Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance. (Not applicable for subject English and Communication Skills).
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgment on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

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	Marks
1. (A) Attempt any THREE of the following:	12
(a) Compare S.I. and C.I. engine on the basis of (i) Thermodynamic cycle (ii) Compression ratio (iii) Power output per unit weight (iv) Fuel consumption	4
Answer : Comparison of SI and CI Engine - *(1 mark for each parameter)*	4

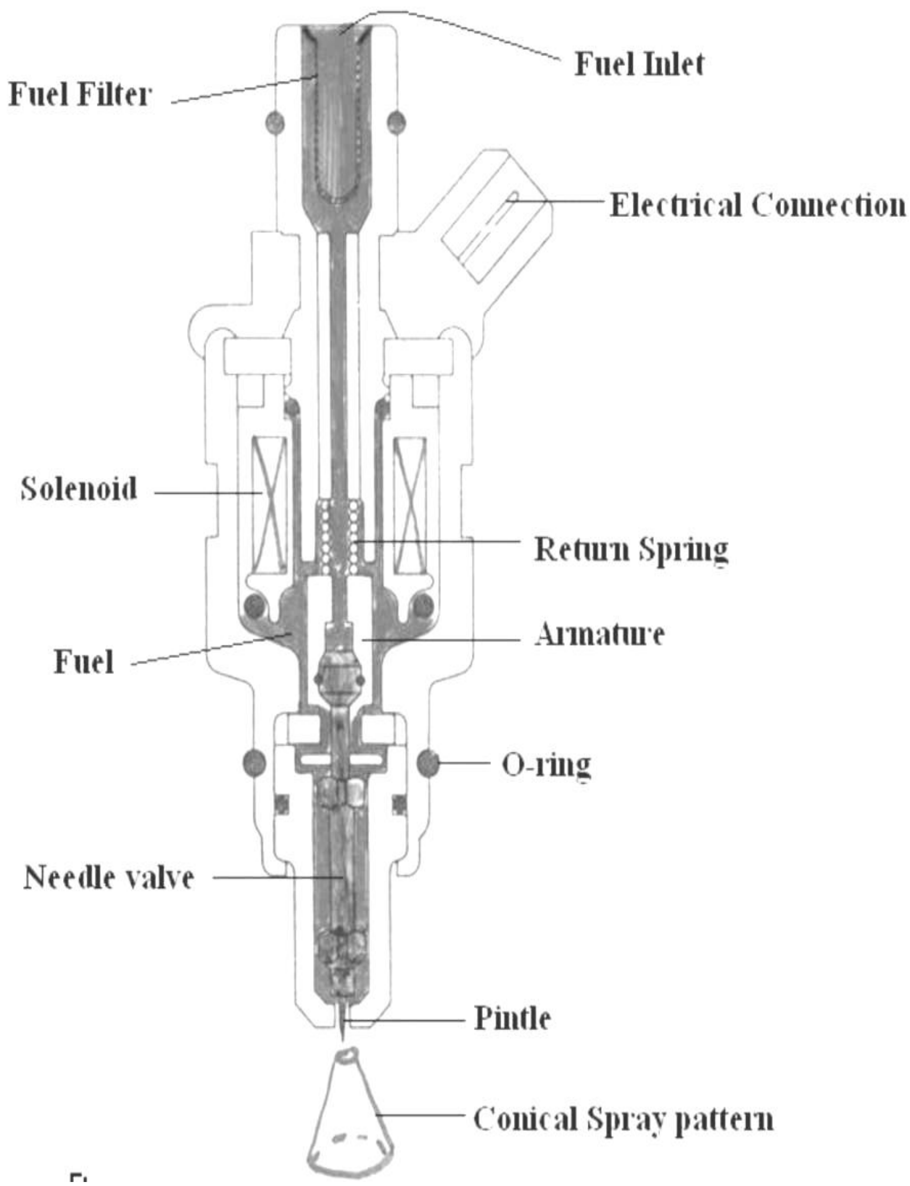
Parameter	S I Engine	C I Engine
i) Thermodynamic cycle	It work's on Otto cycle.	It work's on Diesel cycle.
ii) Compression Ratio	Compression ratio is low, about 10:1, limited by detonation.	Compression ratio is Higher, about 18:1 to 20:1.
iii) Power Output per unit weight	2.7 kg/kW, because of lower compression ratio and lower pressure involved	6.5 kg/kW because of higher compression ratio and higher pressure involved.
iv) Fuel Consumption	In SI engine due to absence of throttling the specific fuel consumption is more.	The CI engine has low fuel consumption as it utilizes a higher compression ratio.

(b) List four drawbacks of carbureted S.I. engine.	4
Answer: Drawbacks of carbureted S.I. engine. *(Any 4 - 1 mark each)* 1. Mal-distribution of charge. 2. Variation in air: fuel ratio. 3. Inaccurate metering of charge. 4. Does not meet emission norms. 5. No temperature compensation.	4

6. No compensation of Exhaust gas recirculation. 7. Fuel atomization depends upon velocity of air in the venture. 8. Wear and tear of parts results in poor efficiency. 9. Backfiring may take place. 10. Carburetor Icing may take place.	
(c) State four advantages of using CRDI system.	4
Answer: Advantages of CRDI system *(Any 4 - 1 mark each)* 1) CRDI engine has lower emission. So, it meets latest emission norms. Finely atomized fuel results in an efficient air-fuel mixing & reduced particulate emissions. 2) It gives improved fuel economy. 3) CRDI engine has lower engine noise level. CRDI engines have capability to deliver stable, small pilot injections can be used for decreased NO_x emissions and noise. 4) Separation of pressure generation and injection allowing flexibility in controlling both the injection rates and timing of CRDI. 5) In CRDI system, Common rail pressure does not depend on the engine speed and load conditions. 6) In CRDI, High injection pressures (about 1500 bar) and good spray preparations are possible even at low engine speeds and loads. 7) In CRDI system, Fuel pump operates with low drive torque.	4
(d) How variable geometry turbo- charging is beneficial over conventional turbo- charging?(2 points)	4
Answer: Variable geometry turbochargers usually designed to provide effective aspect called A/R Ratio) of the turbo to be altered as conditions change. This is done because optimum aspect ratio at low engine speeds is very different from that at high engine speeds. If the aspect ratio is too large, the turbo will fail to create boost at low speeds, if the aspect ratio is too small, the turbo will choke the engine at high speeds, leading to high exhaust manifold pressures, high pumping losses, and ultimately lower power output. By altering the geometry of the turbine housing as the engine accelerates, the turbo's aspect ratio can be maintained at its optimum. When the aspect ratio maintained at its optimum, the following benefits are obtained over conventional turbo-charging-	2
(Any two benefits) 1. VGT is very effective for improving combustion efficiency. 2. Exhaust smoke decreases and BSFC is improved by about 3 - 10 %, at a low engine speed region of 1000 - 1500 rpm. 3. With the VGT, it is possible to raise the boost pressure (intake pressure). 4. Higher air–fuel ratio and higher peak torque at low engine speeds 5. Improved vehicle accelerations 6. Ability to raise exhaust temperature for after-treatment system management	2
(B) Attempt any ONE of the following:	6
(a) Describe the working of electronic fuel injector with the help of suitable sketch.	6
Answer: Working of electronic fuel injector: In MPFI system, Top feed fuel Injector is used. These injectors are solenoid-operated valves that are opened and closed by means of electric pulses from the ECU. The injectors are mounted in the intake manifold and spray onto the back of the intake valves. In general, one injector is used for each cylinder.	3

The injected fuel mass is determined by the injector opening time (for a given pressure drop across the injector). In MPFI systems, each engine cylinder is assigned an electromagnetic fuel injector, which is activated individually for each cylinder. In this way, both the fuel mass appropriate to each cylinder and the correct start of injection are calculated by the control unit (ECU)

The amount of fuel sprayed from the injectors is controlled by cycling the injectors open and close. More fuel will be sprayed out when the injector pulse is longer. In order to operate properly, the fuel must spray as a liquid throughout the injection. Injection pressure is approximately 2 bar to 3.5 bar. Pressure helps to keep the fuel as a liquid throughout the system. When the solenoid coil is energized, the Pintle is pulled up. System pressure then forces fuel between the Pintle and discharge opening to form a fine spray pattern that has a cone shape.



3

Fig. Top Feed Electronic Fuel Injector

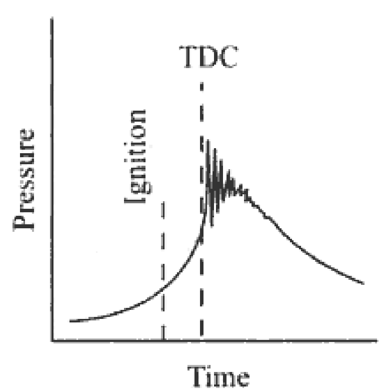
(b) Compare detonation and diesel knock phenomenon (4 points). Give graphical presentation.	6

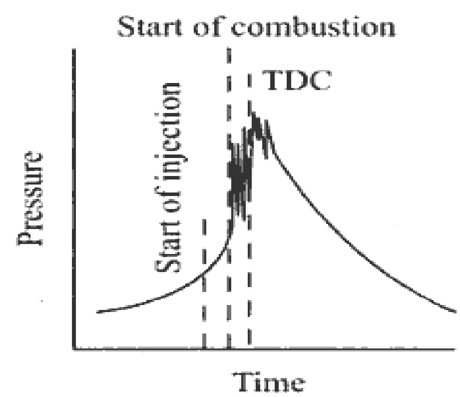
Answer: Comparison of detonation and knocking: *(Comparison: any 4 points – 1mark each; P- ϴ diagram- 2 marks)*

Sr.	Detonation in S I Engine	Knock in C I Engine
1.	Detonation occurs near the end of combustion	Knocking occurs near the beginning of combustion. i.e. at the end of first stage of combustion.
2.	Detonation in S I Engine is of a homogeneous charge causing very heavy rate of pressure rise and high maximum pressure.	Knocking in C I engine is of imperfectly mixed charged and hence the rate of pressure rise is normally lower than that in the detonation in S I Engine.
3.	Pre-ignition may occur.	Fuel is injected into the cylinder only at the end of the compression stroke and there is no question of pre- ignition or premature ignition.
4.	Detonation is easily distinguished from normal combustion.	Knocking is not easy to distinguish from normal combustion.
5.	Larger cylinder promotes detonation	Diesel knock is reduced with increase in size of cylinder.
6.	Compression ratio in S.I. engine is limited by Detonation	In C.I. engines, higher compression ratio causes lesser ignition delay and hence lesser possibility of diesel knock.

4

P- Θ diagram





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2. Attempt any FOUR of the following	16
(a) List four types of combustion chambers used in C.I. engine. Draw neat sketch one type and label it.	4

Answer : Types of combustion chambers used in C.I. engine: *(List any 4 types – 2marks, sketch of any one type -2 marks)*

Direct Combustion Chamber:

1. Shallow depth chamber.
2. Hemispherical chamber.
3. Cylindrical chamber.
4. Toroidal Chamber.

2

Indirect Combustion Chamber:

1. Swirl combustion chamber.
2. Pre-combustion chamber.
3. Air-cell combustion chamber.

Labeled Sketch: *(Any one of following -2marks)*

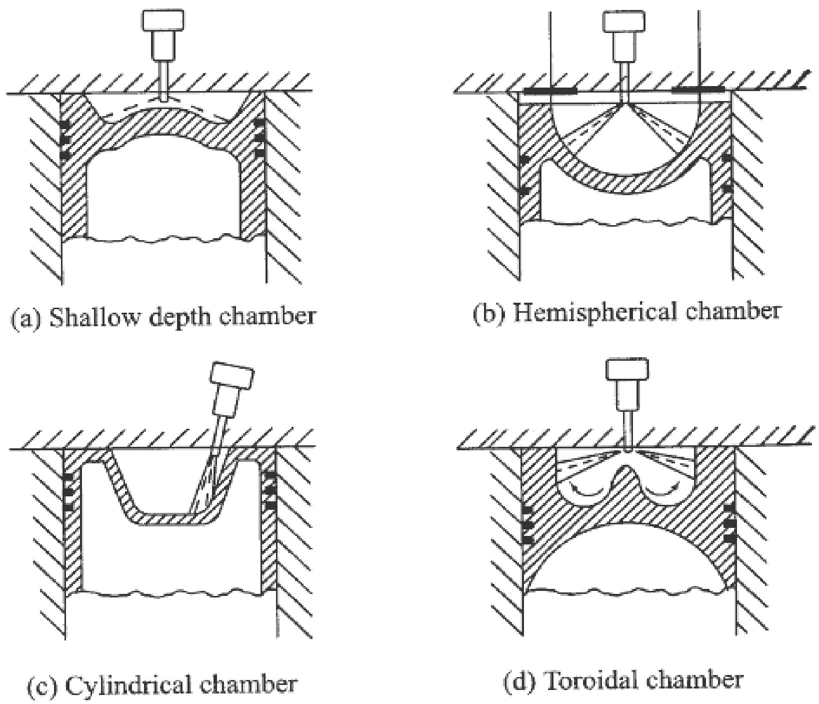
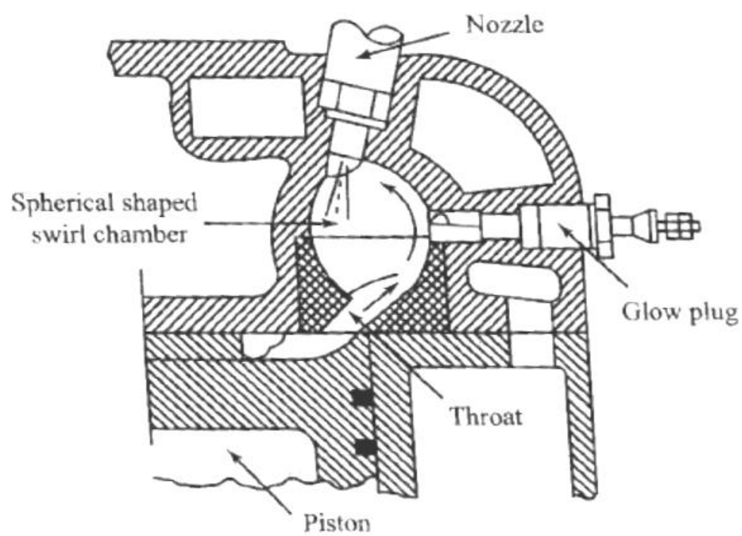
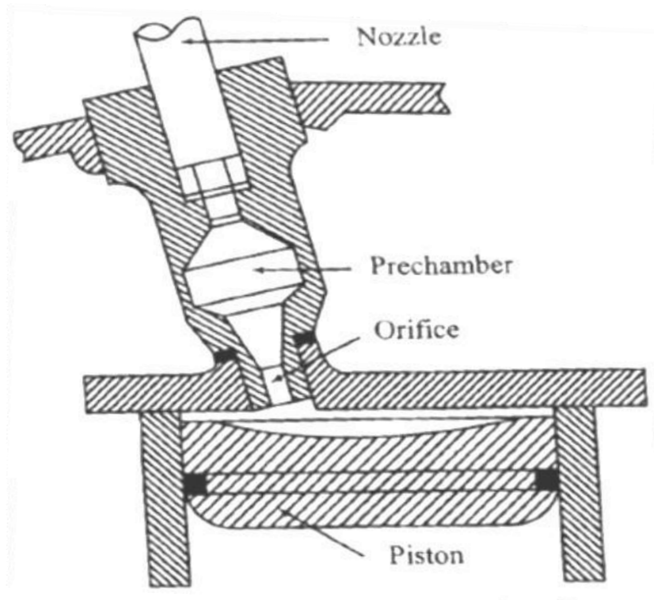


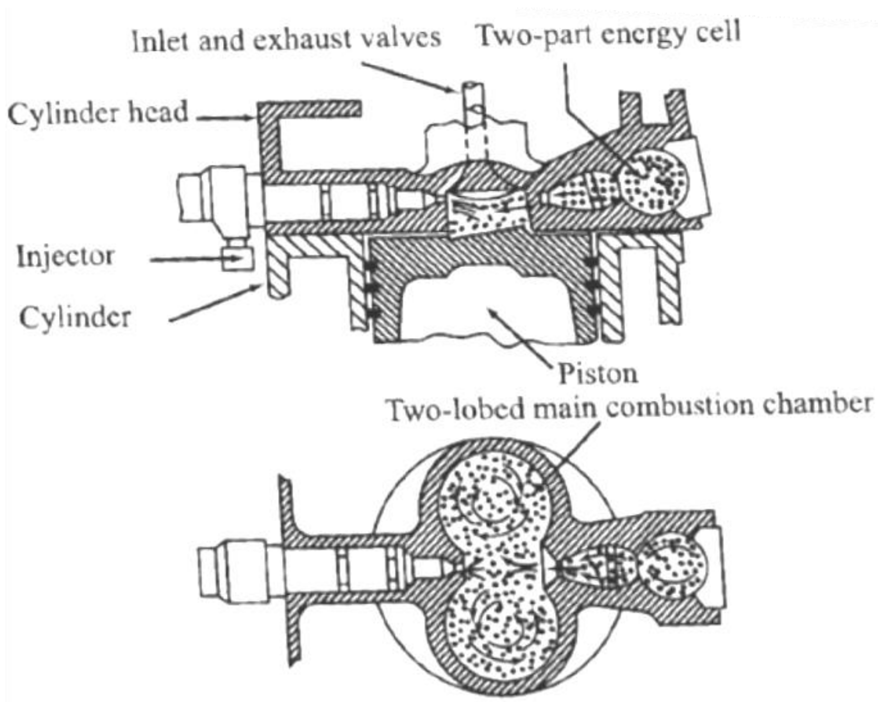
Figure (a, b, c, d): Open type direct combustion chambers



(a): Ricardo Swirl chamber



(b): Precombustion chamber



(c): Air-cell combustion chamber

Figure (a) (b) & (c): Indirect combustion chambers

(b) State four methods of petrol injection. Describe any one.	4
Answer : Methods of petrol injection: *(methods-1 mark, Description of any one – 3marks)* 1. Sequential fuel injection. (SFI) 2. Grouped fuel injection. 3. Simultaneous fuel injection. 4. Continuous injection.	4

1. **Simultaneous Injection:** Injection of fuel occurs at the same time for all cylinders every revolution of the crankshaft. Therefore, fuel is injected twice within each four-stroke cycle. The injection timing is fixed with respect to crank/ cam shaft position.
2. **Group Injection**: The injectors are divided into two groups that are controlled separately. Each group injects once per four-stroke cycle. The offset between the groups is one crankshaft revolution. This arrangement allows.
3. **Sequential Injection:** Each injector is controlled separately. Injection timing, both with reference to crank/ camshaft position and pulse width, can be optimized for each individual cylinder.

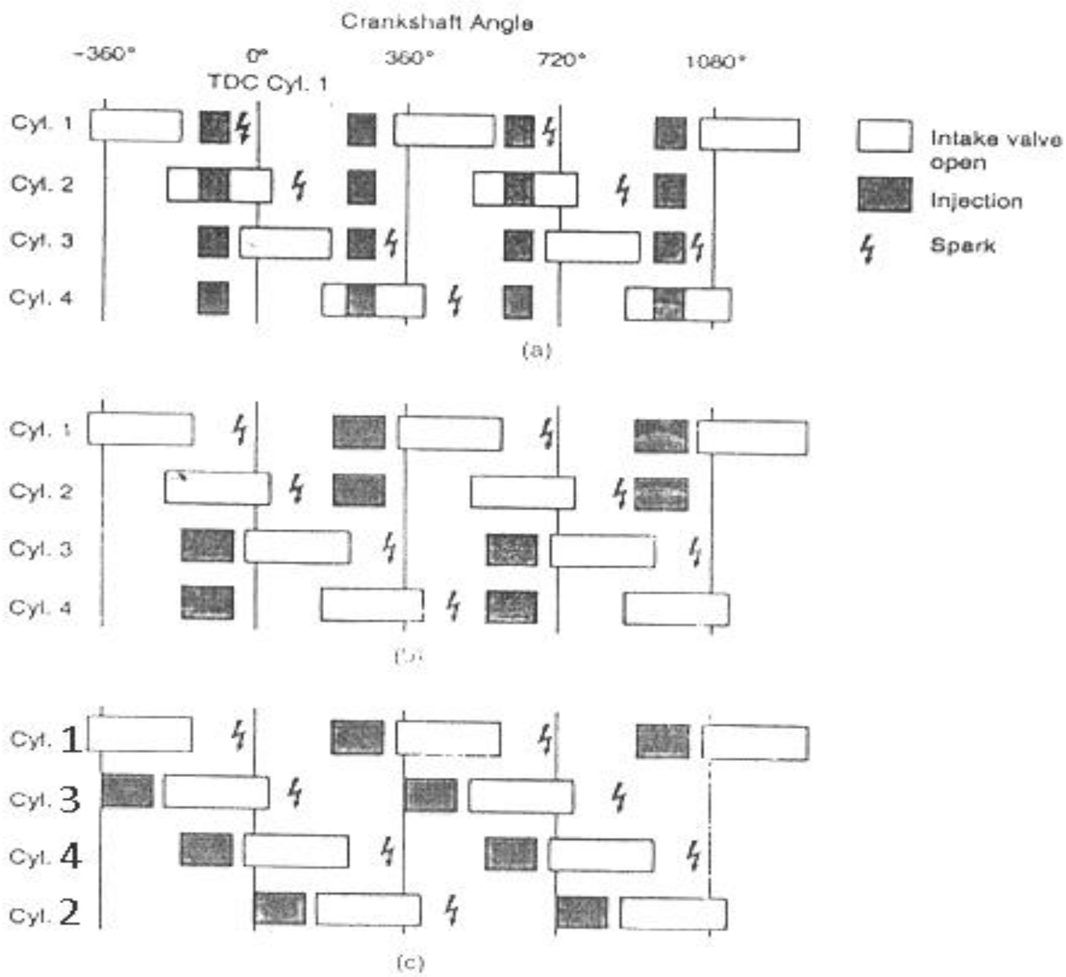


FIGURE Fuel injection strategies: (a) simultaneous injection, (b) group injection, and (c) sequential injection.

4. **Continuous injection:-**This system usually has a rotary pump. The pump maintains a fuel line gauge pressure of about 0.75 to 1.5 bar. The system injects the fuel through a nozzle located in manifold immediately downstream of the throttle plate. In supercharged engine, fuel is injected at the entrance of the supercharger. The timing and duration of the fuel injection is determined by ECU depending upon load and speed.

Note: Above diagram refers to the first three methods of injection, for continuous injection diagram is not needed. credit shall be given to suitable diagram)

(c) Describe construction and function of glow plug. State one application.	4
Answer: Construction: *(Suitable credit shall be given to sketch)* In many of the latest vehicles, self-temp controlling type glow plugs are used. The glow plug has a spiral filament sitting in a glow tube of heat resistant steel, bedded and electrically insulated in a fine magnesium powder, thus protected against vibrations. The filament consists of 3 coils as follows. a) Brake coil b) Balance coil c) Rush coil. These coils are connected in series.	2

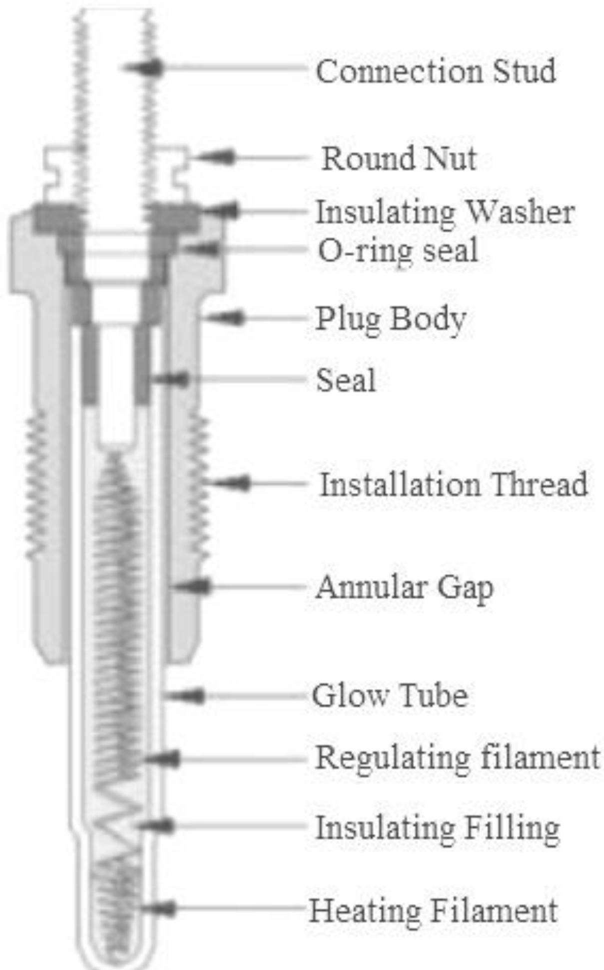
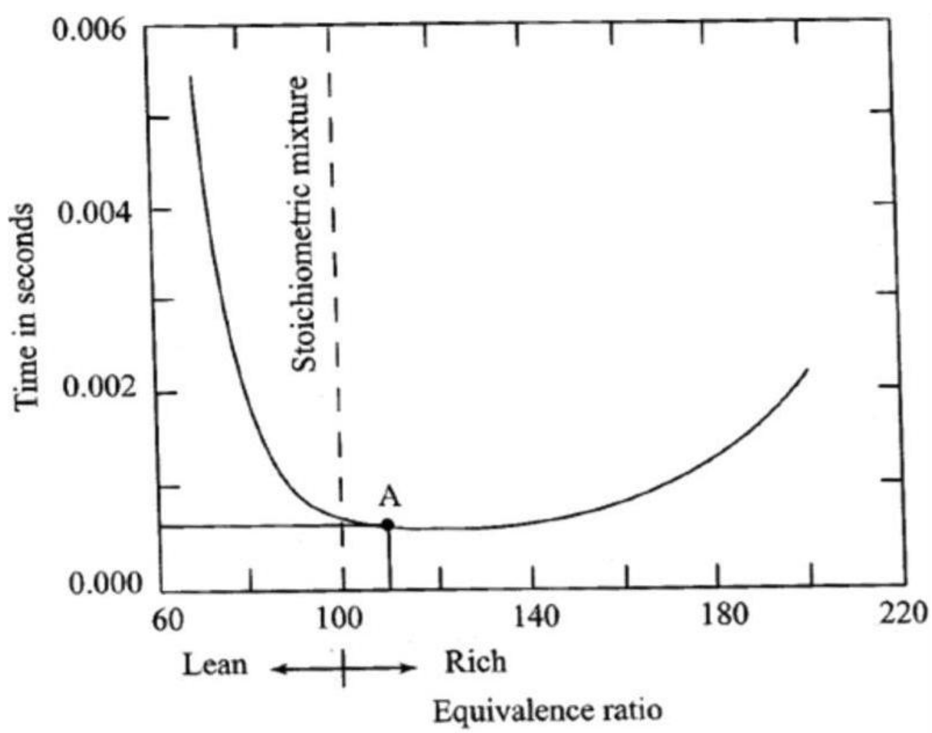


Fig: Glow Plug

Function of Glow plug: The colder the diesel engine, the more difficult it is to start. So, as a starting aid, glow plug is used in diesel engine. The self-ignition temperature of diesel is 250°C. For compression ignition, the charge (air + diesel) should reach a temperature of about 550°C. Cold weather conditions make it difficult to happen. The glow plug heats to starting temperature (approx. 850°C) as rapidly as possible.	1
Application: *(Any one)* 1) Diesel Engine. 2) Aircraft Engine.	1

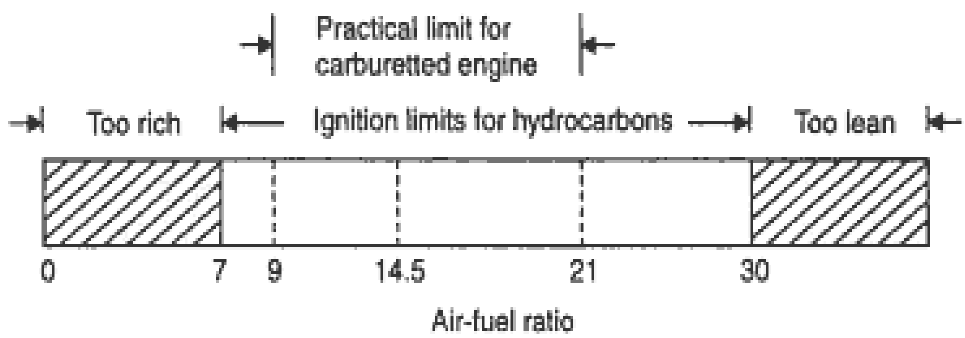
(d) State effect of four engine variable on ignition lag.	4
Answer: Effect of engine variables on ignition lag: *(Any four)* 1. **Fuel:** The ignition lag depends on chemical nature of fuel. The higher, the self-ignition temp of fuel, the longer the ignition lag. 2. **Mixture Ratio:** The ignition lag is smallest for the mixture ratio which gives the maximum temperature. This mixture ratio is somewhat richer than the stoichiometric ratio. 3. **Initial pressure and temperature:** Increasing the intake temperature and pressure, increasing the compression ratio and retarding the spark, all reduce the ignition lag. 4. **Electrode gap:** It affects establishment of the nucleus of flame. If the gap is too small, quenching of the flame nucleus may occur & range of fuel - air ratio for the development of a flame nucleus is reduced. The lower is the C.R., the higher is the electrode gap required. 5. **Turbulence:** It measured in degree of crank-rotation the ignition lag increases almost linearly with engine speed. For this reason. It becomes necessary to advance the spark timing at higher speed.	4
(e) Describe the effect of air fuel ratio on flame speed.	4
Answer: The effect of air-fuel ratio on flame speed: The fuel-air-ratio has a very significant influence on the flame speed. The highest flame velocities (maximum time for complete combustion) are obtained with somewhat richer mixture (point A) as shown in figure which shows the effect of mixture strength on the rate of burning as indicated by the time taken for complete burning in a given engine. When the mixture is made leaner or richer (see point A in figure) the flame speed decreases. Less thermal energy is released in the case of lean mixtures resulting in lower flame temperature. Very rich mixtures lead to incomplete combustion which results again in the release of less thermal energy.  Figure: Effect of mixture strength on the rate of burning	2 2

(f) Explain the term 'Ignition limits'. State the ignition limit for S.I. engine. 4

Answer: Ignition Limits:

Ignition Limit corresponds approximately to that mixture ratio, at lean & rich ends of the scale, where the heat released by spark is no longer sufficient to initiate combustion in the neighboring un-burnt mixture. The flame will propagate only if the temperature of the burnt gases exceeds approximately 1500 K in the case of hydrocarbon-air mixture. 2

The lower & upper ignition limits of the mixture depend upon mixture ratio & flame temperature. The ignition limits are wider at increased temperature because of higher rates of reaction.



Ignition limits for hydrocarbons.

2

Theoretical Ignition limits for Hydrocarbon fuels are 7:1 to 30:1
Actual Ignition limits for hydrocarbon fuels are 9:1 to 21:1.

3. Attempt any FOUR of the following: 16

(a) Distinguish between TBI and PFI systems (4 points) 4

Answer: **Difference between TBI and PFI system**: *(Any 4 points)* 4

Sr.	Throttle Body Injection(TBI)	Port Fuel Injection(PFI)
1	Fuel is injected into the center of the throttle body.	Fuel is injected into the port.
2	TBI uses bottom feed injector	PFI uses top feed injector
3	Fuel injector needs to be flushed continuously- to prevent formation of air bubble.	Fuel injector need not be flushed
4	1 or 2 Fuel injectors are used.	Fuel injectors are equal to the number of cylinders
5	TBI is comparatively low pressure injection (differential pressure = 0.7 to 1 bar)	PFI is comparatively high pressure injection (differential pressure = 2 to 3.5 bar)
6	Cheaper fuel pump is sufficient to generate the required low pressure.	Costly fuel pump is required to generate the required pressure
7	Mixture mal-distribution may occur.	All cylinders receive equal quantity and quality of air: fuel mixture
8	Less accurate fuel injection control gives moderate fuel economy.	More accurate fuel injection control is obtained. Therefore increased fuel economy is obtained
9	This is a cheap system.	This is costly system.

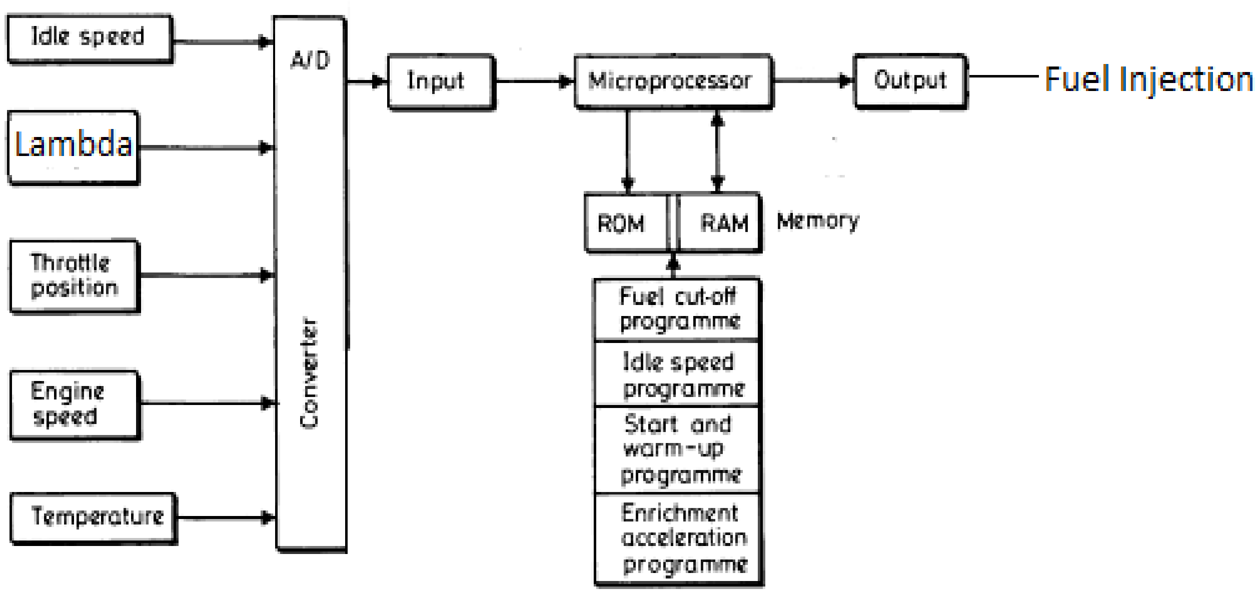
10	Exhaust emission is above the permissible emission norms.	Very low exhaust emission is achieved to meet the strict emission norms.
11	Moderate throttle response as the fuel is injected at the throttle body and longer length of travel for fuel to enter the engine cylinder.	Better throttle response as fuel is injected on hot back side of intake valve and shorter length of travel for fuel – to enter the engine cylinder
12	Lower power output due to lower volumetric efficiency caused by bulky injector body at the throttle body.	Higher power output due to low resistance at intake manifold and higher volumetric efficiency.

(b) Illustrate with example, fuel injection as an output control function of ECM. 4

Answer**: Fuel injection as an output control function of ECM.** *(Description - 2 marks, Illustration– 2 marks)*

ECM controls fuel injection by calculating A: F ratio needed for engine. Engine requires different air fuel ratios while cranking, warm- up, idle, normal running, sudden acceleration and during deceleration. As ECM receives inputs from various sensors such as TPS, CKP, CMP, MAP, CTS and O_2 and other sensors, it calculates the injector pulse width that precisely meets the engine requirement. ECM refers Look-up tables and maps stored in memories (ROM/RAM/KAM). 2

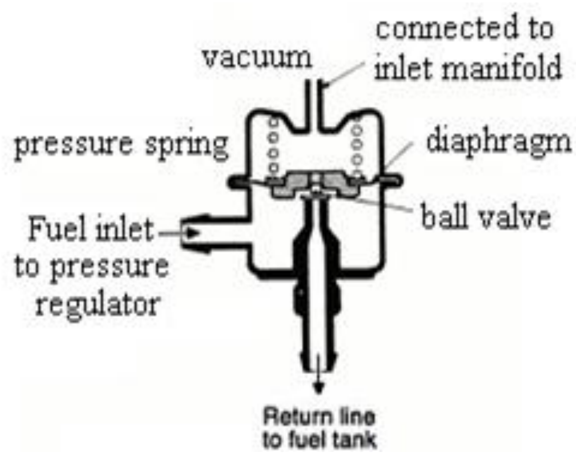
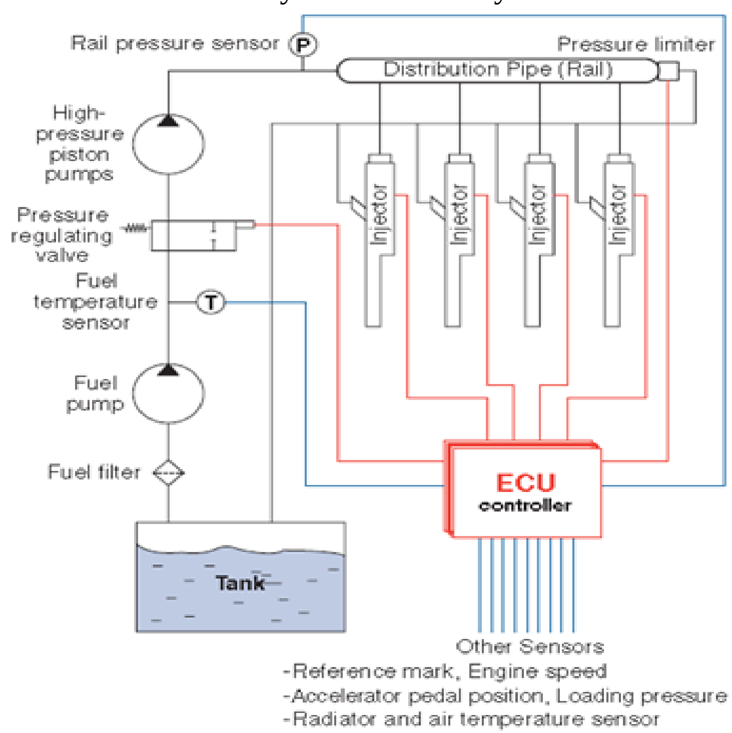
Illustration:



2

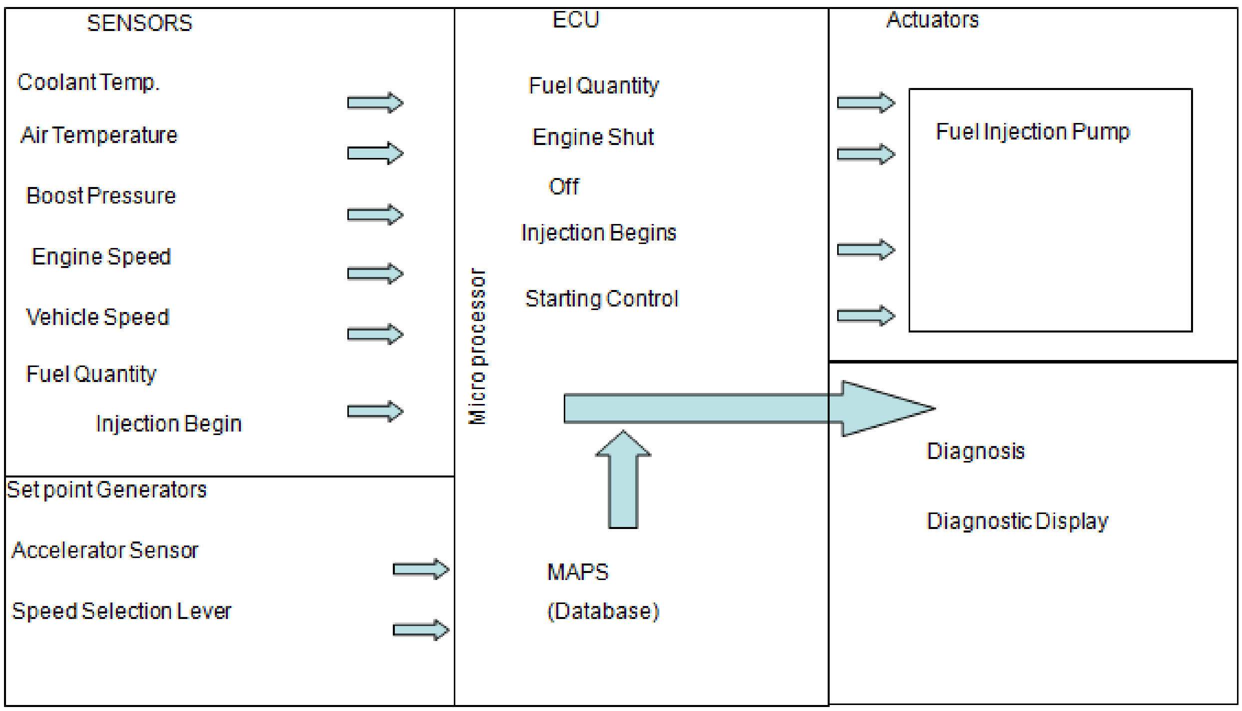
ECM Block diagram and fuel injection control function

When the engine is being cranked by the starter, and when the engine is colder than operating temperature, the ECM sees the low RPM, and quickly goes to the Cranking fuel Table, increasing the Injector pulse width, allowing more fuel to get the engine started. At the same time, the ECU tells the IAC to open, allowing enough air into the engine for start and idle (Throttle body valve is closed).

(c) Describe the working of pressure regulator in PFI system with the help of schematic diagram.	4
Answer: Working of pressure regulator in PFI system: (*Diagram - 2 marks, Description - 2 marks)* The fuel pump provides more fuel than the maximum required by the engine. Fuel not used by the engine is returned to the fuel tank. The fuel rail supplies all injectors. The pressure regulator keeps the pressure drop across the injector fuel line and the intake manifold as constant. It contains a diaphragm that has intake manifold pressure on one side and fuel rail pressure on the other. Normally, it is mounted at the outlet end of the fuel rail. The diaphragm operated a valve which opens at a differential pressure between 2.0 and 3.5 bar and allows excess fuel to return to the fuel tank.  Figure: Fuel Pressure Regulator Operation	2 2
(d) Draw a neat labeled block diagram of electronic control system in CRDI system.	4
Answer: Block diagram of electronic control system in CRDI system  **Figure** A common rail fuel injection system.	4

OR

ELECTRONIC CONTROL SYSTEM BLOCK DIAGRAM



(e) Describe operation of CRDI system.	4

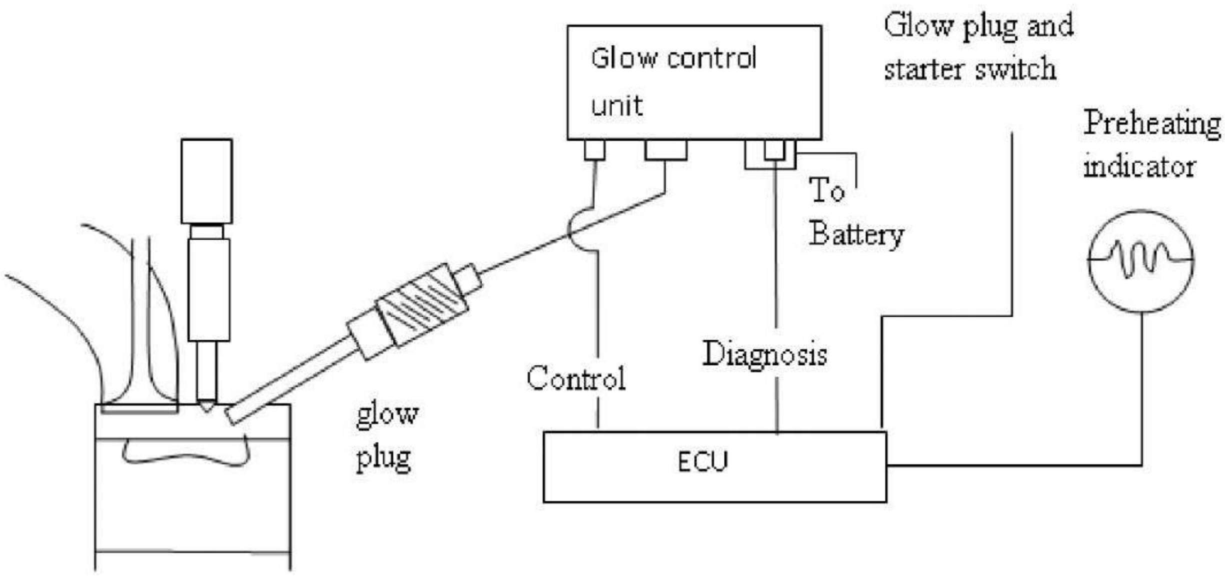
Answer: Operation of CRDI system:

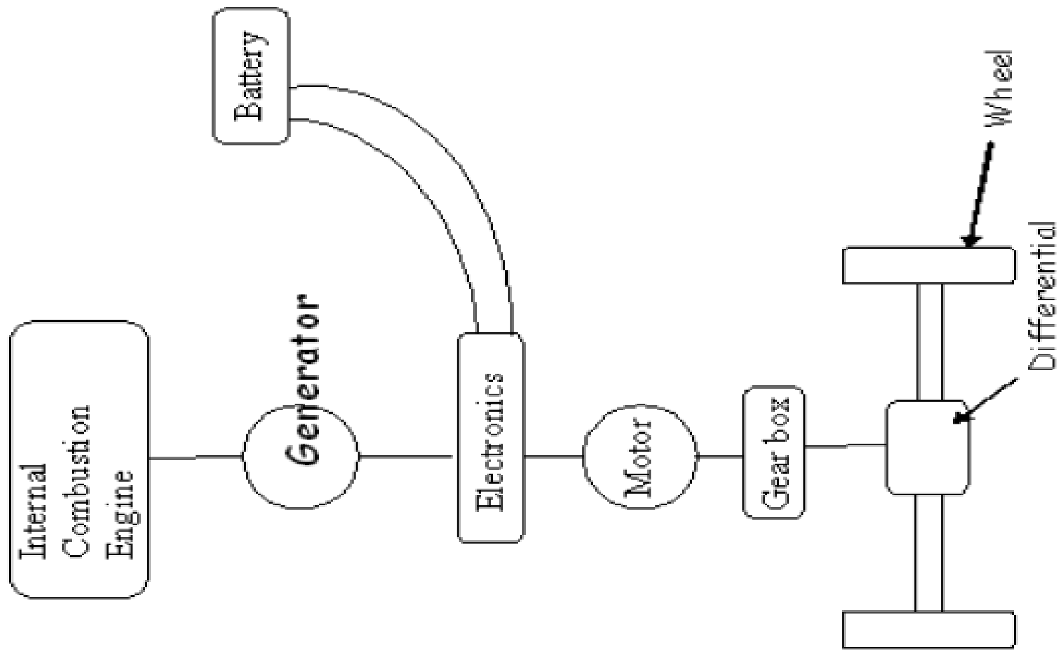
The CRDI system works at consistent high pressure availed by high pressure pump. It consists of three major parts - A high pressure pump, Unit injector, A common rail accumulator.

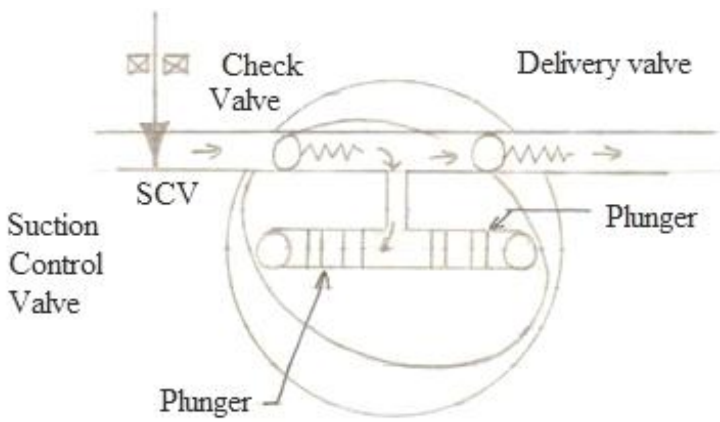
Unit injector has a control plunger above needle valve, control spring and a solenoid. The solenoid valve is mounted horizontally on the top of unit injector. The common rail accumulator is plumbed in between high pressure pump and the unit injector. 4

Working of CRDI engine:

1. High pressure pump provides high pressure fuel to the common rail. The common rail stores the fuel and maintains a constant pressure in the common rail line (approximately 1500 bars.). This pressure is continuously available at injectors.
2. The injection pressure is independent of engine speed. The quantity of fuel injected in the combustion chamber is controlled by actuating solenoid valve in the injector. As solenoid is energized, injection begins. Injector pulse width, multiple injections and duration of injection – all are controlled by EDC of CRDI system.
3. The system pressure is controlled by means of a pressure sensor. Pilot injection and possibly a second, third injection is achieved by repeatedly activating solenoid valve, whereas the injection rate can be modified by controlling the nozzle needle movement.

(f) Draw a neat labelled circuit diagram of glow plug.	4
Answer: *(Circuit diagram - 4 marks)*  Glow plug circuit diagram	4
4. A) Attempt any THREE of the following:	12
(a) State four desirable properties of S.I. engine fuel.	4
Answer: Desirable properties of S.I. engine fuel are as follows: (*four properties, one mark each*) 1. It should mix readily with air and provide uniform manifold distribution. That is, it should easily vaporize. 2. It must be knock resistant. 3. It should not pre-ignite easily. 4. It should be easy to handle. That is, it should have sufficiently high flash point and fire point. 5. It must burn clean and produce no corrosion on engine parts. 6. It must have a high calorific value 7. It should not form gum and varnish.	
(b) Draw a labeled block diagram of series type Hybrid Vehicle. State two advantages.	4
Answer: Series type Hybrid vehicle: (B*lock diagram- 02 marks, two advantages- 2 marks, equivalent block diagram should be credited*) **Advantages of series type Hybrid Vehicle:** (*any two of the following or similar points should be credited*) 1. In this system, internal combustion engine operates at constant speed with maximum efficiency. 2. Minimum exhaust emissions occur since the vehicle is controlled electronically. 3. The electric control simplifies the mechanical gears and the differential.	2

 Block diagram of Series Hybrid vehicle.	2
(c) LPG is used as a fuel for petrol engine. Justify your answer.	4
Answer: (*Description - 04 marks, similar points should be credited*) 1. LPG has a higher octane rating than petrol. 2. It is a clean burning environment friendly fuel, and abundant. It meets emission norms. 3. It can be transported easily to remote places by road and also by rail. 4. It is a cheaper fuel than petrol. 5. It does not pre-ignite easily. 6. It results in increased engine life and smoother engine performance. 7. Crankcase oil dilution is small. So, oil replacement frequency is reduced. 8. Low engine deposits reduce the cost of maintenance. 9. Engine need not be modified. LPG kits are readily available (even for MPFI engines) and the kit cost is mostly affordable. Above are essential requirements of a good S.I. engine fuel. LPG meets the requirements comfortably and is therefore used as a fuel for petrol engine.	4
(d) Describe the concept of variable valve timing	4
Answer: (*Concept- 1 mark, Description- 3 marks, credit should be given to diagram, if drawn*) **Concept of VVT:** Variable valve timing (VVT) is a system for varying the valve opening of an internal combustion engine. This allows the engine to deliver high power, but also to work tractably and efficiently at low power. There are many systems for VVT, which involve changing either the relative timing, duration or opening of the engine's inlet and exhaust valves.	1

Cam changing VVT: **Stage 1 (low speed):** the 3 pieces of rocker arms moves independently. Therefore the left rocker arm, which actuates the left inlet valve, is driven by the low-lift left cam. The right rocker arm, which actuates the right inlet valve, is driven by the medium-lift right cam. Both cams' timing is relatively slow compare with the middle cam, which actuates no valve now. **Stage 2 (medium speed):** hydraulic pressure (painted orange in the picture) connects the left and right rocker arms together, leaving the middle rocker arm and cam to run on their own. Since the right cam is larger than the left cam, those connected rocker arms are actually driven by the right cam. As a result, both inlet valves obtain slow timing but medium lift. **Stage 3 (high speed):** hydraulic pressure connects all 3 rocker arms together. Since the middle cam is the largest, both inlet valves are actually driven by that fast cam. Therefore, fast timing and high lift are obtained in both valves.	3
(B) Attempt any ONE of the following:	6
(a) With the help of neat sketch, describe the working of high pressure pump used in CRDI system.	6
Answer: Working of High pressure fuel pump used in CRDI system (*Sketch - 03 marks, working - 03 marks*)  Figure: Sectional view of High Pressure Fuel pump in CRDI system **Working:** • The fuel inlet to the pump is controlled by the SCV (suction control valve) through the EDC • The rotation of the inner cam pushes the plunger inwards, so that it can pump the fuel. • Plunger outward movement is caused by the pressure of fuel feed pump. Fuel enters the pumping element chamber (intake stroke) • At BDC the check valve closes • The fuel in the chamber is pressurized by the plungers moving inward. • The delivery valve opens and the fuel passes to the common rail. • A constant pressure of about 1400 to 1600 bar is maintained in the common rail.	3 3
(b) Compare LPG and CNG as I.C. engine fuels on the basis of: (i) Fuel tank size (ii) Storage pressure (iii) Cost (iv) Octane rating (v) Availability (vi) Safety	6

Answer: Comparison of LPG and CNG as I.C. engine fuels: 6

Parameter	LPG	CNG
i) Fuel tank size	Comparatively Smaller fuel tank is used since the storage pressure is about 5 to 7 bar. (One third that of CNG)	Larger fuel tank size is needed due to higher storage pressure of about 200 to 250 bar.
ii) Storage pressure	About 5 to 7 bar	About 200 to 250 bar.
iii) Cost	It is cheaper than CNG. (LPG - Approx. Rs 40.53/Litre - Mumbai)	It is costlier than LPG. (CNG- Approx. Rs 43.45/Litre - Mumbai)
iv) Octane rating	111	130
v) Availability	Better availability due to ease of transport by road, deeper penetration throughout country.	Poor availability due to transportation difficulty. Pipeline transport involves huge cost of establishment.
vi) Safety	In event of leak, risk of fire is more than CNG. (Since it is heavier than air and so forms a puddle of fuel near the source of leakage).	CNG is a safe fuel for automotive use since it is lighter in weight. In event of leakage, it disperses easily into atmosphere easily. hence risk of ignition is minimized

5. Attempt any TWO of the following: 16

(a) (i) Briefly describe four effect of detonation. 4

(ii) State four methods of controlling detonation. 4

Answer:

i) Effect of detonation: *(Any four)*

1. **Noise and roughness**: Mild knock is seldom audible and is not harmful. When intensity of knock increases a loud pulsating noise is produced due to development of a pressure wave. The presence of vibratory motion causes crankshaft vibrations and engines rough.
2. **Mechanical damage:** Due to rapid pressure waves, rate of wear is increased and piston head, cylinder head and valves may be pitted. 4
3. **Carbon deposits:** Detonation results in increased carbon deposits.
4. **Increase in heat transfer:** Temperature in detonating engine is higher as compared to non detonating engine and hence scoring away the protecting layer of inactive stagnant gas. So detonation increases the rate of heat transfer to combustion chamber walls.
5. **Decrease in power output and efficiency:** Due to increase in the rate of heat transfer the power output is decreased.
6. **Pre ignition:** Detonation results in over heating of the sparking plug and combustion chamber wall and this overheating leads to ignite the charge before the passage of spark.

ii) Methods of controlling detonation: *(Any four)*

1. Increasing Engine Rpm. 4
2. Retarding Spark timing.
3. Reducing pressure in inlet manifold by throttling. In supercharged engines reducing supercharging pressures to reduce detonation.
4. Making the ratio to lean or too rich, preferably latter.
5. Water injection.

(b) State location and function of two sensor and two actuators used in MPFI engine. 8

Answer: Location and function of two sensor Sensors: (*Any two: 2 mark for each)*

Sr.	Name	Function	Location
1	Oxygen sensor	Measuring the quantity of oxygen in exhaust	Located at inlet and outlet side of catalytic converter
2	Mass air flow (MAF) sensor	It is used to tell the ECU the mass of air entering the engine	Mounted between air filter and turbocharger
3	Coolant temperature sensor	Measures the temperature of the coolant in the system and sends signal to ECU.	there are two sensors fitted on water box
4	Throttle position sensor	It supplies information to the ECU about the position the throttle is in inlet manifold.	The sensor is usually located on the butterfly spindle/shaft so that it can directly monitor the position of the throttle.
5	Crank position sensor	It supplies information to the ECU about the position and rotation of the Crank shaft	This sensor is mounted on the cylinder block behind the flywheel.
6	Vehicle speed sensor	Sends electrical pulses to the ECU about the speed of vehicle.	This sensors is mounted on gear box on speedo output location
7	Cam Sensor	It senses cam position and corresponding signal is sent to the ECU.	This sensor is fitted on cylinder head cover.
8	Knock Sensor	It detects the vibrations generated during the combustion process and supplies signal to the ECU.	This sensor is fitted on cylinder block.

4

Location and function of two sensor Sensors: (*Any two: 1 mark for each)*

Sr.	Name	Location	Function
1	Fuel injector	It is located on Engine	It injects the pressurized
2	Cam actuators	It is fitted on FIP	it actuates the cam according to signals from needle lift sensor and crank angle sensor
3	Idle speed control valve	It is fitted with inlet manifold	It controls the air flow during idling to maintain exact engine RPM at various engine load.
4	Inlet metering valve	This is an inbuilt valve which is control by ECM	This valve controls the flow of fuel to HP pump
5	Vacuum solenoid valve	Inside the EGR valve	This valve regulates vacuum pressure for EGR valve operation and controlled by ECM

4

(c) (i) How does catalytic converter work in oxidation and reduction of exhaust gas? (ii) State chemical reactions. (iii) Why oxygen sensors are fitted at inlet and outlet of catalytic convertor?	2 2 4
Answer: **i) Working of Catalytic Convertor:** **a)** Catalytic converter under oxidation: The **oxidation catalyst** is the second stage of the catalytic converter. It reduces the unburned hydrocarbons and carbon monoxide by burning (oxidizing) them over a platinum and palladium catalyst. This catalyst aids the reaction of the CO and hydrocarbons with the remaining oxygen in the exhaust gas. **b)** Catalytic converter under reduction of exhaust gas: The reduction catalyst is the first stage of the catalytic converter. It uses platinum and rhodium to help reduce the NOx emissions. When an NO or NO_2 molecule contacts the catalyst, the catalyst rips the nitrogen atom out of the molecule and holds on to it, freeing the oxygen in the form of O_2. The nitrogen atoms bond with other nitrogen atoms that are also stuck to the catalyst, forming N_2.	2
ii) Chemical Reactions: **1)** The reduction of nitrogen oxides $2NOx(g) \rightarrow xO_2(g) + N_2(g)$ x can be 1 or 2 as in NO(g) or $NO_2(g)$ 2) The oxidation of poisonous carbon monoxide to carbon dioxide $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$ 3) Oxidation of unburnt hydrocarbons (HC) to carbon dioxide and water: $CxH_2x+2 + [(3x+1)/2]\ O_2 \rightarrow xCO_2 + (x+1)\ H_2O$.	2
iii) Oxygen sensors are fitted at inlet and outlet of catalytic convertor: An exhaust oxygen sensor is used to measure the amount of oxygen in the exhaust gases produced by the engine. PCM uses this data to determine air fuel mixture and spark timing. Oxygen sensor (fitted before and after catalytic convertor) is also called the lambda sensor, since it is used to indicate the amount of oxygen in the exhaust so that the PCM can maintain a lambda that oscillates just above and below 1. With the advent of On-Board Diagnostics Second generation (OBD II), an additional oxygen sensor is placed at the outlet of catalytic convertor. OBD system must detect emission related defects and alert the driver. OBD II monitors catalytic converter operation. The catalytic converter monitor must detect any catalytic converter problem that results in exhaust emissions of one and one half times the standard for NMHC using an average 6400 km aged converter. The PCM monitors the upstream (inlet of catalytic convertor) and downstream (outlet of catalytic convertor) heated oxygen sensors (HO_2S) to monitor the catalytic converter operation. The voltage cycles on the downstream HO_2S should have a lower voltage and slower cycles compared to the upstream HO_2S. If the upstream and downstream HO_2S signals are similar, the PCM takes the necessary action, such as setting a DTC (diagnostic trouble code).	4

6 Attempt any FOUR of the following :	16
(a) Describe the concept of Gasoline in direct injection.	4
Answer: Concept Gasoline Direct Injection (GDI): Gasoline Direct Injection (GDI), also known as Petrol Direct Injection. This system is employed in modern two-stroke and four-stroke gasoline engines. The gasoline is highly pressurized, and injected via a common rail fuel line directly into the combustion chamber of each cylinder, Directly injecting fuel into the combustion chamber requires high pressure injection. The GDI engines operate on full air intake; there is no air throttle plate. Engine speed is controlled by the engine control unit. In this only the combustion air flows through open intake valve on the induction stroke. The engine management system continually chooses among three combustion modes: ultra-lean burn, stoichiometric, and full power output. Each mode is characterized by the air-fuel ratio. The stoichiometric air-fuel ratio for gasoline is 14.7:1 by weight, but ultra-lean mode can involve ratios as high as 65:1 (or even higher in some engines, for very limited periods).These mixtures are much leaner than in a conventional engine and reduce fuel consumption considerably.	4
(b) State four methods to improve fuel economy of an engine.	4
Answer: Methods to improve fuel economy: *(Any four)* 1) Use of multi-functional fuel additives will provide 3 to 4% fuel economy. 2) Good driving habits. 3) Properly maintained fuel supply system. 4) Use of computer controlled fuel injection system. 5) Use of computer controlled ignition system. 6) Use of higher voltage automotive electrical system (42 volts system)	4
(c) What is diesel smoke? State two methods to control diesel smoke.	4
Answer: **Diesel smoke:** Smoke is defined as visible products of combustion, is due to poor combustion. It originates early in the combustion. Rich fuel-air mixture & at pressures developed in diesel engines-produces soot. If soot is not burnt in combustion cycle it will pass in exhaust, & if in sufficient quantity, will become visible.	2
Methods of controlling diesel smoke : *(Any 2 methods)* 1) **De-rating:** At lower loads, the air: fuel ratio obtained will be leaner & hence the smoke developed will be less. However this means a loss of output. 2) **Maintenance:** Maintaining the injection system of engine properly results in a significantly reduced smoke, Best engine performance, Clean exhaust system. Other methods are changes in Combustion chamber geometry. 3) **Smoke suppressant additives:** Some barium compound, if used in fuel, reduces the temperature of combustion, thus avoiding the soot formation, & if formed they break it into the fine particles, thus appreciably reducing smoke. 4) **Fumigation**: Fumigation consists of introducing a small amount of fuel into the intake manifold. This shortens the delay period- curbs thermal cracking which is responsible for soot formation.	2

(d) Describe the working of Evaporative emission control system. 4

Answer: Evaporative emission control system:

Evaporative Emission control systems reduce the emission of petrol vapours from the fuel tank and carburetor vents. In warm weather, petrol evaporates more easily. The vapour pressure of petrol is more closely controlled, which is helping in the control of these emissions also. It consists of a Charcoal Canister. Activated charcoal can store petrol vapours until the right time for them to be drawn into the engine and burnt. When the engine is off, vapours are routed through lines and hoses to a charcoal canister where they are stored. When the engine is running, the vapours are purged from the canister. They are drawn to the intake manifold for burning in the cylinders. When the engine uses fuel injection, the fuel system is sealed to avoid evaporative emissions. The fuel tank is sealed/ provided with a vacuum valve- to prevent vapour loss. 2

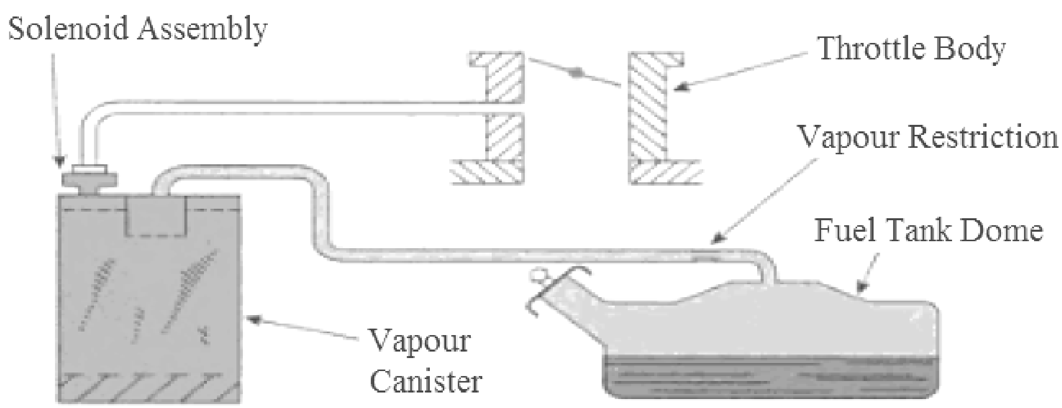


Figure: Evaporative Emission Control System 2

(e) Describe two engine modifications to be done to reduce S.I. engine emission. 4

Answer: **Engine modifications to be done to reduce S.I. engine emission:** *(Any two-2 marks each)* 4

1. **Use of leaner air fuel ratios**:
   The carburetor may be modified to provide relatively lean and stable air fuel mixtures during idling and cruise operation. With this modification idle speed needs to be increased to prevent stalling and rough idle associated with leaner fuel air ratios. Fuel distribution is improved by better manifold design, inlet air heating, raising of coolant temperature and use of electronic fuel injection system.

2. **Retarding ignition timing**:
   Retarding ignition timing allows increased time for fuel burning. The controls are designed to retard the spark timing at idle while providing normal spark advance during acceleration and cruising. Retarding the spark reduces NO_x emission by decreasing the maximum temperatures. It also reduces HC emission by causing higher exhaust temperatures. However retarding the ignition timing results in greater cooling requirement and there is some loss in power and fuel economy

3. **Modification of combustion chamber configuration to reduce quench areas**:
   Modification of combustion chamber using attempts to avoid flame quenching zones where combustion might otherwise be incomplete and resulting in high HC emission. This include reducing surface to volume ratio, reduced squish area, reduced deal space around piston ring and reduced distance of the top piston ring from the top of the piston.

4. **Lower compression ratio**:
The lower compression ratio reduces the quenching effect by reducing the quenching area, thus reducing HC. Lower compression ratio also reduces NO_x emissions due to lower maximum temperature. However reducing the compression ratio results in some loss in power and fuel economy. But there is an advantage of reduced octane number which will make it easier to phase the lead out of petrol i.e. use of unleaded gasoline.

5. **Reduced valve overlap**:
Increased valve overlap allows some mixture to escape directly and increase emission level. This can be controlled by reducing valve overlap.

6. **Alternation in induction system:**
The supply of designed air fuel ratio to all cylinders under all operating conditions can be affected by alterations in induction system which includes inlet air heating, use of carburetors e.g. high velocity carburetors or multi choke carburetors. This also includes the fuel injection manifold.

Note: Suitable credit shall be given to diagrams justifying above description