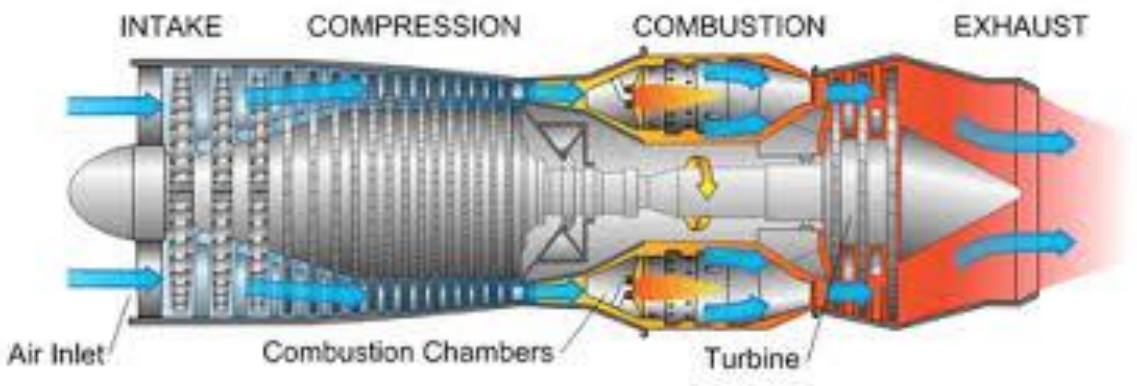
TIKRIT UNIVERSITY

COLLEGE OF ENGINEERING

MECHNICAL DEPARTMENT

INTERNAL COMBUSTION ENGINE



Course Instructor: Assist. Prof. Dr. Khalaf I. Hamada

Academic year: 2024-2024

- **Teaching scheme**: 2 hours lecture and 1 hour tutorial per week Credits: 2.5 per Semester
- **Course description**: This course studies the fundamentals of how the design and operation of internal combustion engines affect their performance, operation, fuel requirements, and environmental impact. Topics include fluid flow, thermodynamics, combustion, heat transfer and friction phenomena, and fuel properties, with reference to engine power, efficiency, and emissions. Students examine the design features and operating characteristics of different types of internal combustion engines: spark-ignition, compression-ignition, four-stroke, and two-stroke engines. Class includes lab experiments in the IC Engines Laboratory.
- **Objective**:

- To get familiar with the fundamentals of IC engines, construction and working principle of an engine, and testing of an engine for analysing its performance.;
- To study the combustion and its controlling factors in order to design efficient engine;
- To study emissions from IC engines and its controlling methods, various emission norms.

- **Course Assessment and Grading Policy**:

Term Tests (at least two tests per semester)	Laboratory	Quizzes, Homework and Assignments	Final Exam
25%	15%	10%	50%

Course Syllabus: *Notes that these are for whole academic year*

Chapter One: Basic Definitions, Components and Classifications of ICEs

Chapter Two: Engine Design and Performance Parameters

Chapter Three: Air Standard Cycles and their Analysis

Chapter Four: Fuel Air and Actual Cycles and their Analyses

Chapter Five: Fuel Chemistry and Combustion Analysis

Chapter Six: Internal Combustion Engine Systems

Chapter Seven: Combustion in SI and CI Engines

Chapter Eight: Engine Testing and Basic Measurement

Chapter Nine: Engine Power Boosting (Super- and Turbo-charging)

Chapter Ten: Air Pollution & Emission Control

TEXT BOOK: Heywood, J. B. *Internal Combustion Engine Fundamentals*. New York, NY: McGraw-Hill, 1988. ISBN: 9780070286375.

Chapter One

Basic Definitions, Components and Classifications of ICEs

Introduction

Engine: Device which converts one form of energy into Mechanical energy. For e.g.

- **Heat Engines:** convert chemical energy of fuel into thermal energy which is utilized into useful work (Fig. a)
- **Electric motor:** Convert Electrical energy into Mechanical energy (Fig. b)

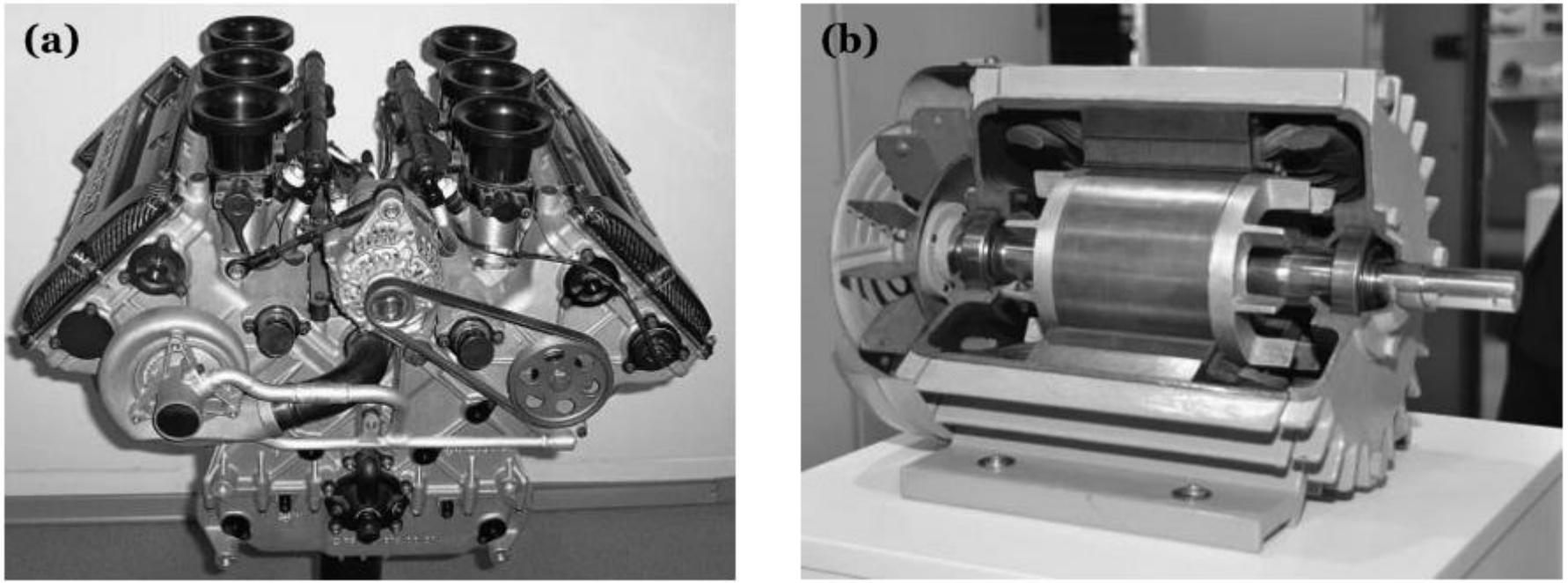
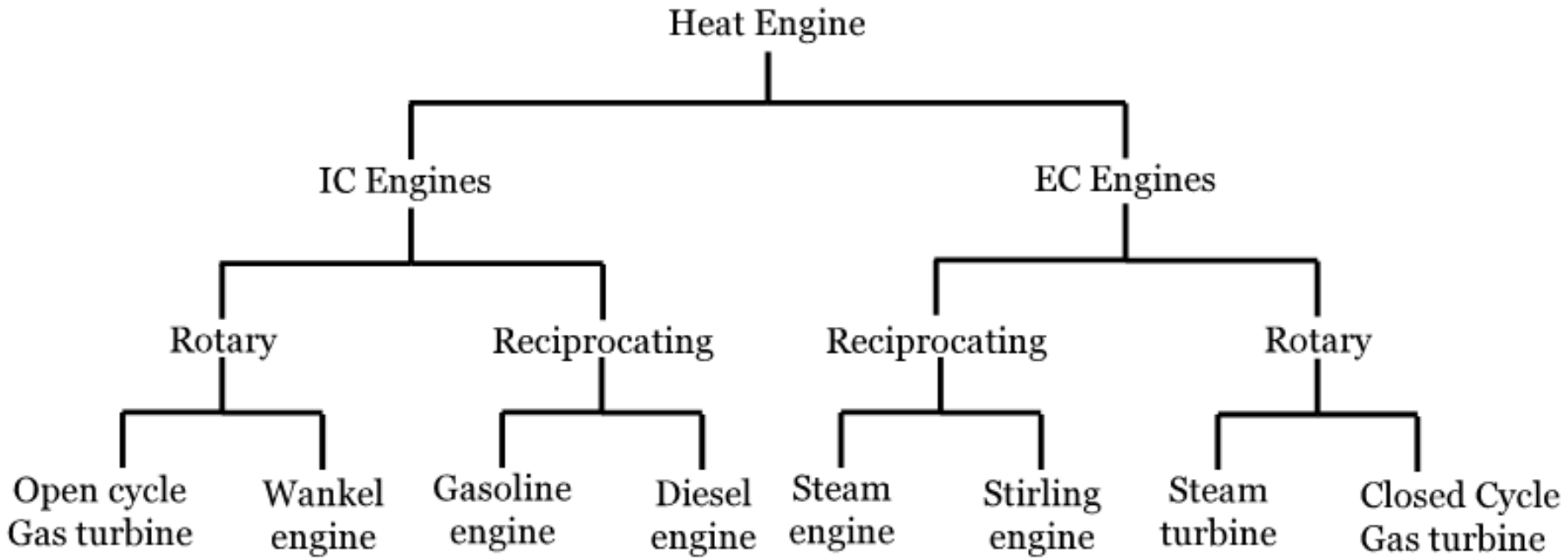


Figure : (a) V6 internal combustion engine from a Mercedes-Benz, (b) Electric motor

What happen in Heat Engine?

- In heat engines, chemical energy of fuel is first converted into heat by combustion.
- Intense heat produced during combustion increases the pressure and temperature of working fluid.
- Heat is then converted into mechanical energy with the help of a working fluid.
- Working fluid then expands resulting in mechanical work.
- Working fluid can be either liquid or gas.

Classification of Heat Engine

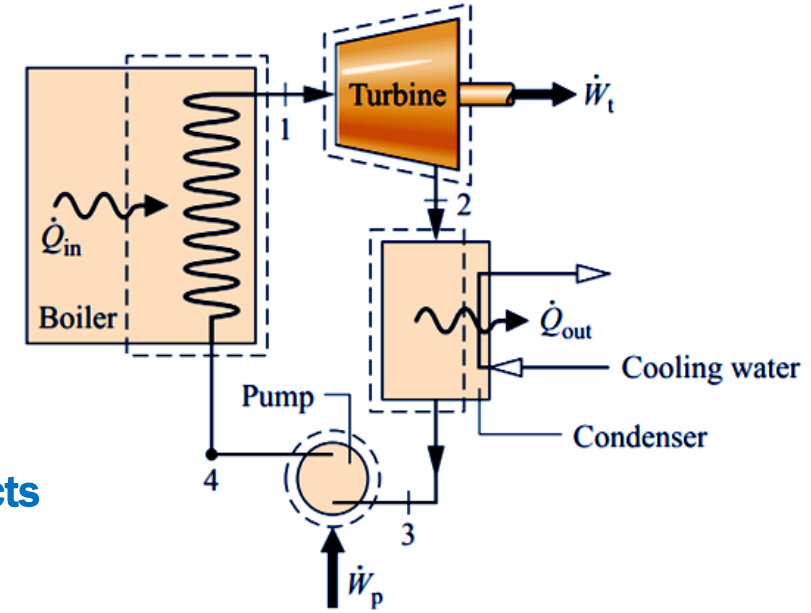


Classification of Heat Engine

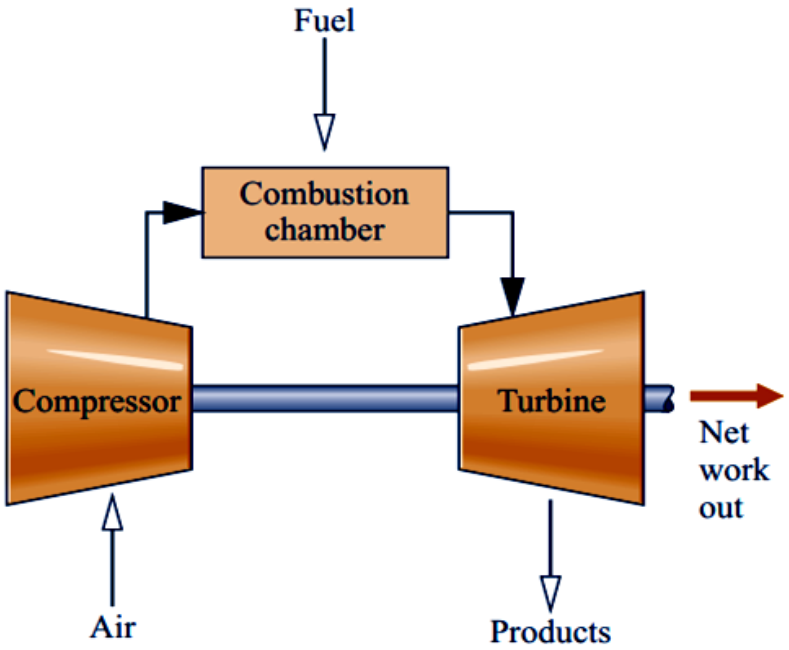
Combustion in engines can take place externally as well as internally

External combustion engine

- Combustion takes place outside the control volume
- Use of heat exchanger to transfer energy to the working fluid
- Open or closed cycle **The working fluid is separate from combustion products**
- Example: steam engine, power plant etc.



External Combustion Engine (Steam power plant)



Internal Combustion Engines (Gas power plant)

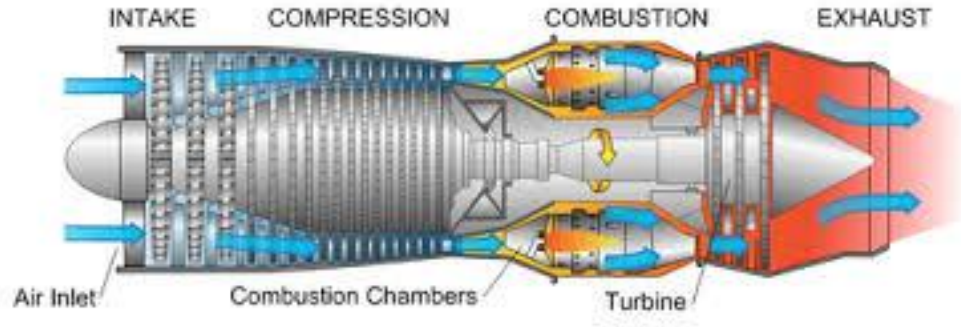
Internal combustion engine

- Combustion occurs within the control volume
- Open cycle: working fluid is replenished in each cycle
- Exhaust gas is dumped into the atmosphere
- Example: Reciprocating engines, gas turbines etc.

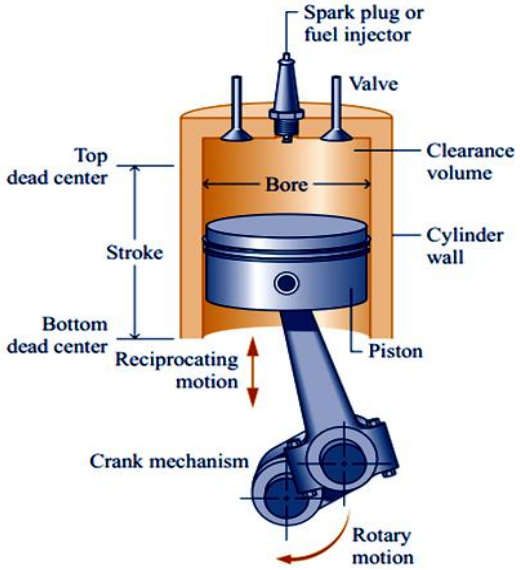
The working fluid is the combustion products itself

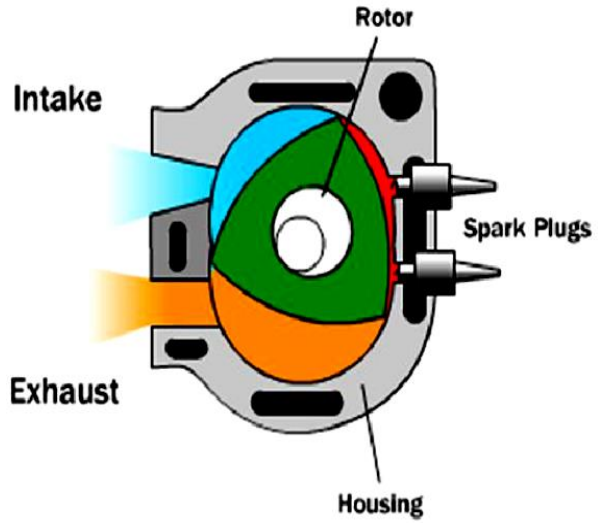
Heat engines also may be classified based on:

❖ Type of combustion process: (1) Intermittent (2) Continuous



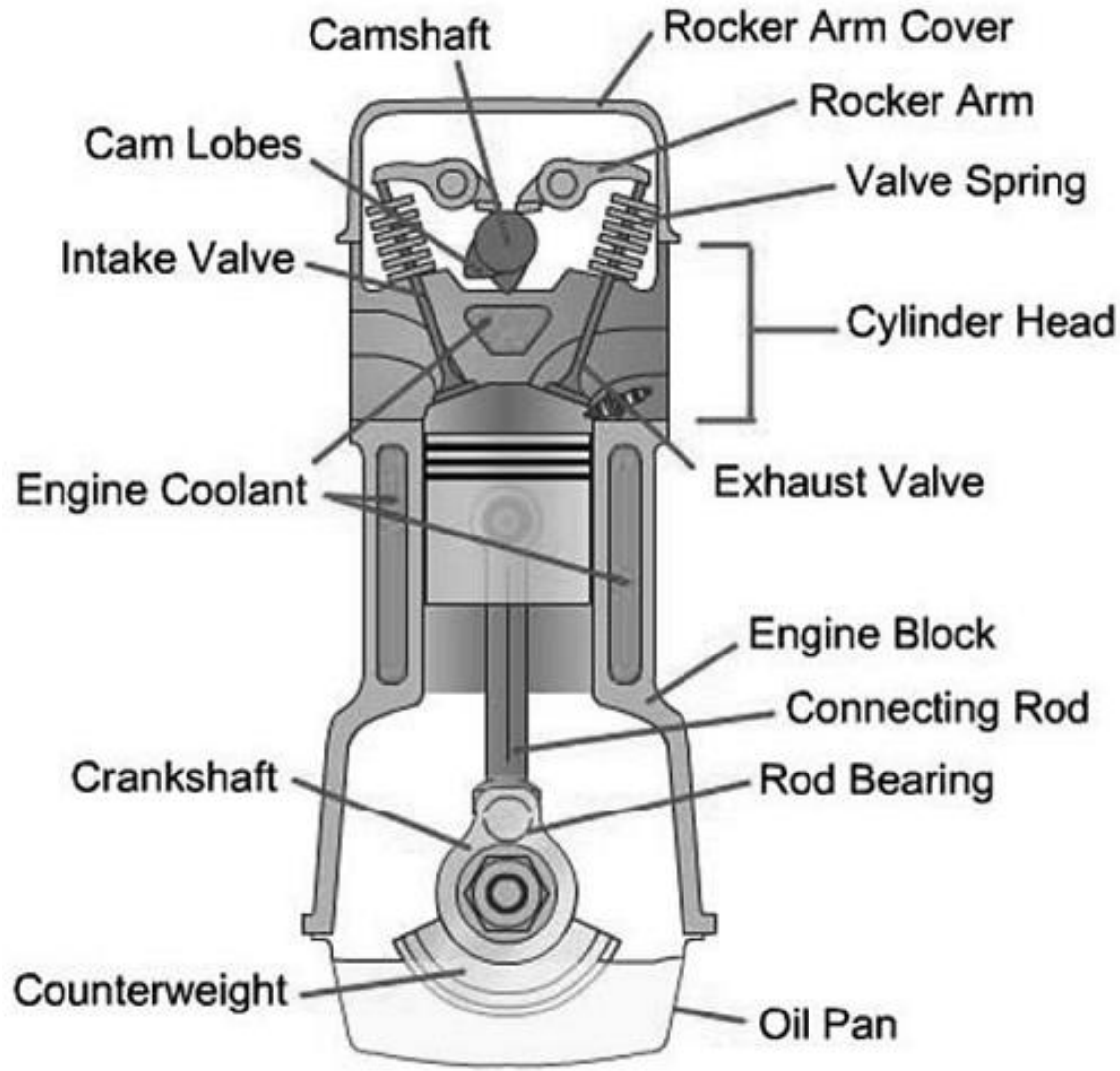
❖ Type of internal motion: (1) Reciprocating (2) Rotating





IC engine components

- **Engine block:** Body of engine
- **Piston**: Reciprocates inside the cylinder and transfers power to crankshaft through connecting rod
- **Cylinder:** Volume inside which the combustion takes place
- **Cylinder head:** Top portion of engine cylinder which holds spark plugs, valves etc.
- **Crankshaft:** Engine output is obtained
- **Connecting rod:** Connects piston to crankshaft
- **Camshaft:** Controls opening and closing of valves
- **Crankcase:** Lower part of engine surrounding the crankshaft.
- **Intake valve:** Allows air-fuel mixture to come in through intake manifold
- **Exhaust valve:** Allows burnt gases discharge through exhaust manifold



Basic components of an IC engine

Engine Terminology

- **Top dead center (TDC):** Extreme piston position close to cylinder top
- **Bottom dead center (BDC):** Extreme piston position close to crankcase
- **Bore, *B*: The diameter of the engine cylinder**
- **Stroke:** Linear distance travelled by piston between TDC and BDC
- **Clearance volume, V_c:** Volume of combustion chamber above piston when it is at TDC
- **Swept volume, V_d:** Volume swept by piston between TDC and BDC

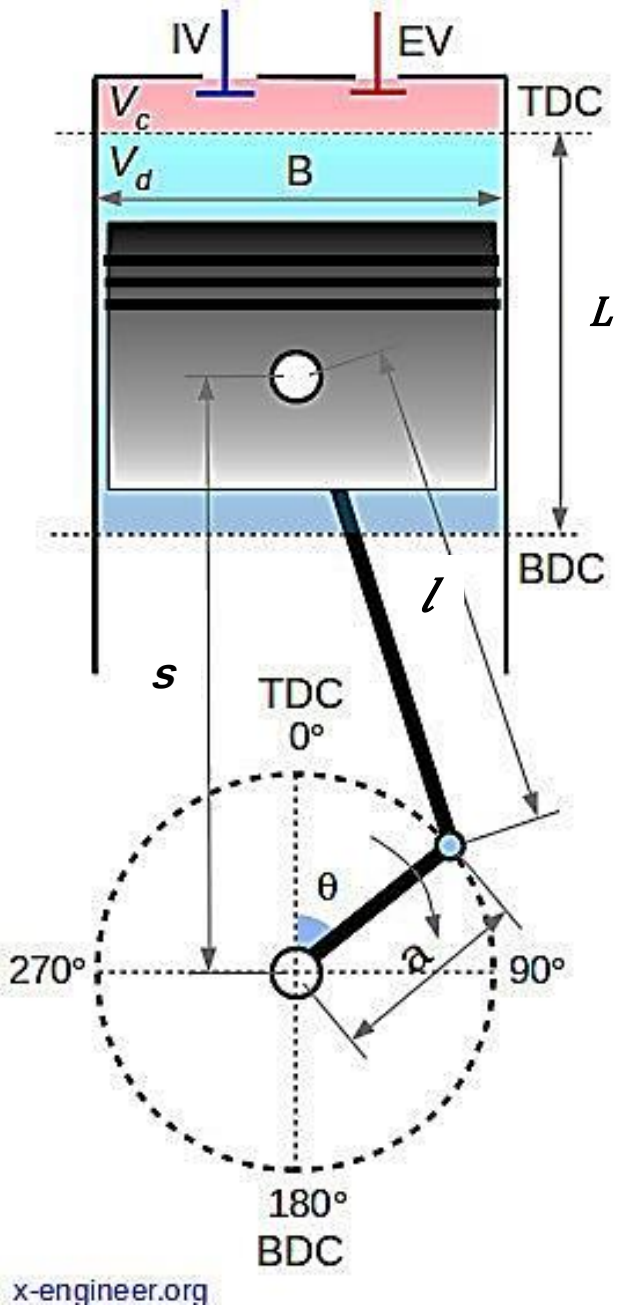
Maximum displacement, or swept, volume (Vd or Vs) :

$$V_d = \frac{\pi B^2}{4} L$$

- **Compression ratio, V_r:** Ratio of maximum to minimum volume. V_r is 8-12 for SI engines and 12-24 for CI engines.

Compression ratio, (Vr or r) :

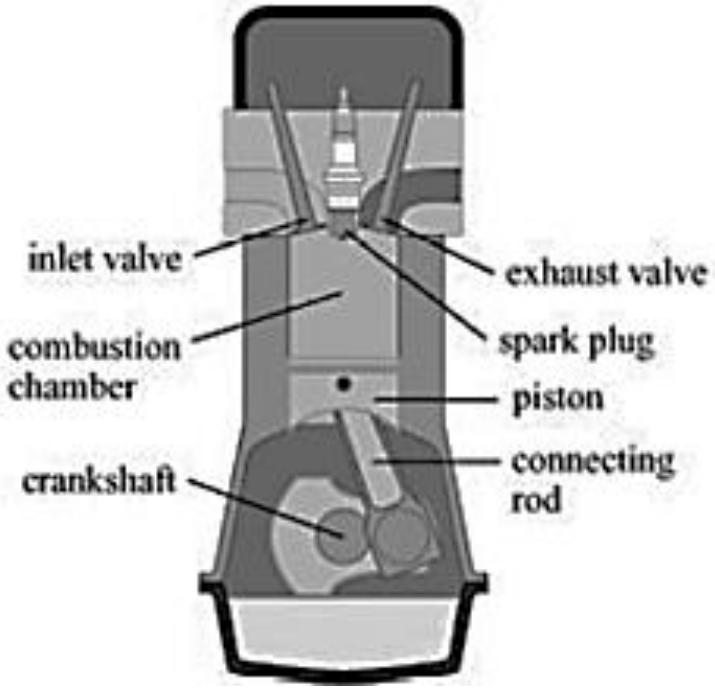
$$r = \frac{V_{BC}}{V_{TC}} = \frac{V_c + V_d}{V_c}$$



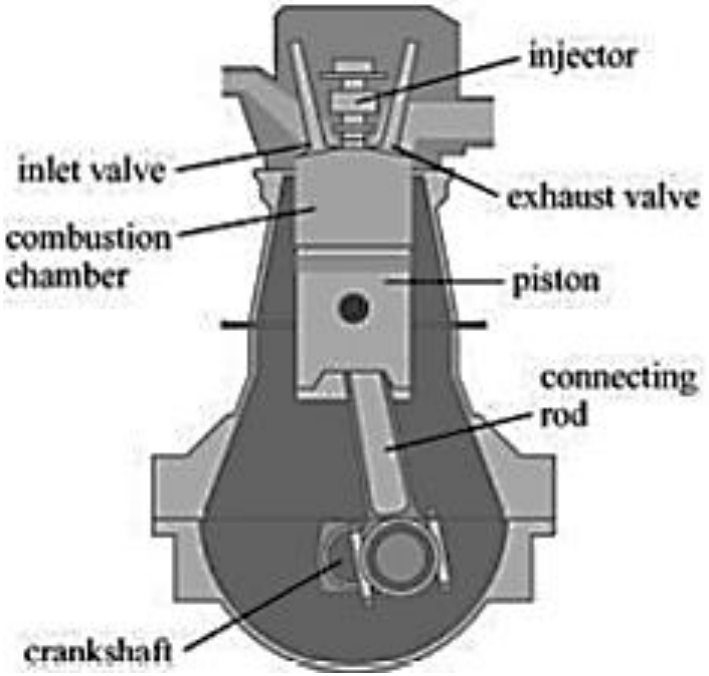
Classification of IC Engines: May be classified the IC engine based on:

(1) Based on Method of Ignition

- **Spark Ignition (SI) Engine**: is an IC engine, generally a petrol engine, where the combustion process of the air-fuel mixture is ignited by a spark from a spark plug.
- **Compression Ignition (CI) Engine:** is an IC engine, typically diesel engines, where the heat generated from compression together with the injection of fuel is enough to initiate the combustion process, without needing any external spark.



A Spark Ignition (SI) Engine

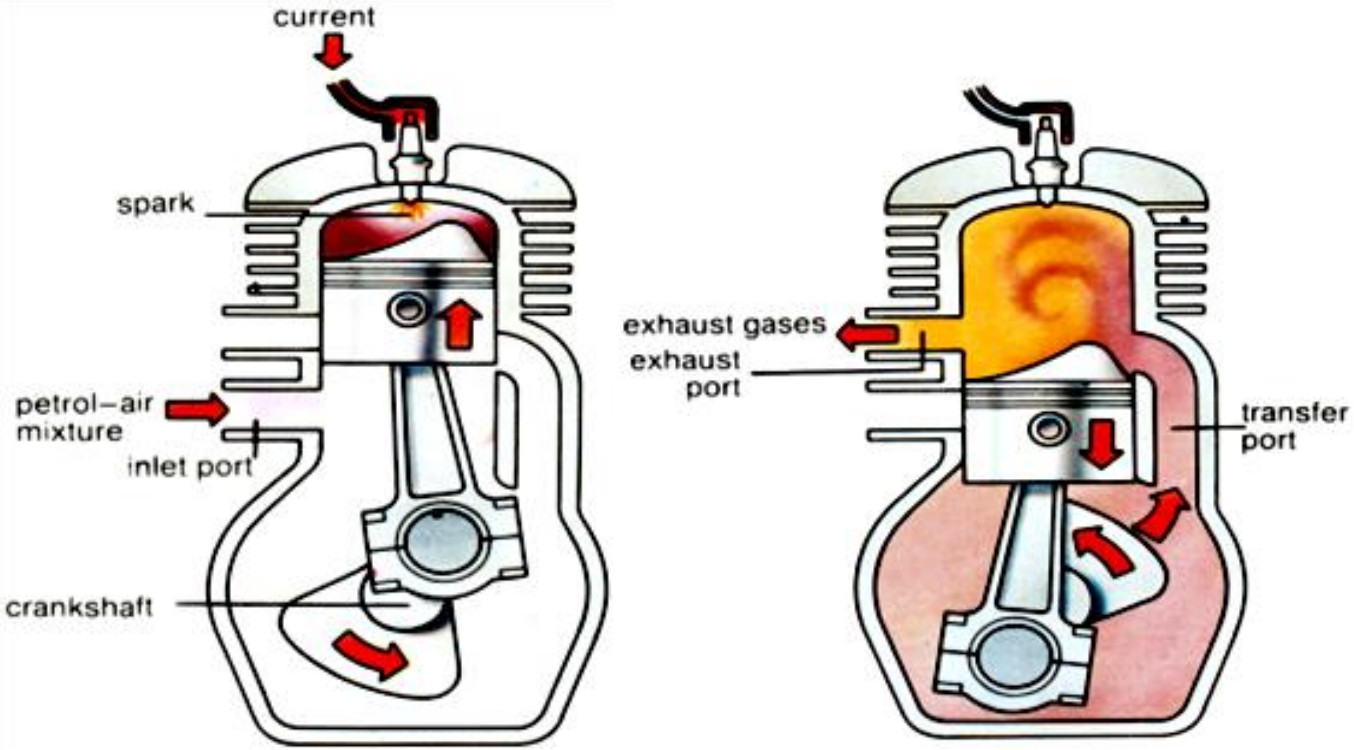


A Compression Ignition (CI) Engine

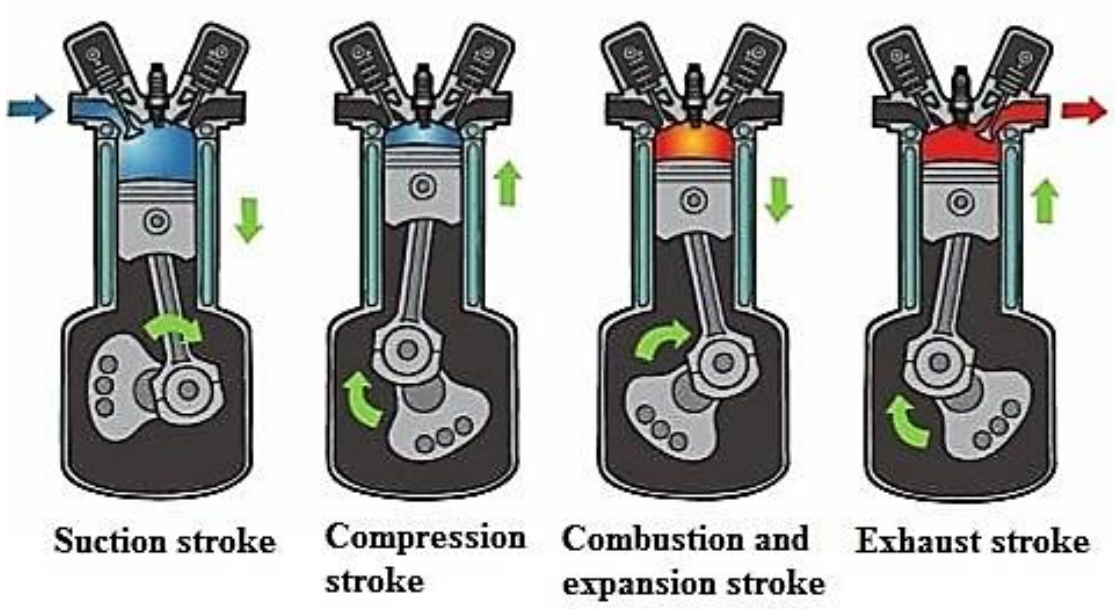
(2) Based on Working Cycle

❖ **Four Stroke Engine:** is a type of IC engine in which the piston completes four separate strokes while turning the crankshaft two revolution during one power cycle. A stroke refers to the full travel of the piston along the cylinder, in either direction.

❖ **Two Stroke Engine:** is a type of IC engine that completes a power cycle with two strokes (up and down movements) of the piston during one power cycle, this power cycle being completed in one revolution of the crankshaft.



A Two-Stroke Engine



A Four-Stroke Engine

(3) Based on Design

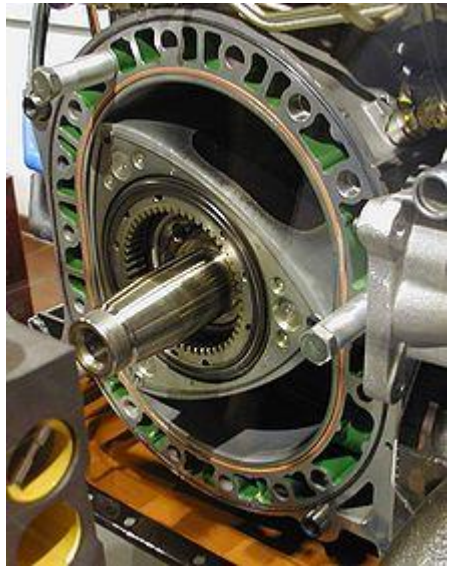
- **Reciprocating Engine:** is typically a heat engine that uses one or more reciprocating pistons to convert pressure inside the cylinder into a rotating motion. Cylinders may be aligned in line (or straight), in a V configuration, horizontally opposite each other, or radially around the crankshaft.

- **Rotary Engine:** is a type of IC piston engine used in some early aircraft, motorcycles, and cars. Virtually the whole engine rotates about a fixed crankshaft. It also includes other engines described as "rotary", such as Wankel engine , Turbine ... etc.

In-line (Straight) Engine

Radially Engine

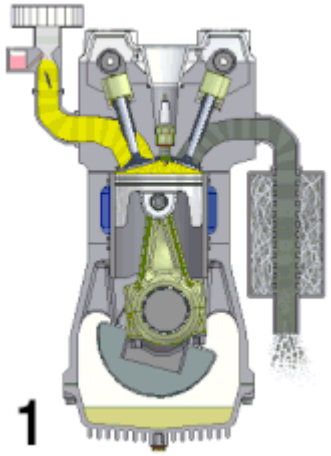
Gas Turbine Engine



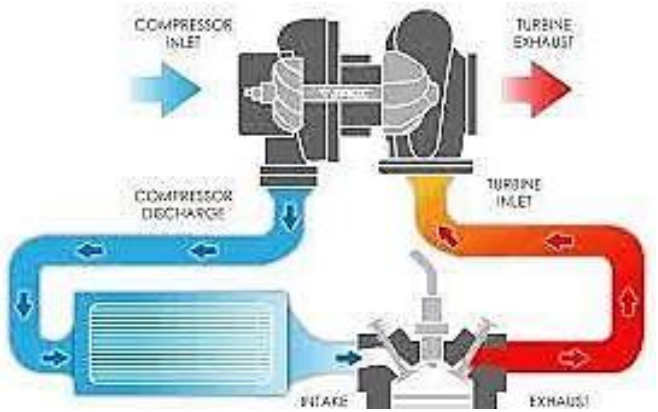
Wankel Engine

(4) Based on Charging Method

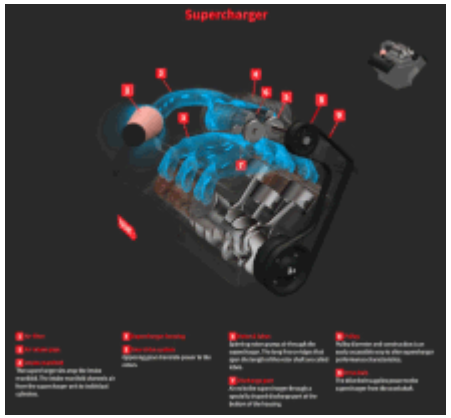
- **Naturally Aspirated (NA) Engine:** is an IC engine in which air intake depends solely on atmospheric pressure and does not have forced induction through a turbocharger or a supercharger.
- **Supercharged and Turbocharged Engine:** is a type of IC engine that supercharged (admitting pre-compressed fresh mixture) mechanically, and turbocharged (admitting fresh mixture compressed in a compressor driven by an exhaust turbine)
- **Crankcase Compressed Engine:** is a type of IC engine that compressed the mixture charge in a sealed crankcase by the descending piston before passing to the combustion chamber.



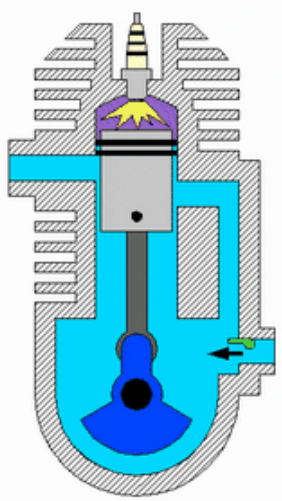
NA Engine



Turbocharged Engine



Supercharged Engine



Crankcase Compressed Engine

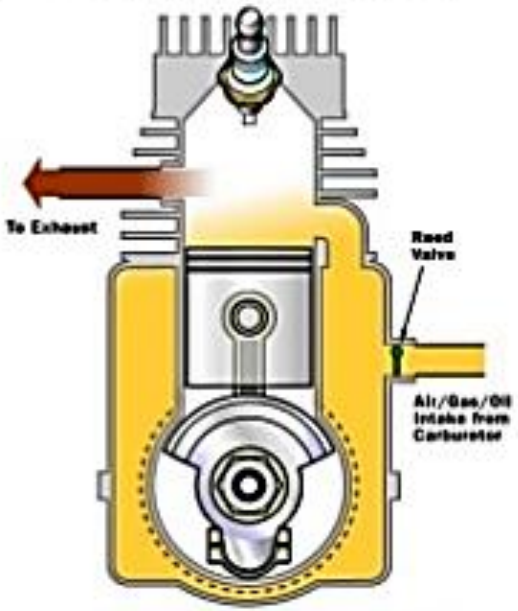
Classification of IC Engines: Another classification of IC engine are:

5. **Based on Method of Cooling**
   - **Water Cooled:** Water is used for cooling the engine.
   - **Air Cooled:** Air is used for cooling the engine.
6. **Based on 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.
   - Loop-Scavenged Porting: Inlet and exhaust ports on same side of cylinder.
   - Through or uniflow scavenged: Inlet and exhaust ports at different ends of cylinder.
7. **Based on fuel**
   - Petrol
   - Diesel
   - Natural gas
   - Liquid petroleum gas
   - Alcohols (methanol, ethanol)
   - Hydrogen
   - Dual fuel
8. **Based on method of load control**
   - Throttling of fuel and air flow together
   - Control of fuel flow alone
   - A combination of these two

Internal Combustion Engines
– two stroke -

1. Power / Exhaust

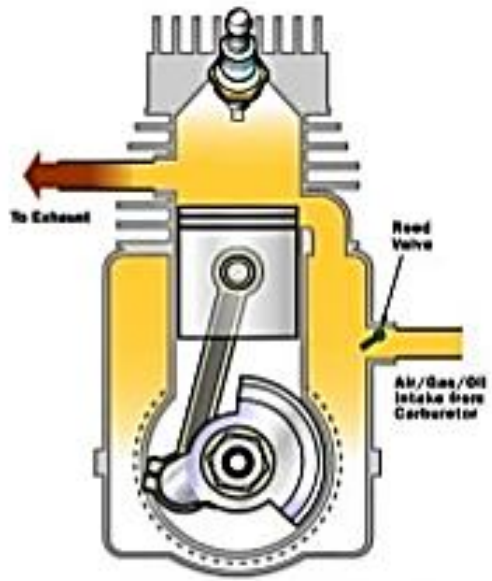
a. ignition
b. piston moves downward compressing fuel-air mixture in the crankcase
c. exhaust port opens



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

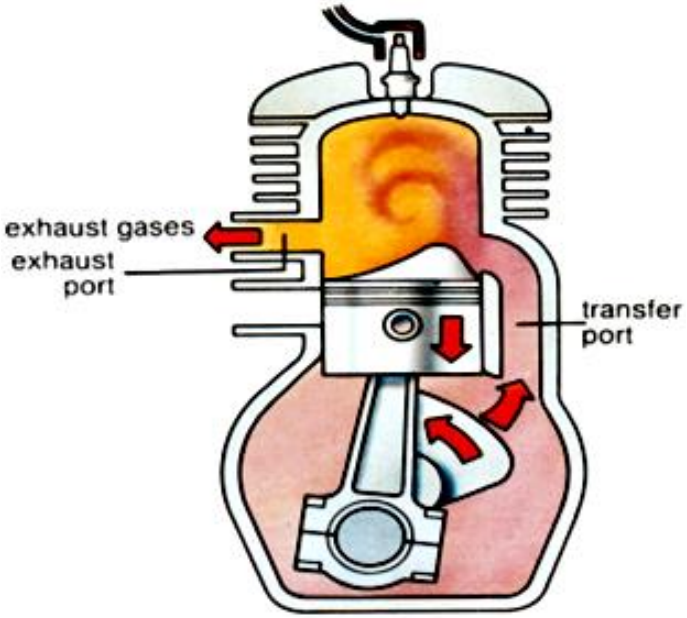


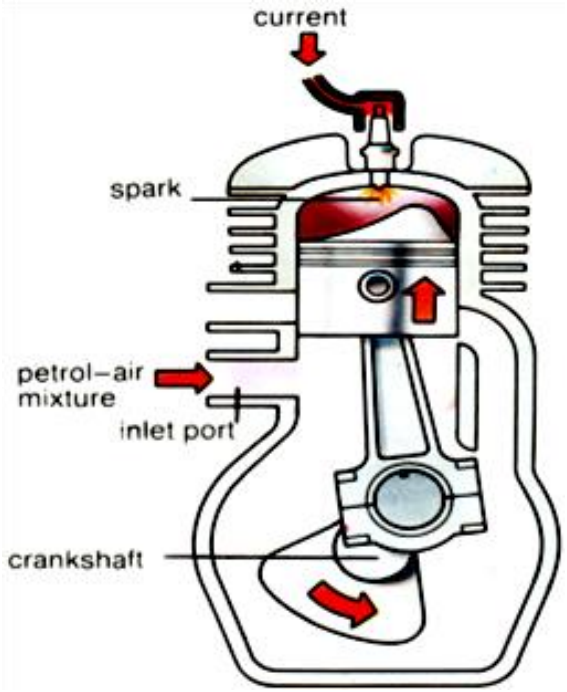
Compression action of a two-stroke engine

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

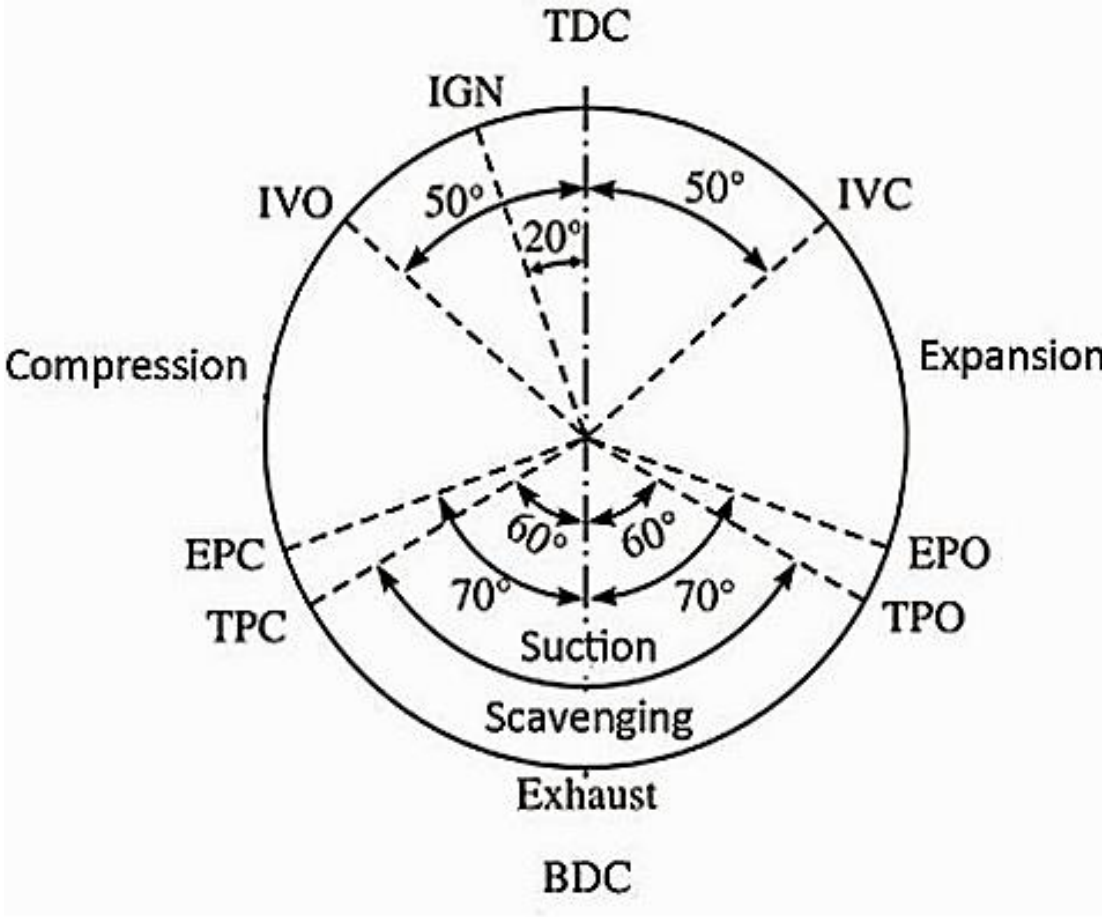
Drawbacks:
- lack of a dedicated lubrication system makes the engine to wear faster.
- necessity of oil addition into the fuel
- low efficiency
- produce a lot of pollution

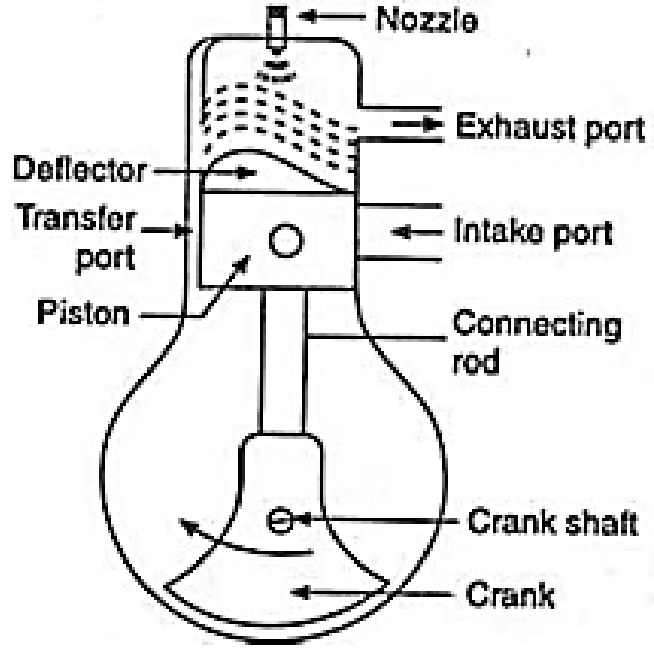
Port timing diagram of Two-Stroke Engine



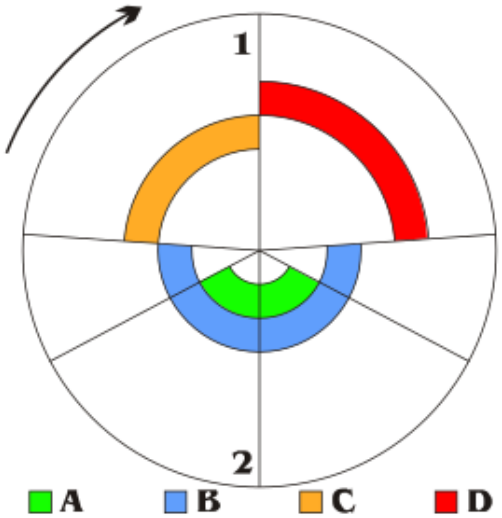


A two-stroke SI engine





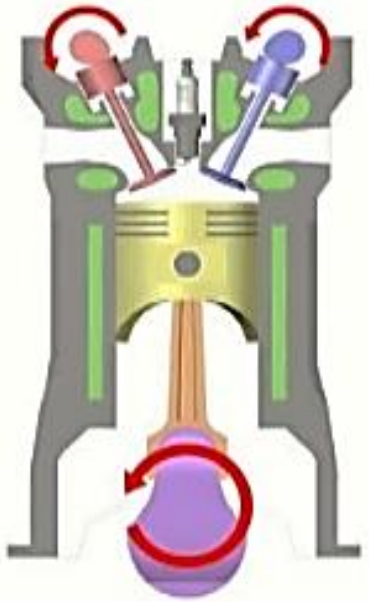
A two-stroke CI engine



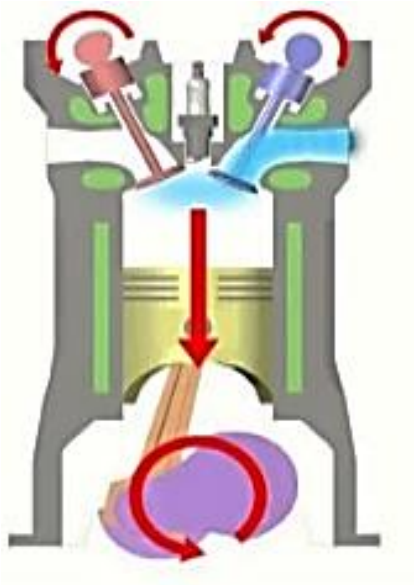
Internal Combustion Engines
– four stroke -

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

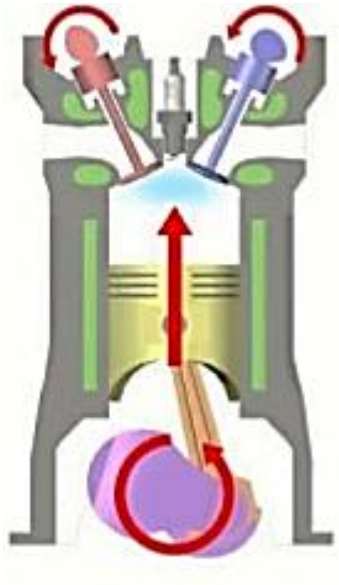


starting position



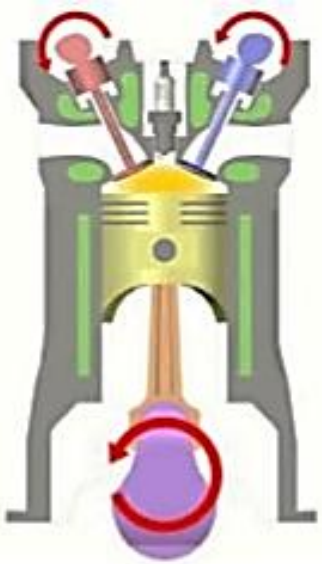
1. intake

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

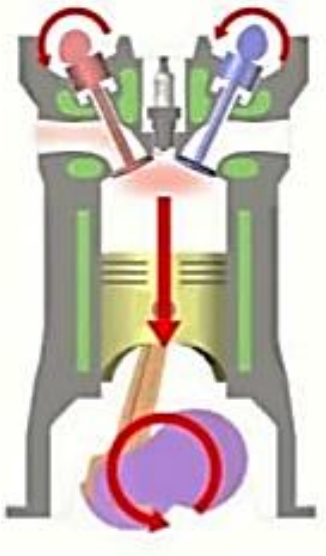


2. compression

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

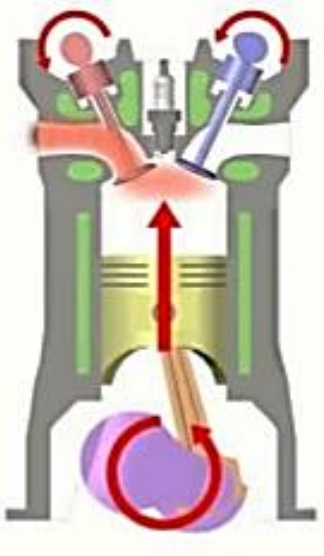


ignition



3. power

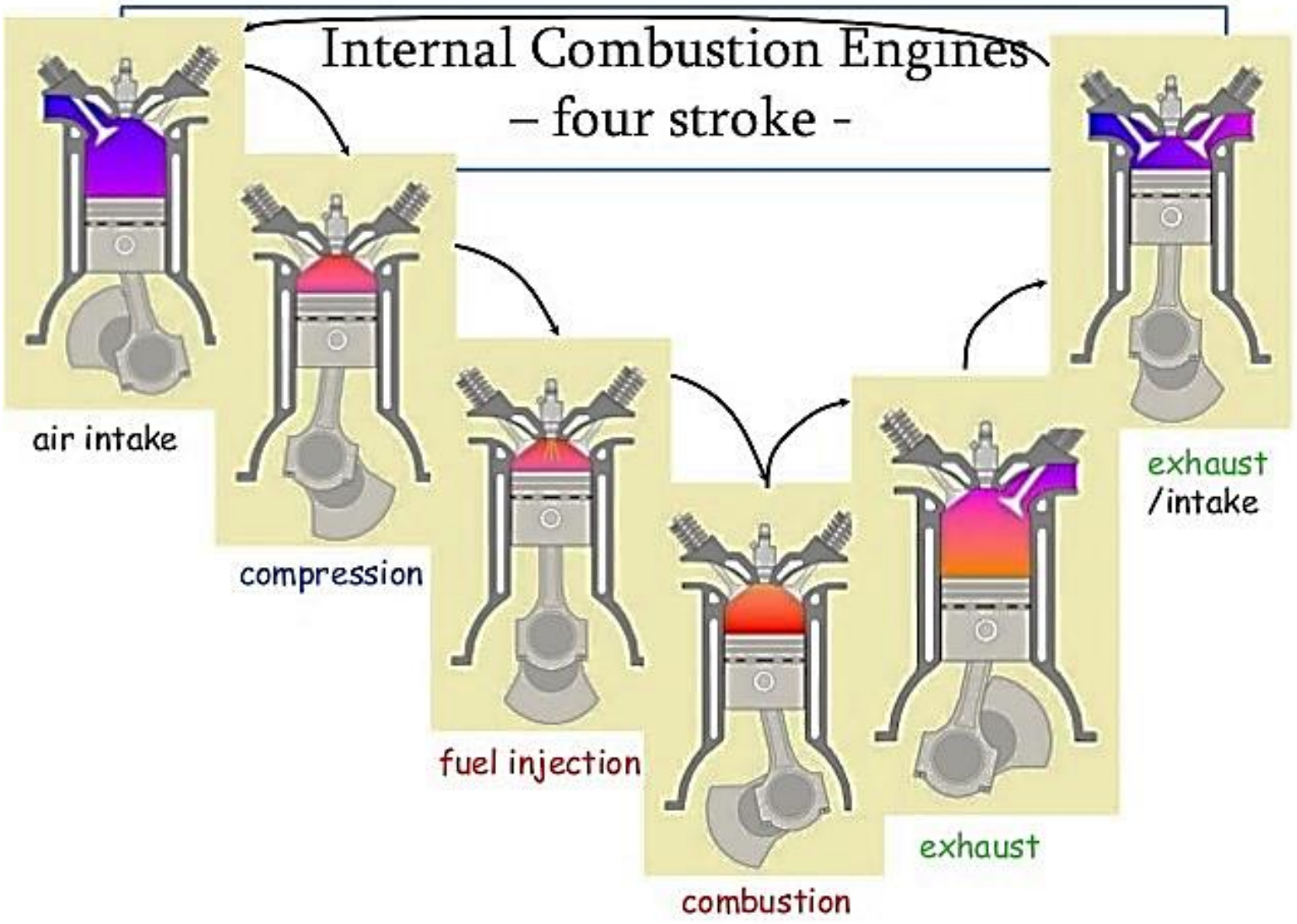
a. air-fuel mixture explodes driving the piston down



4. exhaust

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

4-Stroke Compression Ignition Engine



Advantages of CI Engine Compare to SI Engine

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

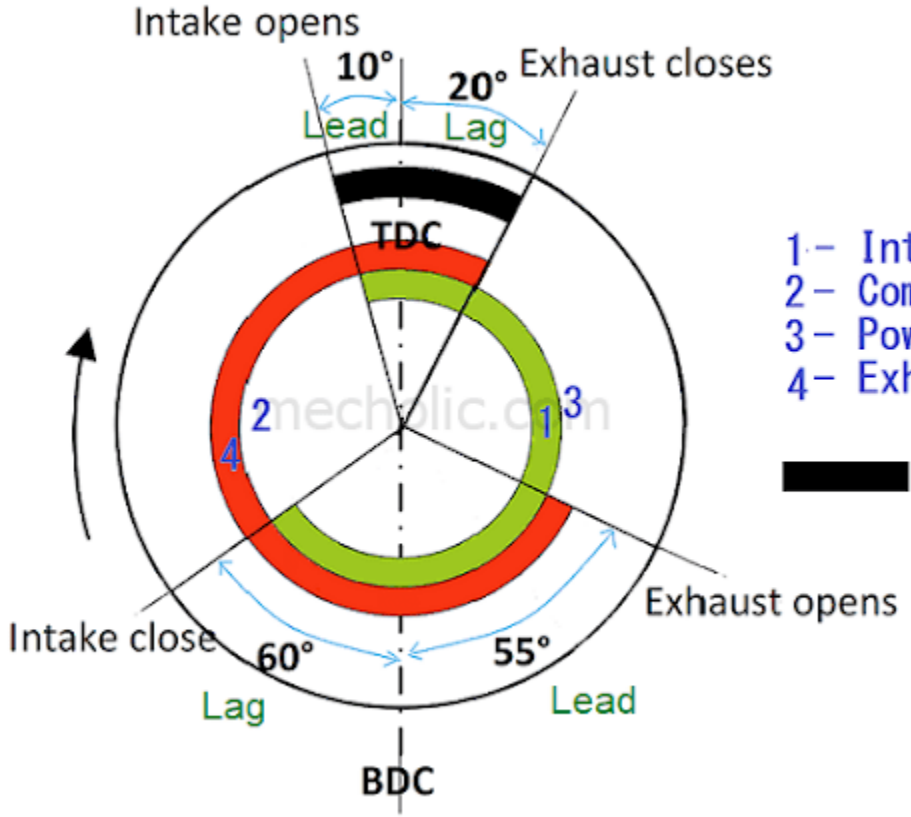
Drawbacks:
- more expensive production
- more weight
- louder
- lower revolutions

Valve timing diagram of Four-Stroke Engine

- The exact moment at which the inlet and outlet valve opens and closes with reference to the position of the piston and crank shown diagrammatically is known as **valve timing diagram**.
- It is expressed in terms of degree crank angle.

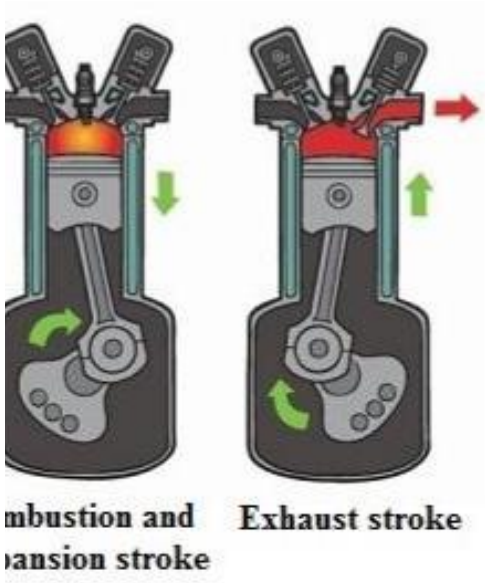
Valve overlap: is the period during engine operation when both intake and exhaust valves are open at the same time.

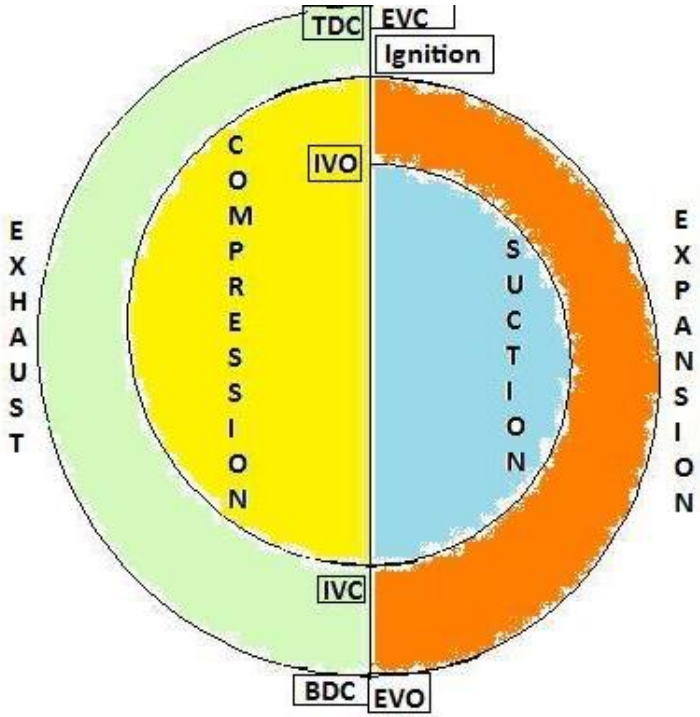
- The theoretical and actual valve timing diagrams are shown below.
- Actual valve timing diagram is different from theoretical one due to mechanical and dynamic factors.



1- Intake stroke
2- Compression stroke
3- Power stroke
4- Exhaust stroke

Overlap





Actual valve timing diagram of 4-Stroke Engine

Theoretical valve timing diagram of 4-Stroke Engine