SSC-JE 2025

Staff Selection Commission

Junior Engineer Examination

Mechanical Engineering

IC Engines

Well Illustrated **Theory** *with*
Solved Examples and **Practice Questions**

MADE EASY PUBLICATIONS

IC Engines

Contents

CHAPTER 01

Basics and Air Standard Cycles

1.1 Introduction

An engine is a device which transforms one form of energy into another form. Their conversion efficiency is limited from second law of thermodynamics. Normally most of the engines convert thermal energy into mechanical work and therefore are called Heat Engines.

A heat engine is a device which transforms the chemical energy of a fuel into thermal energy and uses this energy to produce mechanical work.

1.2 Classification of Heat Engines

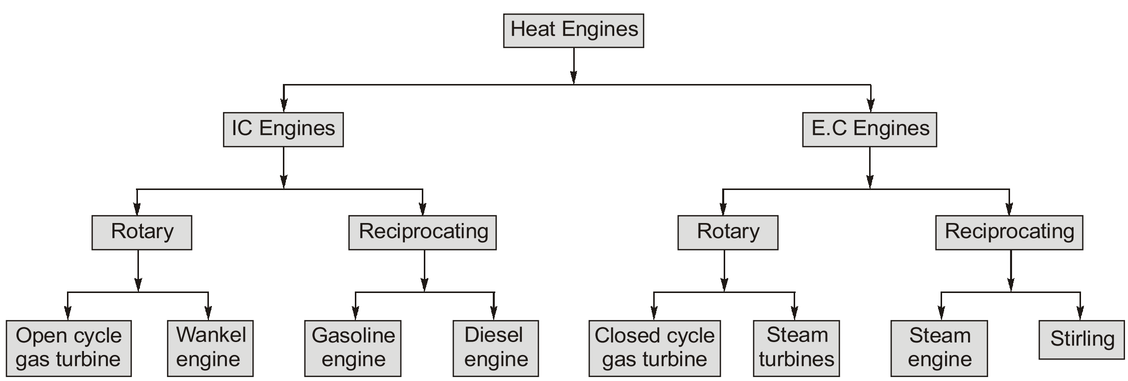


Figure 1.1

- IC : Internal combustion
  EC : External combustion

1.2.1 IC Engine vs Steam Turbines

- In IC engine, no heat exchangers are there (boiler or condenser). This results in mechanical simplicity and thus high mechanical efficiency.
- In IC engines very high working fluid temperatures can be employed resulting in higher thermal efficiency.
- Weight to power ratio is quite less in I.C. engines.
- I.C engines suffer from vibration problem caused by reciprocating components.

1.2.2 Materials for Construction of I.C Engine Parts

Table 1.1

Part	Materials
Cylinder	Cast Iron
Piston	Aluminium Alloy
Piston ring	Silicon cast iron
Connecting rod	Steel
Crank shaft	Alloy steel
Bearing	White metal
Cylinder Liner	Nickel alloy steel

1.2.3 Components of IC Engine

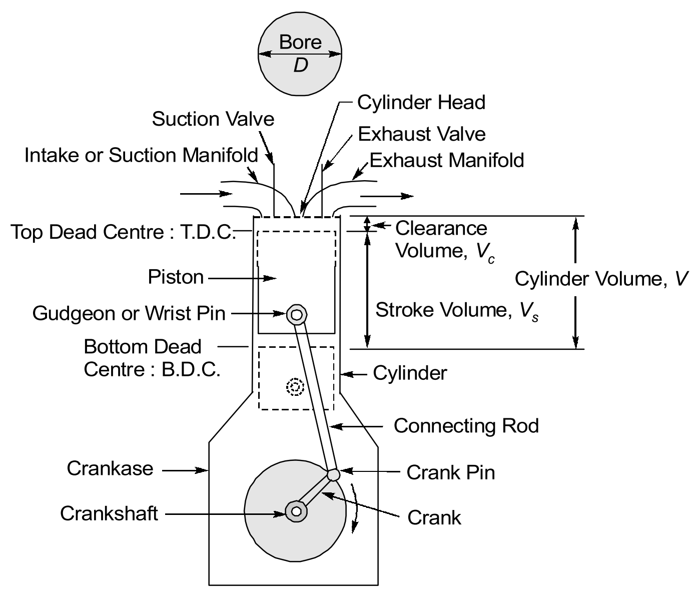


Figure 1.2

- **Piston:** Cylindrical component fitted into the cylinder forming moving boundary of the combustion system.
    - Top surface of piston : Piston crown
    - Bottom surface of piston: Piston skirt.
- **Combustion chamber:** Space enclosed in the upper part of the cylinder head and the piston top during the combustion process.
- **Connecting rod:** Connects piston and crank shaft and transmits power from piston to crankshaft.
    - It has two ends: small end and big end.
    - Small end is connected to the piston by the gudgeon pin. Big end is connected to the crankshaft by crankpin.
- **Piston rings:** Two or three rings are provided on the piston to provide a tight seal between the piston and the cylinder wall and thus preventing leakage of combustion gases. These also transfer heat from piston to the cylinder walls.
- **Crank case:** It is the housing of the crank and body of the engine of which cylinder and other parts are fastened.
    - It also stores lubricating oil in two stroke engines.

- **Spark Plug:** It is provided on petrol engines. It produces a high-intensity spark which initiates the combustion process of the charge.
- **Fuel Injector:** It is provided on Diesel engines. The Diesel fuel is injected in the cylinder at the end of the compression through a fuel injector under very high pressure.
- **Carburettor:** It is provided with a petrol engine for preparation of a homogeneous mixture of air and fuel (petrol). This mixture, as a charge, is supplied to engine cylinder through suction valve or port.
- **Fuel Pump:** It is provided with a Diesel engine. The diesel is taken from the fuel tank, its pressure is raised in the fuel pump and then it is delivered to fuel injector.

1.3 Basic Terminology

The basic terminology used for volumes and measurements in the cylinder region is presented and shown in figure.

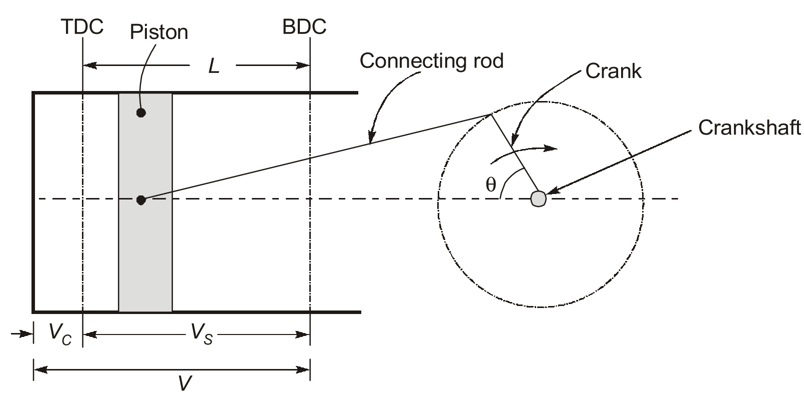


Figure 1.3

- **Stroke (*L*):** Distance covered by piston between top and bottom dead centres.
- **Dead Centre:** Extreme positions of the stroke.
    - TDC: - Top dead centre
      - Piston is farthest from crank.
      - It is called as inner dead centre in case of horizontal cylinder.
    - BDC: - Bottom dead centre
      - Piston is nearest to the crank.
      - It is called as outer dead center in case of horizontal cylinder.
- **Clearance volume (V_C):** Volume of the combustion chamber above the piston when is at TDC. (In case of vertical cylinder) or IDC (in case of horizontal cylinder) .
- **Displacement or Swept volume (V_s):** Volume swept by the working piston when travelling from one dead centre to other.

$$V_s = A \times L = \frac{\pi}{4} d^2 L$$

  where *d* is bore or cylinder diameter.
- **Cubic capacity or Engine capacity:** $V_s \times k$; where '*k*' is the number of cylinder.
- **Compression ratio (*r*):** Ratio of volume when piston is at BDC and volume when piston is at TDC.

$$r = \frac{V_{total}}{V_C} = \frac{V_C + V_s}{V_C} = 1 + \frac{V_s}{V_C}$$

NOTE : With increase in carbon deposits on the cylinder head, V_c decrease and hence effective compression ratio increase.

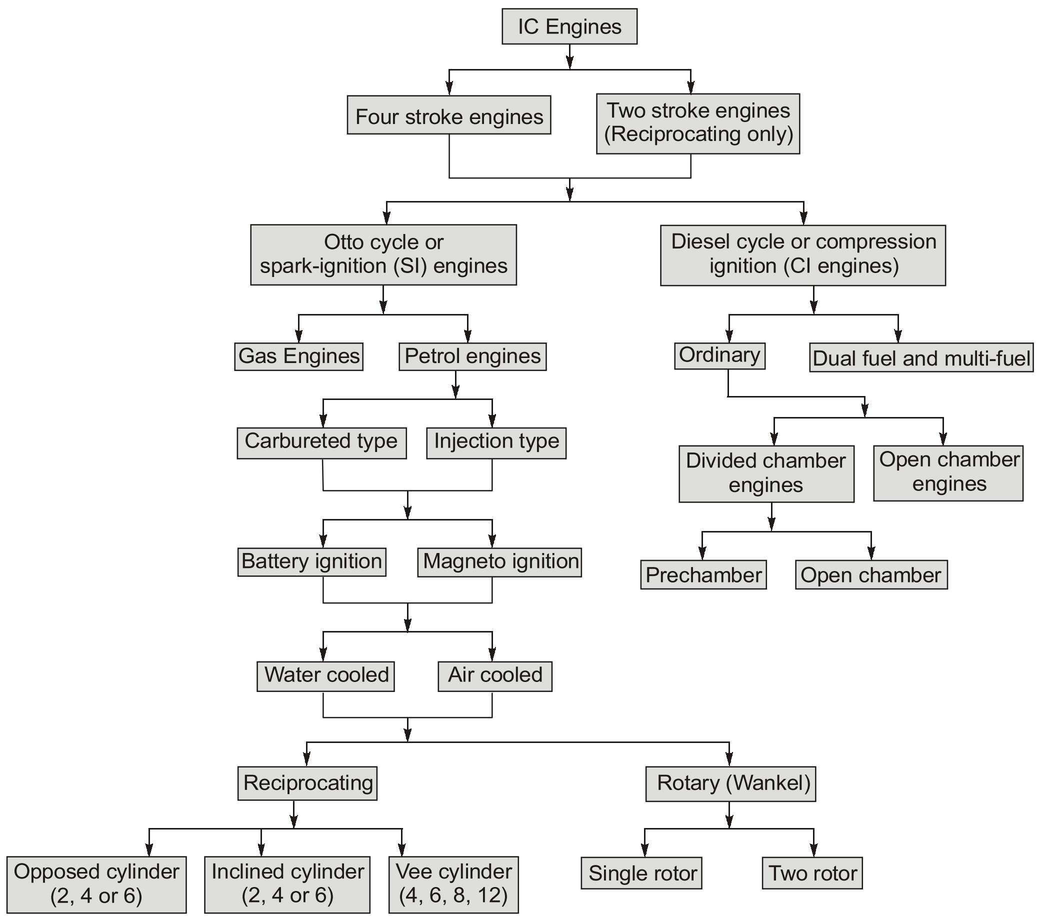


Figure 1.4

1.4 Four Stroke Engine

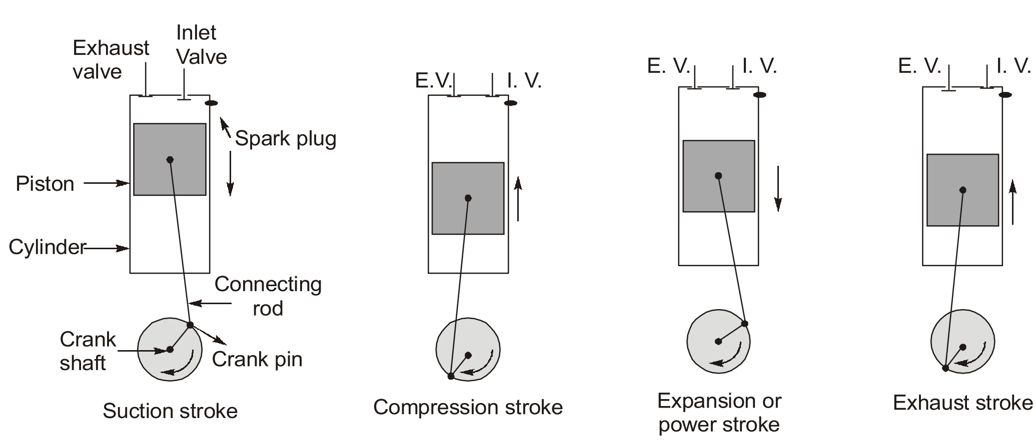


Figure 1.5

- In a four stroke engines, following events take place:
  - Suction
  - Compression
  - Combustion
  - Expansion
  - Exhaust
- A thermodynamic cycle is drawn by removing the constant pressure exhaust and suction events.
- In the four stroke engines, the cycle is completed in 4 strokes or 2 revolutions of the crank.

1.4.1 Four Stroke Petrol Engine

- In four stroke petrol engine, the operation is as follows:

  (i) **Suction Stroke :** The suction valve opens, exhaust valve remains closed as shown in figure. The piston moves from the top dead centre to the bottom dead centre, the charge (mixture of fuel and air prepared in the carburettor) is drawn into the cylinder.

  (ii) **Compression Stroke :** When the piston moves from the bottom dead centre to top dead centre, and the suction valve is closed, exhaust valve remains closed as shown in figure. The trapped charge in the cylinder is compressed by the upward moving piston. As the piston approaches the top dead centre, the compression stroke completes.

  (iii) **Expansion Stroke :** At the end of the compression stroke, the compressed charge is ignited by a high-intensity spark created by a spark plug, combustion starts ad the high-pressure burning gases force the piston downward as shown in figure. The gas pressure performs work, therefore, it is also called working stroke or power stroke. When the piston approaches the bottom dead centre in its downward stroke then this stroke is completed. In this stroke, both valves remains closed.

  (iv) **Exhaust Stroke :** When the piston moves from the bottom dead centre to the top dead centre, only the exhaust valve opens and burnt gases are expelled to surroundings by upward movement of the piston as shown in figure. This stroke is completed when the piston approaches the top dead centre. Thus, one cycle of a four stroke petrol engine is completed. The next cycle begins with piston movement from the top dead centre to the bottom dead centre.

- **Valve Timing :** Theoretically, in a four-stroke cycle engine, the inlet and exhaust valves open and close at dead centres as shown in figure.
  A typical valve-timing diagram for a four-stroke petrol engine is shown in figure. The angular positions in terms of crank angle with respect to TDC and BDC position of piston are quoted on the diagram. When the inlet valve and exhaust valve remain open simultaneously, it is called a valve overlap.

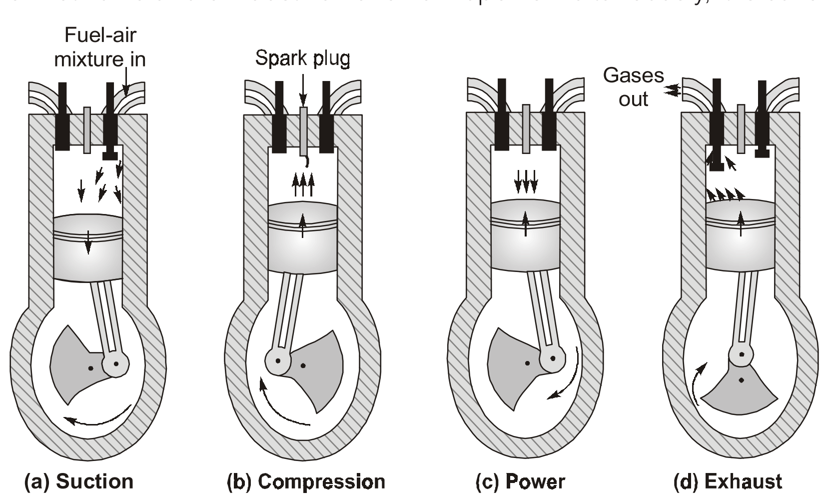


Figure 1.6

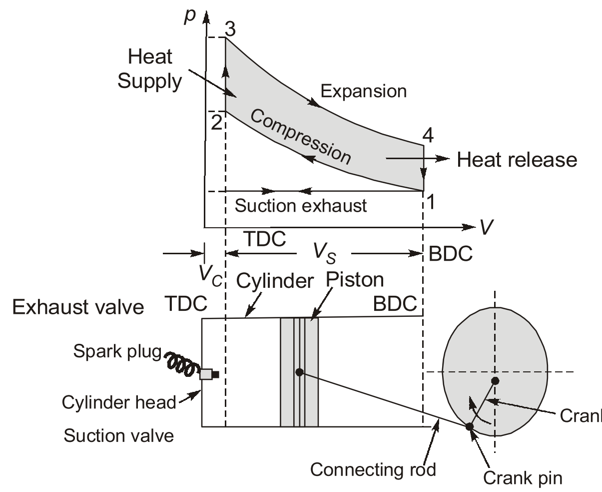
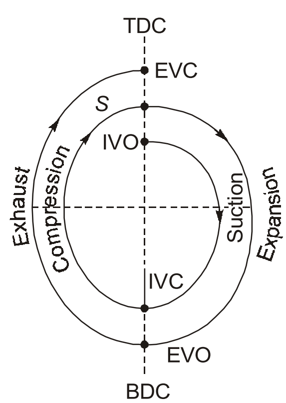
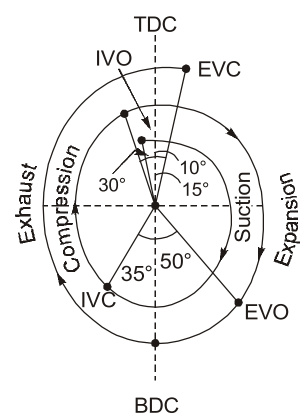


Figure 1.7 : Theoretical p-V diagram for a four-stroke petrol engine



(a) Theoretical valve timing diagram of a four stroke cycle



(b) The typical valve timing diagram for a four stroke petrol engine

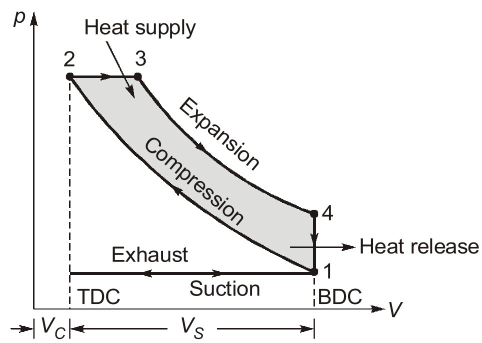
IVO = Inlet valve opens when piston at TDC
IVC = Inlet valve closes, when piston reaches BDC
S = Spark produces, when piston reaches TDC
EVO = Exhaust valve opens when piston at BDC
EVC = Exhaust valve closes, when piston at TDC

IVO = Inlet valve opens about 15° before TDC
IVC = Inlet valve closes 20° – 40° after BDC to take advantage of rapidly moving gas
S = Spark occurs 20° – 40° before TDC
EVO = Exhaust valve opens about 50° before BDC
EVC = Exhaust valve close about 0° to 10° after TDC

Figure 1.8

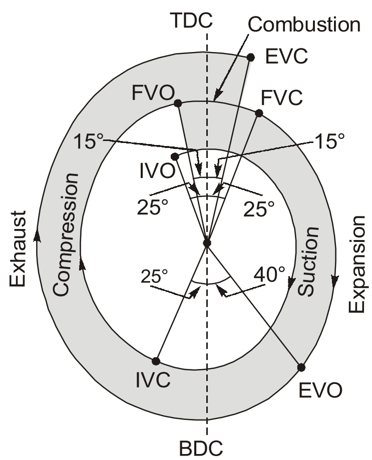
1.4.2 Four Stroke Diesel Engine

- All engines (four stroke or 2 stroke) using diesel as a fuel operate on the diesel cycle.
- They work similar to a petrol engine except they take in only air as charge during suction and fuel is injected at the end of the compression stroke.
- The diesel engines use a high compression ratio in the range of 14 to 21. The temperature of intake air reaches quite a high value at the end of compression. Therefore, the injected fuel is self ignited.
- The diesel engines use a heterogeneous air-fuel mixture ratio ranging from 20 to 60.
- All the strokes are same as that of petrol engines with the difference that only air is compressed and fuel is injected at the end of compression.
- Valve timing diagram is also different.



Theoretical p-v diagram

Figure 1.9



IVO : Inlet valve opens 10° to 30° before TDC
IVC : Inlet valve closes 20° – 50° after BDC
EVO : Exhaust valve opens approximately 40° before BDC
EVC : Exhaust valve closed approximately 15° after TDC
FVO : Fuel injection starts 5° to 15° before TDC
FVC : Fuel injection stops 15° to 25° after TDC

Figure 1.10: Valve Timing Diagram for a Four-Stroke Diesel Engine

1.5 Two Stroke Engines

- In four stroke engines, there are two unproductive strokes (suction and exhaust). So there is only one power stroke for two revolutions of crank. In two stroke these two events are served alternatively without piston stroke such that cycle is completed in two strokes or one revolution of crank.
- In such an engine the theoretical power output is double for the same speed as compared to a four stroke engine.
- In the two stroke engine, the filling process is accomplished along with compression stroke and exhaust process with power stroke. The effective stroke is reduced.
- Near the end of expansion stroke, the piston uncovers the exhaust port and the cylinder pressure drops to atmospheric pressure as the combustion products leave the cylinder.
- Further movement of piston uncovers the transfer ports, permitting the slightly compressed charge in the crankcase to enter the engine cylinder.
- The piston top usually has a projection to deflect the fresh charge towards the top of the cylinder preventing the flow through the exhaust ports. This serves the double purpose of scavenging the combustion products from the upper port of the cylinder and preventing the fresh charge from flowing out directly through the exhaust ports.

NOTE : (i) If '*N*' is the rpm of the engine, then number of working strokes per minute in two stroke engines are '*N*' and '*N*/2' in four stroke engines.
(ii) Four stroke engines have valves while two stroke engines have ports.

- In actual practice power output is not exactly doubled but increased by only 30% to 35% due to
  - (i) Reduction in effective expansion store.
  - (ii) Some fresh charge escaping unburnt during the scavenging process. This increases fuel consumption. This is not a problem in diesel engine.
  - (iii) Increased heating caused by increased number of power strokes which limits the maximum speed. This also calls for greater cooling and lubricating oil requirements.

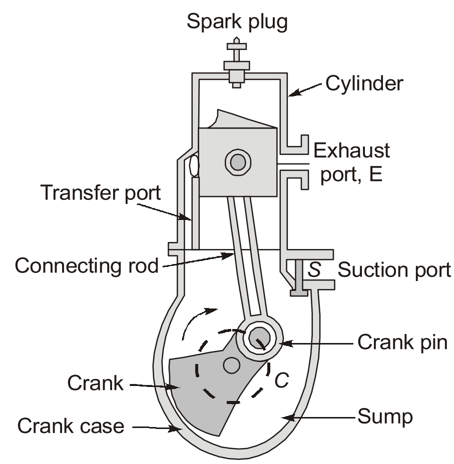


Figure 1.11: Two Stroke Petrol Engine

1.6 Scavenging Process

- The process of cleaning the cylinder after the expansion stroke is scavenging. Here the fresh fuel or mixture pushes the exhaust to exhaust port.

1.6.1 Type of scavenging process

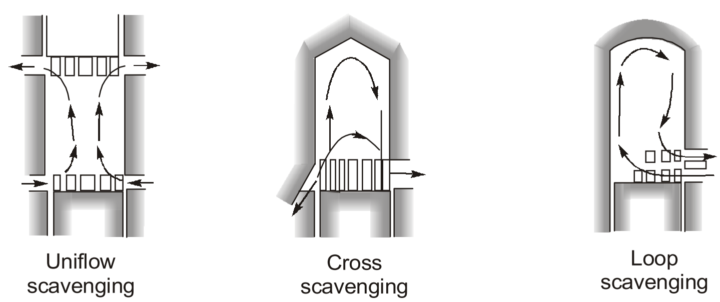


Figure 1.12

- Uniflow system has highest scavenging efficiency

1.7 Comparison of four stroke and two-stroke engines

Table 1.2

Four Stroke Engine	Two Stroke Engine
The Cycle is completed in four strokes of the piston.	The cycle is completed in two strokes of the piston.
It has one power stroke in two revolutions of crankshaft.	It has one power stroke in one revolution of crankshaft.
Heavier flywheel is needed.	Lighter flywheel is required.
For the same power heavier engine is required.	For the same power lighter engine is required.
Lesser requirement of Cooling and lubrication.	Greater cooling and Lubrication are required.
It contains valves and valve mechanisms so higher in cost.	It contains ports so cheaper in cost.
More volumetric and thermal efficiency.	Less volumetric and thermal efficiency.
Used in high efficiency motor cycles, cars, buses, trucks, aeroplanes, power generation.	Used in lawn mover, scooters, motor cycles, mopeds, ships.
Low power to weight ratio.	High power to weight ratio.