UNIT - II

ENGINE CONTROL SYSTEM

FUEL CONTROL

* The purpose of a fuel control system is to prepare or control from ambient air and fuel in the tank an air fuel mixture that satisfies the requirement of the engine.

* The optimum air-fuel ratio for an engine is that which gives the required power output with the lowest fuel consumption.

The fuel Induction systems for SI engines are classified as:

* Carburettors (Natural Fuel Induction system)
* Throttle body Fuel Injection system [Mechanical / Electrical]
* Multi point Fuel Injection system

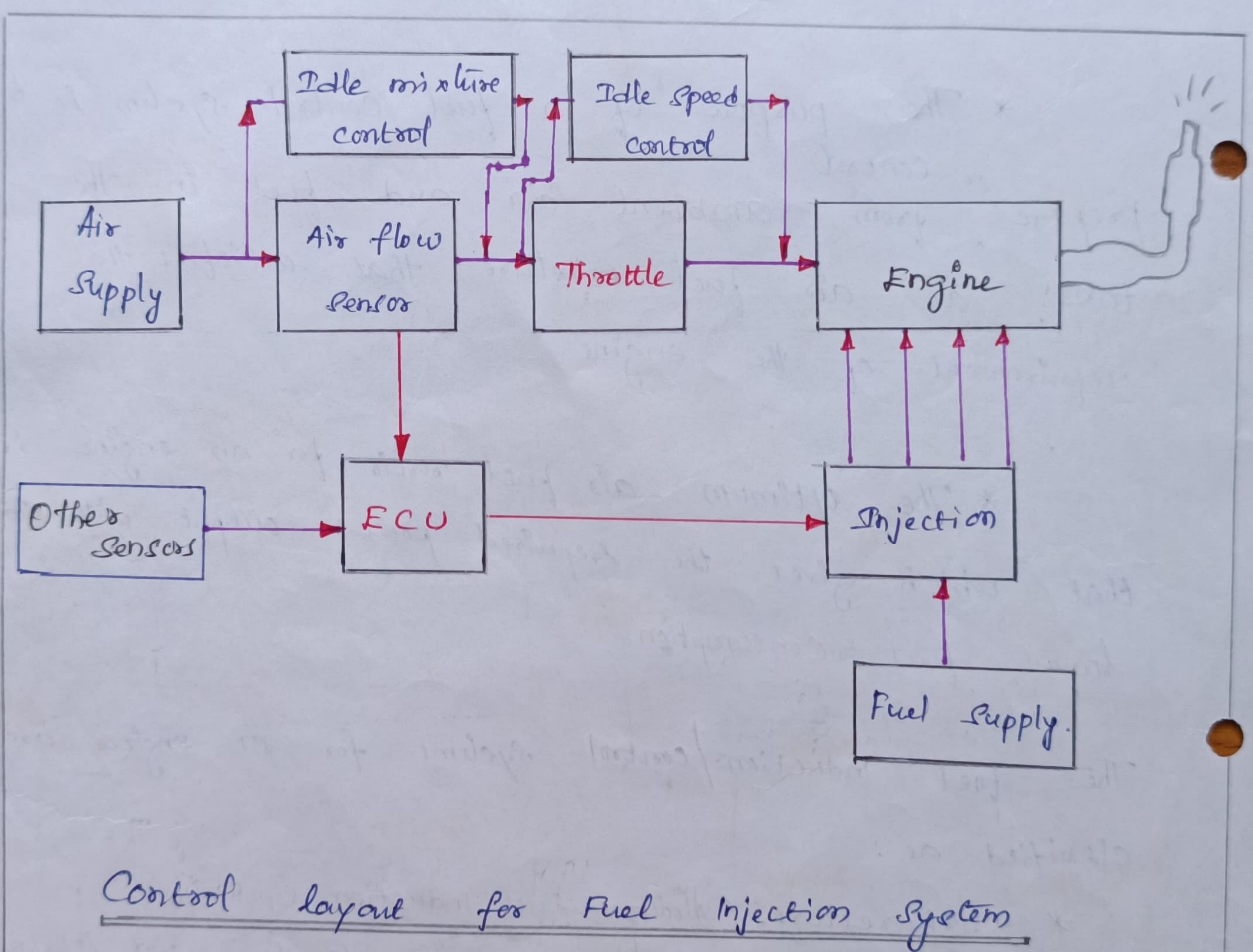
Electronic Fuel Injection System [EFI]

The EFI System works with aid of electric source whereas mechanical system works by linkages.

The Electronic Fuel Injection System can be divided into three basic sub-systems. They are:

* Fuel delivery system
* Air Induction system
* Electronic control system

* Fuel Delivery System:



Control layout for Fuel Injection System

* Fuel Injection

The basic principle of fuel injection is that if petrol is supplied to an injector (electronically controlled valves), at constant differential pressure, then amount of fuel injected will be directly proportional to the injector open time.

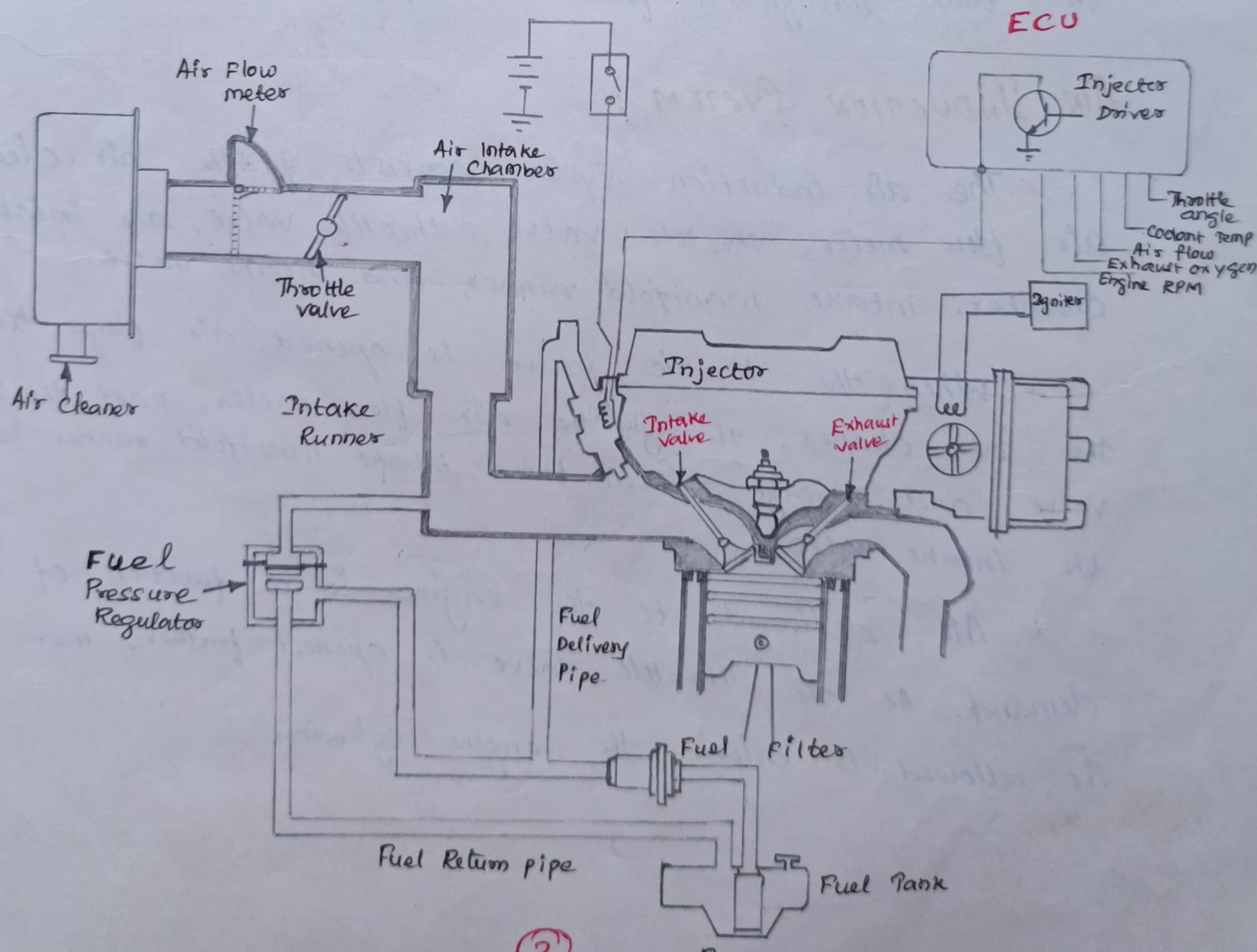
Most systems are now electronically controlled even if containing some mechanical metering components. This allows the operation of injection system to very closely matched to the requirements of the engine.

Electronic Fuel Injection [EFI]

The electronic fuel Injection can be divided into three basic sub-systems.

* Fuel Delivery system
* Air Induction system
* Electronic Control system

Layout of EFI:



FUEL DELIVERY SYSTEM:

* The fuel delivery system consists of the fuel tank, fuel pump, fuel filter, fuel delivery pipe (fuel rail), fuel injector, fuel pressure regulator & fuel return pipe.

* Fuel is delivered from the tank to the injector by means of an electric fuel pump.

* The pump is typically located in or near the fuel tank. Contaminents are filtered out by a high capacity in line fuel filter

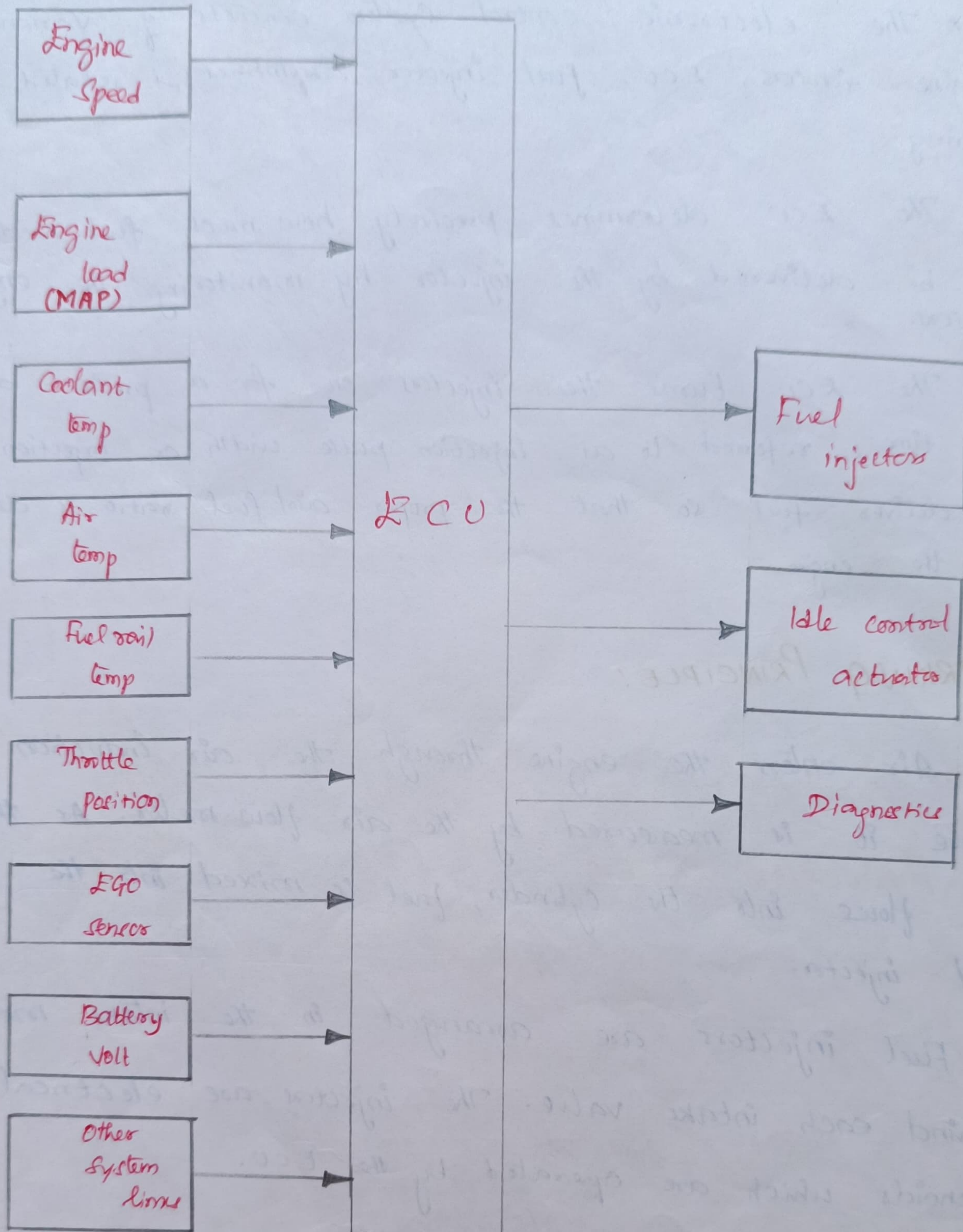
* Fuel is maintained at a Const. pressure by means of a fuel pressure regulator. Any fuel which is not delivered to the intake manifold by the injector is returned to the tank through a fuel return pipe.

AIR INDUCTION SYSTEM:

* The air Induction system consists of the air cleaner, air flow meter, throttle valve, throttle valve, air intake chamber, intake manifold runner, and intake valve.

* When the throttle valve is opened, air flows through the air cleaner, through the air flow meter, past the throttle valve, and through a well tuned intake manifold runner to the intake valve

* Air delivered to the engine is a function of driver demand. As the throttle valve is opened further, more air is allowed to enter the engine Cylinders.



Block Diagram of Fuel Control System.
(inputs & Outputs to ECU)

ELECTRONIC CONTROL SYSTEM :

* The electronic control system consists of various engine sensors, ECU, fuel injector assemblies & related wiring.

* The ECU determines precisely how much fuel needs to be delivered by the injector by monitoring the engine sensors.

* The ECU turns the injectors on for a precise amount of time, referred to as injection pulse width or injection duration to deliver fuel so that the proper air fuel ratio is delivered to the engine.

WORKING PRINCIPLE:

* Air enters the engine through the air induction system where it is measured by the air flow meter. As the air flows into the cylinder, fuel is mixed into the air by fuel injector.

* Fuel injectors are arranged in the intake manifold behind each intake valve. The injectors are electrical solenoids which are operated by the ECU.

* The ECU pulses the injectors by switching the injector ground circuit 'ON' and 'OFF.'

* When the injector is turned 'ON', it opens, spraying atomized fuel at the backside of the intake valve.

* As fuel is sprayed into the intake air stream, it mixes with the incoming air and vaporizes due to the low pressures in the intake manifold. The ECU signals the injector to deliver just enough fuel to achieve an ideal air/fuel ratio of 14.7:1, often referred to as stoichiometric ratio.

* The precise amount of fuel delivered to the engine is a function of ECU control. The ECU determines the basic injection quantity based upon measured intake air volume and engine speed.

* Depending on engine operating conditions, injection quantity will vary. The ECU monitors variables such as coolant temp, engine speed, throttle angle, & exhaust oxygen content & makes injection corrections which determine final injection.

Advantages of EFI:

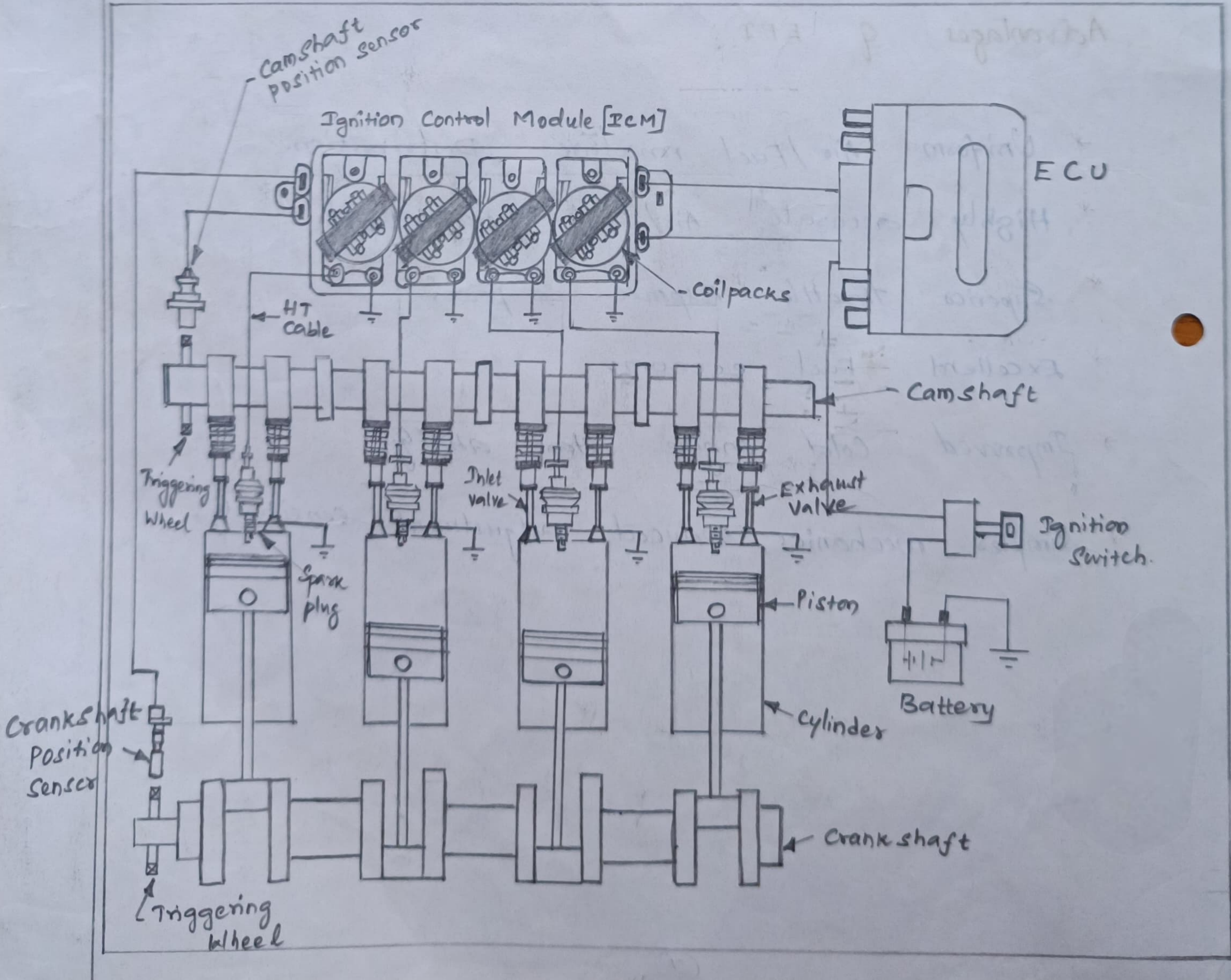
* Uniform Air/Fuel mixture Distribution.
* Highly accurate Air/Fuel Ratio control
* Superior throttle Response & power
* Excellent Fuel economy
* Improved cold engine start ability
* Simpler mechanics, reduced adjustment sensitivity.

Ignition Control in SI Engines.

Methods of Controlling Timing:

* Centrifugal Advance mechanism
* Vacuum Advance mechanism
* Electronic Advance

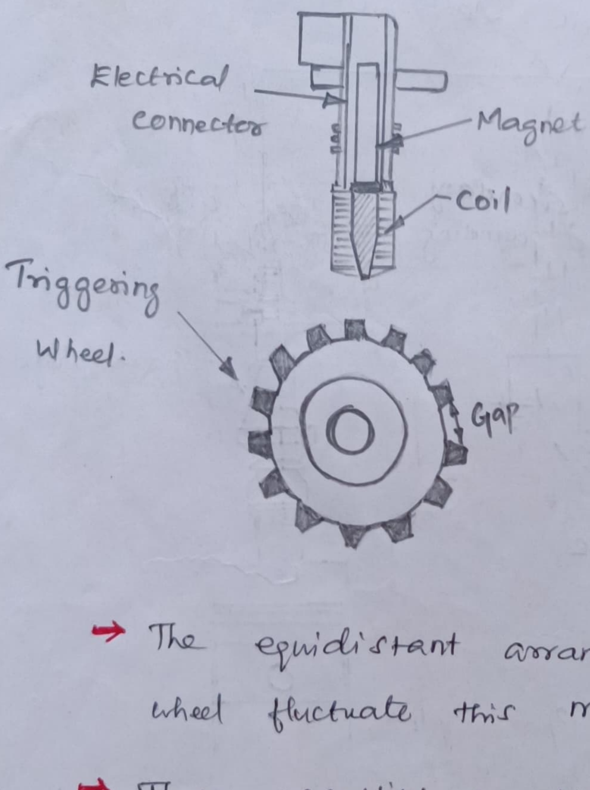
Layout of Electronically Controlled Ignition System [Direct Ignition System]



* Direct Ignition System (DIS) uses triggering devices to sense the exact position of the crankshaft and camshaft

* Coil Packs:
  - Coil packs are nothing but the replicas of the ignition coils with primary and secondary wire coils used in a conventional 'Point Ignition System'

* A sensor attached to the triggering wheels send signals to the Ignition Control Module (ICM) to make and break the primary circuit in the coil packs.



→ The gap that is wider than the rest informs the ignition module that the position is at TDC

→ Crankshaft & camshaft position sensors consist of a magnetic coil that constantly generates magnetic field, as the toothed wheel keeps spinning on the crankshaft.

→ The equidistant arrangement of teeth on the triggering wheel fluctuate this magnetic field.

→ These resulting magnetic oscillations serve as input signals for the ICM, based on which the ICM calculates the position of crankshaft/camshaft.

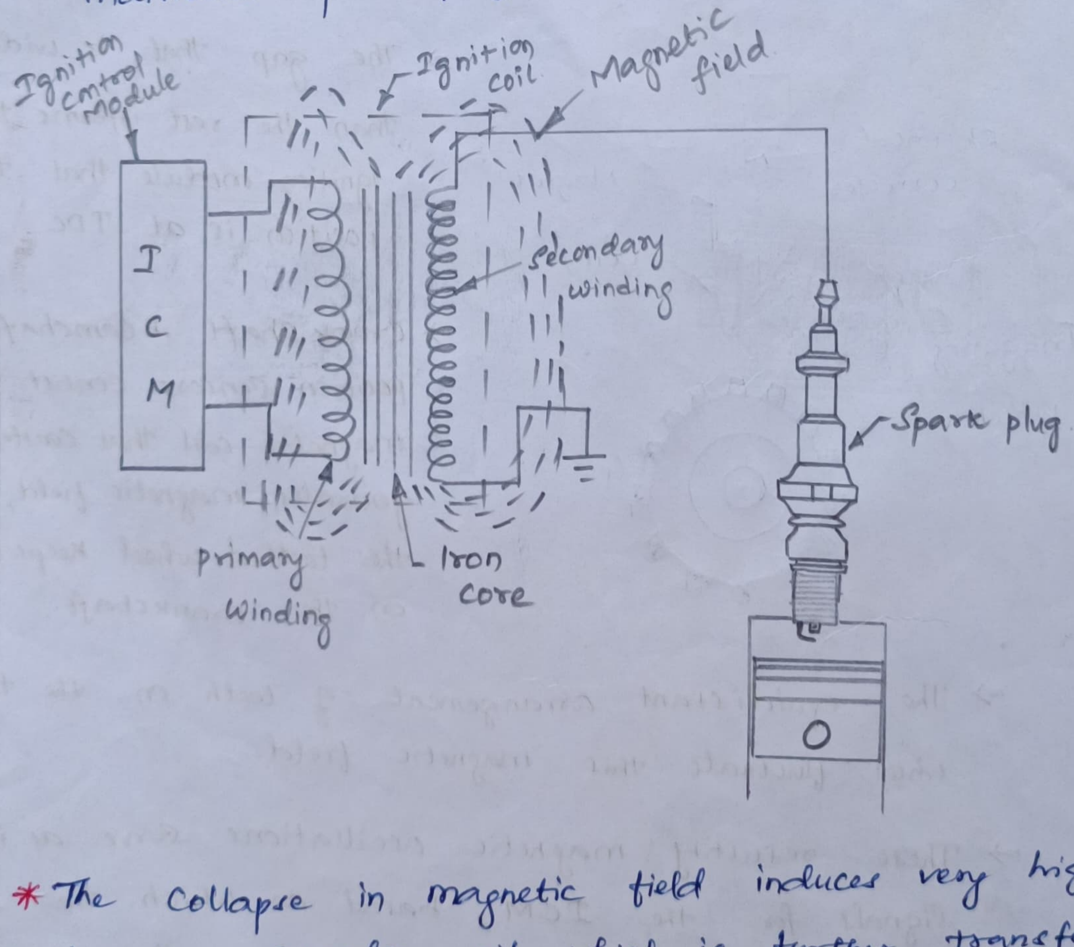
→ The signals from the crankshaft position sensors are transferred to the ICM

* The cam-shaft position sensors shares the same Operating principle and technique as that of the crankshaft position sensor.

* The signals from both the sensors assist the ICM in determining the position of the piston with respect to the position of the crankshaft and the camshaft.

* Furthermore, these signals also assist the ICM in advancing and retarding the spark with varying engine speeds.

* The Ignition control module distributes the voltage to individual spark plugs.



* The Collapse in magnetic field induces very high voltage in the secondary coil, which is further transferred to the spark plug.

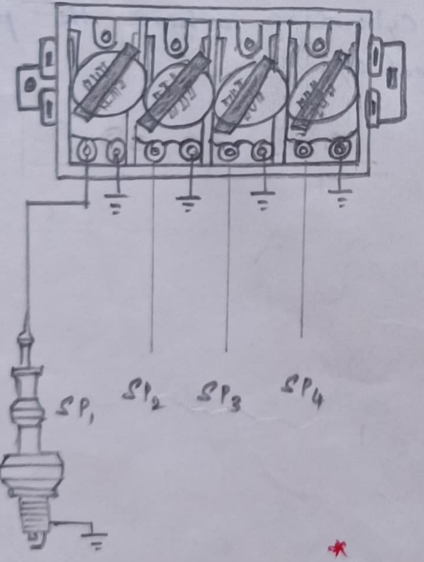
* Spark is induced when voltage jumps across the plug's electrode gap

* ECU supplies battery voltage to the coil packs & simultaneously calculates the Ignition timing too, which is all based upon the information transmitted to it by ICM

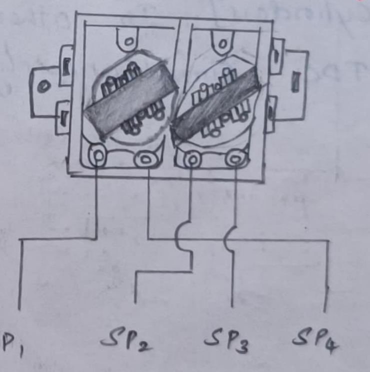
* The advantage of Direct Ignition System over the conventional system lies in the fact that the use of single coil pack per plug facilitates in controlled and precise timing.

* The DIS can function with either a seperate coil pack for each spark plug or also with a common coil pack b/w two spark plugs.

Seperate coil pack for each spark plug



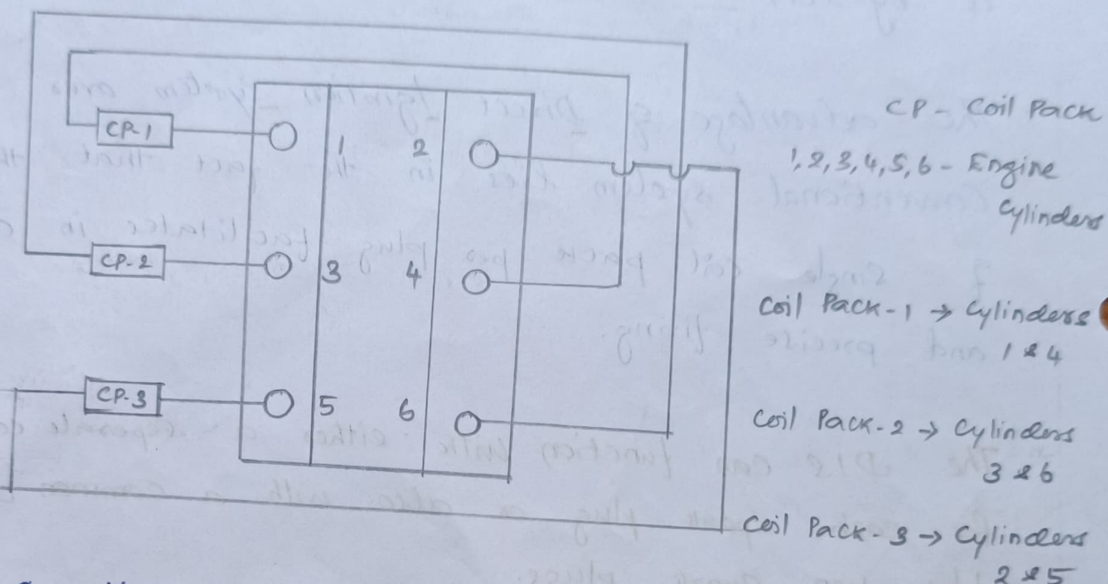
Common coil packs between two spark plugs.



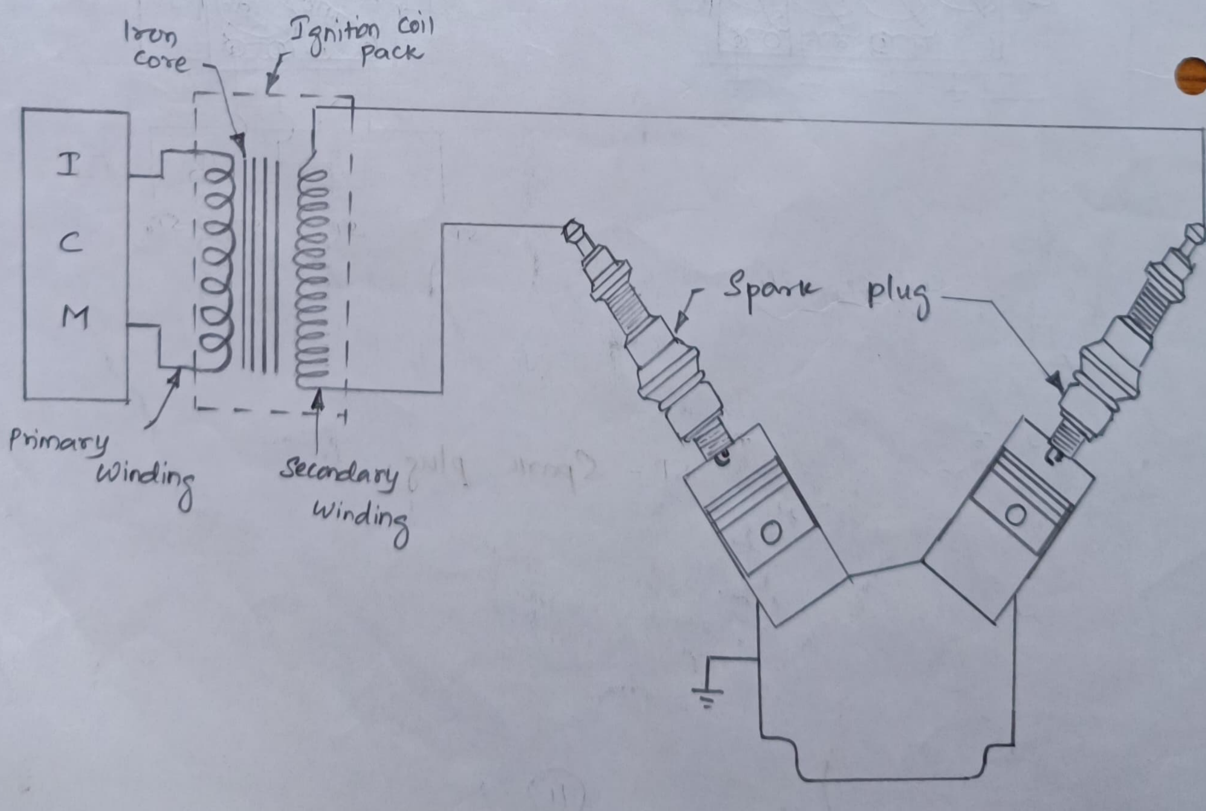
* SP - Spark plug.

Waste Spark Phenomenon:

* The concept of 'Waste spark' is applicable to both inline as well as V-type multi cylinder engines with coil packs shared between two spark plugs.



* For a V-Engine, the cylinders with opposite firing order are paired upto a common coil pack [also known as companion or sister cylinders]. In other words, cylinders where the position reach TDC simultanously are paired up.



* Event Cylinder:
  - The cylinder nearing the end of compression stroke and ready for the power stroke is called the 'Event cylinder'

* Waste Cylinder:
  - The Companion cylinder, with exhaust stroke nearing its end is called 'Waste cylinder'

* In a conventional ignition system, all the spark plugs fire in the same forward direction i.e. from the central electrode and towards the ground electrode

* In Direct Ignition System one plug fires in forward direction whereas the other spark plug in the companion cylinder fires in the reverse direction ie. from the ground electrode to the central electrode.

* The high voltage generated in the secondary winding is supplied to the spark plugs through a HT cable.

* This current travels in forward direction and generates spark after bridging the air gap between the two electrodes.

* In the companion cylinder, this current travels in opposite direction [from ground electrode to the central electrode] before firing occurs.

* The current then flows back to its origin through the H.T lead to complete the circuit.

* Based on the inputs from the ECU & ICM, the firing order is decided.

* The spark generated at the end of the exhaust stroke is termed as waste spark; that is owed to the fact that it is just meant to complete the circuit and not to serve any other task.

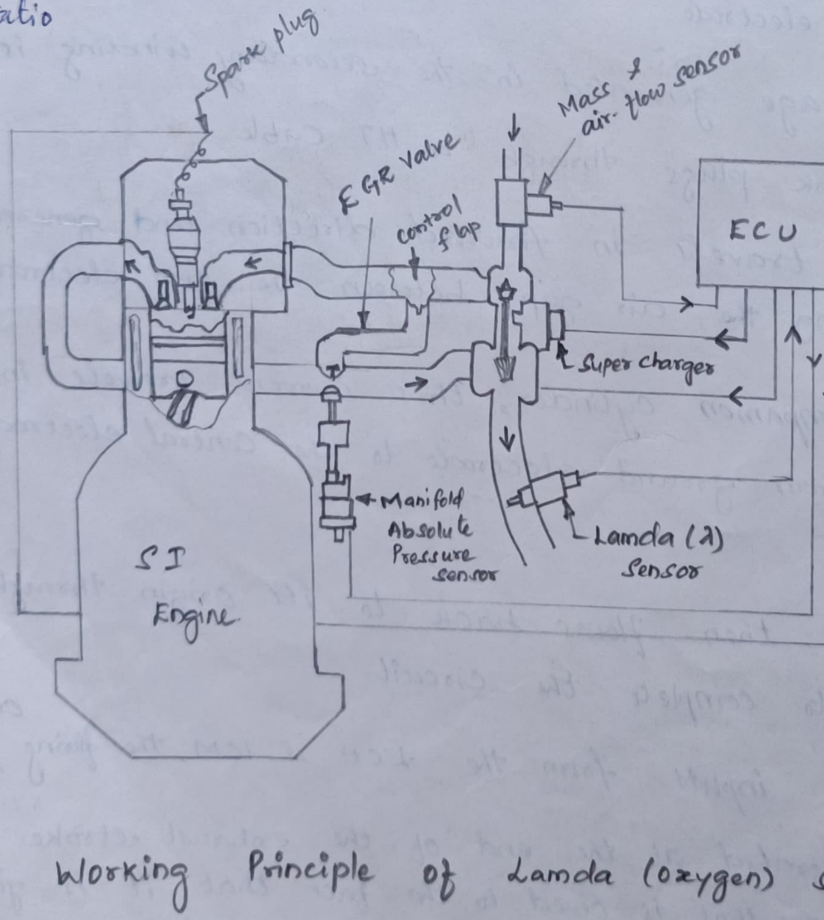
Lamda Control:

* A sensor signal arises which the engine control Unit [ECU] uses in order to change the mixture composition.

* The diagnostic sensor measures the remaining oxygen in the processed exhaust.

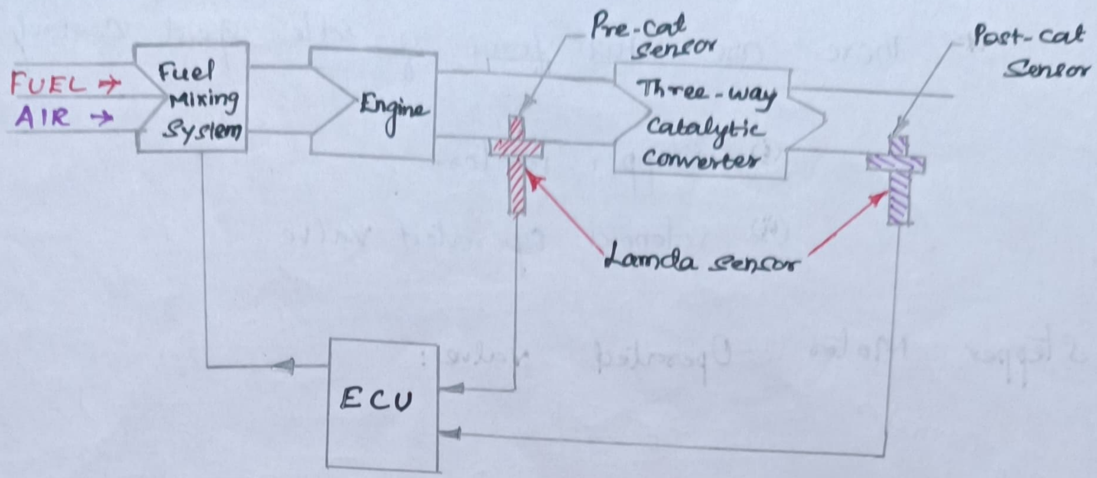
* Lamda (oxygen) sensor & ECU from a closed loop control system.

* The amount of oxygen sensed in the exhaust is directly related to the mixture strength, or air-fuel ratio



Working Principle of Lamda (oxygen) Sensor

Block diagram - Lamda Control



* The ideal air-fuel ratio of 14.7:1 by mass is known as a lamda (λ) value of one.

Stoichiometric mixture:

The ideal ratio of air and fuel for a petrol engine is present if 14.7 kg of air come with 1 kg of fuel. It is also called a "stoichiometric mixture".

* Exhaust Gas Oxygen (EGO) sensors are placed in the exhaust pipe near to the manifold to ensure adequate heating.

* The amount of oxygen in the exhaust gas is used as an indirect measurement of the air/fuel ratio.

* According to the inputs given by the lamda sensor the ECU determines / adjust the appropriate level of mixture to ensure greater fuel efficiency.

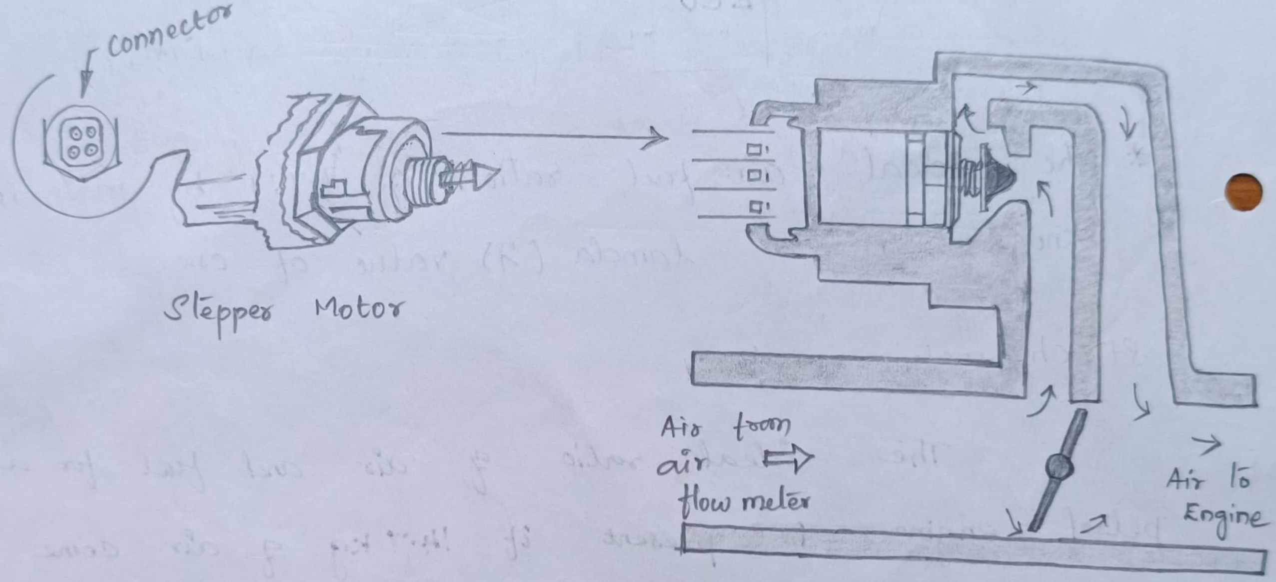
Idle Speed Control:

* There are two forms of idle speed control (ISC)

(i) Stepper motor

(ii) Solenoid Operated valve.

Stepper Motor Operated valve:



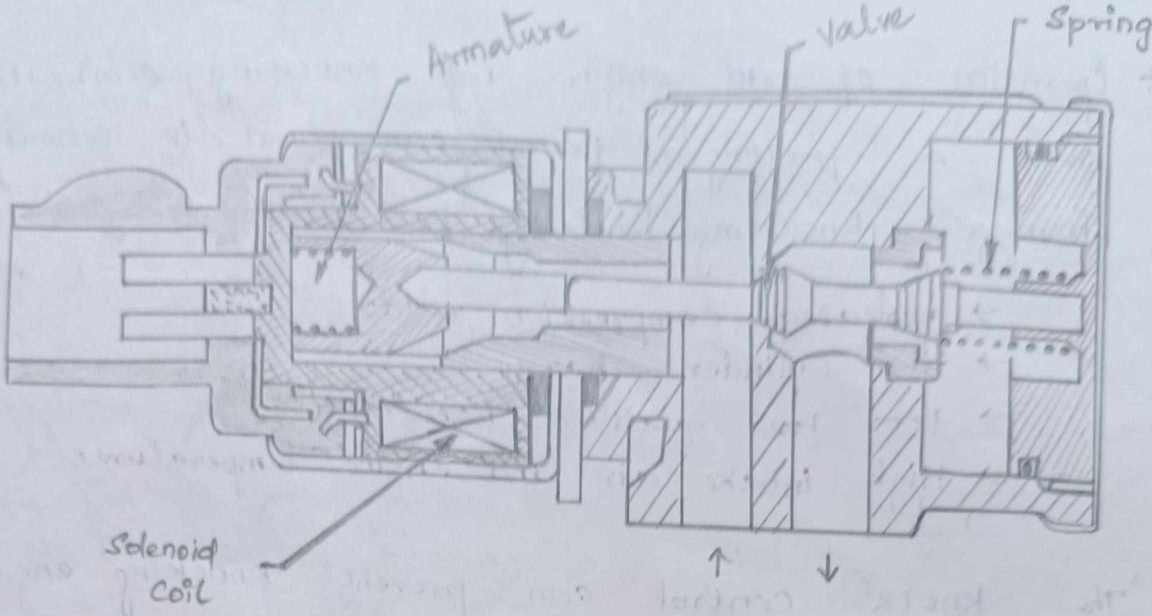
* The ECM controls the stepper motor by pulses.

* The ECM pulses the transistor bases, in the correct sequence, so that the stepper motor moves the air valve to provide the correct air supply, for any given condition.

* In addition, other sensor signals will enable the ECU to provide the correct amount of fuel to ensure the engine continues to run smoothly.

* The stepper motor with multiple pin connection is typical type of connection that is used to electrically connect the stepper moter to the ECU.

Solenoid Operated Idle Speed Control Valve:



* This type of valve regulates the amount of air that by-passes the throttle valve through the medium of a solenoid-operated valve

* In the rest position, the valve is closed by the spring and the armature of the solenoid is pushed back inside the solenoid coil.

* When operating, the energized solenoid opens the valve and admits air into the induction system.

* The quantity of air admitted is controlled by duty cycle pulses that are sent from the ECM.

Knock Control :

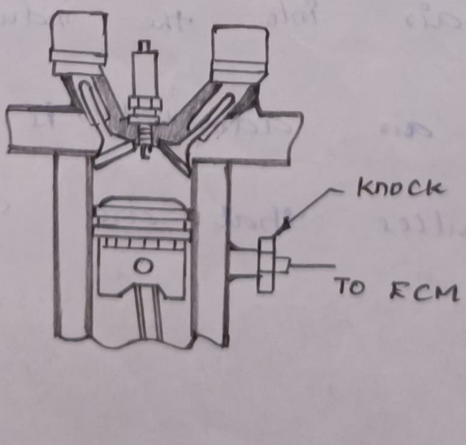
* Operation of an engine with knocking combustion over a prolonged period can lead to serious damage. knocking tendency is increased by
  - → Increased compression ratio
  - → High cylinder charge
  - → Poor fuel quality (RON / MON)
  - → High intake air and engine temperatures.

* The knock control can prevent knocking engine Operation.

* It retards the ignition timing of the affected cylinder only as far as necessary and only if there is an actual risk of knocking.

* The main component in this system is the knock sensor.

* These piezo electric sensors record the structure-borne sound of the individual cylinders & convert them into voltage signals.



* When knocking combustion occurs, the affected cylinder emits a characteristic structure-borne sound profile that is picked up by the knock sensor.

* Based on this signal, the ignition is retarded for a certain number of cycles.

* As soon as combustion knock is no longer detected, the ignition point gradually approaches the original value.

* Retarding the ignition timing can be controlled individually for each cylinder.

Cylinder Balancing:

* The need for balancing is obvious on the simple thesis that to start matter in motion requires a force, and to stop it demands another force, while the greater the "weight" of matter and the more sudden the starting & stopping, the greater forces involved.

* In an engine, the major reciprocating parts are piston, rings, gudgeon pin and part of the connecting rod, set up forces along their line of travel.

* If the engine is unbalanced, the forces acting through its structure and mountings, set up vibration.

* Lightness in the reciprocating parts is important to keep the forces as small as possible.

* In high speed engines, it is customary to employ aluminium-alloy pistons and duralumin connecting rods.

* In certain type of engines, good balance achieved in opposing one set of reciprocating parts by another.