

Q.1. Answer the following (Any **Four**) :-

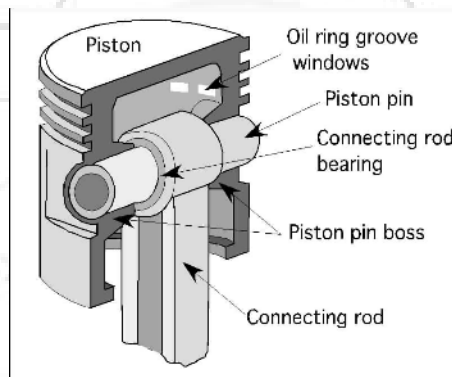
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(a) What are the basic components of I.C. Engine? Explain at least three components with sketches.

Ans:-

Piston-Acts as moveable end of the combustion chamber and must withstand pressure fluctuations, thermal stress, and mechanical loads.

- May use elliptical shape
  - Elliptical when cold
  - Diameter at piston pin bore expands more than thin edge of piston.
  - Round when hot
  - Some piston pins are offset
  - Piston must be orientated correctly in bore.
  - Windows are used in oil ring groove to allow excess oil to return to crankcase.



Piston rings-The job of the rings is to fill the space between the piston and the cylinder walls.

- The combustion chamber is sealed by a thin film of oil between the rings and the piston and between the rings and the cylinder wall.
- Usually constructed of cast iron.
- The total number of rings per piston can vary, but there are three types of rings on each piston.

Valves-Control flow of air-fuel into and exhaust gases out of the cylinder.

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- Types
    - One piece
    - Two piece
    - Projection-tip
  - Valve hardfacing
  - Valve stem surface treatments
  - Valve head design
    - Interference interface angle
    - Face can be resurfaced
  - Valve dynamics
    - Most valves rotate slightly each time they open and close.
    - Rotation improves temperature distribution
    - Rotation helps clean valve interface.
- Rotation can be enhanced through use of valve rotators



Valve Guide-Controls the position of the valves

- Subject to fluctuations in temperature, chemical corrosion, ingestion of foreign material and for the exhaust valve, high temperatures.
- Must provide a predictable and consistent clearance between itself and the valve stem.
- Can be aluminum, brass or sintered iron.

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**Crankshaft:** It converts the reciprocating motion of the piston into useful rotary motion of the output shaft. In the crankshaft of a single cylinder engine there are a pair of crank arms and balance weights. The balance weights are provided for static and dynamic balancing of the rotating system. The crankshaft is enclosed in a crankcase.

**Piston Rings:** Piston rings, fitted into the slots around the piston, provide a tight seal between the piston and the cylinder wall thus preventing leakage of combustion gases.

**Gudgeon Pin:** It forms the link between the small end of the connecting rod and the piston.

**Camshaft:** The camshaft and its associated parts control the opening and closing of the two valves. The associated parts are push rods, rocker arms, valve springs and tappets. This shaft also provides the drive to the ignition system. The camshaft is driven by the crankshaft through timing gears.

**Cams:** These are made as integral parts of the camshaft and are designed in such a way to open the valves at the correct timing and to keep them open for the necessary duration.

**Fly Wheel:** The net torque imparted to the crankshaft during one complete cycle of operation of the engine fluctuates causing a change in the angular velocity of the shaft. In order to achieve a uniform torque an inertia

mass in the form of a wheel is attached to the output shaft and this wheel is called the flywheel.

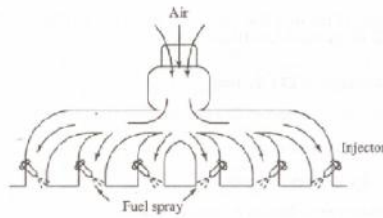
(b) Describe briefly the MPFI system with neat sketches.

Ans:-

The main purpose of the Multi-Point Fuel Injection (MPFI) system is to supply a proper ratio of gasoline and air to the cylinders. These systems function under two basic arrangements, namely

- (i) Port injection
  - (ii) Throttle body injection
- Port injection

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In the port injection arrangement, the injector is placed on the side of the intake manifold near the intake port (Fig.10.3), The injector sprays gasoline into the air, inside the intake manifold. The gasoline mixes with the air in are reasonably uniform manner. This mixture of gasoline and air then passes through the intake valve and enters into the cylinder.

Every cylinder is provided with an injector in its intake manifold. If there are six cylinders, there will be six injectors. Figure 10.4 shows a simplified view of a port or multi point fuel injection (MPFI) system.

Throttle body injection

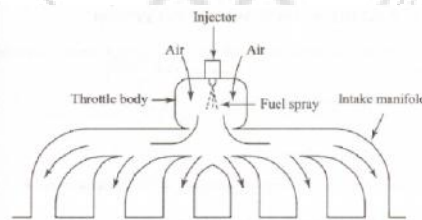


Figure illustrates the simplified sketch of throttle body injection system (Single point injection). This throttle body is similar to the carburetor throttle body, with the throttle valve controlling the amount of air entering the intake manifold. An injector is placed slightly above the throat of the throttle body. The injector sprays gasoline into the air in the intake manifold where the gasoline mixes with air. This mixture then passes through the throttle valve and enters into the intake manifold. As already mentioned, fuel-injection systems can be either timed or continuous. In the timed injection system, gasoline is sprayed from the injectors in pulses. In the continuous injection system, gasoline is sprayed continuously from the injectors. The port injection system and the throttlebody injection system may be either pulsed systems or continuous systems. In both systems, the amount of gasoline injected depends upon the engine.

(c) Compare knock in SI and CI engine.

Ans:-

It may be interesting to note that knocking in spark-ignition engines and compression-ignition engines is fundamentally due to the autoignition of the fuel-air mixture. In both the cases, the knocking depends on the autoignition lag of the fuel-air mixture. But careful examination of the knocking phenomenon in spark-ignition and the compression-ignition engines reveals the following differences. A comparison of the knocking process in SI and CI engines is shown on the pressure-time diagrams . In spark-ignition engines, the auto ignition of the end gas away from the spark plug, most likely near the end of the combustion causes knocking. But in compression-ignition engines the autoignition of the charge causing knocking is at the start of

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combustion. It is the first charge that autoignites and causes knocking in the compression-ignition engines. The explosive auto-ignition is more or less over before the peak pressure for the compression-ignition engines. But for spark-ignition engines, the condition for explosive autoignition of the end charge is more favourable after the peak pressure. In order to avoid knocking in spark-ignition engines, it is necessary to prevent autoignition of the end gas to take place at all. In compression-ignition engine, the earliest possible autoignition is necessary to avoid knocking.

*(d) Explain how supercharging helps to improve power output.*

Ans:-

The question arises in the mind of the students, what should be the optimum or maximum pressure of the supercharged air supplied to the engine. It is obvious from the previous discussion that the BP and *bsfc* both are in favour of supercharging but one cannot go on increasing the supercharged pressure as there are other limitations which limit the maximum supercharged pressure. The factors which affect the maximum supercharged pressure to be used are discussed here. The dependence of thermal efficiency and maximum IP upon the supercharge ratio. It is assumed that the engine design is such that a compression ratio of 6 (S.I. engine) can be used without detonation. Considering the total compression ratio is 6 and entire field is exposed considering complete compression takes place either in the engine alone or it takes place in the supercharger alone. It can be seen from Fig. 16.45 that the thermal efficiency is maximum when the complete compression carried out in the engine and drops to zero when the compression takes place entirely in the supercharger and no compression in the engine. There is also no expansion and hence no work developed.

*e) The requirement of air motion and swirl in a C.I. engine combustion chamber is much more stringent than in a S.I. engine. Justify.*

Ans:-

The most important function of the CI engine combustion chamber is to provide proper mixing of fuel and air in a short time. In order to achieve this, an organized air movement called the air swirl is provided to produce high relative velocity between the fuel droplets and the air. The effect of swirl. The fuel is injected into the combustion chamber by an injector having a single or multi hole orifices. The increase in the number of jets reduces the intensity of air swirl needed. When the liquid fuel is injected into the combustion chamber, the spray cone gets disturbed due to the air motion and turbulence inside. The onset of combustion will cause an added turbulence that can be guided by the shape of the combustion chamber. Since the turbulence is necessary for better mixing, and the fact that it can be controlled by the shape of the combustion chamber, makes it necessary to study the combustion chamber design in detail. CI engine combustion chamber are classified into two categories:

(i) *Direct-Injection (DI) Type*. This type of combustion chamber is also called an open combustion chamber. In this type the entire volume of the combustion chamber is located in the main cylinder and the fuel is injected into this volume.

*(f) What are the disadvantages of LPG as a I.C. Engine fuel?*

Ans:-

- 1) Low power output.
- 2) Filter unit required.
- 3) Maintenance is more.
- 4) Filling stations available rarely.
- 5) Tank required for storage.

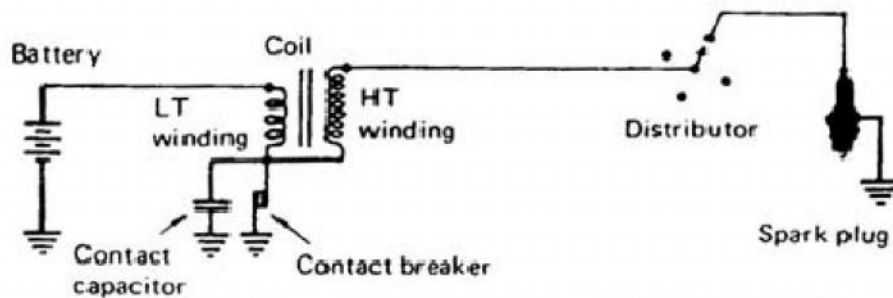
2. (a) Explain the function of the following components of the S.I. engine battery

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ignition system :- .

- (i) Ballast resistor
- (ii) Capacitor
- (iii) Spark plug
- (iv) Ignition coil
- (v) Contact breaker. '1

Ans:-



(i) Ballast resistor-A ballast resistor is provided in series with the primary winding to regulate the primary current. The object of this is to prevent injury to the spark coil by overheating if the engine should be operated for a long time at low speed, or should be stalled with the breaker in the *closed* position. This coil is made of iron wire, and iron has the property that its electrical resistance increases very rapidly if a certain temperature is exceeded. The coil is therefore made of wire of such size that if the primary current flows nearly continuously, the ballast coil reaches a temperature above that where this rapid increase in resistance occurs. This additional resistance in the primary circuit holds the primary current down to a safe value. For starting from

(ii) Capacitor

(iii) Spark plug-The spark plug provides the two electrodes with a proper gap across which the high potential discharges to generate a spark and ignite the combustible mixture within the combustion chamber.

(iv) Ignition coil- The primary winding, located outside the secondary coil is generally formed of 200-300 turns of 20 gauge wire to produce a resistance of about 1.150. The ends are connected to exterior terminals. More heat is generated in the primary than in the secondary and with the primary coil wound over the secondary coil, it is easier to dissipate the heat.

The entire unit when assembled, is enclosed in a metal container and forms a neat and compact unit. The top of the coil assembly is the heavily insulated terminal block, which supports three

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terminals. To the two smaller terminals (Fig.11.3), usually marked SW (switch wire) and CB (contact breaker) the two ends of the primary are connected. As can be seen in Fig.11.3, one end of the secondary winding is connected to the central high-tension terminal in the molded cover of the distributor. The other end is connected to the primary. An external high tension wire connects this central terminal to the central terminal of the distributor.

(v) Contact breaker. This is a mechanical device for making and breaking the primary circuit of the ignition coil. It consists essentially of a fixed metal point against which, another metal point bears which is being on a spring loaded pivoted arm. The metal used is invariably one of the hardest metals, usually tungsten and each point has a circular flat face of about 3 mm diameter. The fixed contact point is earthed by mounting it on the base of the contact breaker assembly whereas the arm to which the movable contact point is attached, is electrically insulated. When the points are closed the current flows and when they are open, the circuit is broken and the flow of current stops. The pivoted arm has, generally, a heel or a rounded part of some hard plastic material attached in the middle and this heel bears on the cam which is driven by the engine. Consequently, every time the cam passes under the heel, the points are forced apart and the circuit is broken. The pivoted arm is spring loaded, so that when the points

(b) A simple jet carburetor is required to supply 6 kg of air and 1 g of fuel per minute. The fuel specific gravity is 0.75. The air is initially at 1 bar and 300K. Calculate the throat diameter of the choke for a flow velocity of 110 m/s. Velocity coefficient is 0.8. If the pressures drop across the fuel metering orifice is 0.80 of that of the choke, calculate orifice diameter assuming,  $C_d = 0.60$  and  $\gamma = 1.4$ . 10

Ans:-

$$\text{Velocity at throat} = C_2 = V_c * (2 * C_p * T_1 [1 - (P_2/P_1)^{-\gamma}])^{1/2}$$

$$110 = 0.8 * (2 * 1005 * 300 [1 - (P_2/1)^{0.286}])^{1/2}$$

$$P_2 = 0.894 \text{ bar}$$

$$P_1 U_1 = mRT_1$$

$$U_1 = (287 * 300) / 10^5$$

$$U_1 = 0.861 \text{ m}^3/\text{kg}$$

$$P_1 U_1 = P_2 U_2$$

$$U_2 = U_1 * (P_1/P_2)^{1/\gamma}$$

$$U_2 = 0.861 * (1/0.894)^{0.714}$$

$$U_2 = 0.932 \text{ m}^3/\text{kg}$$

$$\text{Throat area} = A_2 = (m_a * U_2) / C_2$$

$$A_2 = (6 * 0.932 * 10^4) / (110 * 60)$$

$$A_2 = 9.32 \text{ cm}^2$$

$$d_2 = (9.32 * 4 / 3.14)^{1/2}$$

$$d_2 = 3.44 \text{ cm}$$

$$P_a = 1 - 0.894 = 0.106 \text{ bar}$$

$$P_f = 0.8 * 0.106 = 0.0848 \text{ bar}$$

$$m_f = A_f * C_f * (2 * \gamma * P_f)^{1/2}$$

$$0.4/60 = (3.14 * d_f^2 / 4) * 0.6 * (2 * 750 * 0.0848 * 10^5)^{1/2}$$

$$d_f = 1.99 \text{ mm.}$$

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3. (a) With the help of neat diagram explain the forced circulation pressure cooling system used in modern automobiles. Also, Explain the construction and operation of thermostat and pressure cap used in the system. 10

Ans:-

Water Cooling can be done by any of the following methods,

01) Direct Method:-

In this method, water from a storage tank is directly supplied through an inlet valve to the engine cylinder. The hot water is simply discharged and not cooled for reuse. It is suitable for large industrial units and where plenty of water is easily available.

02) Thermosyphon Method:-

In this method, hot water from engine cylinder flows towards radiator, which has comparatively cold water, and get cool down.

In order to ensure that the coolest water is always made available to the water jackets the latter should be located at as low a level as possible with respect To the radiator.

This system is useful due its simplicity and automatic operation, but there is disadvantage of water freezing in cold weather condition. We have to use large Quantity of water, as there is slow rate of circulation observed.

03) Impeller Thermosyphon Method:-

Here the flow of water takes place by convection assisted by a pump. The latter is made non-positive type, which even when stationary; allows the flow of water to take place. Thus when the working of pump fails water can still circulate on the thermosyphon system.

In its simplest form, water flow from radiator to engine and back to radiator. A thermostat is employed in system, which prevents the flow of water below a certain temperature, from the engine to the radiator. This we have to do to acquire some of the temperature at starting of the engine.

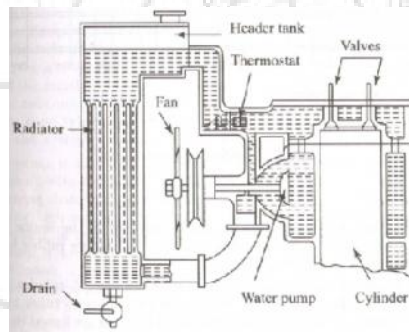
This system has three major parts, (The details about this parts will be covered in coming post.)

01) Radiator

02) Fan and Pump

03) Thermostat

04) Full Pump Circulation Method:-



In this method, a positive supply of water by a centrifugal pump placed in the system. This system works on higher Velocity of circulating water due to which less quantity of water is

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required hence we can use smaller radiator. In some designs the piston is cooled by oil squirted against the piston crown underside through a nozzle located in the connecting rod small end.

05) Evaporative Cooling Method:-  
 In this method, the engine may be cooled by evaporating the water in the cylinder jackets, into the steam, which absorbs Large quantity of heat and raise to the top of the engine from where it flows into a tank at the bottom of the radiator and then flows upwards and gets Condensed before reaching the top. Due to large quantity of latent heat absorbed during evaporation of water into steam the weight of the circulating water is only 40% of that in other water Cooling methods. Hence smaller radiator can be employed. This system is quite useful where plenty of water is not available. The higher running temperature no doubt reduces the friction in the piston but the volumetric efficiency is reduced and the engine is also liable to detonate.

(b) A four-cylinder, four-stroke diesel engine develops a power of 170 kW at 1600 rpm. The bsfc is 0.2 kg/kW h. At the beginning of injection pressure is 30 bar and the maximum cylinder pressure is 60 bar. The injection is expected to be at 190 bar and maximum pressure at the injector is set to be about 550 bar. Assuming the following :-  
 Cd for injector = 0.7  
 S.G.of fuel = 0.875  
 Atmospheric pressure = 1 bar  
 Effective pressure difference = Average pressure difference over the injection period  
 Determine the total orifice area required per injector if the injection takes place over 140 crank angles. **10**

Ans:-

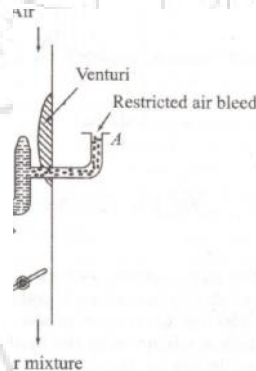
Power output/cylinder = 170/4 = 42.5 kw  
 Fuel consumption / cylinder = 42.5\*bsfc = 42.5\*0.2/60 = 0.14 kg/min  
 Fuel injection per cycle = 0.14/(RPM/2) = 0.14/(1600/2) = 1.74\*10<sup>-4</sup> kg  
 Time for injection = 140/(360\*rpm/60) = 14/(360\*1600/60) = 1.4583\*10<sup>-3</sup> s  
 Pressure difference at beginning = 190-30 = 160 bar  
 Pressure difference at end = 550-60 = 490 bar  
 Avg pressure difference = (490 + 160)/2 = 325 bar  
 Velocity of injection  $V_{inje} = cd * (2(Pinj - Pcyln) / \rho)^{1/2}$   
 $V_{inje} = 0.7 * (2(325 * 10^5) / 875)^{1/2}$   
 $V_{inje} = 190.78 * 10^{-7} \text{ m}^3/\text{cycle}$   
 $Af = 190.78 * 10^{-7} / (190.78 * 1.4583 * 10^{-6})$   
 $Af = 0.714 * 10^{-6} \text{ m}^2$

4. (a) Explain the function of the following with neat sketches :- **12**  
 (i) Air bleed jet  
 (ii) Anti dieseling system  
 (iii) Emulsion tube  
 (iv) Economizer system.

Ans:-

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(i) Air bleed jet-The compensating well is supplied with fuel from the main float chamber through a restricting orifice. With the increase in air flow rate, there is decrease of fuel level in the compensating well, with the result that fuel supply through the compensating jet decreases. The compensating jet thus progressively makes the mixture leaner as the main jet progressively makes the mixture richer. The sum of the two tends to keep the fuel-air mixture more or less constant as shown in Fig.8.14. The main jet curve and the compensating jet curve are more or less reciprocals of each other.



(ii) Anti dieseling system-An SI engine sometimes continuous to run for a very small period even after the ignition is switched off. This phenomenon is called dieseling (after running or run-on). Dieseling may take place due to one or more of the following:

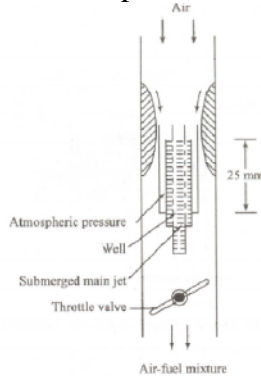
- (i) Engine idling speed set to high.
- (ii) Increase in compression ratio due to carbon deposits.
- (iii) Inadequate or low octane rating.
- (iv) Engine overheating.
- (v) Too high spark plug heat range.
- (vi) Incorrect adjustment of idle fuel-air mixture (usually toluene).
- (vii) Sticking of throttle.
- (viii) Requirement of tune up of engine.
- (ix) Oil entry into the cylinder.

Some modern automobiles use anti dieseling system to prevent dieseling system. This system has a solenoid valve operated idling circuit.

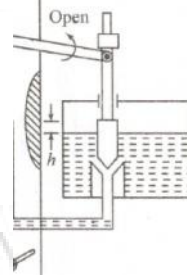
(iii) Emulsion tube- The mixture correction is attempted by air bleeding in modern carburetor. In one such arrangement as shown in Fig., the main metering jet is kept at a level of about 25 mm below the fuel level in the float chamber. Therefore, it is also called submerged jet. The jet is located at the bottom of a well. The sides of the well have holes. As can be seen from the figure these holes are in communication with the atmosphere. In the beginning the level of petrol in the float chamber and the well is the same. When the throttle is opened the pressure at the venturi throat decreases and petrol is drawn into the air stream. This results in progressively uncovering the holes in the central tube leading to increasing air-fuel ratios or decreasing richness of mixture when all holes have been uncovered. Normal flow takes place from the main jet. The air is drawn

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through these holes in the well, and the fuel is emulsified and the pressure differential across the column of fuel is not as high as that in simple carburetor.



(iv) Economizer system- throat so that even at low engine speeds the carry the fuel particles along. Otherwise, ate out providing only a lean mixture to the mixing tube is finite and small then engine at a sufficiently rapid rate at high this drawback the *down draught* carburetor ced at a level higher than the inlet manifold 3 generally follow a downward course. Here lifted by air friction as in the up draught yinders by gravity even if the air velocity and throat can be made large which makes )ecific outputs possible. A *cross-draught* mixing tube with a float chamber on one a cross-draught carburetor in engines, one passage is eliminated and the resistance to



(b) A Morse Test on 12 cylinder, Two stroke compression ignition engine of bore 35 cm and stroke 60 cm, running at 210 rpm, gave the following results, 8

**Condition Brake load Condition Brake load**

- All firing 2040 7th Cylinder 1835
- 1st Cylinder 1830 8th Cylinder 1860
- 2nd Cylinder 1850 9th Cylinder 1820
- 3rd Cylinder 1850 10th Cylinder 1840
- 4th Cylinder 1830 11th Cylinder 1850
- 5th Cylinder 1840 12th Cylinder 1830
- 6th Cylinder 1855 All firing 2060

The output is found from the dynamometer using the relation  $Bp = WN/180$   
 Where,  $W$  = brake load in Newton and  $N$  is Speed in rpm. Calculate Indicated Power Mechanical Efficiency and Brake Mean Effective Pressure of the Engine.

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Ans:-

Power output when all cylinders fires =  $(2040 + 2060)/2 * (210/180) = 2391.66 \text{ kw}$

Power output when  $k^{\text{th}}$  cylinders is cut off =  $N/180 \sum_{k=1}^{12} Wk$

Cylinder number cut off	B P of $k^{\text{th}}$ cylinders is cut off = $N/180 \sum_{k=1}^{12} Wk$
1	257
2	234
3	234
4	257
5	245
6	227
7	251
8	221
9	268
10	245
11	234
12	257

I P = 2930 kw

$\eta_m = 2391.66/2930 = 81.63 \%$

$b_{mep} = (B P * 60000)/(L * A * n * k) = (2391.66 * 60000 * 4)/(0.6 * 3.14 * 0.35 * 210 * 12)$

$b_{mep} = 9.86 \text{ bar}$

5. (a) *What are the theories of detonation? Explain each theory in detail.*

10

Ans-

Knocking (also called knock, detonation, spark knock, pinging or pinking) in spark-ignition internal combustion engines occurs when combustion of the air/fuel mixture in the cylinder starts off correctly in response to ignition by the spark plug, but one or more pockets of air/fuel mixture explode outside the envelope of the normal combustion front. The fuel-air charge is meant to be ignited by the spark plug only, and at a precise time in the piston's stroke cycle. The peak of the combustion process no longer occurs at the optimum moment for the four-stroke cycle. The shock wave creates the characteristic metallic "pinging" sound, and cylinder pressure increases dramatically. Effects of engine knocking range from inconsequential to completely destructive. It should not be confused with pre-ignition (or preignition), as they are two separate events.

Pre-ignition

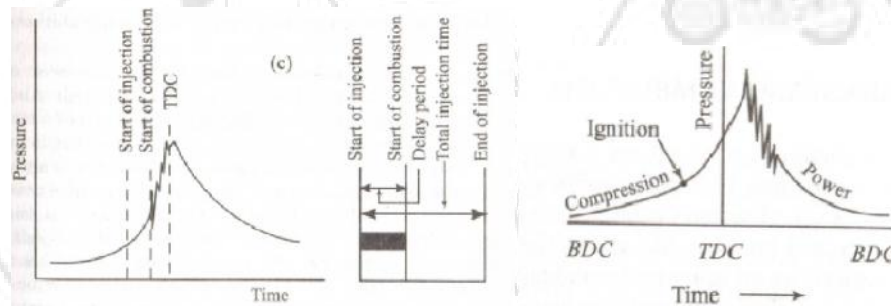
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Pre-ignition (or preignition) in a spark-ignition engine is a technically different phenomenon from engine knocking, and describes the event wherein the air/fuel mixture in the cylinder ignites before the spark plug fires. Pre-ignition is initiated by an ignition source other than the spark, such as hot spots in the combustion chamber, a spark plug that runs too hot for the application, or carbonaceous deposits in the combustion chamber heated to incandescence by previous engine combustion events.

Causes of pre-ignition

Causes of pre-ignition include the following:

- Carbon deposits form a heat barrier and can be a contributing factor to preignition. Other causes include: An overheated spark plug (too hot a heat range for the application). Glowing carbon deposits on a hot exhaust valve (which may mean the valve is running too hot because of poor seating, a weak valve spring or insufficient valve lash).
- A sharp edge in the combustion chamber or on top of a piston (rounding sharp edges with a grinder can eliminate this cause).
- Sharp edges on valves that were reground improperly (not enough margin left on the edges).
- A lean fuel mixture.
- Low coolant level, slipping fan clutch, inoperative electric cooling fan or other cooling system problem that causes the engine to run hotter than normal.



(b) A three-liter four-stroke diesel engine develops 10 kW per m<sup>3</sup> of free air 10 inducted per minute. The volumetric efficiency is 80% at 3500 rpm referred to atmospheric condition of 1 bar and 27 °C. A rotary compressor which is mechanically coupled to the engine is used to supercharge the engine. The pressure ratio and the isentropic efficiency of the compressor are 1.6 and 75% respectively. Calculate the percentage increase in brake power due to supercharging. Assume mechanical efficiency of the engine to be 85% and air intake to the

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*cylinder to be at the pressure equal to delivery pressure from compressor and temperature equal to 5.6°C less than delivery temperature of the compressor. Also assume that cylinder contains volume of charge equal to swept volume.* 10

Ans:-

Swept volume  $V_s = (3 \times 3600) / (1000 \times 2) = 5.25 \text{ m}^3/\text{min}$   
 $V_a = V_s \times v = 5.25 \times 0.8 = 4.2 \text{ m}^3/\text{min}$   
 Power =  $4.2 \times 10 = 42 \text{ kw}$   
 $P_a = 1 \times 1.6 = 1.6 \text{ bar}$   
 By isentropic process  
 $T_d = T_a \cdot (P_d)^{-1/\gamma} = 300 \cdot (1.6)^{0.4114} = 343.12 \text{ k}$   
 $\frac{v_c}{v} = \frac{T_s}{T_c}$   
 $0.75 = (343.12 - 300) / (T_{ac} - 300)$   
 $T_{ac} = 357.69 \text{ k}$   
 Engine intake temperature =  $357.69 - 5.6 = 351.89 \text{ k}$   
 Volume induced =  $(5.25 \times 1.6 \times 300) / (1 \times 351.89) = 7.161 \text{ m}^3/\text{min}$   
 Volume increase =  $7.161 - 4.2 = 2.961 \text{ m}^3/\text{min}$   
 $I P_{\text{increase}} = 2.961 \times 10 = 29.61 \text{ kw}$   
 $I P_{\text{increase due to pressure}} = P \cdot V_s / 60000$   
 $I P_{\text{increase due to pressure}} = (1.6 - 1) \times 10^5 \times 5.25 / 60000 = 5.25 \text{ kw}$   
 $I P_{\text{TOTAL INCREASE}} = 29.61 + 5.25 = 34.86 \text{ kw.}$   
 $m_a = (1.6 \times 10^5 \times 5.25) / (300 \times 351.89) = 7.95 \text{ kg/min}$   
 Power required to run a compressor =  $m_a \cdot C_p \cdot \Delta T_a$   
 $= 7.95 \times 1.005 \times (357.69 - 300) / 60 = 7.68 \text{ kw}$   
 $B P_{\text{NET INCREASE}} = 34.86 - 7.68 = 27.18 \text{ kw}$   
 $\% \text{ age increase} = (27.18 / 42) \times 100 = 64.71 \%$

6. (a) "A good CI engine fuel is a bad SI engine fuel and vice a versa". Discuss the validity 10 of the above statement in the light of the eight factors to reduce knocking in SI and CI engines. 10

Ans:-

Eight factors to reduce knocking in SI and CI engines.

Sr. No.	Characteristics SI Engines CI Engines	SI Engines	CI Engines
1	Ignition temperature of fuel High Low	High	Low
2	. Ignition delay Long Short	Long	Short
3	Compression ratio Low High	Low	High
4	. Inlet temperature Low High	Low	High
5	Inlet pressure Low High	Low	High
6	Combustion wall temperature	Low	High
7	Speed,rpm	High	Low
8	Cylinder size	Small	Large

(b) The following observations were made during a trial of a single cylinder, four-stroke 10 cycle gas engine having cylinder diameter of 15 cm and stroke 20 cm.  
 Duration of trial = 30 min  
 Total number of revolution = 8000  
 Total number of explosion = 4400  
 Mean effective pressure = 5 bar  
 Net load the brake wheel = 45 kg  
 Effective diameter of brake wheel = 1m  
 Total gas used at NTP = 2.4 m<sup>3</sup>  
 Calorific value of gas at NTP = 19 MJ/m<sup>3</sup>  
 Total air used = 36m<sup>3</sup>  
 Pressure of air = 720 mm Hg  
 Temperature of air = 1rc  
 Density of air at NTP = 1.29 kg/m<sup>3</sup>  
 Temperature of exhaust gas = 350°C  
 Room temperature = 1rc  
 Specific heat of exhaust gas = 1 kJ/kg K  
 Cooling water circulated = 70 kg  
 Rise in temperature of cooling water = 30°C  
 Draw a heat balance sheet and estimate the mechanical and indicated thermal efficiencies. Take R = 287 J/kg K.

Ans:-

$$IP = (P_{im} * L * A * N) / 60000 = (5 * 10^5 * 0.2 * 3.14 * 0.15^2 * 4400) / (60000 * 30 * 4)$$

$$IP = 4.319 \text{ kw}$$

$$BP = (3.14 * N * d * W) / 60000 = (3.14 * 8000 * 1 * 45 * 9.81) / (60000 * 30) = 6.16 \text{ kw}$$

$$Q_{NTP} = (2.4/30) * 19000 = 1520 \text{ kJ/min}$$

$$Q_{BP} = 6.16 * 60 = 369.6 \text{ kJ/min}$$

$$Q_{WATER} = (70/30) * 4.18 * 30 = 292.6 \text{ kJ/min}$$

Air used = 36 m<sup>3</sup> at 720 mm of Hg

$$V_a = (36 * 273 * 720) / (290 * 760) = 32.1 \text{ m}^3$$

$$m_a = (32.1 * 1.29) / 30 = 1.38 \text{ kg/min}$$

$$m_g = (P * V) / (R * T) = (1 * 10^5 * 2.4) / (273 * 287 * 30) = 0.102 \text{ kg/min}$$

$$m_{g \text{ Total}} = 1.38 + 0.102 = 1.482 \text{ kg/min}$$

$$Q_{Exhaust} = 1.482 * 1 * (350 - 17) = 493.5 \text{ kJ/min}$$

$$Q_{Radiation} = 1520 - (369.6 + 292.6 + 493.5) = 364.3 \text{ kJ/min}$$

$$\eta_{mech} = 6.16 / 4.319 = 142\%$$

$$\eta_{ith} = (4.319 * 60 * 100) / 1520 = 17.84 \%$$

HEAT BALANCE SHEET

Heat Energy	kJ/min	% age
Q TOTAL	1520	100
Q BP	369.6	24.31

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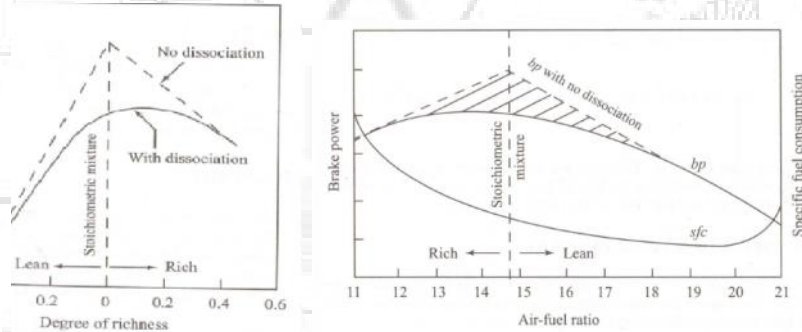
$Q_{\text{WATER}}$	292.6	19.25
$Q_{\text{EXHAUST}}$	493.5	32.46
$Q_{\text{RADIATION}}$	364.3	23.96

7. Write Short Notes (Any Five):- 20

(a) Phenomenon of Dissociation

Ans:- The gases tends to prevent dissociation of fuel mixture, which, by producing more CO

On the other hand, there is no dissociation fuel -air mixture. This is mainly due to the fact is too low for this phenomenon to occur. dissociation occurs in the burnt gases of the mixture when the temperatures are expected to In leaner and richer mixtures. I.C. engines heat transfer to the cooling in the maximum temperature and pressure. 'ing the expansion stroke the separated cont absorbed during dissociation is thus again the stroke to recover entirely the lost power. carried away by the exhaust gases. al curve that indicates the reduction in the ~as mixtures due to dissociation with respect dissociation maximum temperature is attained . With dissociation maximum temperature slightly rich. Dissociation reduces the maxi 100 DC even at the chemically correct air-fuel mixtures and rich mixtures are marked clear.



The effect of dissociation on output power is shown in for a typical four-stroke spark-ignition engine operating at constant speed. If there is no dissociation, the brake power output is maximum when the mixture ratio is stoichiometric. The shaded area between the brake power graphs shows the loss of power due to dissociation. When the mixture is quite lean there is no dissociation. As the air-fuel ratio decreases i.e., as the mixture becomes rich the maximum temperature raises and dissociation commences. The maximum dissociation occurs at chemically correct mixture strength. As the mixture becomes richer, dissociation effect tends to decline due to incomplete combustion.

(b) Alternative fuels for I C engines

Ans:-

Alternative fuels, also known as non-conventional or advanced fuels, are any materials or substances that can be used as fuels, other than conventional fuels. Conventional fuels include: fossil fuels (petroleum (oil), coal, propane, and natural gas), and nuclear materials such as uranium.

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Some well known alternative fuels include biodiesel, bio alcohol (methanol, ethanol, butanol), chemically stored electricity (batteries and fuel cells), hydrogen, non-fossil methane, non-fossil natural gas, vegetable oil and other biomass sources.

### Biofuel

Biofuels are also considered a renewable source . Although renewable energy is used mostly to generate electricity, it is often assumed that some form of renewable energy or at least it is used to create alternative fuels.

### Biomass

Biomass in the energy production industry is living and recently dead biological material which can be used as fuel or for industrial production.

### Alcohol fuels

Alcohol fuel, Ethanol fuel, and Methanol fuel

Methanol and Ethanol fuel are typically primary sources of energy; however, they are not convenient fuels for storing and transporting energy. These alcohols can not be used in "internal combustion engine as alternative fuels"

### Hydrogen

Hydrogen as a fuel has been suggested to have the capability to create a hydrogen economy.

### HCNG

HCNG (or H<sub>2</sub>CNG) is a mixture of compressed natural gas and 4-9 percent hydrogen by energy

### Liquid nitrogen

Liquid nitrogen is another type of emission less fuel.

### Compressed air

The air engine is an emission-free piston engine using compressed air as fuel. Unlike hydrogen, compressed air is about one-tenth as expensive as fossil oil, making it an economically attractive alternative fuel.

### Alternative fossil fuels

Compressed natural gas (CNG) is a cleaner burning alternative to conventional petroleum automobile fuels. The energy efficiency is generally equal to that of gasoline engines, but lower compared with modern diesel engines. CNG vehicles require a greater amount of space for fuel storage than conventional gasoline power vehicles because CNG takes up more space for each GGE (Gallon of Gas Equivalent). Almost any existing gasoline car can be turned into a bi-fuel (gasoline/CNG) car. However, natural gas is a finite resource like all fossil fuels, and production is expected to peak gas soon after .

### *(c) Stratified charge engine*

Ans:-

An internal-combustion engine with a divided ignition cylinder that uses the ignition of rich fuel in a small chamber near the spark plug to improve the combustion of a very lean mixture throughout the rest of the cylinder.

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The stratified charge engine is a type of internal-combustion engine, similar in some ways to the Diesel cycle, but running on normal gasoline. The name refers to the layering of fuel/air mixture, the *charge* inside the cylinder.

In a traditional Otto cycle engine the fuel and air are mixed outside the cylinder and are drawn into it during the intake stroke. The air/fuel ratio is kept very close to stoichiometric, which is defined as the exact amount of air necessary for a complete combustion of the fuel. This mixture is easily ignited and burns smoothly.

The problem with this design is that after the combustion process is complete, the resulting exhaust stream contains a considerable amount of free single atoms of oxygen and nitrogen, the result of the heat of combustion splitting the O<sub>2</sub> and N<sub>2</sub> molecules in the air. These will readily react with each other to create NO<sub>x</sub>, a pollutant. A catalytic converter in the exhaust system recombines the NO<sub>x</sub> back into O<sub>2</sub> and N<sub>2</sub> in modern vehicles.

The much cleaner combustion in stratified charge petrol engines allows for the elimination of the catalytic converter and allows the engine to be run at leaner mixtures, using less fuel. It has had a similar effect on diesel engine performance. Today's diesels are cleaner and can be twice as powerful as before, while maintaining similar fuel economy.

(d) EURO norms

Ans:-

Gas sent into the atmosphere by the engine, carbon monoxide (CO) and nitrogen oxide (NO<sub>x</sub>) visible for air pollution. These pollutants are known problems. Therefore there are laws on emission the amount of each pollutant in the exhaust gas IC engine. have been followed for some time in the developed U.S.A., Europe, and Japan which have their own a is in favour of the "European Model" developed. The European emission norms are called 'Euro industries have developed the "Euro" norms, re enforced in the New Delhi Capital Region from 1996.

15.1 Euro I and Euro II norms for new petrol and diesel cars followed in India

Norm/Year	CO gm/km		HC + NO gm/km		PM gm/km	
	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel
1996	8.68 - 12.40	5.7	3.00 - 4.36	2.2		
Euro I	3.16	3.16	1.13	1.13		0.18
Euro II	2.20	1.00	0.50	0.70 - 0.90		0.080 - 0.10

gm/km      gram per kilometre      CO      Carbon Monoxide  
 HC      Hydrocarbons      NO      Nitrogen Oxides  
 PM      Particulate Matter

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(e) *Rating of fuel*

Ans:- Octane Number

The **octane rating** is a measure of the resistance of petrol and other fuels to autoignition in spark-ignition internal combustion engines.

The octane number of a fuel is measured in a test engine, and is defined by comparison with the mixture of 2,2,4-trimethylpentane (iso-octane) and heptane which would have the same anti-knocking capacity as the fuel under test: the percentage, by volume, of 2,2,4-trimethylpentane in that mixture is the octane number of the fuel. For example, petrol with the same knocking characteristics as a mixture of 90% iso-octane and 10% heptane would have an octane rating of 90.<sup>[1]</sup> This does not mean that the petrol contains just iso-octane and heptane in these proportions, but that it has the same detonation resistance properties. Because some fuels are more knock-resistant than iso-octane, the definition has been extended to allow for octane numbers higher than 100.

Octane rating does not relate to the energy content of the fuel (see heating value). It is only a measure of the fuel's tendency to burn in a controlled manner, rather than exploding in an uncontrolled manner. Where octane is raised by blending in ethanol, energy content per volume is reduced.

It is possible for a fuel to have a Research Octane Number (RON) greater than 100, because iso-octane is not the most knock-resistant substance available. Racing fuels, AvGas, liquefied petroleum gas (LPG), and alcohol fuels such as methanol or ethanol may have octane ratings of 110 or significantly higher — ethanol's RON is 129 (116 MON, 122 AKI). Typical "octane booster" gasoline additives include MTBE, ETBE, isooctane and toluene. Lead in the form of tetra-ethyl lead was once a common additive, but since the 1970s, its use in most of the industrialised world has been restricted, and its use is currently limited mostly to aviation gasoline.

Cetane number

Cetane number is actually a measure of a fuel's ignition delay; the time period between the start of injection and start of combustion (ignition) of the fuel. In a particular diesel engine, higher cetane fuels will have shorter ignition delay periods than lower cetane fuels. Cetane numbers are only used for the relatively light distillate diesel oils. For heavy (residual) fuel oil two other scales are used CCAI and CII.

Generally, diesel engines run well with a CN from 40 to 55. Fuels with higher cetane number which have shorter ignition delays provide more time for the fuel combustion process to be completed. Hence, higher speed diesels operate more effectively with higher cetane number fuels. There is no performance or emission advantage when the CN is raised past approximately 55; after this point, the fuel's performance hits a plateau.

(f) *Different methods of scavenging for 2-stroke engines*

Ans:-

Crossflow-scavenged

In a crossflow engine the transfer ports and exhaust ports are on opposite sides of the cylinder and a deflector on the top of the piston directs the fresh intake charge into the upper part of the cylinder pushing the residual exhaust gas down the other side of the deflector and out of the

## **Internal Combustion Engines**

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exhaust port. The deflector increases piston's weight and its exposed surface area, and also makes it difficult to achieve an efficient combustion chamber shape. This design has been largely superseded by loop scavenging method (below), although for smaller or slower engines the crossflow-scavenged design can be an acceptable approach.

### **Loop-scavenged**

In this method of scavenging uses carefully shaped and positioned transfer ports to direct the flow of fresh mixture toward the combustion chamber as it enters the cylinder. The fuel/air mixture strikes the cylinder head then follows the curvature of the combustion chamber then is deflected downward. This not only prevents the fuel/air mixture traveling directly out the exhaust port but creates a swirling turbulence which improves combustion efficiency, power and economy. Usually a piston deflector is not required, so this approach has a distinct advantage over the cross flow scheme (above).

### **Uniflow-scavenged**

In a uniflow engine the mixture, or air in the case of a diesel, enters at one end of the cylinder controlled by the piston and the exhaust exits at the other end controlled by an exhaust valve or piston. The scavenging gas-flow is therefore in one direction only, hence the name uniflow. The valved arrangement is common in diesel locomotives (Electro-Motive Diesel) and large marine two-stroke engines (Wärtsilä). Ported types are represented by the opposed piston design in which there are two pistons in each cylinder, working in opposite directions such as the Junkers Jumo and Napier Deltic.<sup>[5]</sup> The once-popular split-single design falls into this class being effectively a folded uniflow. With advanced angle exhaust timing uniflow engines can be supercharged with a crankshaft driven (piston<sup>[6]</sup> or Roots) blower.

### **(g) Water cooling and air cooling**

**Ans:-**

In water-cooling method, the advantage of superior convective and conductive properties of water is used. Water is circulated continuously through the Cylinder with an annular space known as Water Jacket. To avoid unequal expansion in the cylinder bore and burning of lubricating oil, the water jackets are so designed that they will cover the entire length of piston stroke.

For the cleaning of water jackets in large cylinders, cleaning doors are provided. This method is also employed in large reciprocating air compressor where we have to add cooling tower in addition to cool the circulating water.

Air Cooling is mostly used in motorcycles, scooters where the forward motion of the machine gives a good velocity of air to cool the engine. Air Cooling is also provided in small industrial engines. In bigger unit a circulating fan is employed. But the fan absorbs 5% of the power developed by the engine.

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Air Cooling is the simplest method in which the heat is carried out by the air flowing over and around the engine cylinder. In this system a current of air is made to blow past the outside of cylinder barrel whose outer surface area has been considerably increased by providing radiating fins. The cooling fins are arranged so that they are perpendicular to the axis of the cylinder.

In this system there is no such problem as corrosion or clogging of the radiator occurs, since there is no radiator is used (Radiator is used in water cooled Engines). There is also a complete absence of water freezing in cold weather conditions as in water-cooled engine.

Air Cooling is particularly advantageous where there are extreme climatic conditions as arctic or where there is lack of water as in deserts. It gives less Starting troubles.

Beside above advantages, this cooling system has some disadvantages also. Air-cooled engines on the average have limited size, non-uniform cooling and Higher working temperatures. They also produce more noise, gives a less petrol economy, lower maximum allowable compression ratio and lower output.