THEORY & OBJECTIVE

# THERMODYNAMICS APPLICATION

## (I.C, RAC & POWER PLANT)

*By*
*Team of*
*Engineers Academy*

- State Engineering Services Examinations.
- Public Sector Examinations.
- JEn (SSC, DMRC & State Level).
- Other Technical Competitive Exams.


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# CONTENTS


# INTRODUCTION TO INTERNAL COMBUSTION ENGINE

## THEORY

## 1.1 HEAT ENGINES

A heat engine is a device which transforms the chemical energy of a fuel into thermal energy and used this energy to produce mechanical work. Heat engines are classified into two broad types :

(a) External combustion engines

(b) Internal combustion engines

### *1.1.1 External Combustion Engines*

In an external combustion engine, the products of combustion of air and fuel transfer heat to a second fluid which is the working fluid of the cycle, as in the case of a steam engine or a steam turbine plant where the heat of combustion is employed to generate steam which is used in a piston engine or a turbine. Stirling engine is also an external combustion engine.

***Advantage of External Combustion Engines :***

- Use of cheaper fuels including solid fuels
- High starting torque.

### *1.1.2 Internal Combustion Engines*

In an internal combustion engine, the products of combustion are directly the motive fluid. Petrol, gas, and diesel engines, Wankel engines and open cycle gas turbines are examples of internal combustion engines. Jet engines and rockets are also internal combustion engines.

***Advantages of Internal Combustion Engines :***

- Greater mechanical simplicity.
- Lower ratio of weight and bulk to output due to absence of auxiliary apparatus like boiler and condenser.
- Lower cost.
- Higher overall efficiency.
- Lesser requirement of water for dissipation of energy through cooling system.

## 1.2 Engine Components and Basic Engine Nomenclature

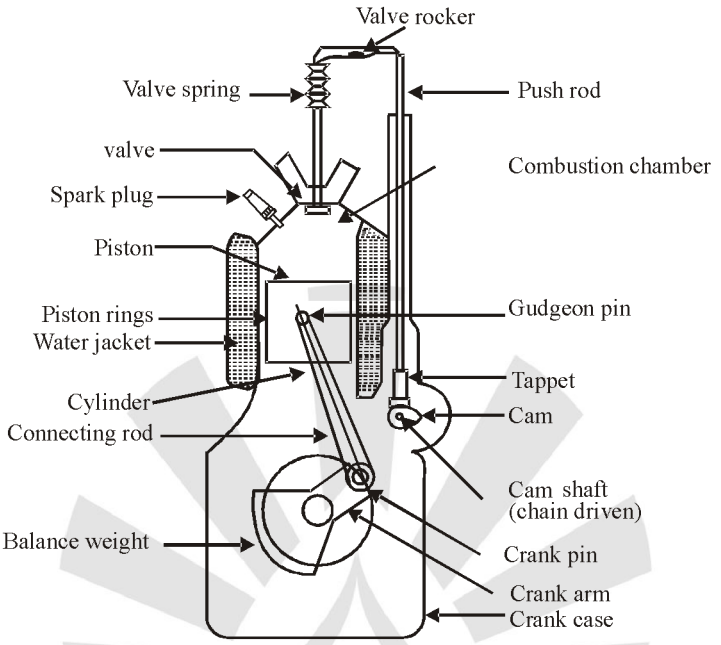



*Fig Cross-section of spark-ignition engine*

The figure shows the cross-section of a single cylinder spark-ignition internal combustion engine. The cylinder is supported in position by the cylinder block at the top end is covered by cylinder head.

In the cylinder, a piston travels in reciprocating motion. The space enclosed between the upper part of the cylinder and the top of the piston during the combustion process is called the combustion chamber.

**(1) Spark Plug :** The spark plug supplies the spark that ignites the air/fuel mixture so that combustion can occur. The spark must happen at just the right moment for things to work properly.

**(2) Valves :** The intake and exhaust valves open at the proper time to let in air and fuel and to let out exhaust. Note that both the valves are closed during compression and combustion so that the combustion chamber is sealed.

**(3) Piston :** A piston is a cylindrical piece of metal that moves up and down inside the cylinder.

**(4) Piston Rings :** Piston rings provide a sliding seal between the outer edge of the piston and the inner edge of the cylinder.

**(5) The Rings Serve Two Purposes**

(i) They prevent the fuel/air mixture and exhaust in the combustion chamber from leaking into the sump during compression and combustion.

(ii) They keep oil in the from leaking into the combustion area, where it would be burned and lost. Most cars that "burn oil" and have a quart added every 1,000 miles are burning it because the engine is old and the rings no longer seal things properly.

**(6) Connecting Rod :** The connecting rod connects the piston to the crankshaft. It can rotate at both ends so that its angle can change as the piston moves and the crankshaft rotates.

**(7) Crank Shaft :** The crank shaft turns the piston up and down motion into circular motion just like a crank on a jack-in-the-box does.

**(8) Sump :** The sump surrounds the crankshaft. It contains some amount of oil, which collects in the bottom of the sump (the oil pan.)

- A mixture of air and fuel enters the cylinder through the carburettor in spark-ignition engine via the inlet manifold i.e. the pipe which connects the inlet port of the engine of the air intake.
- In carburettor a throttle is provided to control the mass of mixture entering the combustion chamber. In the cylinder head there are inlet valves for taking the charge in the cylinder and exhaust valves for discharging the products of combustion. A spark plug near the top of the cylinder initiates the combustion.
- The energy of the expanding gas is transmitted by the piston (having piston rings to prevent leakage) through the gudgeon pin to the connecting rod.
- The connecting rod and the crank arm of the crankshaft translate the reciprocating motion of the piston into rotational motion of the crank shaft. The crankshaft is supported in bearings attached to the crankcase.
- The crankcase is the main body of the engine to which the cylinder is attached. The products of the combustion leave through exhaust port and exhaust manifold, both the intake and exhaust valves are operated by the valve mechanism.
- Crankshaft is driven by the crankshaft through timing gears. Lobed cams on the camshaft actuate the push rods and rocker arms for opening the valve against the force of valve springs.

## 1.3 The Standard Terminology Used in Internal Combustion Engines

**(1) Cylinder Bore (D) :** The nominal inner diameter of the working cylinder.

**(2) Piston Area (A) :** The area of a circle of diameter of the working cylinder.

*Note :* For an engine, in which a piston rod passes through the combustion space, as in a double-acting engine, this area must be reduced by the area of the cross-section of the piston rod

**(3) Stroke (L) :** The nominal distance through which a working piston moves between two successive reversals of its direction of motion.

**(4) Dead Centre :** The piston of the working piston and the moving parts which are mechanically connected to it at the moment when the direction of the piston motion is reversed (at either end point of the stroke).

**(5) Bottom Dead Centre (BDC) :** Dead centre when the piston is nearest to the crankshaft. In horizontal engines it is also called outer dead centre (ODC).

**(6) Top Dead Centre (TDC) :** Dead centre when the piston is farthest from the crankshaft. In horizontal engines it is also called inner dead centre (IDC).

**(7) Displacement Volume or Piston Swept Volume (Vs) :** The nominal volume generated by the working piston when travelling from one dead centre to next one, calculated as the product of piston area and stroke.

$$V_s = A \times L$$

**(8) Clearance Volume (Vc) :** The nominal volume of the space on the combustion side of the piston at top dead centre.

**(9) Cylinder Volume (V) :** The sum of piston swept volume and clearance volume.

$$V = V_S + V_C$$

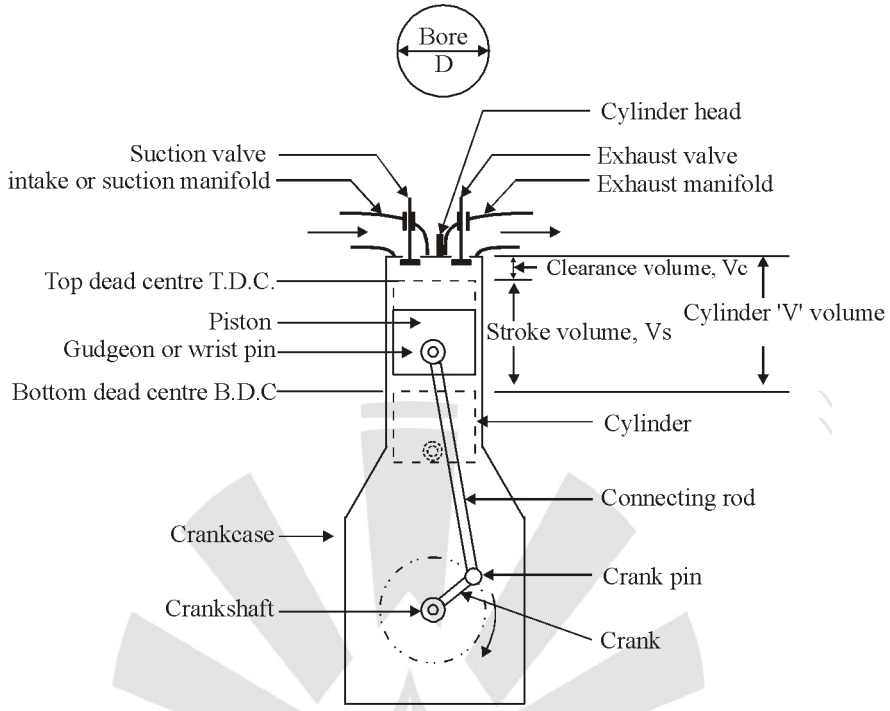



**Fig.** Important positions and volumes in reciprocating engine

**(10) Compression Ratio (CR or r) :** The numerical value of the cylinder volume divided by the numerical value of the combustion space volume or clearance volume.

$$\text{Compression ratio} = r = \frac{V}{V_c}$$

## 1.4 IC Engine Classification

- **Basic engine design :** Reciprocating engines, rotary (Wankel) engines.
- **Working cycle :** Engines working on Otto cycle (spark-ignition or S.I. engines), and engines working on diesel cycle (Compression -ignition or C.I. engines).
- **Number of strokes :** Four-stroke engines and two-stroke engines (both SI and CI engines).
- **Method of cooling :** Water cooled or air cooled.

## 1.5 Four-Stroke Cycle Spark-Ignition Engine

The cycle of operation is completed in four-strokes of the piston or two revolutions of the crankshaft. Each stroke consists of 180° of crankshaft rotation and hence a cycle consists of 720° of crankshaft rotation.

- **Suction Stroke :** Suction stroke 0-1 starts when the piston is at top dead centre and about to move downwards. The inlet valve is open at this time and the exhaust valve is closed. Due to the suction created by the motion of the piston towards bottom dead centre, the charge consisting of fresh air mixed with the fuel is drawn into the cylinder. At the end of the suction stroke the inlet valve closes.
- **Compression Stroke :** The fresh charge taken into the cylinder during suction stroke is compressed by the return stroke of the piston 1-2. During this stroke both inlet and exhaust valves remain closed.

The air which occupied the whole cylinder volume is now compressed into clearance volume. Just before the end of the compression stroke the mixture is ignited.

- **Expansion or Power Stroke :** Due to high pressure the burnt gases force the piston towards bottom dead centre, stroke 3-4, both the inlet and exhaust valves remains closed. Thus, power is obtained during this stroke. Both pressure and temperature decrease during expansion.

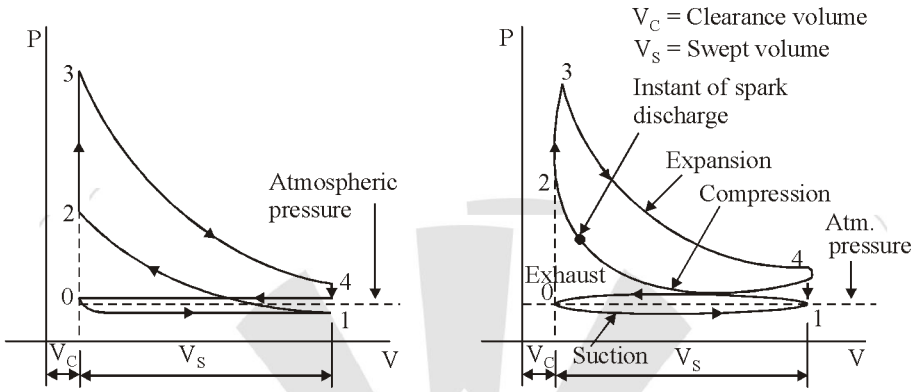
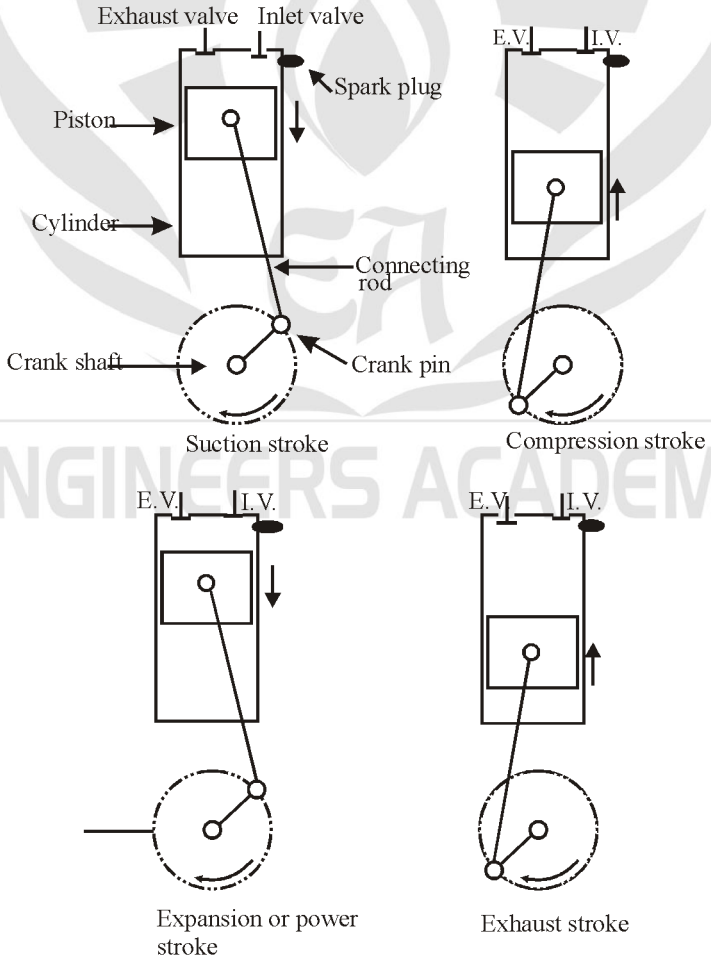



**Fig.** Ideal and actual indicator diagrams for four-stroke SI engine

- **Exhaust Stroke :** At the end of the expansion stroke the exhaust valve opens, the inlet valve remains closed, and the piston is moving form bottom dead centre to top dead centre sweeps out the burnt gases from the cylinder, stroke 4-0.



| *Stroke* | *Valve position* |
|---|---|
| Suction stroke. | Suction valve open. |
| | Exhaust valve closed. |
| Compression stroke. | Both valve closed. |
| Expansion stroke. | Both valves closed. |
| Exhaust stroke. | Exhaust valve open. |
| | Suction valve closed. |

***Note :*** *The exhaust valve closes at the end of the exhaust stroke and some 'residual' gases remain in the cylinder. One revolution of the crankshaft occurs during the suction and compression stroke, and second revolution during the power and exhaust strokes.*

Most of the spark-ignition internal combustion engines are of the four-stroke type.

**Acutal Valve timing of four-stroke Petrol Engine**

Valve timing is the regulation of the points in the cycle at which the valves are set to open and close. As described above in the ideal cycle inlet and exhaust valves open and close at dead centres, but in actual cycles they open or close before or after dead centres as explained below.

There are two factors, one mechanical and other dynamic, for the actual valve timing to be different from the theoretical valve timing.

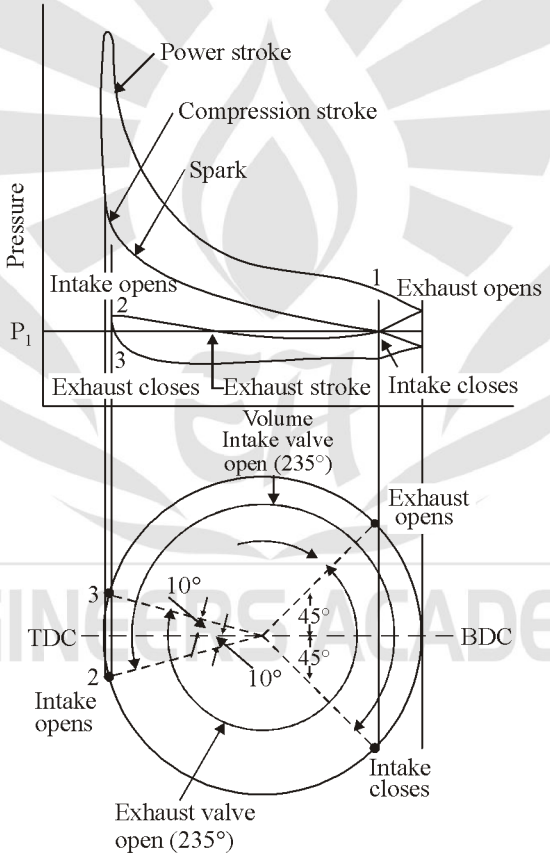



**Fig.** Four-stroke petrol engine valve timing diagram in relation to the pressure volume diagram

## 1.6 Four-Stroke Compression Ignition (CI) Engines

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. In the CI engine a high pressure fuel pump and an injector is provided to inject fuel into combustion chamber.

**14.** Two stroke engine is usually identified by
(a) size of flywheel
(b) absence of valves
(c) weight of engine
(d) location of fuel tank

**15.** A two stroke engine has
(a) suction port and exhaust port
(b) suction port and transfer port
(c) exhaust port and transfer port
(d) suction port, exhaust port and transfer port

**16.** Match the following and select the correct answer

| Operating mode of SI engine | Air-fuel ratio |
|---|---|
| **A.** Idling | **1.** 16.0 |
| **B.** Cold starting | **2.** 22.0 |
| **C.** Cruising | **3.** 12.5 |
| **D.** Maximum power | **4.** 3.0 |
| | **5.** 9.0 |

| *Codes:* | **A** | **B** | **C** | **D** |
|---|---|---|---|---|
| (a) | 1 | 5 | 3 | 2 |
| (b) | 5 | 4 | 3 | 1 |
| (c) | 5 | 4 | 1 | 3 |
| (d) | 3 | 1 | 2 | 4 |

**17.** The tendency for knocking in S. I. engines increases with
(a) advancing the spark timing
(b) delaying the spark timing
(c) spark timing has no effect on knocking in S. I. engines
(d) None of the above

**18.** No. of revolutions of crankshaft in case of 4-stroke engine is
(a) 4 (b) 2
(c) 1 (d) 1/2

**19.** Ignition of fuel in diesel engine is carried out by
(a) spark plug
(b) fuel injector
(c) ignitor
(d) heat resulting from compression of air in the combustion chamber

**20.** Relative efficiency is the ratio of
(a) Indicated thermal efficiency to air standard efficiency
(b) Brake thermal efficiency to air standard efficiency
(c) Volumetric efficiency to air standard efficiency
(d) None of these

**21.** Equivalent ratio ($\phi > 1$) shows
(a) Lean mixture
(b) Rich mixture
(c) Chemically correct mixture
(d) None of these

**22.** Air standard Otto cycle efficiency is expressed as
(a) $1-\left(\frac{1}{r}\right)^{\frac{\gamma-1}{\gamma}}$ (b) $\left(\frac{1}{r}\right)^{\frac{\gamma}{\gamma-1}}$
(c) $1-\left(\frac{1}{r}\right)^{\gamma-1}$ (d) $1-\left(\frac{1}{r}\right)^{\gamma+1}$

**23.** Scavenging is the process of
(a) Forcing air for engine cooling
(b) Using air for forcing burnt gases out of cylinder during exhaust period
(c) Mixing air & fuel
(d) Igniting fuel in diesel engine

**24.** The increase in the intake air temperature of I. C. Engine will
(a) increase the efficiency
(b) decrease the efficiency
(c) have no effect on efficiency
(d) None of the above

**25.** The constant volume process in I. C. Engines is the characteristic of
(a) C.I Engine (b) S. I. Engine
(c) Steam engine (d) Gas engine

**26.** Compression ratio in case of S. I. engines is generally

(a) 2 to 3 (b) 7 to 10

(c) 16 to 22 (d) 23 to 30

**27.** Compression ratio is the ratio of

(a) total volume of cylinder and clearance volume

(b) stroke volume and clearance volume

(c) pressure after compression and before compression

(d) cylinder volume and swept volume

**28.** Indicated horse power of a 4-stroke engine is

(a) $\frac{P_m LAN}{4500}$ (b) $\frac{P_m LAN}{2 \times 4500}$

(c) $\frac{2P_m LAN}{4500}$ (d) $\frac{2P_m LAN}{4 \times 4500}$

**29.** Because of detonation in an I. C. engine, which of the following parameter attains high value.

(a) rate of rise of temperature

(b) horse power

(c) rate of rise of pressure

(d) All of the above

**30.** The inlet valve of 4-stroke engine remains open for

(a) 275° (b) 235°

(c) 200° (d) 180°

**31.** Volumetric efficiency of a vertical compression engine would be reduced by

(a) exhaust valve closing after top dead centre

(b) opening inlet valve before top dead centre

(c) closing inlet valve before bottom dead centre

(d) closing inlet valve after bottom dead centre

**32.** Knock rating of S.I. engine fuels is decided by which of the following reference fuels

(a) iso-octane and n-hexane

(b) iso-octane and alpha-methyl naphthalene

(c) cetane and alpha-methyl naphthalene

(d) n-heptane and iso-octane

**33.** In actual working cycle, the effect of variations in specific heats is to

(a) increase maximum pressure and maximum temperature

(b) increase maximum pressure and decrease maximum temperature

(c) reduce maximum pressure and maximum temperature

(d) decrease maximum pressure and increase maximum temperature

**34.** In SI engine NOx is formed because of

1. Incomplete combustion
2. High temperature
3. Availability of oxygen

Select the correct answer

(a) 1 and 3 (b) 2 and 3

(c) 1 only (d) 3 only

**35.** The power lost in suction and exhaust stroke is

(a) brake horse power

(b) indicated horse power

(c) friction power

(d) pumping power

**36.** Indicated horse power is determined by

(a) mechanical indicator

(b) thermal indicator

(c) dial indicator

(d) None of the above.

**37.** The power developed inside the cylinder of an I. C. engine is,

(a) pumping power

(b) brake horse power

(c) indicated horse power

(d) All of the above

**38.** Which of the following is not an I.C. engine

(a) 2-stroke petrol engine

(b) diesel engine

(c) steam turbine

(d) 4-stroke diesel engine

**39.** For the same compression ratio.
(a) Diesel cycle is more efficient than otto cycle
(b) Otto cycle is more efficient than diesel
(c) Compression ratio has no effect on efficiency
(d) Both have equal efficiencies

**40.** The pressure of fuel injection in diesel engine is
(a) 40-80 kg/cm$^2$ (b) 200-250kg/cm$^2$
(c) 90-130kg/cm$^2$ (d) 130-200kg/cm$^2$

**41.** Stroke bore ratio in case of air craft engines is normally
(a) above 1
(b) below 1
(c) equal to 1
(d) None of the above

**42.** Supplying the intake of an engine with air at a density greater than the density of the surrounding atmosphere is called,
(a) Scavenging (b) Supercharging
(c) Suction (d) Injection

**43.** Optimum spark advance is the timing which develops
(a) maximum efficiency
(b) maximum power
(c) maximum torque
(d) minimum torque

**44.** Chemical process in which molecules of a compound become larger is called
(a) Atomisation (b) lonisation
(c) Polymerisation (d) Mole formation

**45.** Self-ignition temperature of diesel as compared to petrol is,
(a) lower (b) same
(c) higher (d) can't be predicted

**46.** The knocking in S.I. engines increases with_____in compression ratio
(a) increase
(b) decrease
(c) does not depend on compression ratio
(d) None of the above

**47.** The knocking in C.I. engines increases with_____in compression ratio
(a) increase
(b) decrease
(c) does not depend on compression ratio
(d) None of the above

**48.** Which of the following relates to S. I. engine?
(a) fuel pump (b) fuel injector
(c) carburettor (d) governor

**49.** An engine will generate maximum torque when it
(a) runs at max. speed
(b) develops max. power
(c) runs at lowest speed.
(d) consumes minimum fuel.

**50.** The internal loss in turbine are
(a) Leakage loss (b) Nozzle loss
(c) Blade friction loss (d) All of above

**51.** Ignition quality is basically as
(a) Centane number
(b) Octane number
(c) Peformance number
(d) Highest useful compression ratio

**52.** Aim of supercharging is to
(a) Increase power output
(b) Lower engine temperature
(c) Minimum friction
(d) Increase the engine speed

**53.** Swirl in C.I. engines is
(a) Circulatory motor produced exhaust air
(b) Circulatory motion produced to sucked air
(c) Removing oil from cylinder
(d) Increased knocking

**54.** Important consideration in the design of turbine blades is
(a) Fuel air ratio
(b) Outlet temperature
(c) Inlet temperature
(d) Creep

**55.** Knocking behavior in C.I. engine increases
(a) Increased compression ratio
(b) Decreased compression ratio
(c) Increased inlet air temperature
(d) None of these

**56.** Function of clearance volume in reciprocating air compressors is
(a) Increase the overall efficiency
(b) Accommodate valves in the heat of the compressor
(c) Reduce the work done per kg of air delivered
(d) Create high heat

**57.** Knocking behaviours in petrol engine increases due to
(a) Increased speed (b) Decreased speed
(c) Rich air-fuel ratio (d) Lean air fuel ratio

**58.** Piston compression rings are made of
(a) cast iron (b) bronze
(c) aluminium (d) white metal

**59.** The mechanical efficiency of a single-cylinder four-stroke engine is 80%. The frictional power is estimated t be 20 kW. What is the brake power developed by the engine?
(a) 80 kW (b) 50 kW
(c) 70 kW (d) 75 kW

**60.** The intake charge in a diesel engine consists of
(a) air alone
(b) air + lubricating oil
(c) air + fuel
(d) air + fuel + lubricating oil

**61.** The cubic capacity of a four-storke SI engine is 250 cc. The oversquare ratio of engine is 1.2 and the clearance volume is 30 cc. What is the compression ratio of the engine?
(a) 8.5 (b) 9
(c) 9.33 (d) 10.33

**62.** The engine of a car has three cylinder with total displacement of 770 cc. The compression ratio is 8.7. What is the clearance volume of each cylinder?
(a) 34.4 cc (b) 33.33 cc
(c) 32.33 cc (d) 35.2 cc

**63.** The top of the piston in two stroke engine is
(a) flat (b) slanted
(c) crown shaped (d) convex shaped

**64.** Thermal efficiency of CI engine is higher than that of SI engine due to
(a) fuel used
(b) higher compression ratio
(c) constant pressure heat addition
(d) none of the above

❑❑❑

## ANSWERS AND EXPLANATIONS

1. *Ans. (b)*
2. *Ans. (a)*
3. *Ans. (b)*
4. *Ans. (a)*
5. *Ans. (b)*
6. *Ans. (c)*
7. *Ans. (c)*
8. *Ans. (c)*
9. *Ans. (b)*
10. *Ans. (c)*
11. *Ans. (c)*
12. *Ans. (b)*
13. *Ans. (c)*
14. *Ans. (b)*

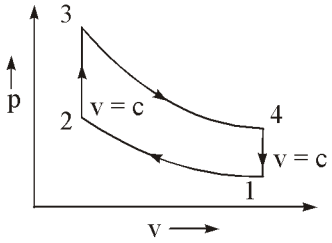
    Ports are mounted instead of valves.
15. *Ans. (d)*
16. *Ans. (c)*
17. *Ans. (a)*

    Advancing the spark timing increases the tendency to preignite
18. *Ans.* **(b)**
19. *Ans.* **(d)**

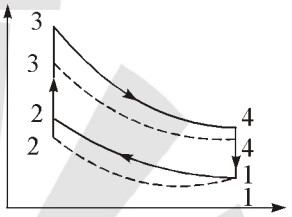
    Diesel engine is compression ignition engine.
20. *Ans. (a)*
21. *Ans. (b)*
22. *Ans. (c)*
23. *Ans. (b)*
24. *Ans. (b)*

    As the intake air temperature increases, the tendency of air to mix up with fuel decreases.
25. *Ans. (b)*

    S. I. engine works on otto cycle.




26. *Ans. (b)*
27. *Ans. (a)*
28. *Ans. (b)*
29. *Ans. (c)*
30. *Ans. (b)*
31. *Ans. (c)*
32. *Ans. (d)*
33. *Ans. (c)*




1–2–3–4– with constant specific heat.
1 –2 –3 –4 – with variable specific heat.

As temperature increases the value of $\gamma$ decreases.

34. *Ans. (b)*

    Oxidation of $N_2$ takes place at high temperature with availability of enough oxygen
35. *Ans. (d)*
36. *Ans. (a)*
37. *Ans. (c)*

    Definition of indicated horse power.
38. *Ans. (c)*

    In steam turbine the heat of combustion of fuel is first transferred to water to convert it into steam. Then steam is used as working fluid.
39. *Ans. (b)*