exhaust valves are closed.

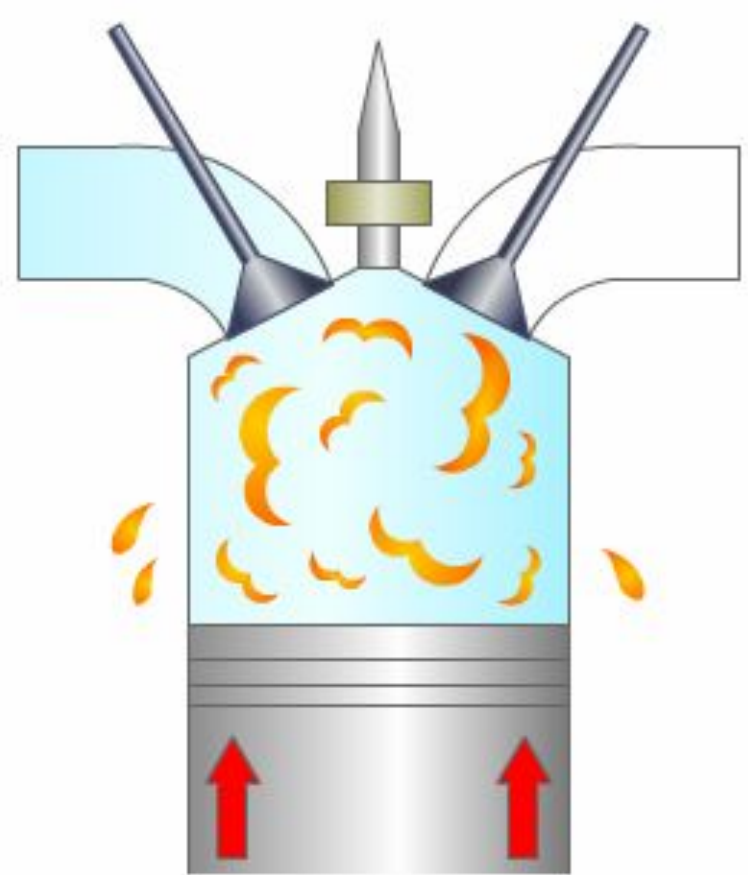
When the piston moves down the inlet valve opens to intake a charge of fuel into the cylinder



## 4.2 Compression Stroke

On reaching the lowest position (bottom dead center) the piston begins to move upward into the closed upper part of the cylinder.

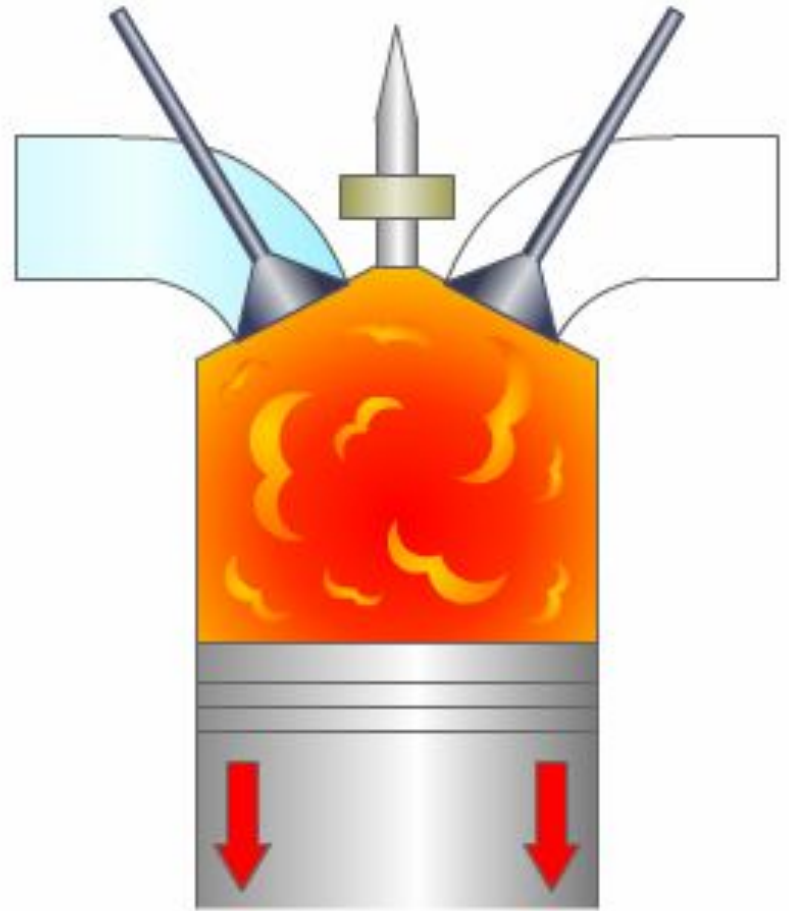
The inlet valve is closed and the mixture is compressed by the rising piston.



## 4.3 Power stroke

As the piston again reaches the top dead center the spark plugs ignite the mixture, both valves being closed during its combustion.

As a result of burning mixtures the gases expand and great pressure makes the piston move back down the cylinder

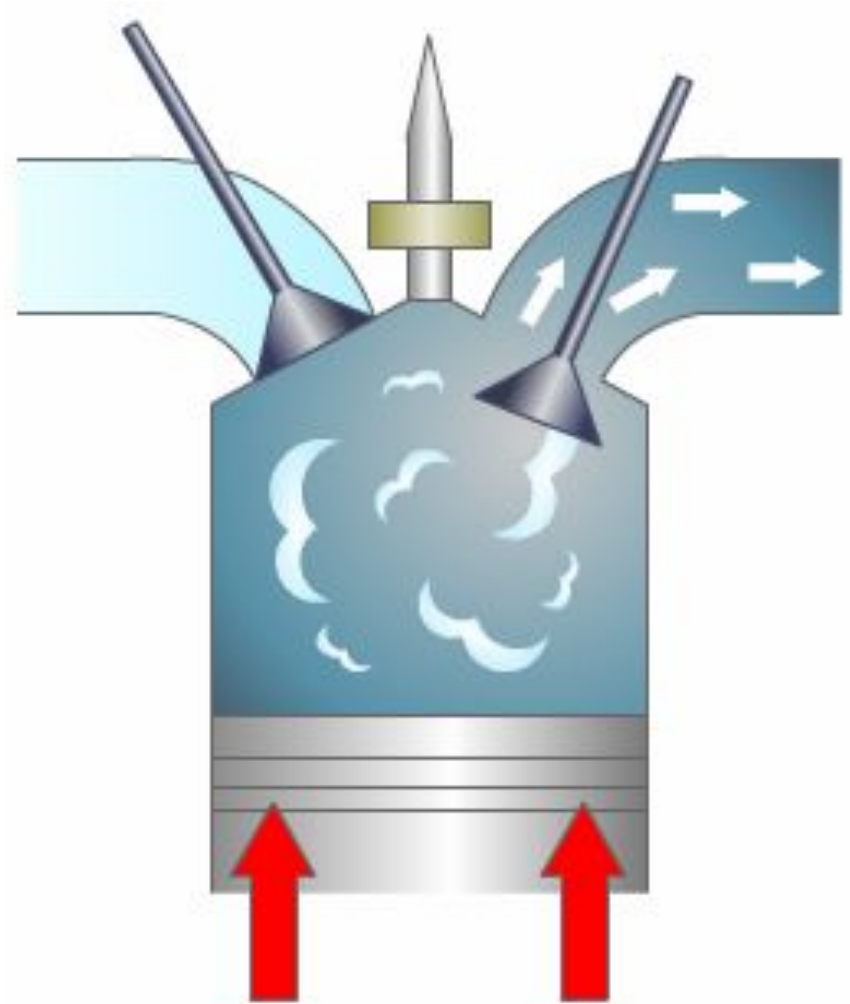




## 4.4 Exhaust stroke

When the piston reaches the bottom of its stroke, the exhaust valve is opened, pressure is released, and the piston again rises.

It lets the burnt gas flow through the exhaust valve into the atmosphere



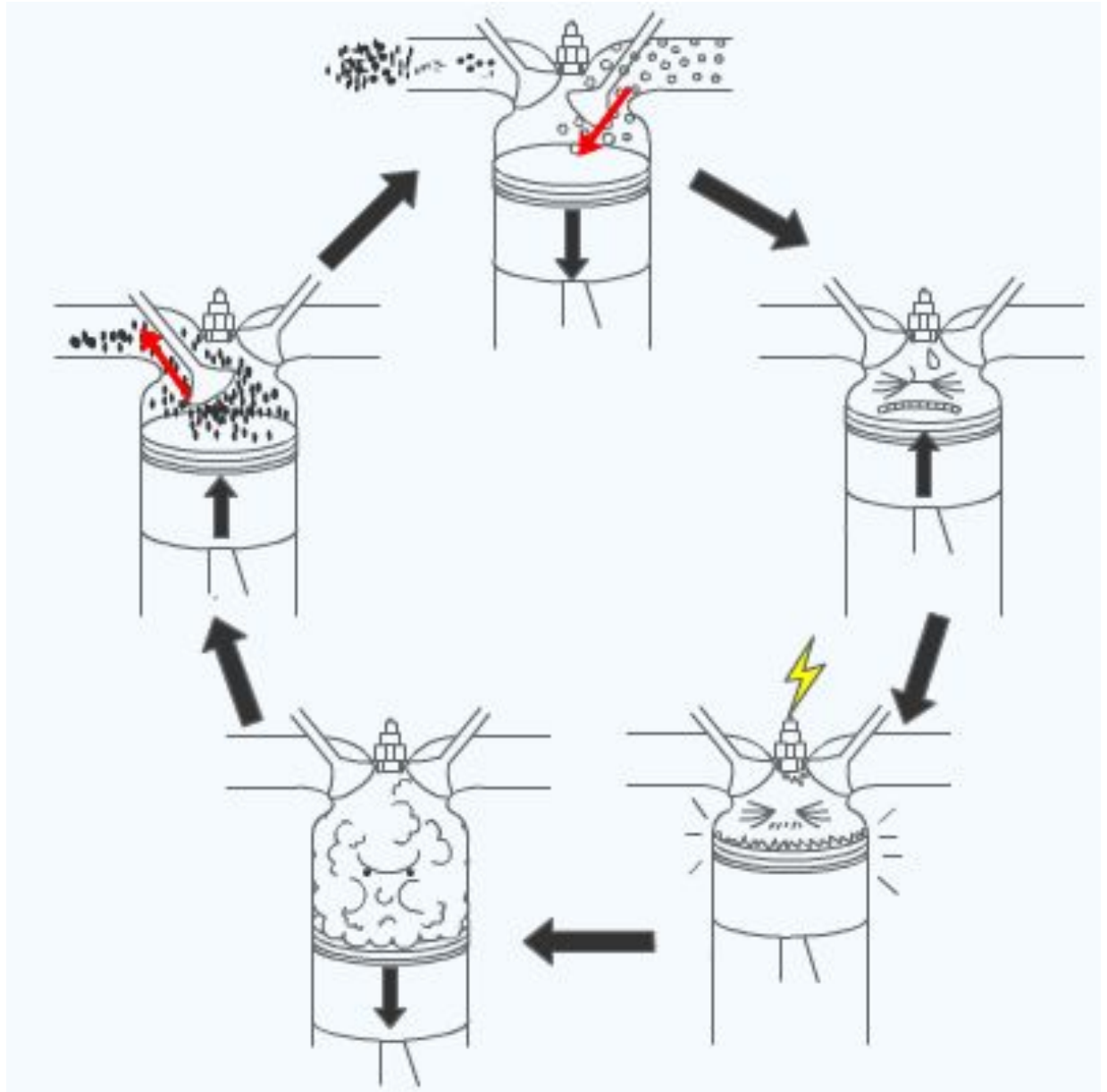
**So the piston  
moves in the  
cylinder**

**down  
(intake stroke),**

**up  
(compression  
stroke),**

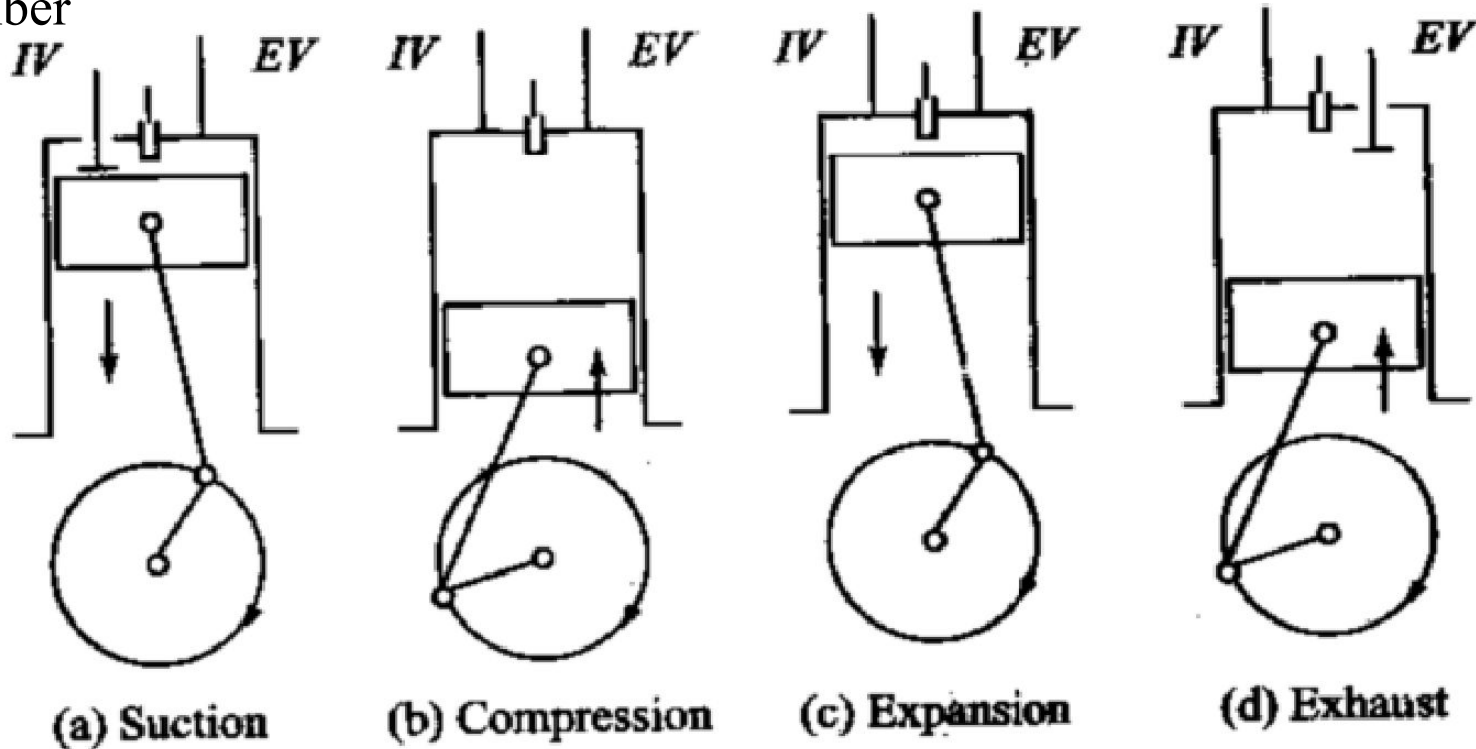
**down  
(power stroke),**

**up (exhaust stroke)  
and after the cycle is  
repeated**



# 5. Four-stroke CI Engines. Principle of operation

Due to high compression ratio, the temperature at the end of compression stroke is sufficient to ignite the fuel which is injected into the combustion chamber



The carburettor and ignition system, necessary in the SI engine, are not required in the CI engine.

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# Four-stroke CI Engines

- **1.Suction stroke**

Only air is inducted during the suction stroke. During this stroke intake valve is open and exhaust valve is closed.

- **2.Compression stroke**

Both valves remain closed during compression stroke.

- **3. Expansion or power stroke**

Fuel is injected in the beginning of the expansion stroke. The rate of injection is such that the combustion maintains the pressure constant. After the injection of fuel is over (*i.e.* after fuel cut off) the products of combustion expand. Both valves remain closed during expansion stroke.

- **4. Exhaust stroke.**

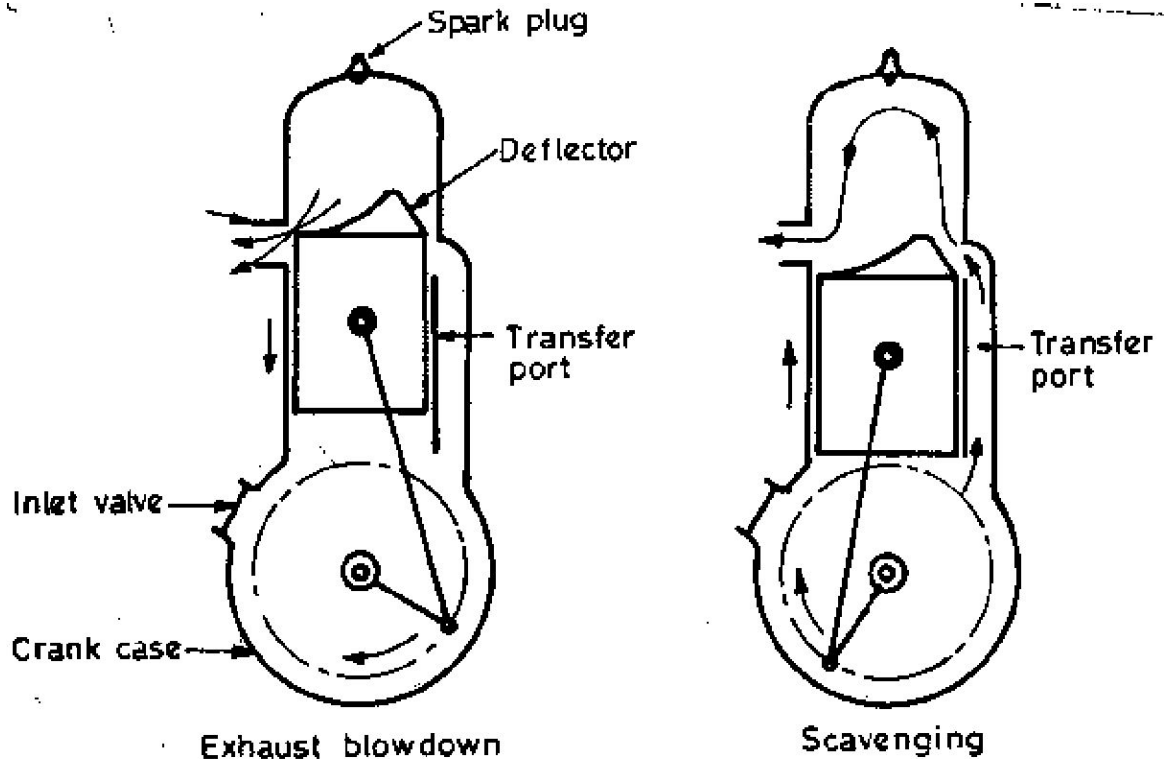
The exhaust valve is open and the intake valve remains closed in the exhaust stroke.

Due to higher pressures the CI engine is heavier than SI engine but has a higher thermal efficiency because of greater expansion. CI engines are mainly used for heavy transport vehicles, power generation, and industrial and marine applications.

## 6. Two-stroke Cycle Engines – Principle of operation

In two-stroke engines the cycle is completed in two strokes, that is, one revolution of the crankshaft as against two revolutions of four-stroke cycle. The difference between two-stroke and four-stroke engines is in the method of filling the cylinder with the fresh charge and removing the burned gases from the cylinder.

Figure shows the simplest type of two-stroke engine – the crankcase scavenged engine.



# Two-Stroke Cycle

The air or charge is sucked through spring-loaded inlet valve when the pressure in the crankcase reduces due to upward motion of the piston during compression stroke.

After the compression, ignition and expansion takes place in the usual way: during the expansion stroke the air in the crankcase is compressed. Near the end of expansion stroke piston uncovers the exhaust port, and the cylinder pressure drops to atmospheric as the combustion products leave the cylinder.

Further motion of the piston uncovers transfer ports, permitting the slightly compressed air or mixture in the crankcase to enter the engine cylinder. The top of the piston sometimes has a projection to deflect the fresh air to sweep up to the top of the cylinder before flowing to the exhaust ports. This serves the double purpose of scavenging the upper part of the cylinder of combustion products and preventing the fresh charge from flowing directly to the exhaust ports. The same objective can be achieved without piston deflector by proper shaping of the transfer port.

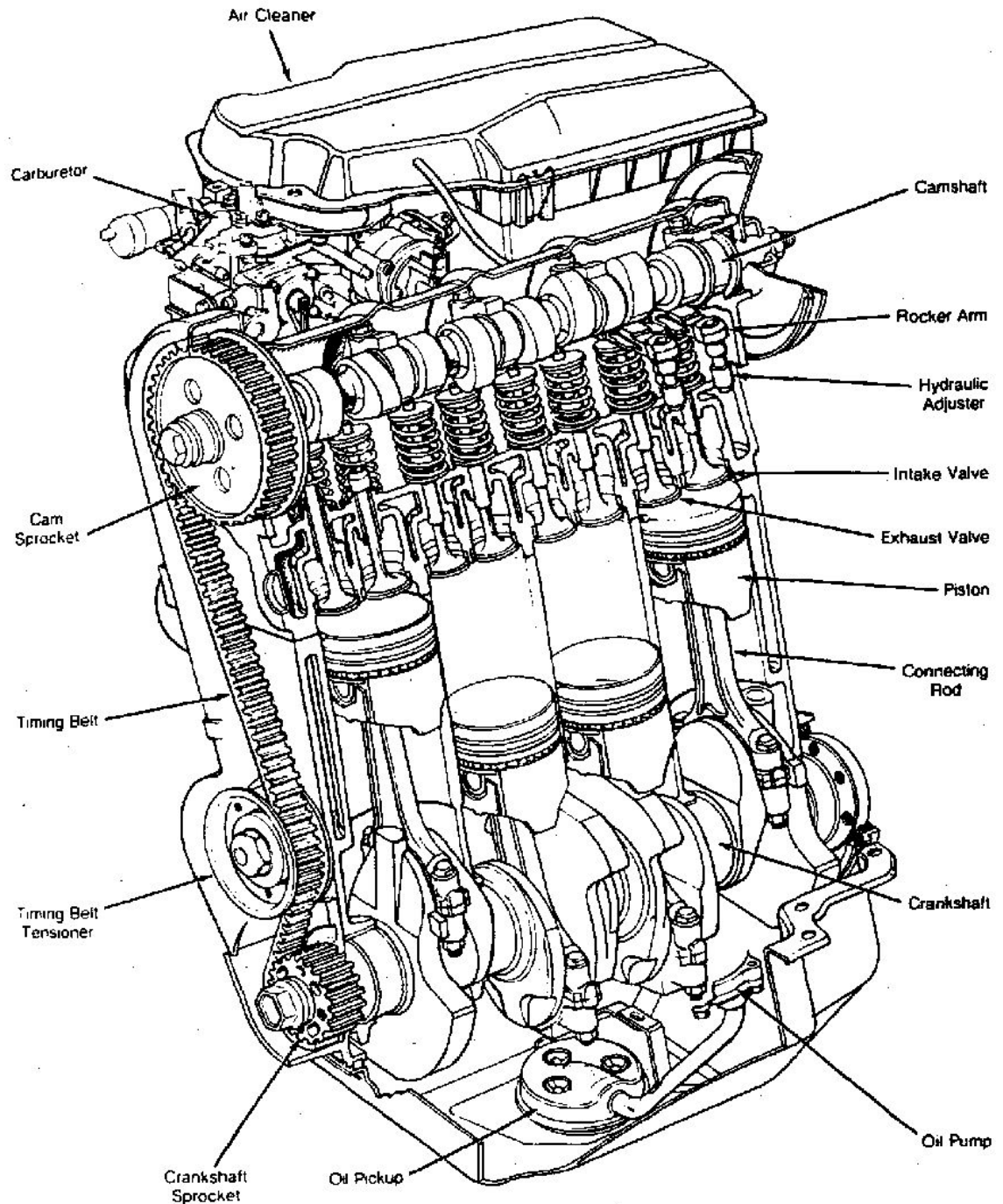
During the upward motion of the piston from bottom dead centre, the transfer ports and then the exhaust port close and compression of the charge begins and the cycle is repeated.



# 7. SI Engine Components

Labeled cutaway drawings of a four-stroke SI engine shown in Figure.

The spark-ignition engine is a four cylinder in-line automobile engine.



# 8. CI Engine Components

Labeled cutaway drawings of a two-stroke CI engine shown in Figure.

The diesel is a large V eight-cylinder with a uniflow scavenging process.

