



**INSTITUTE OF AERONAUTICAL ENGINEERING**

(Autonomous)

Dundigal, Hyderabad - 500 043

# **AUTOMOBILE ENGINEERING**

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# UNIT-I

# CHASSIS, FRAMES AND DRIVES

# FRAME , CHASSIS & BODY

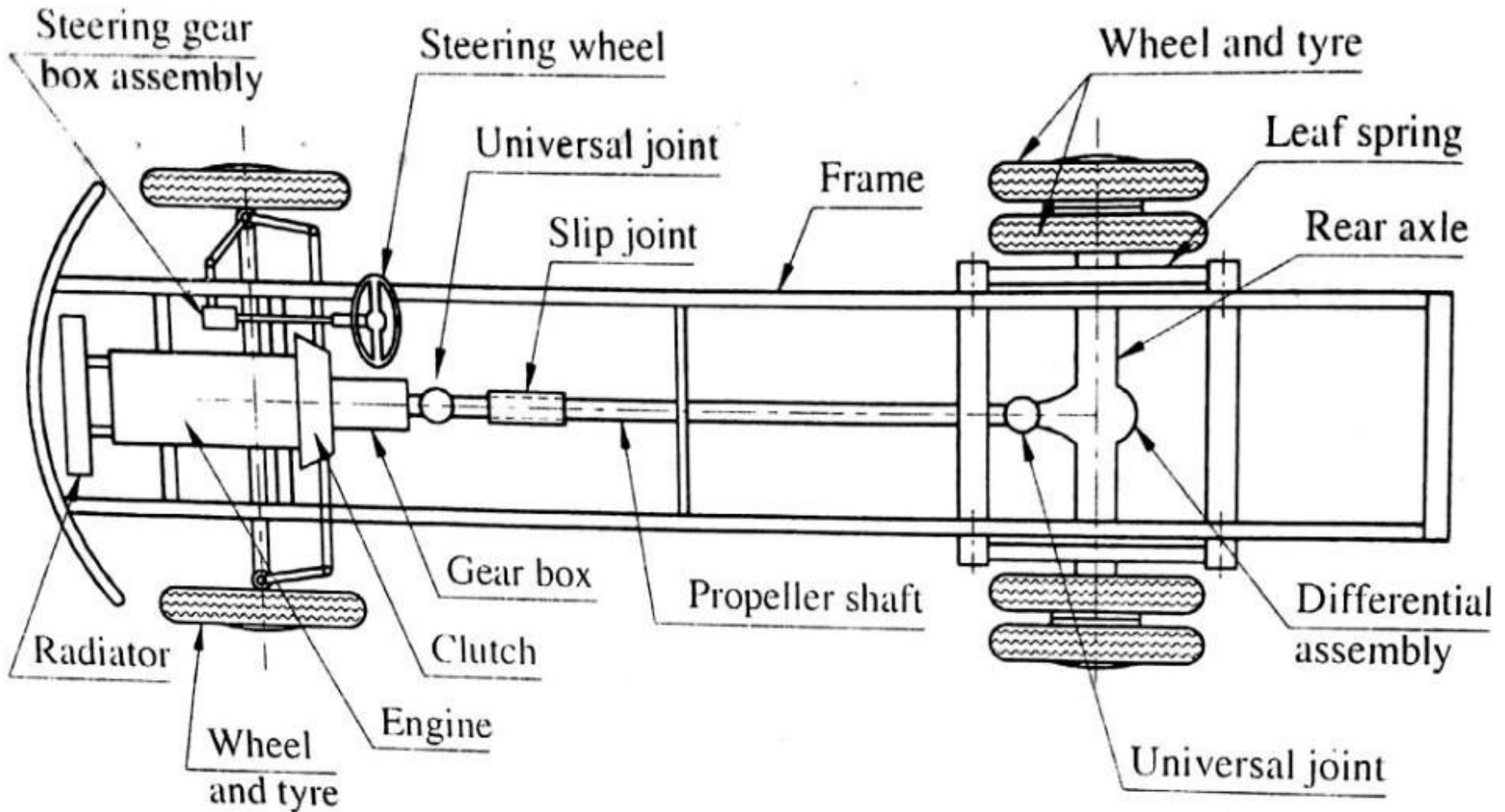
## FRAME

- It is the supporting component of automobile vehicle.
- It is the foundation for carrying the engine, transmission system & steering system by means of spring , axle , rubber pads etc.
- The frame are made of box , tubular channels or U-shaped section , welded or riveted together.

## CHASSIS

- When engine , transmission system , steering & wheels are fitted on the frame , the assembly known as the “chassis”.
- It is the backbone of the vehicle.
- It is the vehicle without body.
- It contains all the major units necessary to propel the vehicle.
- Vehicle can be driven after placing the driver seat on the chassis.

# SIMPLE CONSTRUCTION OF TRUCK CHASSIS



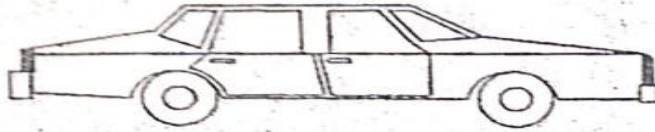
- **Chassis consist of following components:**

1. Engine
2. Wheels
3. Radiator
4. Brakes
5. Fuel tank
6. Steering system
7. Suspension system
8. Transmission system (clutch , propeller shaft , differential , rear axle)

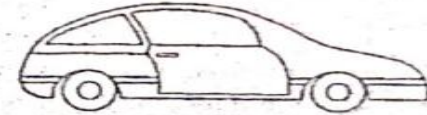
## **BODY**

- It is a super structure of the vehicle.
- Chassis & body makes the complete vehicle.
- For small & light car body & chassis are made as a single unit but in large vehicles both are made as a single unit.
- Generally it is made from metal or fibre.
- Main purpose of car body is to provide comfort & protection to the passenger & also the good look.

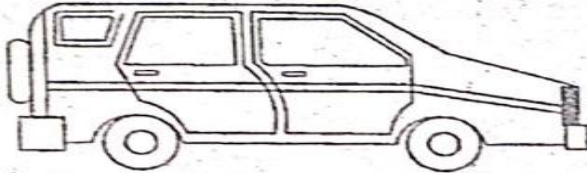
# TYPES OF BODIES FOR CAR



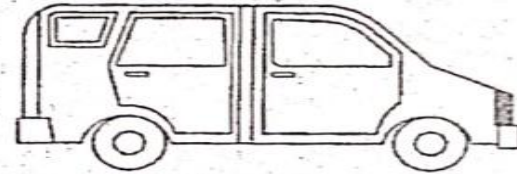
(a) *Saloon*



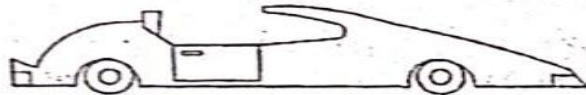
(b) *Coupe*



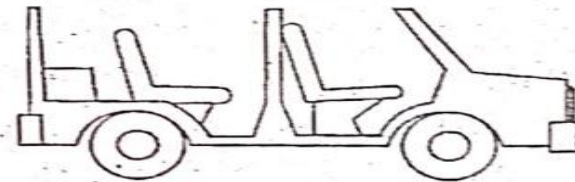
(c) *Hatchback*



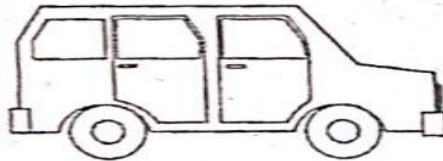
(d) *Limousine*



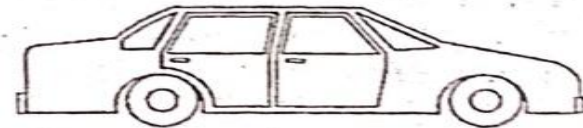
(e) *Sport*



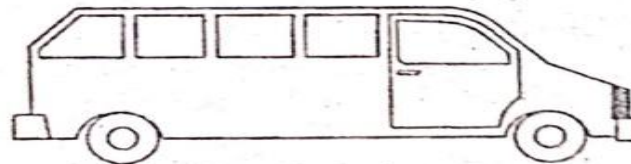
(f) *Trax*



(g) *Jeep*



(h) *Estate car*



(i) *Station wagon*

Fig. 2.11 Different types of bodies for car

## **FUNCTION OF FRAME**

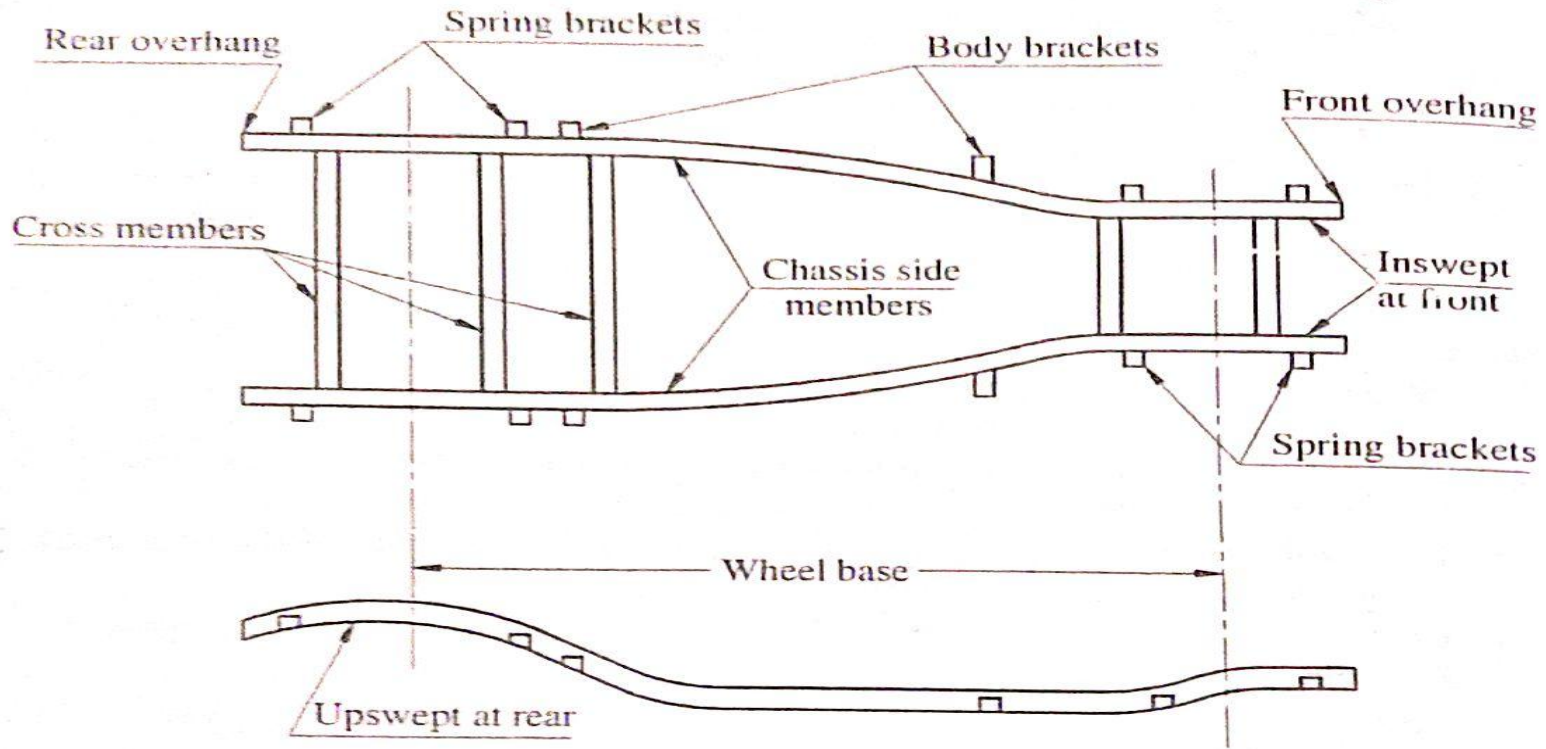
1. To support chassis components & the body.
2. To withstand the static & dynamic load of different components of chassis.
3. To withstand load of the body.
4. To carry load of passengers/goods carried in body.
5. To withstand stresses caused due to uneven road conditions.
6. To withstand force caused due to turning of vehicle & sudden braking or acceleration.

## **TYPES OF FRAME**

1. Conventional frame
2. Integral or Unit construction or Frameless chassis



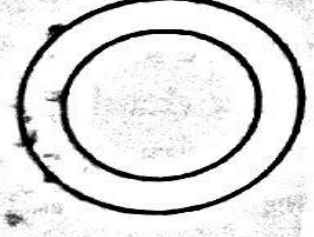
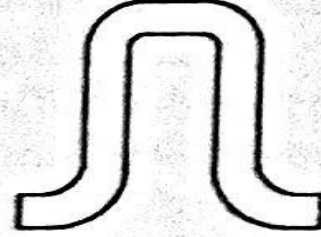
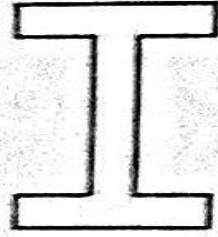
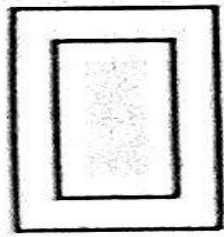
## (i) CONVENTIONAL FRAME



*Fig. 2.3 Conventional frame construction*

- It is used in most of the heavy vehicles.
- Construction of frame varies according to the type of vehicle.
- Generally made from the steel sections.
- This type of frame has “ 2 long side members” & “ 5 to 6 cross members” joined together with the help of rivets or bolts.
- Cross members are used to increase the strength of the frame.
- They are inswept (Narrow) at the front & are upswept (Broad) at the rear.

- The frame is narrowed down at the front (inswept) to have a better steering lock which provides space for pivoting & swinging of the front wheels.
- Upswept at the rear provided to give room for the vertical movement of the rear axle as it travels over road bumps & other road inequalities.
- Body brackets are provided to support the body of the vehicle.
- Spring brackets are provided for mounting the body of the vehicle.
- Extension of chassis frame ahead of the front axle known as front overhung.
- Extension of chassis beyond the rear axle known as rear overhung.
- Different sections are used for long & cross members. Generally channel section & box section are used for long side members & other sections like I section, hat section, tubular section are used for cross members.



*Channel section*

*Box section*

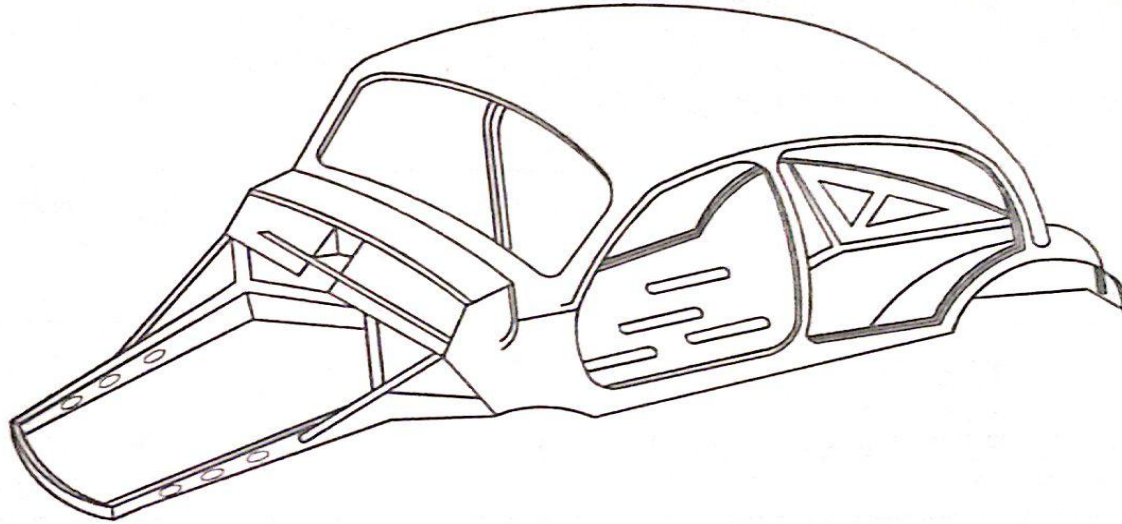
*I-section*

*Hat section*

*Tubular section*

**Fig. 2.4 Frame sections**

## (ii) INTEGRATED FRAME CHASSIS or FRAMELESS CHASSIS

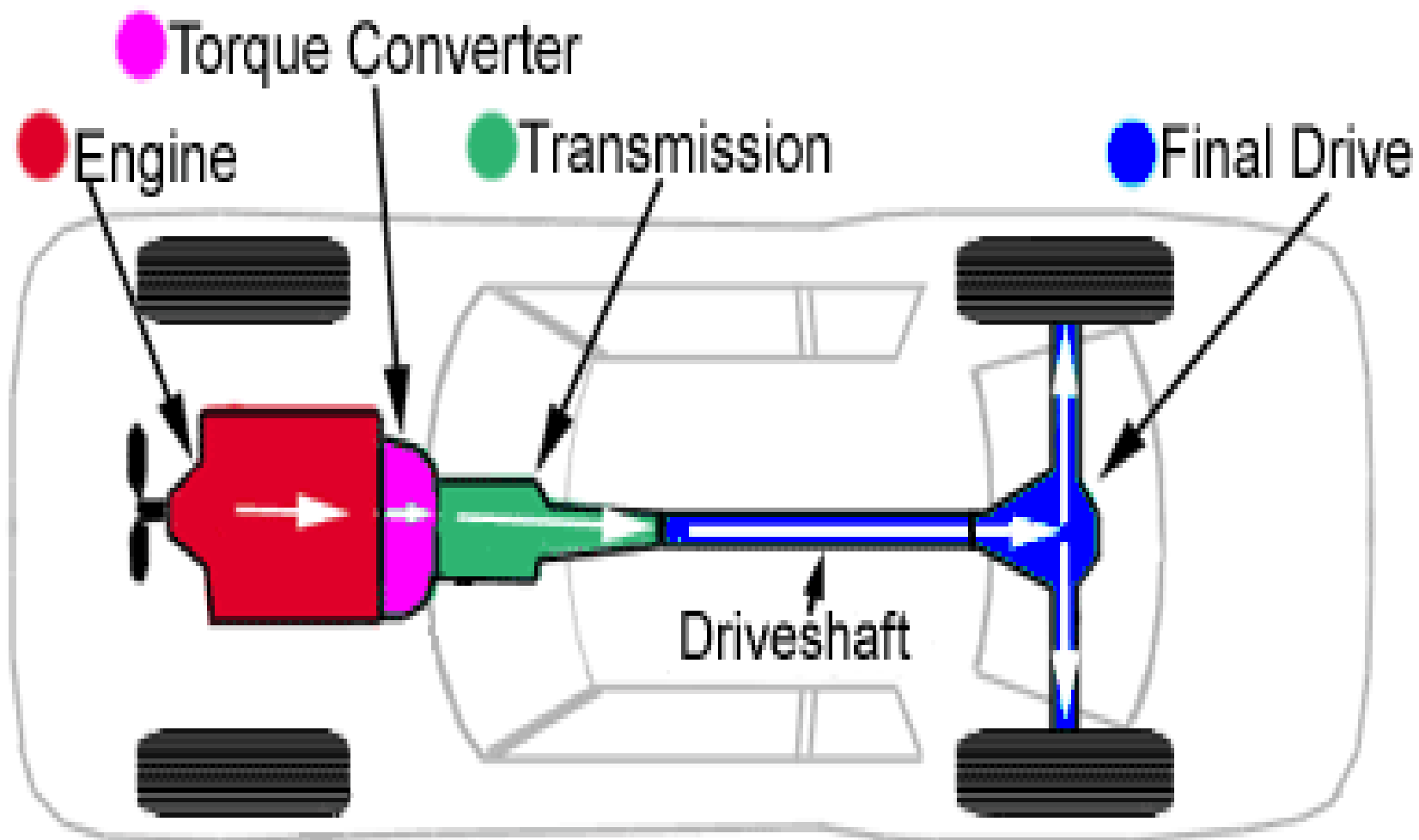


*Fig. 2.5 Integrated body and frame construction*

- This frame construction, now-a-days used in most of the motor cars called as a frameless or chassisless or mono or unit construction in which the floor assembly & frame form one integral unit.
- Need of the heavy side members are eliminated ,which is used in conventional frame & the floor is strengthened by cross members & body , all welded together.
- In some cases sub-frames are also used on which various chassis components are mounted. This sub-frames are supported by main frame.
- The main purpose of sub-frame are to provide isolation , flexibility & simplified production.
- So, in this type of construction all components like cross member , floor , body are welder or bolted together as one assembly.
- This type of construction gives more strength & rigidity.

# FRONT ENGINE – REAR WHEEL DRIVE

- In this chassis layout ,the engine is fitted at the front.
- The engine ,clutch and gear box are fitted at front while drive to the rear axle is given with the help of propeller shaft
- This chassis layout is one of the oldest and still remain popular for heavy commercial vehicle.



Rear Wheel Drive Layout

# ADVANTAGE OF FRONT ENGINE –REAR WHELL DRIVE

- The weight distribution is reasonably balanced between the front and rear wheels, which gives good handling characteristics.
- Due to engine and radiator are at front , the forward facing radiator takes full benefit of the natural air stream , created by vehicle's movement .hence reduce the power losses for a large fan.

- The weight of vehicle is shifted to rear driving wheels during acceleration and on steeps resulting in better road grip ,hence ,there are less chances of wheel slipping .
- Since the front wheel are used only to steer the vehicle , hence steering mechanism become simple in design and easy to operate.
- Accessibility to various components like engine , gear box and rear axle is better in comparison to outer layout

- The control linkages –accelerator ,clutch ,choke ,and gear box are shot and simple.
- Large luggage space is available at back of vehicle which providing increased carrying capacity as well as space for easy body extension .

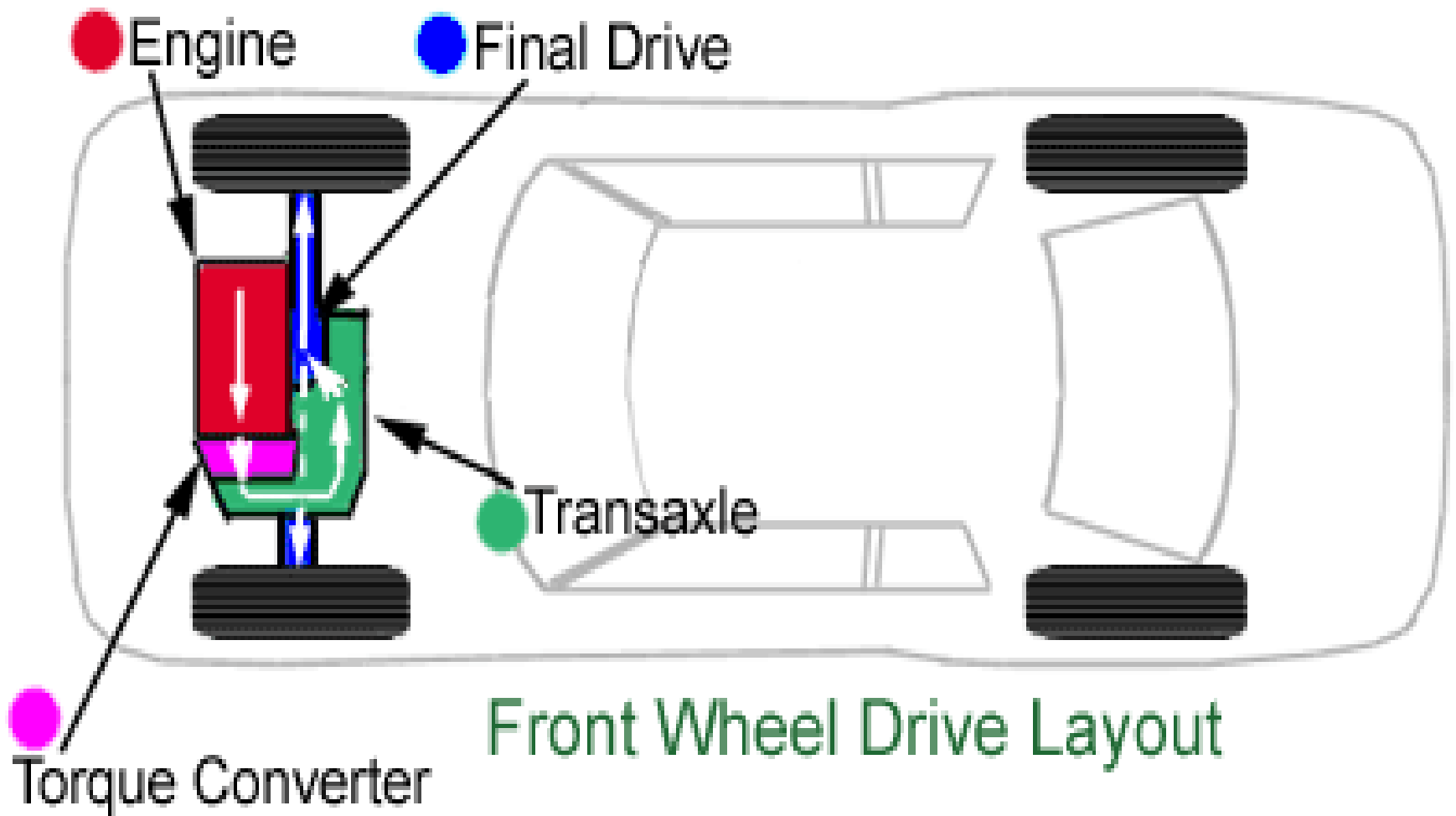


# DISADVANTAGE

- During the breaking ,weight of vehicle is fitted to front wheels and weight on rear wheels decreased , results in decreased breaking effort developed
- It required long propeller shaft and differential at rear ,therefore height of floor area is increased .Also, due to long propeller shaft transmission problems and weight are increased.
- Due to less weight on driving rear wheels , there is less adhesion on road and result in less holding capacity .therefore there is less chance of skidding on slippery surface.

# FRONT ENGINE –FRONT WHEEL DRIVE

- In this type of chassis layout the engine is fitted at front and drive is also given to the front wheel .No propeller shaft is used in this layout and differential are included in the same assembly.
- This layout provides optimum body luggage space and flat floor line .However , due to all assemblies at front ,it make very difficult to accommodate the steering mechanism.



# ADVANTAGE OF FRONT- WHEEL DRIVE

- Due to more weight placed on driving front wheel , the vehicle has more adhesion on road. Hence good road holding capacity even on the curves and slippery roads .
- This layout provides low floor , since no propeller shaft and the differential placed at front instead of rear.
- The clutch ,gearbox, and final drive usually made as one unit thereby coast of vehicle is reduce.

- The wheels do not take to sharply turn into the curve due to tendency of understeering. The understeer condition generally preferred by many drivers are promoted by this type of chassis.
- Either a transverse or longitudinal engine position can be used. In case of transverse mounted engine, as the engine crankshaft and wheels already rotate in the parallel planes, therefore, they do not require their drive to be turned through 90 degree as in case of conventional longitudinally mounted engines.

# DISADVANTAGE

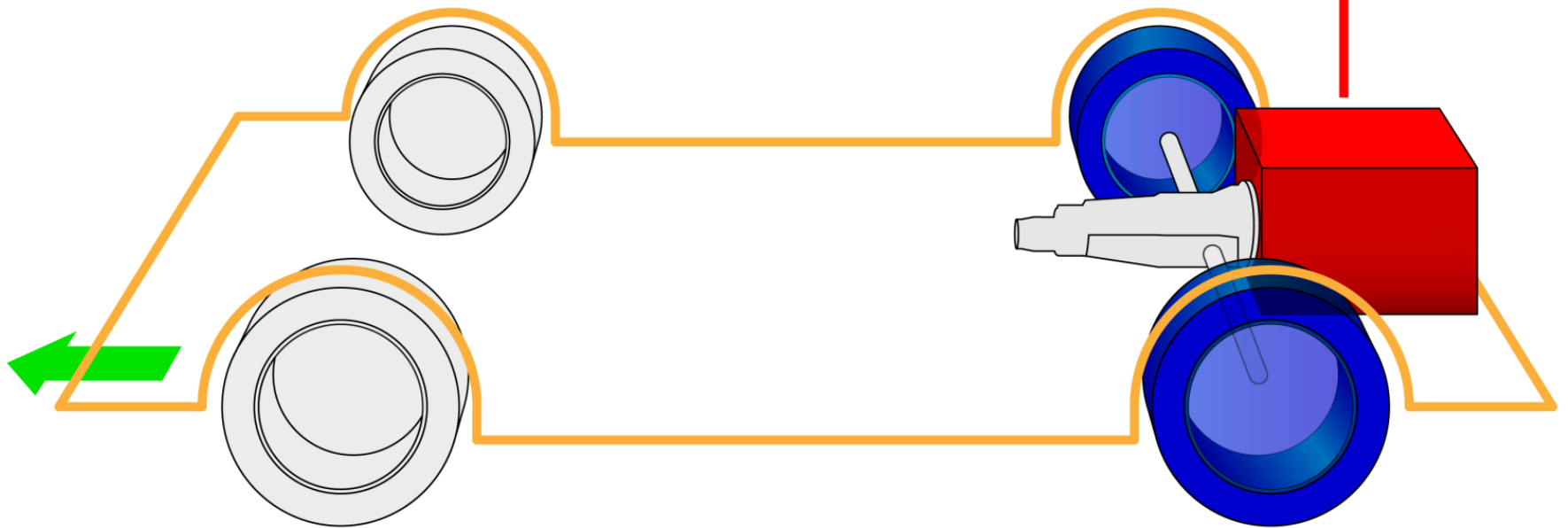
- The weight on the driving front wheels is reduced during acceleration and climbing of steep gradient due to weight of the vehicle shifting to the rear wheels . Hence ,result in decreased tractive effort.
- This dis advantage become more serious on slippery gradient.
- The steering mechanism become more complicated due to accommodation of engine ,clutch ,gearbox & final drive all at front of vehicle.

# REAR ENGINE-REAR WHEEL DRIVE

- In this chassis layout engine is fitted at the back and drive is also given to rear wheel
- This arrangement eliminate the necessity for a propeller shaft because engine is mounted near the driven wheel.
- The passenger are kept away from inconveniences like noise, heat and fumes because engine at back of vehicle

**RR**

Rear-engine



Rear-wheel drive



# DISADVANTAGES

- Efficient cooling becomes very difficult to obtain due to air passes through side part of the body
- Long linkages are required to connect the control panel and engine , gear box ,accelerator and clutch.
- The wheel get turned too sharply into the curve due to tendency of oversteering

# 4 WHEEL DRIVE

- 4X2 = 4 Wheel vehicle and 2 Wheels can receive torque.
- 4X4 = 4 Wheel vehicle and all 4 Wheels can receive torque.
- E.g. are Jeeps, SUVs(Sports Utility Vehicle), etc.
- Games derived it's name from 4WD only.
- Used mostly in defense services or where graveled or slick roads are present.

# WHY 4WD ARE USED?

- To get enough “TRACTION” between wheels and road surfaces.
- To move vehicle on slick surfaces, dirt, slippery roads, sand roads and snowy, muddy roads etc.



# PART TIME 4WD

- Manual Shift.
- Equipped with Switching mechanism.
- Select 2WD under normal condition and 4WD on off-road situation.



# ADVANTAGES

- Increased Traction is obtained in slippery surfaces.
- More balanced axle load distribution.
- Even tire wear.

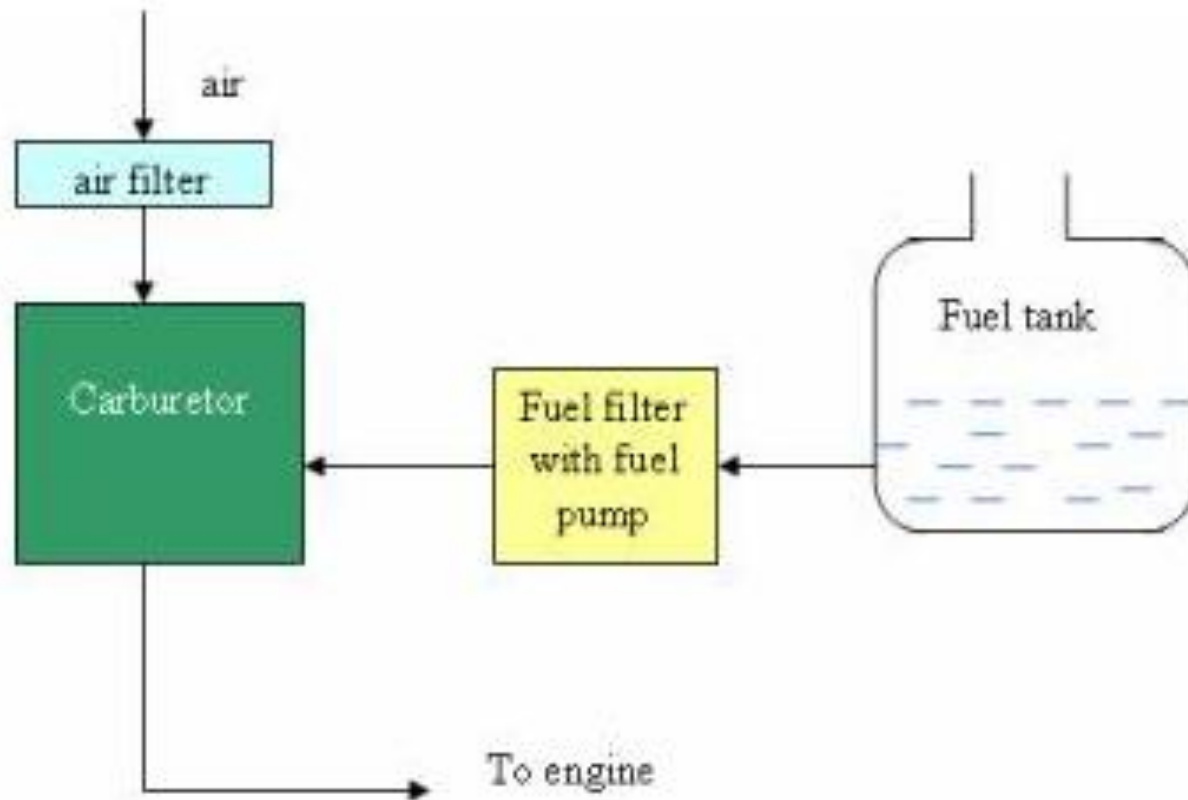
# DISADVANTAGES

- Weight of vehicle is increased.
- Cost vehicle is increased.
- Maximum speed of vehicle is reduced.
- Less fuel economy than 2WD.

# FUEL SUPPLY SYSTEMS

- The fuel passes through a number of stages before reaching the combustion chamber.
- It includes the filtration and atomization of fuel into fine particles.
- It is necessary to atomize the fuel before entering into the combustion chamber so that complete combustion of fuel can take place.
- There are different fuel supply systems for spark ignition (petrol) and compression ignition (diesel) engine.

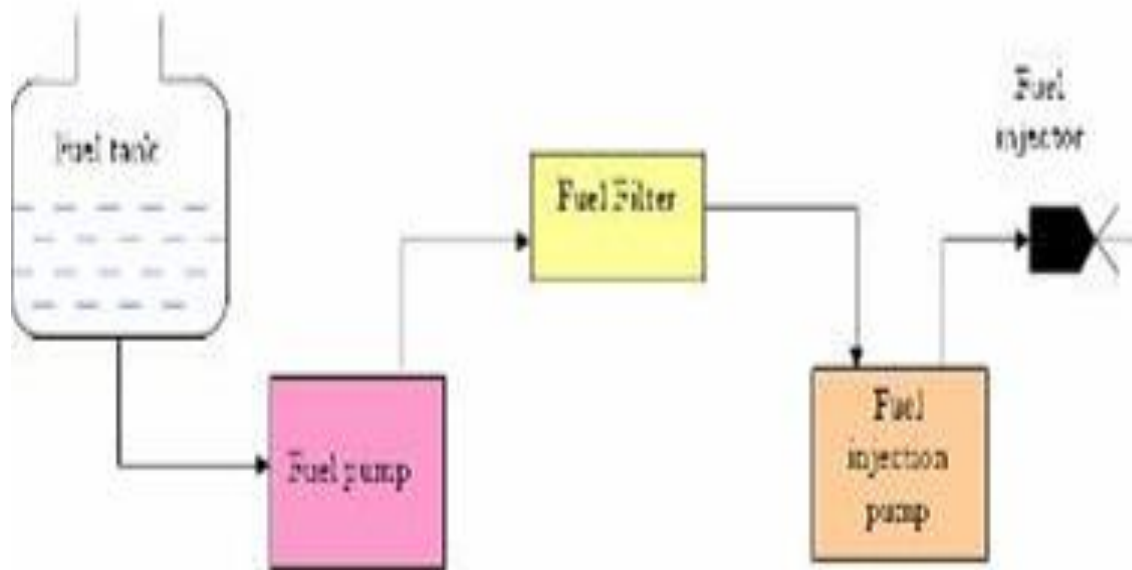
# Fuel Supply System Of SI Engine



- In petrol engine the combustible mixture of fuel is prepared outside the combustion chamber.
- Proper air-fuel ratio is maintained with the help of a device known as carburetor and this mixture is inducted into the combustion chamber.
- The air fuel ratio depends upon the various conditions. The engine needs a richer mixture while starting and leaner mixture at normal running conditions.
- Such conditions must be fulfilled before entering the combustion chamber.
- The fuel from the tank is delivered to the float chamber attached to the carburetor with the help of fuel pump.
- The fuel pump maintains the constant pressure. In carburetor fuel is mixed with air in required proportion.
- After that the mixture of fuel and air is inducted into the combustion chamber.



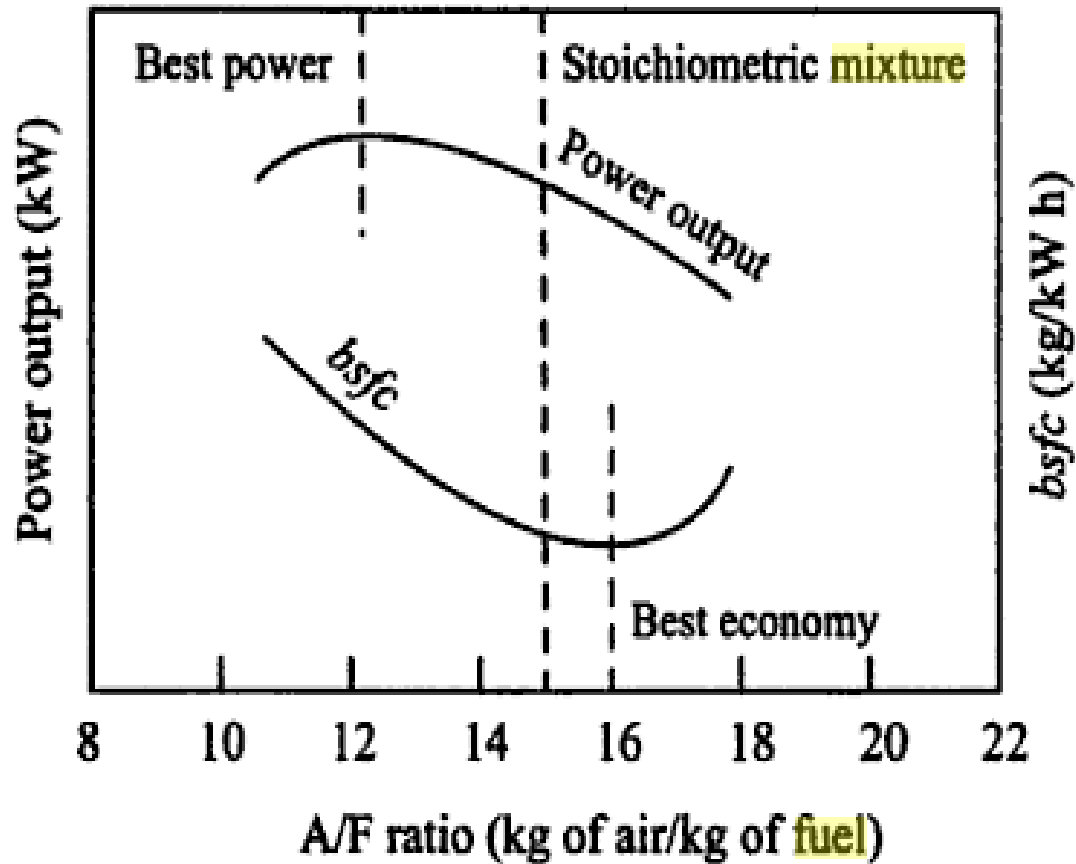
# Fuel Supply System Of CI Engine



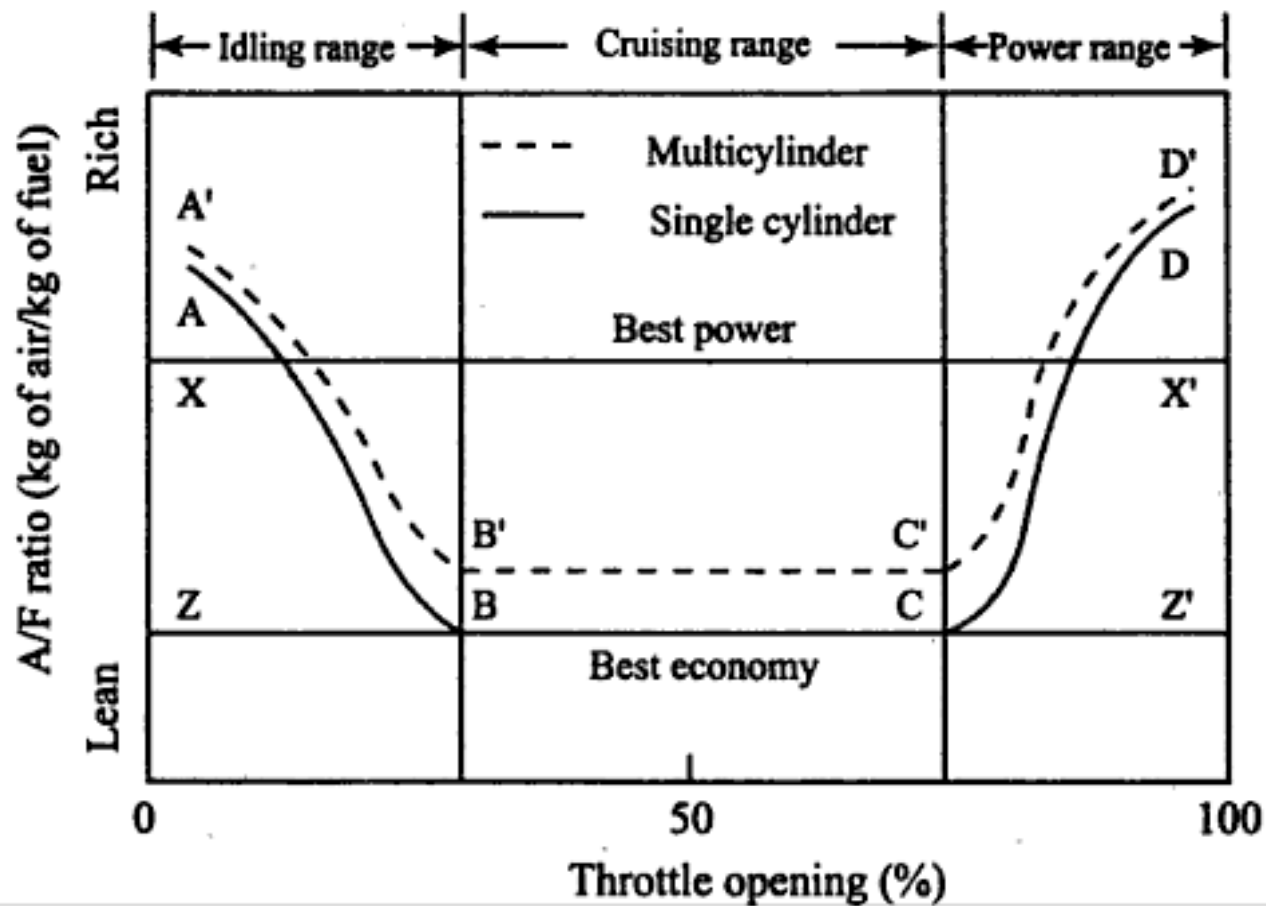
- In diesel engine only air is injected during the suction stroke and it is compressed during compression stroke.
- Fuel is injected into the combustion chamber in the form of fine spray at the end of compression stroke.
- A fuel injection system in a diesel engine has to satisfy the following requirements:
  1. To inject the fuel at the right time in the cycle.
  2. The fuel should be properly atomized.
  3. The correct quantity of fuel should be injected depending upon the load.

- Fuel pump takes the fuel from fuel tank and delivers it to the fuel filter.
- When the pressure is developed in the injection pump the fuel flows from injection pump to the fuel injector under pressure.
- The fuel injector is either a single hole nozzle or multi-hole nozzle.

# Mixture Requirements of SI Engine



- Under normal conditions it is desirable to run the engine on the maximum economy mixture, viz., around 16:1 air-fuel ratio.
- For quick acceleration and for maximum power, rich mixture viz., 12:1 air-fuel ratio is required.

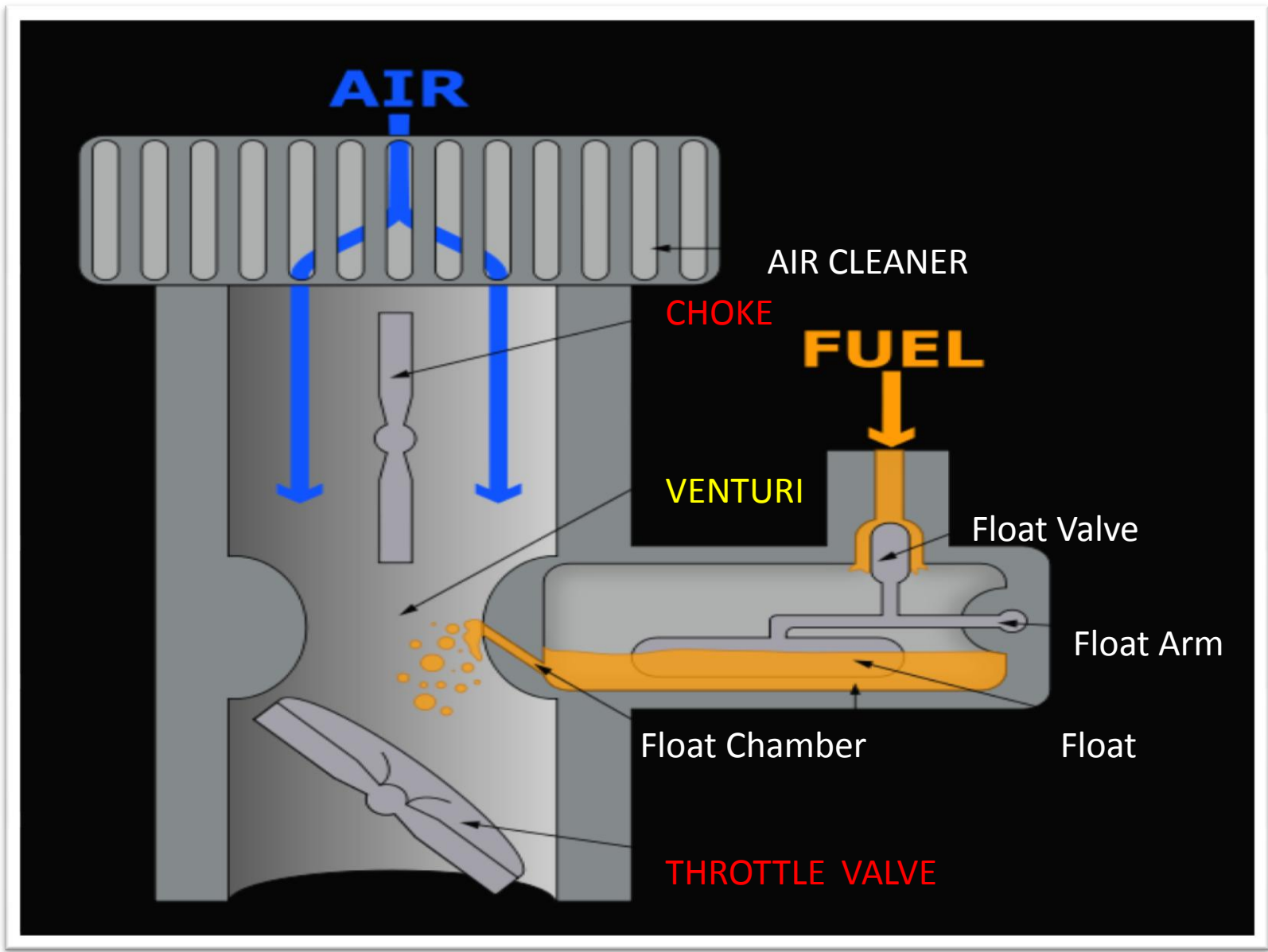


- An SI engine works with the Air-fuel mixture ranging from 8:1 to 18.5:1. But the Ideal ratio would be one that provides both maximum power and best economy, while producing the least emissions.
- But such a ratio does not exist because fuel requirements of an engine vary widely depending upon temperature, load, and speed conditions .
- For complete combustion , thorough mixing of fuel in excess air is needed.
- Lean mixtures are needed for best economy and rich mixtures are needed to suppress combustion knock.
- A rich mixture is required for High load and high speed and idling conditions.
- Best economy is expected at part throttle.
- A carburettor should supply the mixture ratio according to the engine requirements

# CARBURETTOR

- Carburettor is the device that mixes petrol and air in correct proportions and supplies to the combustion chamber in right quantity.
- A Carburettor atomises, vaporises and mixes the petrol in correct proportions with air as required by the engine and supplies the right quantity of the mixture to the engine.





**AIR**

AIR CLEANER

CHOKe

**FUEL**

VENTURI

Float Valve

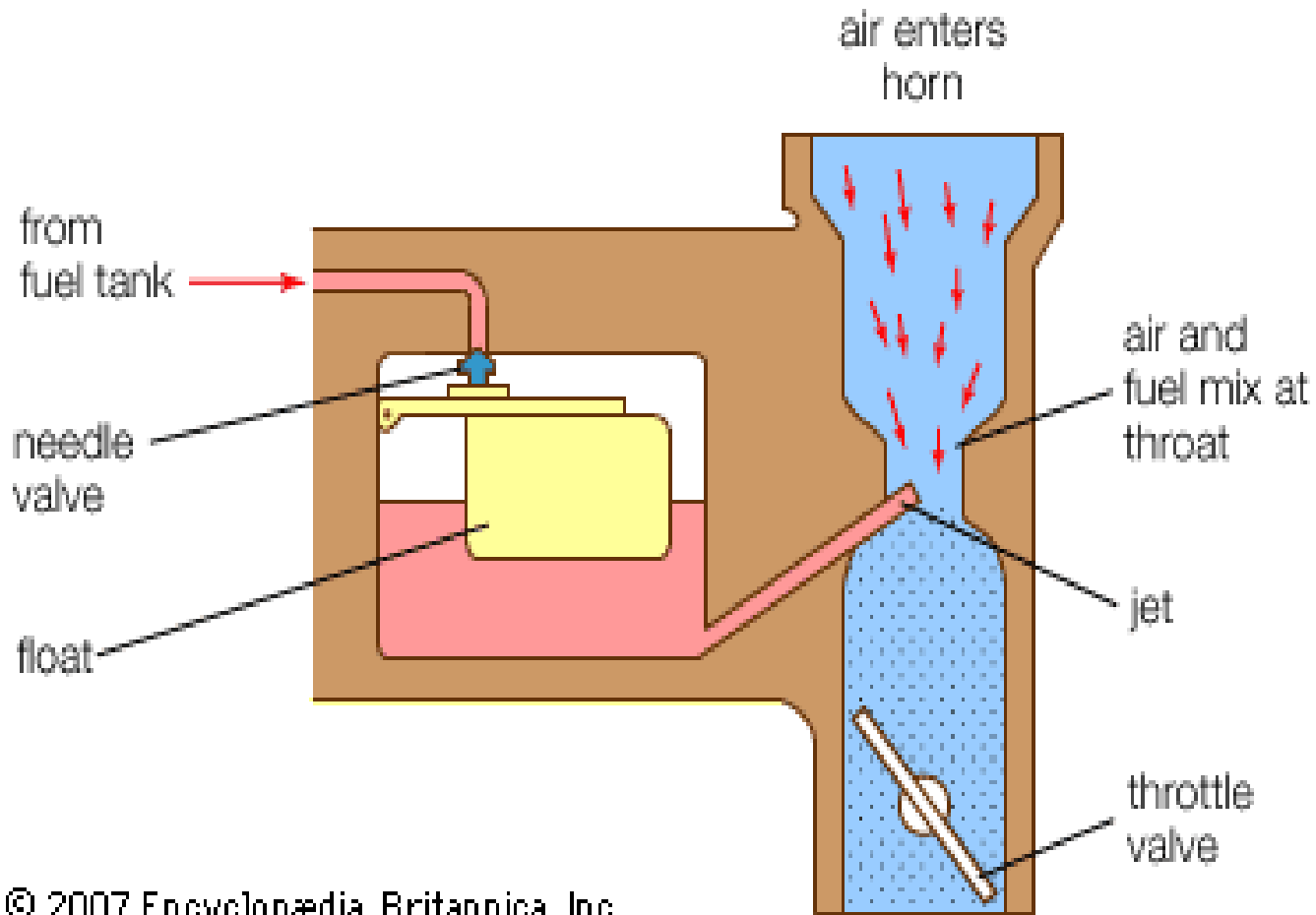
Float Arm

Float Chamber

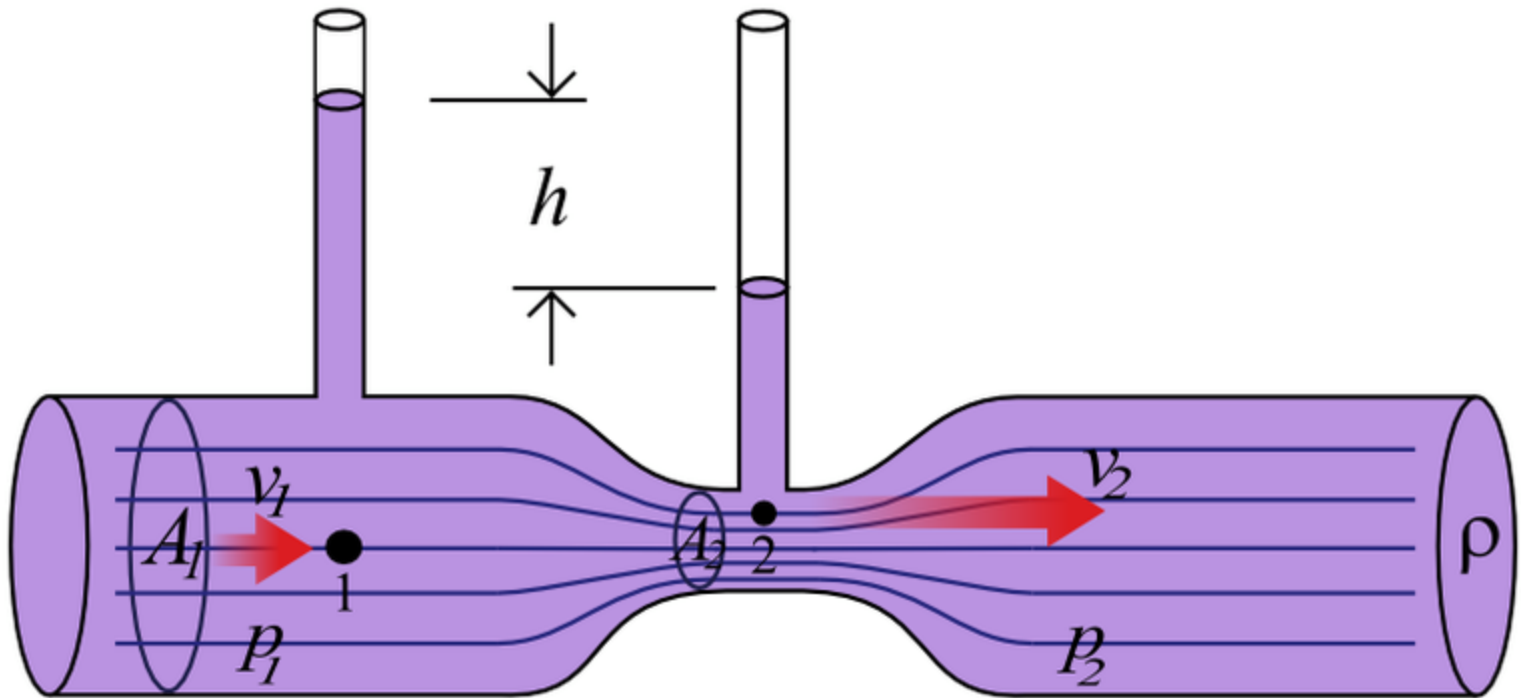
Float

THROTTLE VALVE

# Simple Carburettor



# Venturi Principle



**The pressure at "1" is higher than at "2" because the fluid speed at "1" is lower than at "2".**

# Construction and Working of Simple Carburettor

- ❑ Simple carburettor consist of a venturi and a fuel jet.
- ❑ For maintaining the level of fuel in the jet, a float chamber is usually required.
- ❑ A throttle valve in the form of a flat circular metal disc mounted on spindle is provided for controlling the flow of air-fuel mixture to the induction manifold. A rotary type valve also can be used instead of disc type.

- The level of fuel is just kept slightly below the top of the jet to prevent the leakage when not in operation.
- Usually 1.5 mm difference is kept between the top of the jet and the surface of the fuel in float chamber.
- A needle valve controls the passage of fuel from the fuel pump, when the air begins to flow past the jet, a low pressure zone is created in the venturi because of the increased velocity of air.

- ❑ The fuel begins to rise because of the difference in the [air pressure](#) on the fuel which is equal to the pressure of the atmosphere and on the fuel in the jet at the venturi and issue out from the jet in the form of fine spray. A minute [petrol particles](#) present a large surface area being exposed to the air stream. The fuel is not completely vaporized in carburettor and some globules of fuel still enter the induction manifold and are vaporized during the compression stroke in [engine cylinder](#). A choke valve controls the flow of air into the carburettor. A gas tight connection is provided between the carburettor and the induction manifold.
- ❑ When two concentric [venturies](#) are provided, the discharge end of the inner venturi called "Primary Venturi", which lies just at the throat of the main venturi. A higher velocity of air which aids in the atomization of the fuel, is obtained at the throat of primary venturi due to lower pressure comparing to main venturi.

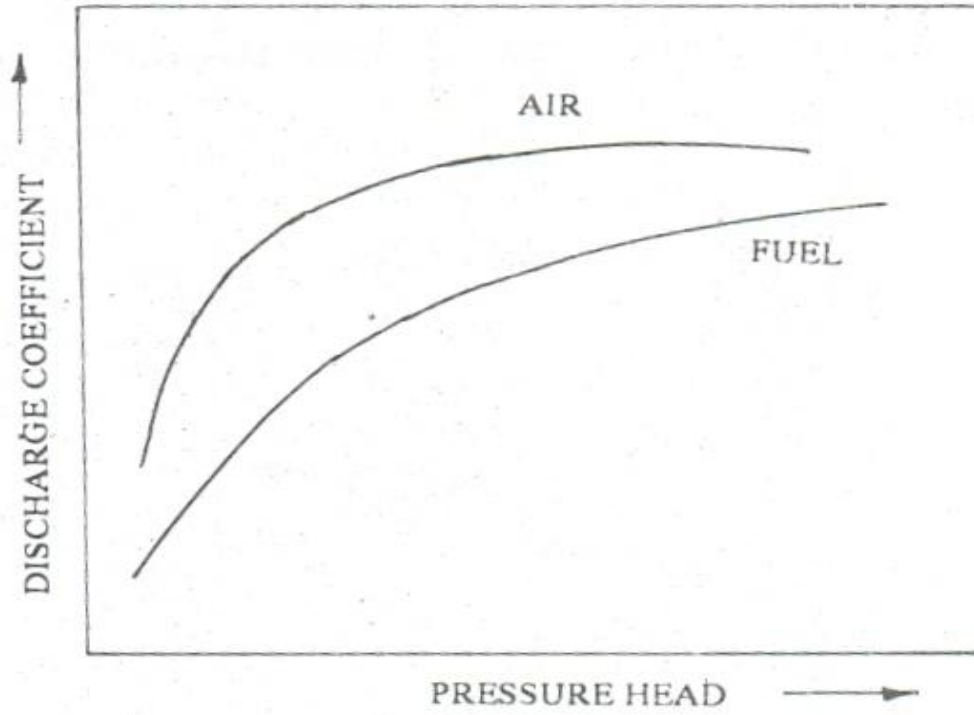
# DEFECTS IN THE SIMPLE CARBURETTOR

- The simple carburettor, would work well if the engine is running at one particular speed and load.
- The nozzle and the venturi sizes then can be set once and the carburettor will then work satisfactorily at that particular speed and load.
- But in actual practice, the engine has to run at different speeds and loads ranging from the lowest to the highest therefore certain irregularities creep in the functioning of this simple carburettor.

The two basic reasons for defects are:

1. If the carburettor is designed to work at high speeds at full throttle, it will not work at low speeds and part throttle, reason being that in the later case the suction created at the venturi will not be sufficient to draw fuel from the nozzle.
2. The coefficients of discharge for air and fuel vary in different amounts with the change of depression. Whereas the coefficient of discharge for air becomes almost constant at certain value of depression, the coefficient for fuel increases gradually. Therefore, if the carburettor is set at one particular speed, it will give richer mixture at higher speeds and leaner mixture at lower speeds.



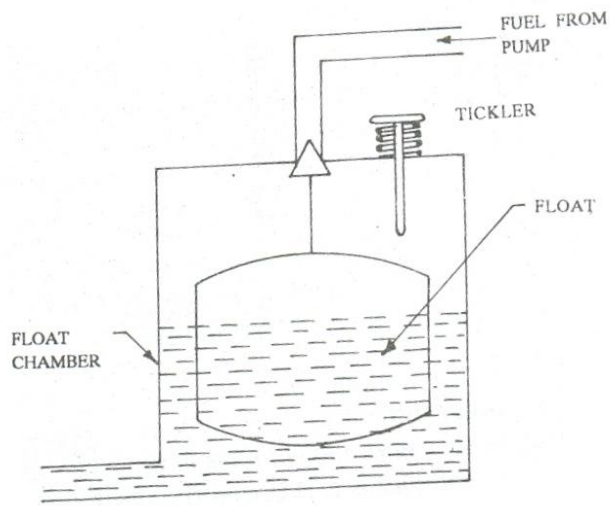


## Starting difficulty

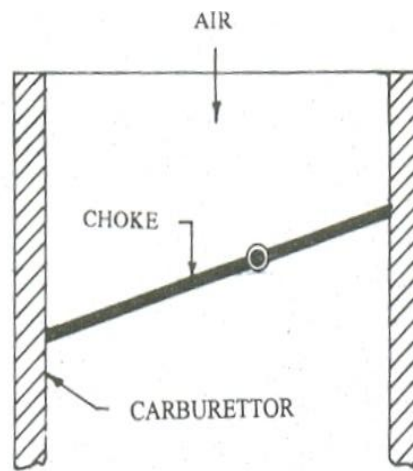
For starting, it is seen that very rich mixture is required, but actually the mixture provided by the simple carburettor will be very lean. The different methods to provide for enrichment of fuel at very low speeds are :

(a) **Ticklers:** These are devices used to cause flooding of carburettor at the start.

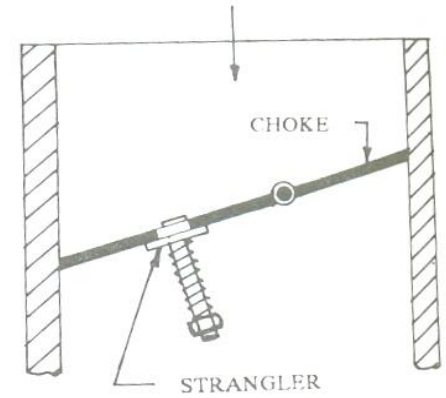
(b) **Choke:** This is a simple butterfly valve fitted at the top of air horn. For starting, choke is closed so that very small amount of air gets past it and the throttle valve is open which delivers sufficient fuel to provide a mixture rich in quality, though small in quantity.



**TICKLERS**



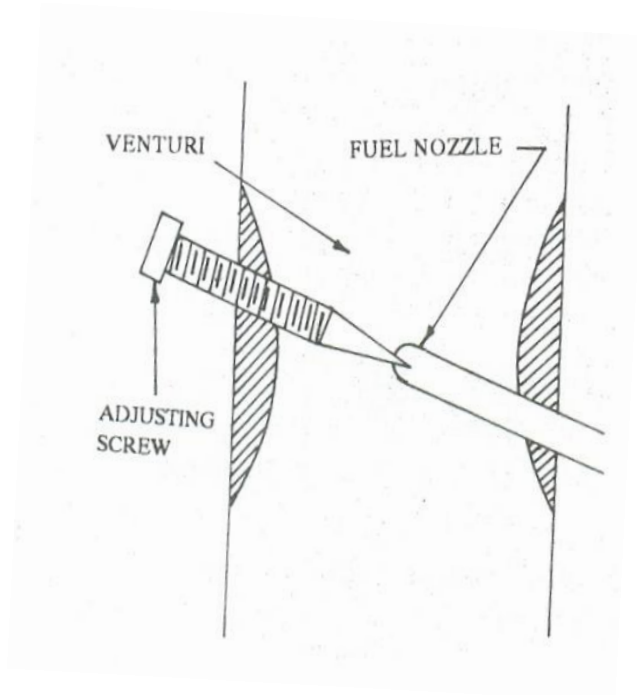
**ECCENTRIC CHOKE**



**CHOKE WITH STRANGLER VALVE**

### (C) Adjustable Area Jet:

A long tapered needle is used which is screwed into the jet as shown in the figure. For starting the screw is loosened so that the jet area providing fuel is increased and thus rich mixture is provided for the start.



The choke valve must be opened immediately when the engine starts. This is achieved by any of the following methods:

(i) by mounting the **choke eccentrically**. With this, when the engine starts, the forces due to pressure on the two sides of the choke spindle are unequal, their difference producing a turning moment to open the choke.

(ii) by the use of **strangler valve fitted on the choke**. As soon as the engine is started, the air pressure forces open the strangler against the spring pressure and the air enters the carburettor avoiding the mixture being over-rich.

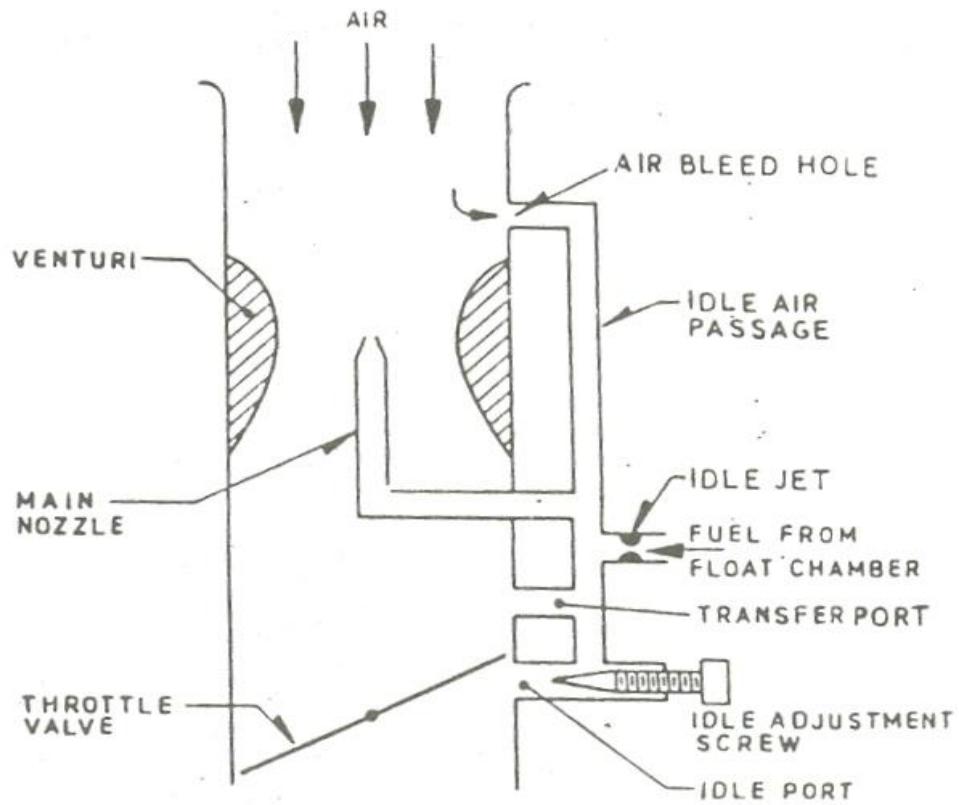
By this time the driver also presses the choke knob to open the choke valve. An automatic choke employed in modern automobiles.

## **Idling Difficulty**

- During idling suction at the main nozzle is insufficient

to draw fuel from the chamber since throttle is closed.

- Therefore a separate supply circuit of fuel must be provided on the engine side of the throttle valve during idling.
- This is done by providing a separate idle jet and an air bleed hole, so that metered quantities of air and fuel are drawn into the



**IDLING CIRCUIT**

## Operation at different speeds

- A simple carburettor provides richer mixture at high speeds and leaner mixture at low speeds.
- The process of adjusting the mixture strength at all the speeds so that throughout the whole range correct proportions of air fuel mixture are maintained is compensated.

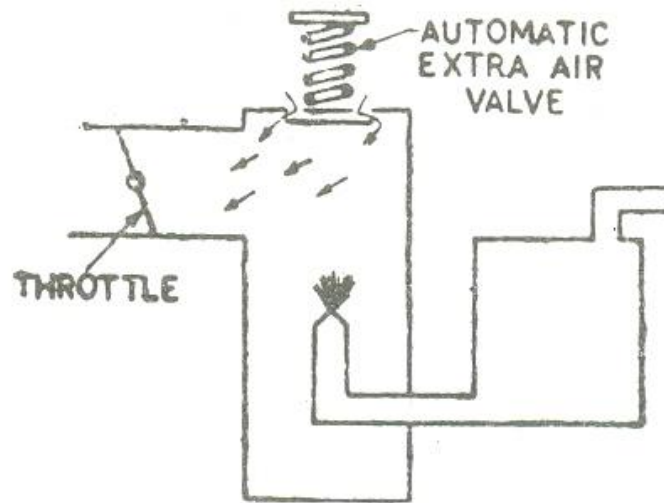
Various devices used for providing compensation are

- Extra air valve
- Compensating jet
- Air bleed compensation
- Multiple jet compensation
- Suction controlled devices

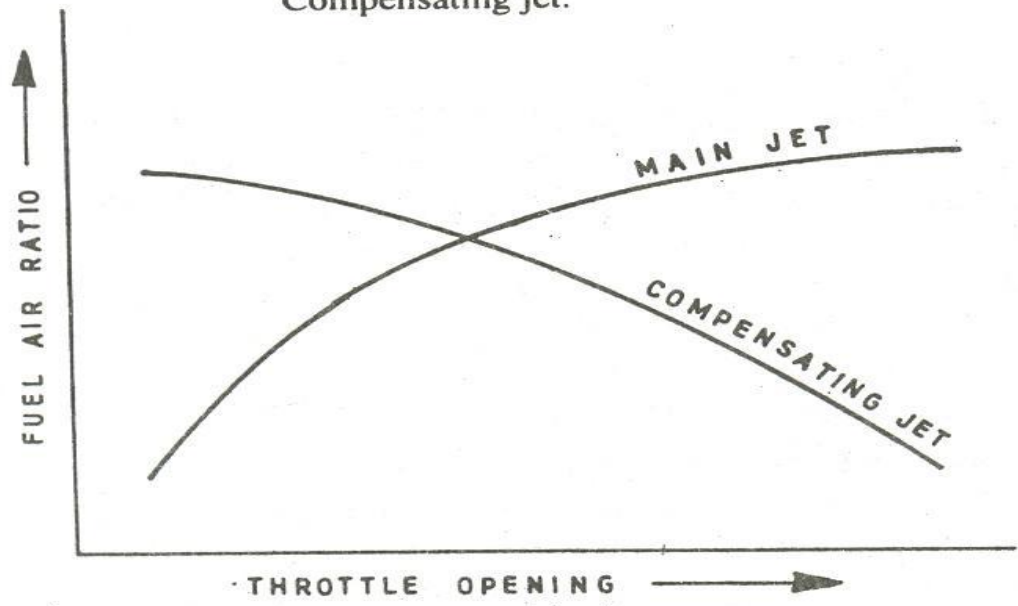
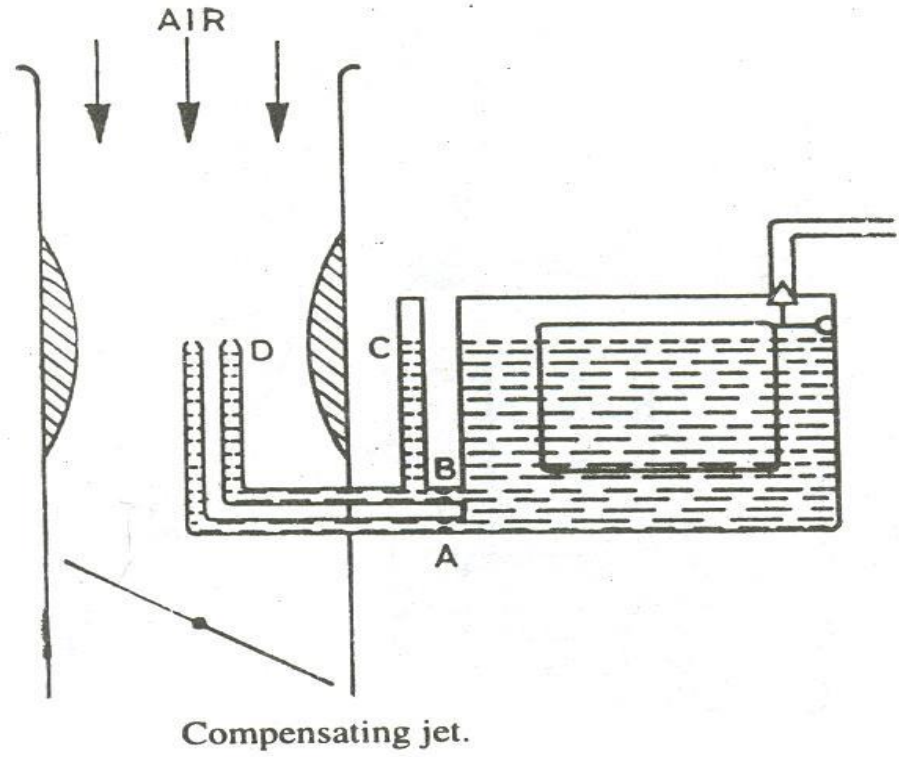


# Extra Air valve

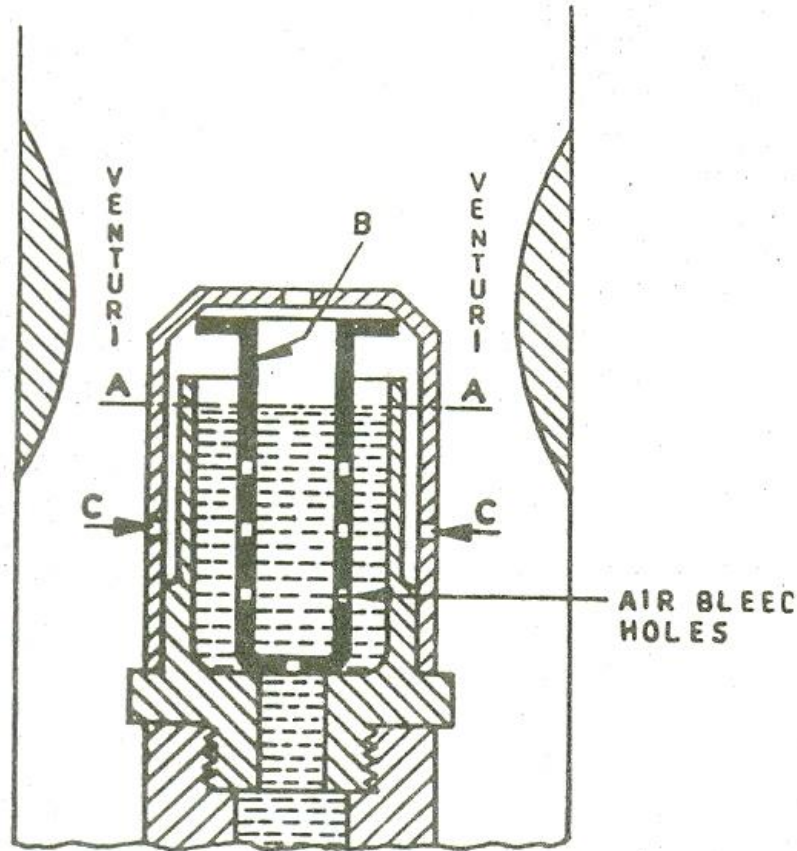
- This is a spring loaded valve arranged to open by means of engine suction as shown in the figure. It is thus controlled by the spring stiffness and engine suction



Cc



# Air bleed compensation



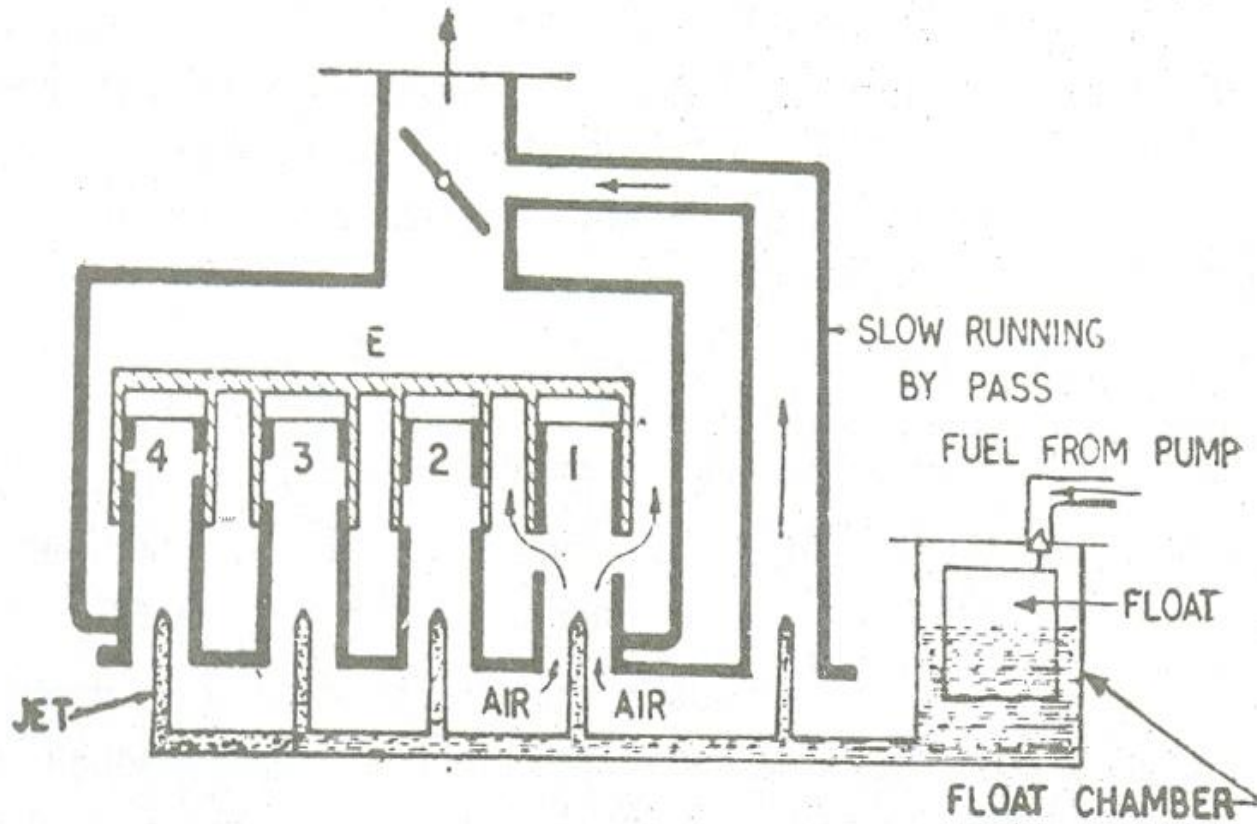
A-A: no load

B-jet tube having air bleed holes

C-holes communicating the air bleed holes to atmosphere

- As the throttle is opened gradually, due to depression at the venturi, the fuel in the tube and the nozzle around it is consumed, providing gradually richer mixture.
- Simultaneously, the level of fuel in the jet tube and nozzle drops uppermost holes in the jet tube to put them in direct communication with atmosphere through holes C.
- This destroys the depression to some extent and the fuel flow thus decreases.
- More and more demand for fuel increases more fuel is consumed and more holes will communicate with the atmosphere thus compensating for the richness of the mixture at larger depression.

# Multiple Jet Compensation

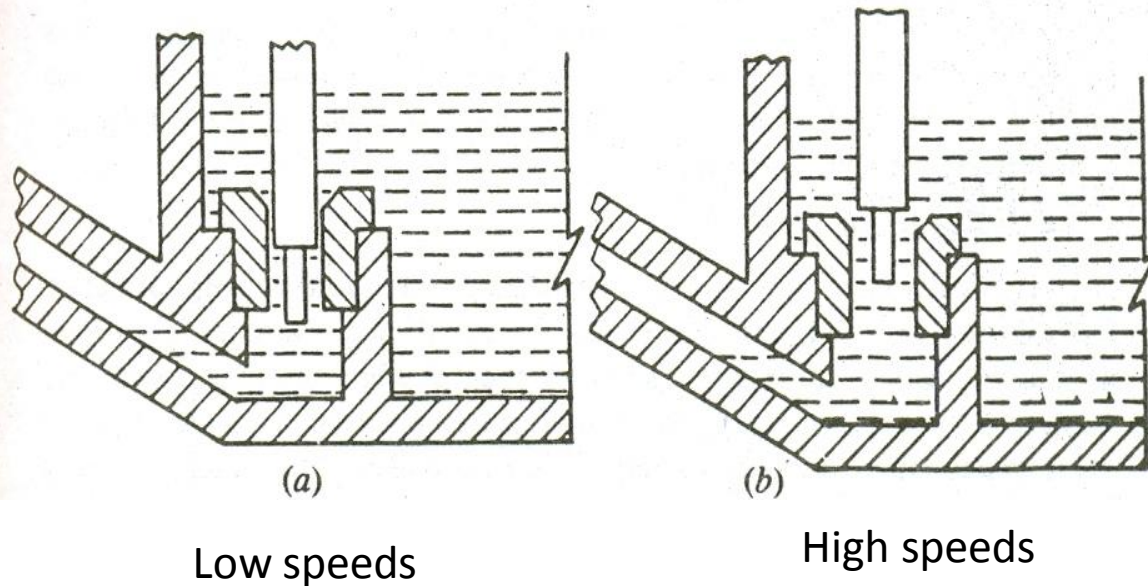


- As the depression increases throttle is opened more and more and cap E is lifted progressively and jets open to air one by one.
- First jet is open more and it supplies more fuel compared to second nozzle thus compensating the mixture .

### Suction controlled devices:

Here engine suction is used to actuate a needle which decreases the effective nozzle area as speed is increased, thus providing compensation

## Difficulty at high speeds



- Weak air-fuel mixtures supplied by the single jet carburettor will not give enough power at High speeds.
- A metering rod with stepped diameter end in the main jet is used for this purpose.
- At high speeds metering rod is pulled up so that small diameter part is in the well supplying more fuel

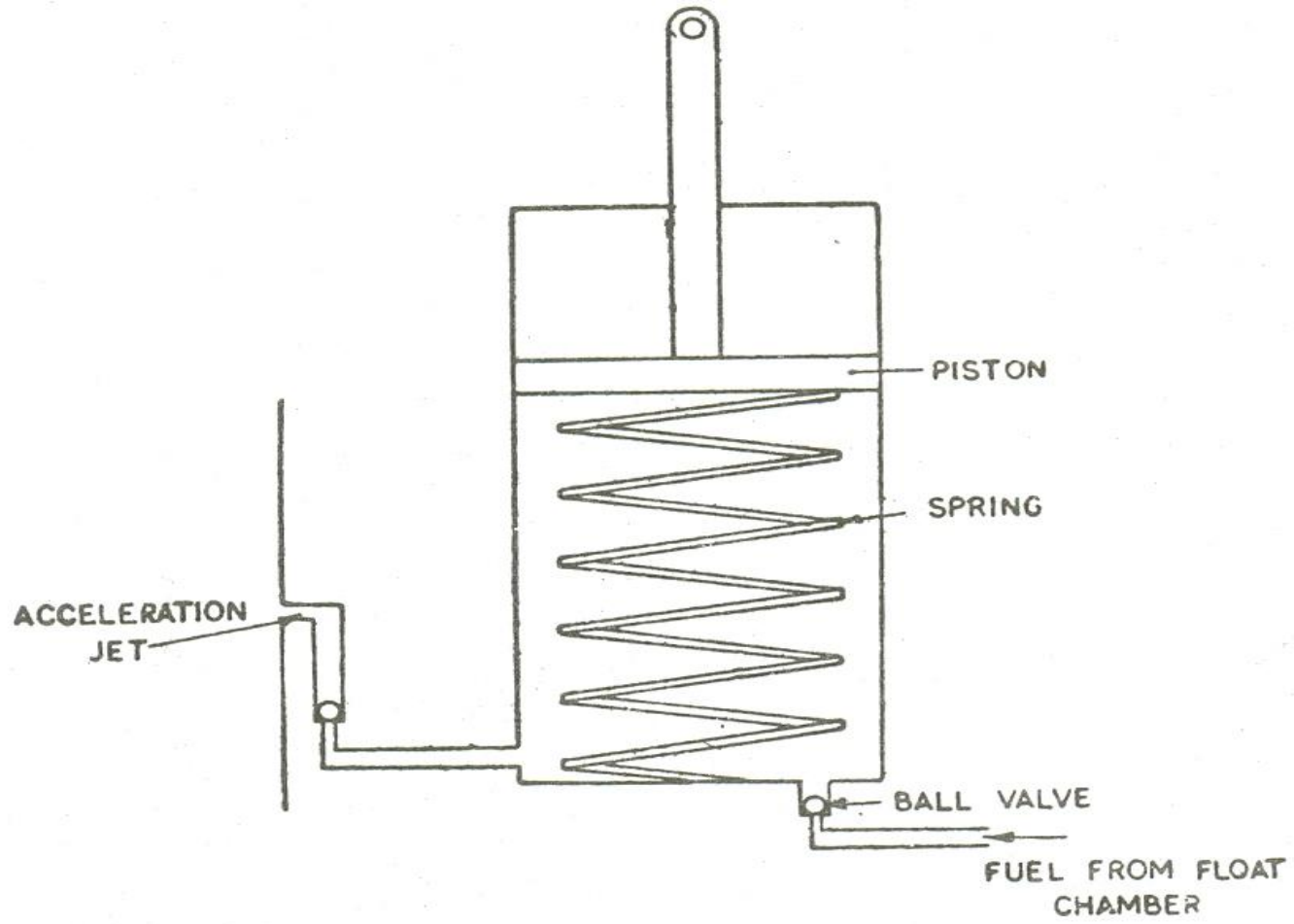
# Acceleration Difficulty

When sudden acceleration is required, the throttle is opened suddenly. This causes the maximum amount of air to come at once but the fuel supply lags there by causing 'engine stumble' or 'hesitation' which is due to weak mixture. To avoid this a separate **pump** which provides fuel momentarily till the rich mixture is delivered is used.

when the accelerator pedal is pressed, the outlet valve is opened and the fuel is forced out of the acceleration jet.

When the pedal is released, piston moves up there by sucking the fuel from the float chamber. Thus pump is ready for the next discharge





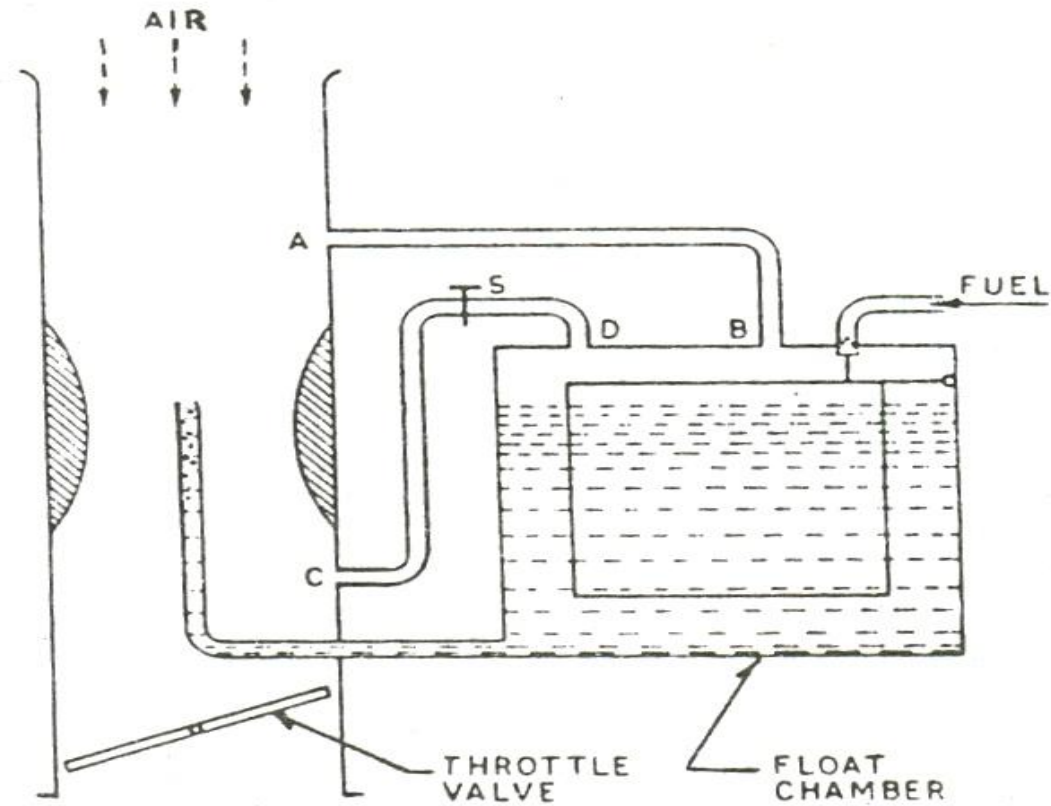
Acceleration Pump

# Influence of Weather

As already explained simple carburettor can be set to deliver correct air fuel mixture only at particular speed. If a carburettor is set for a particular weather for instance Summer ,during winter it supplies weak mixture because density of air increases more compared to fuel. Similarly carburettor set for winter will give rich mixture during summer.

In modern carburettor climatic control devices are provided. These control the mixture strength by varying either fuel jet area or air intake.

# Influence of Altitude



At higher altitudes , the air density decreases due to fall in pressure eventhough temperature decreases. This makes the carburettor to deliver rich mixtures at higher altitudes. To overcome this an arrangement is shown in the figure.

Two pipes AB and CD connect the top of the float chamber to the air horn. S is a valve in the pipe CD. For ordinary low altitudes S is closed and thus the fuel in the float chamber is under atmospheric pressure because of pipe AB. As the altitude is increases valve S is opened gradually and by doing so engine suction is applied to the float chamber, thus decreasing the pressure here which decreases the fuel supply making the mixture weak.

# Icing Trouble

As the fuel is atomised and evaporated in the carburettor, it causes cooling of surrounding areas

. In

localities which are cold, there is thus always the danger

of ice formation and choking of venturi tube. Some methods used to prevent ice formation are

- i) By heating the carburettor idle ports and throttle valve area by means of the engine exhaust.
- ii) By providing engine hot water passes around the carburettor.

# Types of Carburettor

Depending on the choke area carburettors are classified

As:

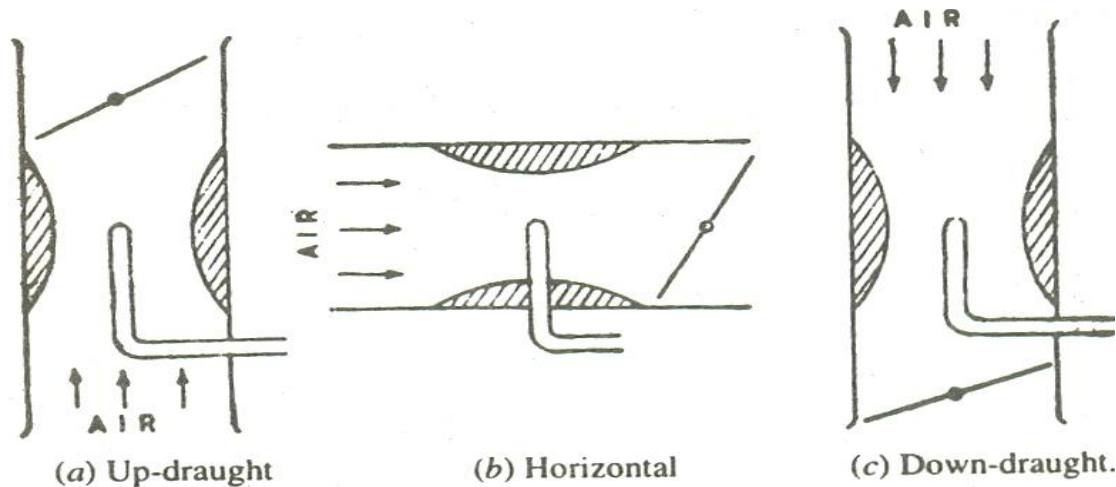
1. Open Choke or constant choke carburettor

2. Variable Choke or Constant depression carburettor

Carburettors are also classified as

a) Up-draught b) Horizontal c) Down-draught

Carburettors.



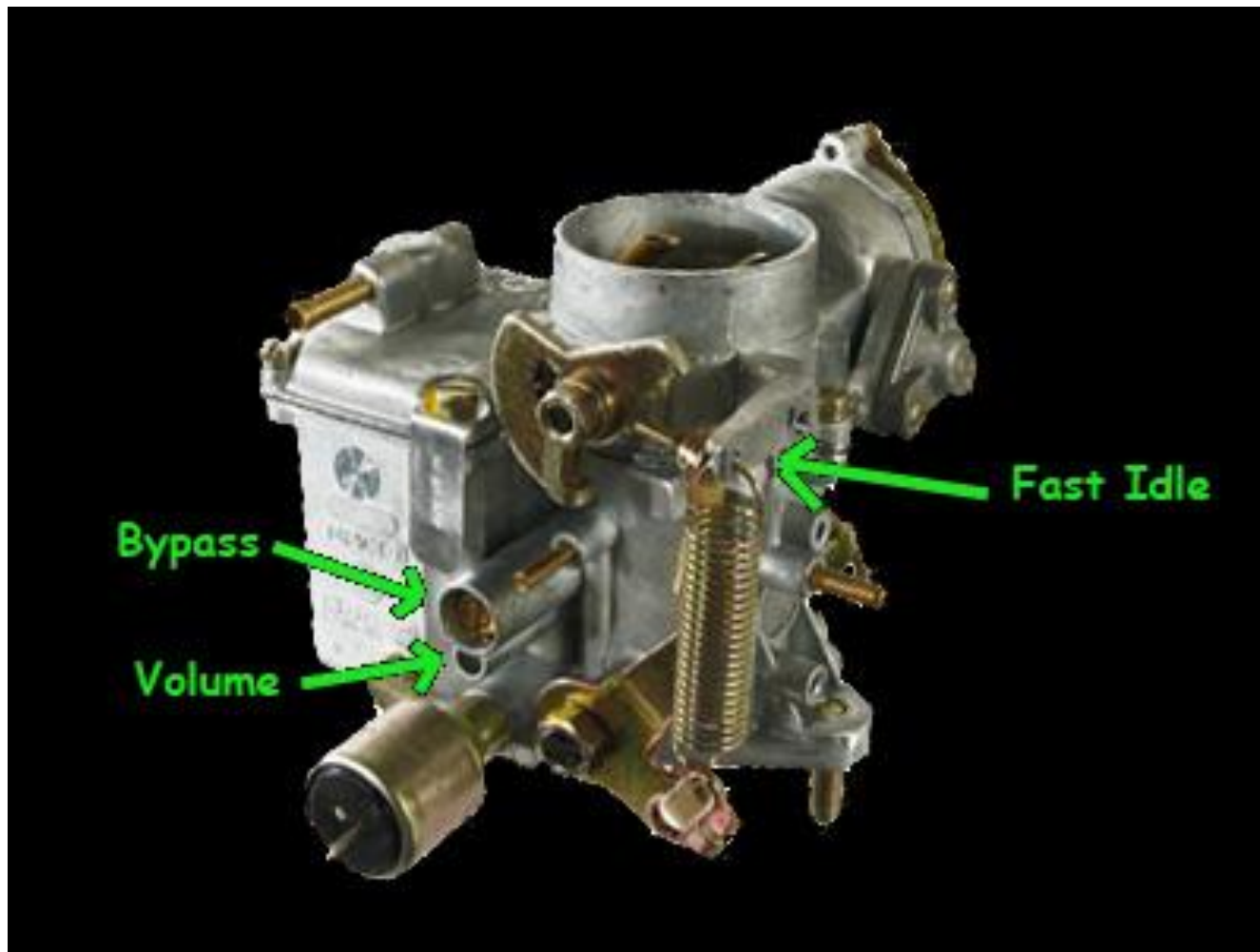
# Constant Choke Carburettor

- Here the main orifice known as the choke tube or venturi is of fixed dimensions and metering is affected by varying the pressure drop across it

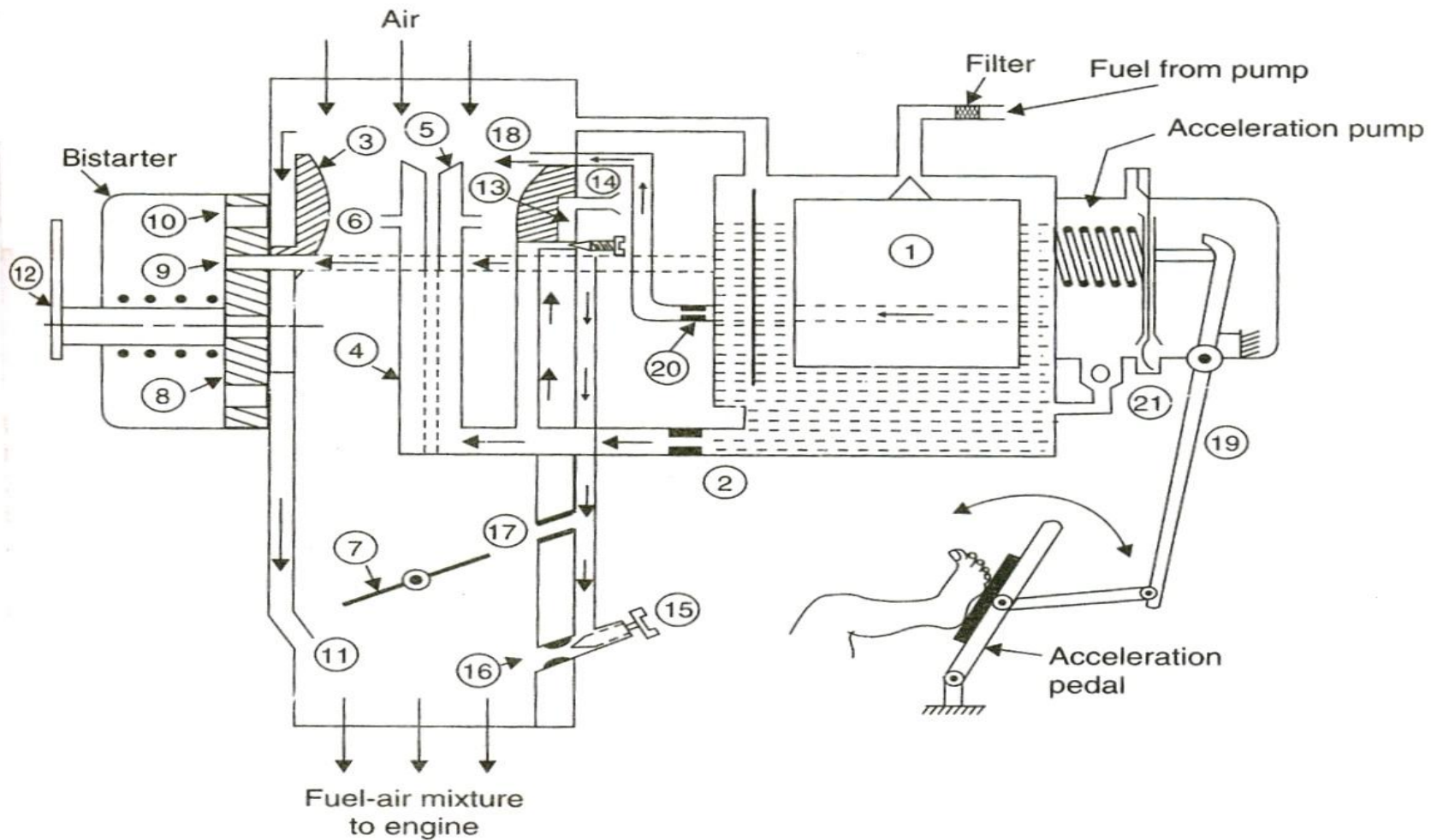
e.g

1. Zenith carburettor
2. Solex carburettor
3. Carter carburettor
4. Stromberg carburettor

# Solex Carburettor







1. Conventional float
3. Choke tube or venturi
5. Air correction jet
7. Conventional butterfly valve
9. Starter petrol jet
11. Starting passage
13. Pilot jet
15. Idling volume control screw
17. By-pass orifice

2. Main jet
4. Emulsion tube
6. Spraying orifice or nozzles
8. Flat disc with holes of different sizes
10. Jet
12. Starter lever
14. Small pilot air bleed orifice
16. Idle port
18. Pump injector
20. Pump jet

# Working of Solex Carburettor

## 1. Normal running

- Solex carburettor consist of a conventional float(1) in a float chamber
- The fuel is provided through the main metering jet(2) and the Air by the choke tube or Venturi(3)
- The fuel from main jet passes into the well of air bleed emulsion system; (4) is the emulsion tube which has lateral holes.
- Air correction jet (5),calibrates the air entering through it and ensures automatically the correct balance of air and fuel.
- The metered emulsion of fuel and air is discharged through spraying orifice or nozzle(6) drilled horizontantly in the vertical stand pipe in the middle of the chock tube
- (7) is the conventional butterfly valve.

## 2. Cold starting and warming:

The provision of a Bi-starter or progressive starter is the Unique feature of *soloex carburettor*.

- starter valve is in the form of a flat disc(8) with holes of different sizes
- These holes connect the starter petrol jet (9) and starter air jet sides to the passage which opens into a hole just below the throttle valve at (11). Either bigger or smaller holes come opposite to the passage depending upon the position of the starter lever(12).The starter lever is operated by flexible cable from dash board control
- For starting the lever 12 is fully pulled out and bigger holes are in contact and throttle is closed and the entire suction is applied is applied to passage 11 sucking petrol from jet 9 and air from jet 10.
- Just after starting for some time both starter jet and main jet are supplying the fuel and intermediate holes are in contact with throttle open partially
- When the engine reaches the normal running temperature starter is brought to 'off' position

### 3. Idling and slow running:

- From the lower part of the well of the emulsion system a hole leads off to pilot jet(13)
- At idling throttle partly closed and engine suction is applied at pilot jet. Fuel from the pilot jet mixes with small amount of air from the small pilot air bleed orifice(14)
- The rich mixture for idling is discharged into the throttle body past the idling control screw(15).
- By-pass orifice(17) provided on the venturi side of the throttle valve ensures smooth transfer of idle and low speed circuit to the main jet circuit .

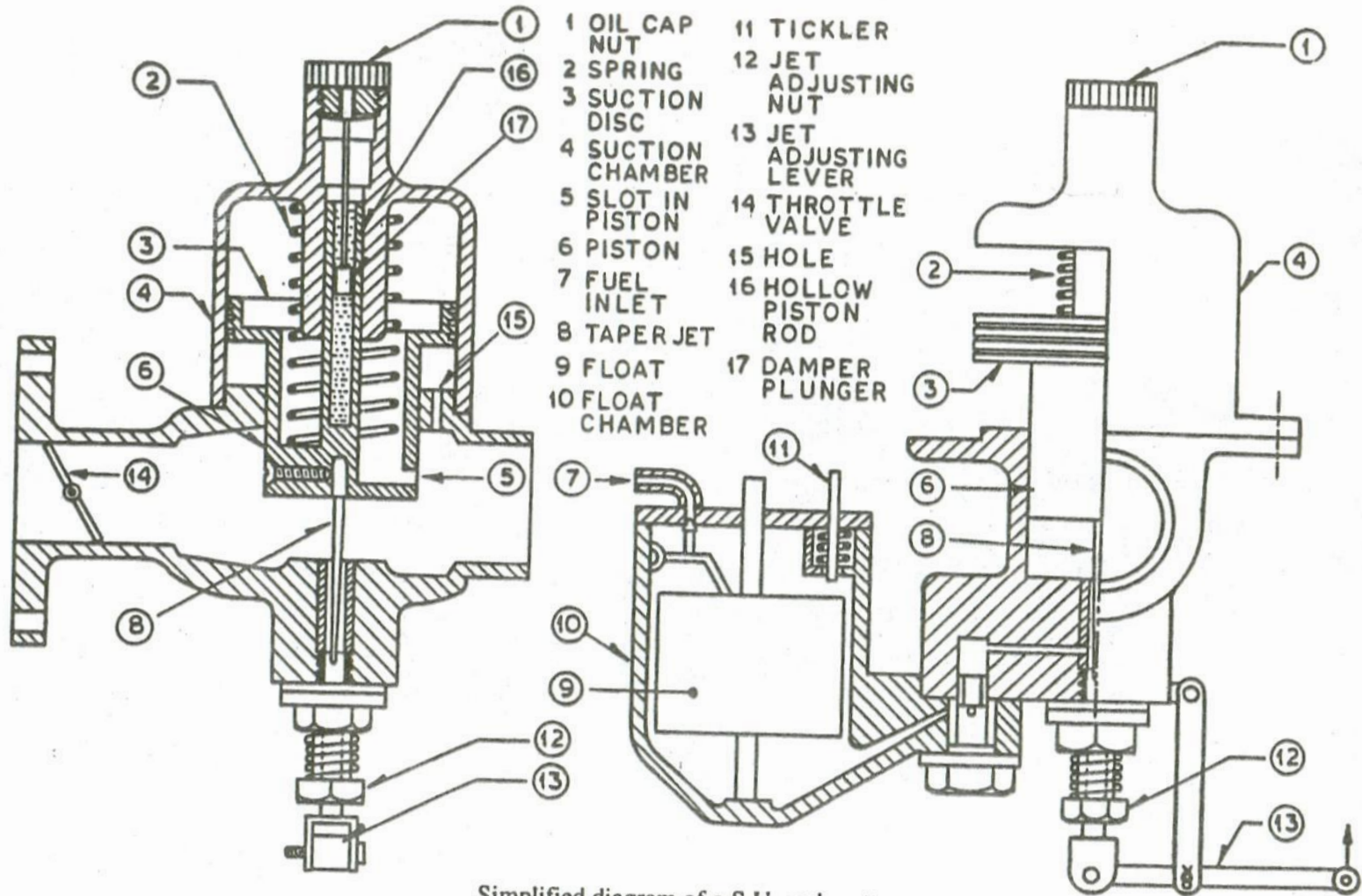
#### 4. Acceleration:

- A diaphragm type acceleration pump supplies spurt of extra fuel needed for acceleration through pump injector(18)
- Pump lever (19) is connected to the accelerator so that pressing the pedal, the lever moves towards the left, pressing the membrane towards the left, thus forcing the petrol through pump jet (20) and injector(18).
- On making the pedal free, the lever moves the diaphragm back towards right creating vacuum towards left which opens the pump inlet valve(21) and thus admits the petrol from the chamber into pump.

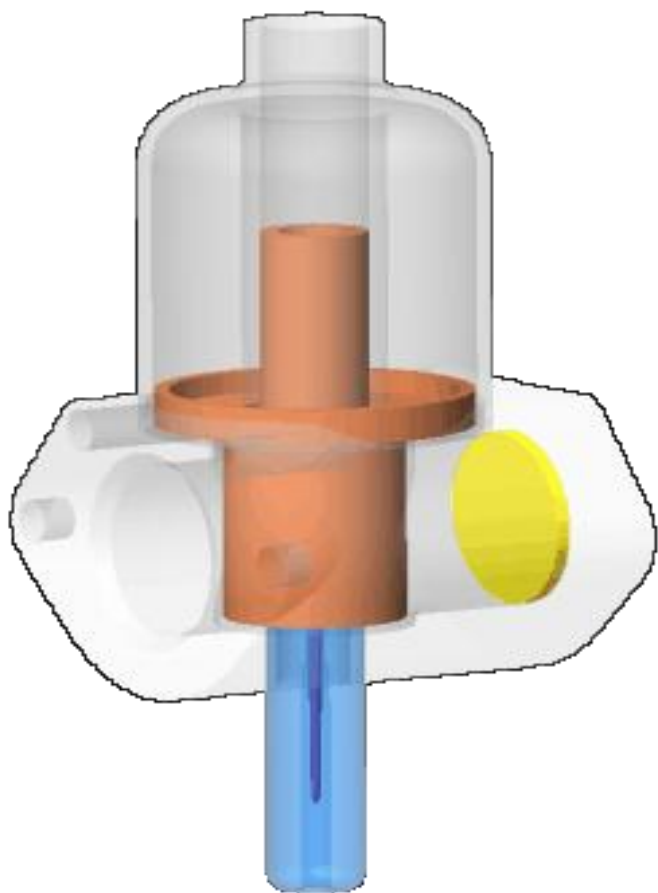
# Constant Depression Carburettor

- SU CARBURETTOR

**SU Carburettors** (named for [Skinners Union](#), the company that produced them) were a brand of [carburettor](#) usually of the side draught type but down draught variants were also used



Simplified diagram of a S.U. carburettor.





# Working of SU carburettor

- The flow of air through the venturi creates a reduced [static pressure](#) in the venturi. This pressure drop is communicated to the upper side of the piston via slot cut in the piston. The underside of the piston is open to atmospheric pressure. The difference in pressure between the two sides of the piston lifts the piston. Opposing this are the weight of the piston and the force of a spring that is compressed by the piston rising. Because the spring is operating over a very small part of its possible range of extension, its force is approximately constant. Under steady state conditions the upwards and downwards forces on the piston are equal and opposite, and the piston does not move.

- If the airflow into the engine is increased - by opening the throttle plate (usually referred to as the "butterfly"), or by allowing the engine revolutions to rise with the throttle plate at a constant setting - the pressure drop in the venturi increases, the pressure above the piston falls, and the piston is sucked upwards, increasing the size of the venturi, until the pressure drop in the venturi returns to its nominal level. Similarly if the airflow into the engine is reduced, the piston will fall. The result is that the pressure drop in the venturi remains the same regardless of the speed of the airflow - hence the name "constant depression" for carburetors operating on this principle - but the piston rises and falls according to the speed of the airflow.

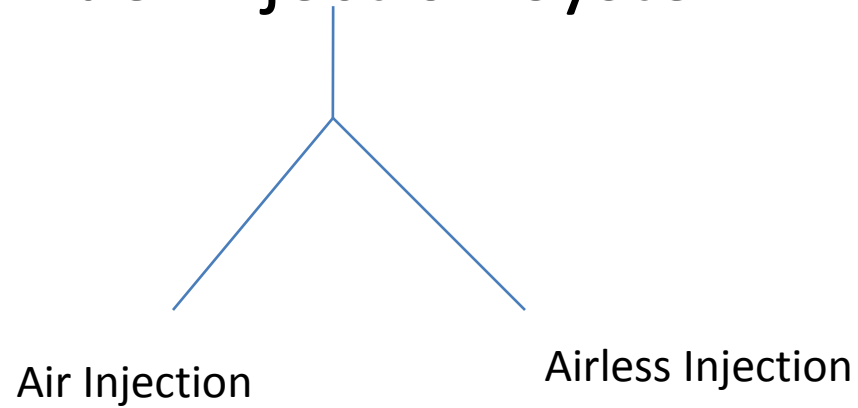
- Since the position of the piston controls the position of the needle in the jet and thus the open area of the jet, while the depression in the venturi sucking fuel out of the jet remains constant, the rate of fuel delivery is always a definite function of the rate of air delivery. The precise nature of the function is determined by the profile of the needle. With appropriate selection of the needle, the fuel delivery can be matched much more closely to the demands of the engine than is possible with the more common fixed-venturi carburettor, an inherently inaccurate device whose design must incorporate many complex fudges to obtain usable accuracy of fuelling. The well-controlled conditions under which the jet is operating also make it possible to obtain good and consistent atomisation of the fuel under all operating conditions.

# Diesel Engine Fuel Injection Systems

## Functions of a Fuel injection system:

- Filter the fuel
- Measure the correct quantity of fuel to be injected
- Time the fuel injection
- Control the rate of fuel injection
- Atomize the fuel
- Distribute the fuel in the combustion chamber

# Fuel Injection System



## Air Injection:

In this method of fuel injection air is compressed in a compressor to high pressure and injected into the fuel Nozzle. The rate of fuel admission can be controlled by varying the pressure of injection air.

### Adv:

- It provides better atomization and distribution of the fuel
- As the combustion is more complete the BMEP is higher
- Inferior fuels can be used

### Dis Adv:

- It requires high pressure multi stage compression
- A separate mechanical linkage is required to time the operation of fuel valve
- Due to compression and linkage the size of the engine increases
- Since the fuel burns very near to the nozzle it is overheated

Types of modern fuel injection system:

1. Common Rail Injection System
2. Individual Pump Injection System
3. Distributor System

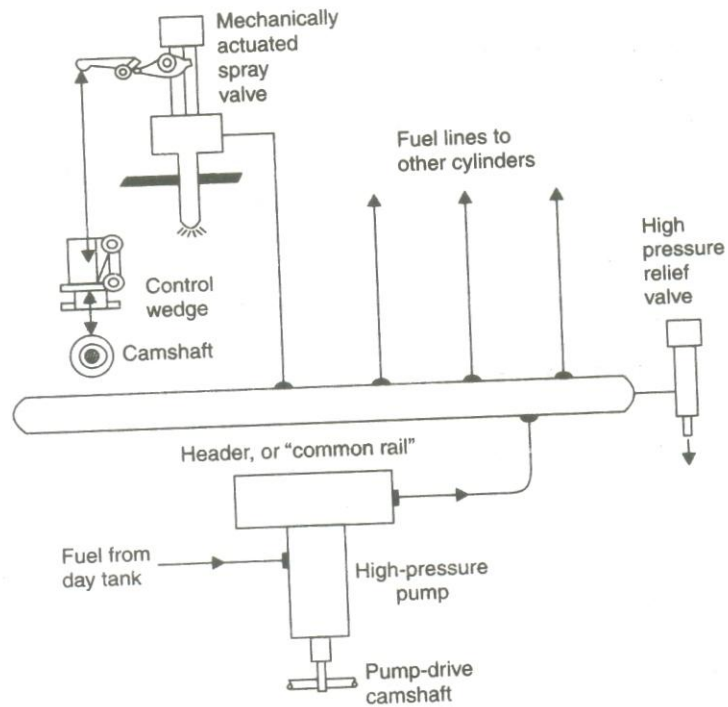
Atomisation of the fuel is done by either 'airblast'  
or

'pressure spray'

Solid injection at about 100 and 200 bars pressure  
has

reduced the need of having compressor .

# Common Rail Injection System





A single pump supplies high pressure fuel to header, a relief valve holds the pressure constant. The control wedge adjusts the lift of mechanically operated valve to set amount and time of injection.

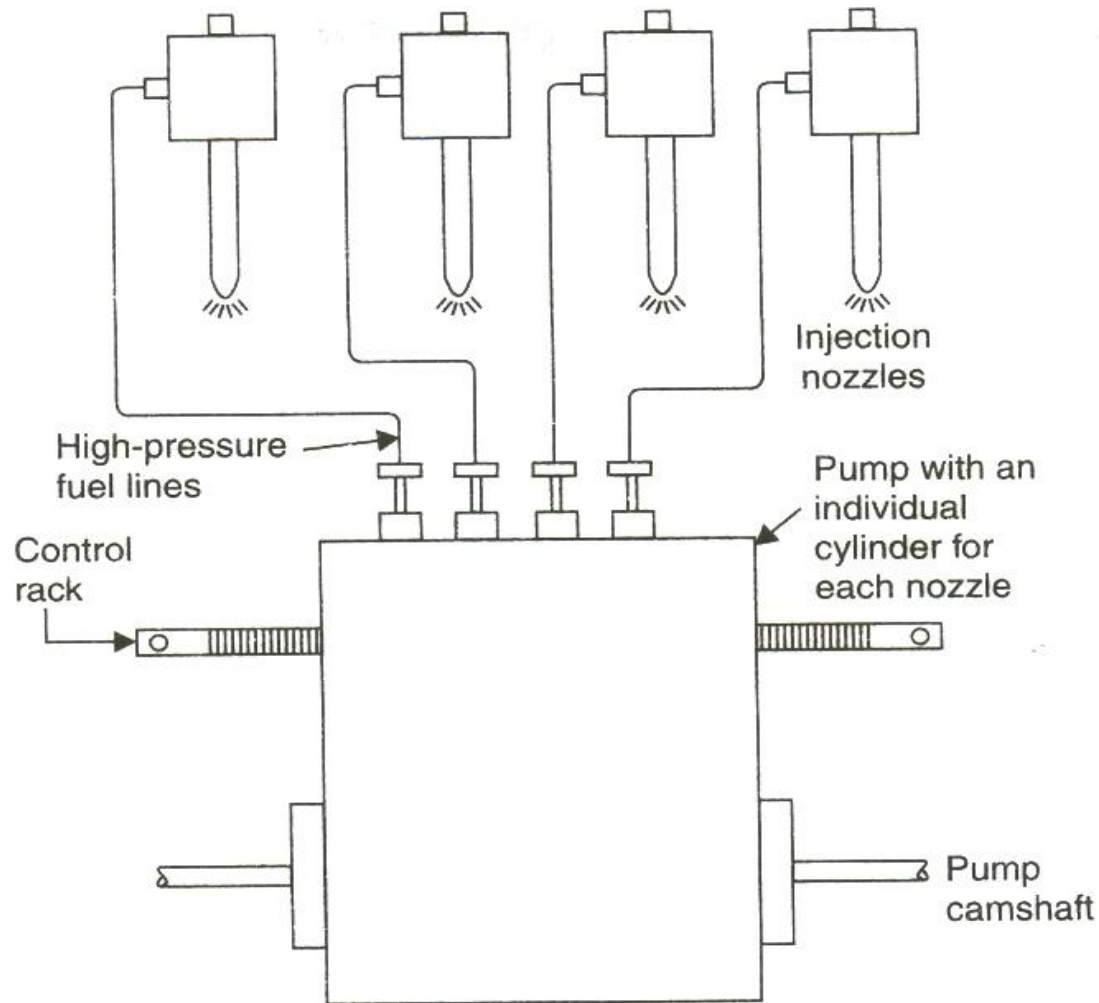
Adv:

1. System is simple and less maintenance cost
2. Only one pump is sufficient for multi cylinder engine
3. It fulfills requirements of either constant load with variable speeds or variable loads with constant speed
4. Variation in pump supply pressure affects all the cylinders equally

Dis adv:

1. Leaks in the injection valve
2. Accurate design and workmanship is required

# Individual pump injection system

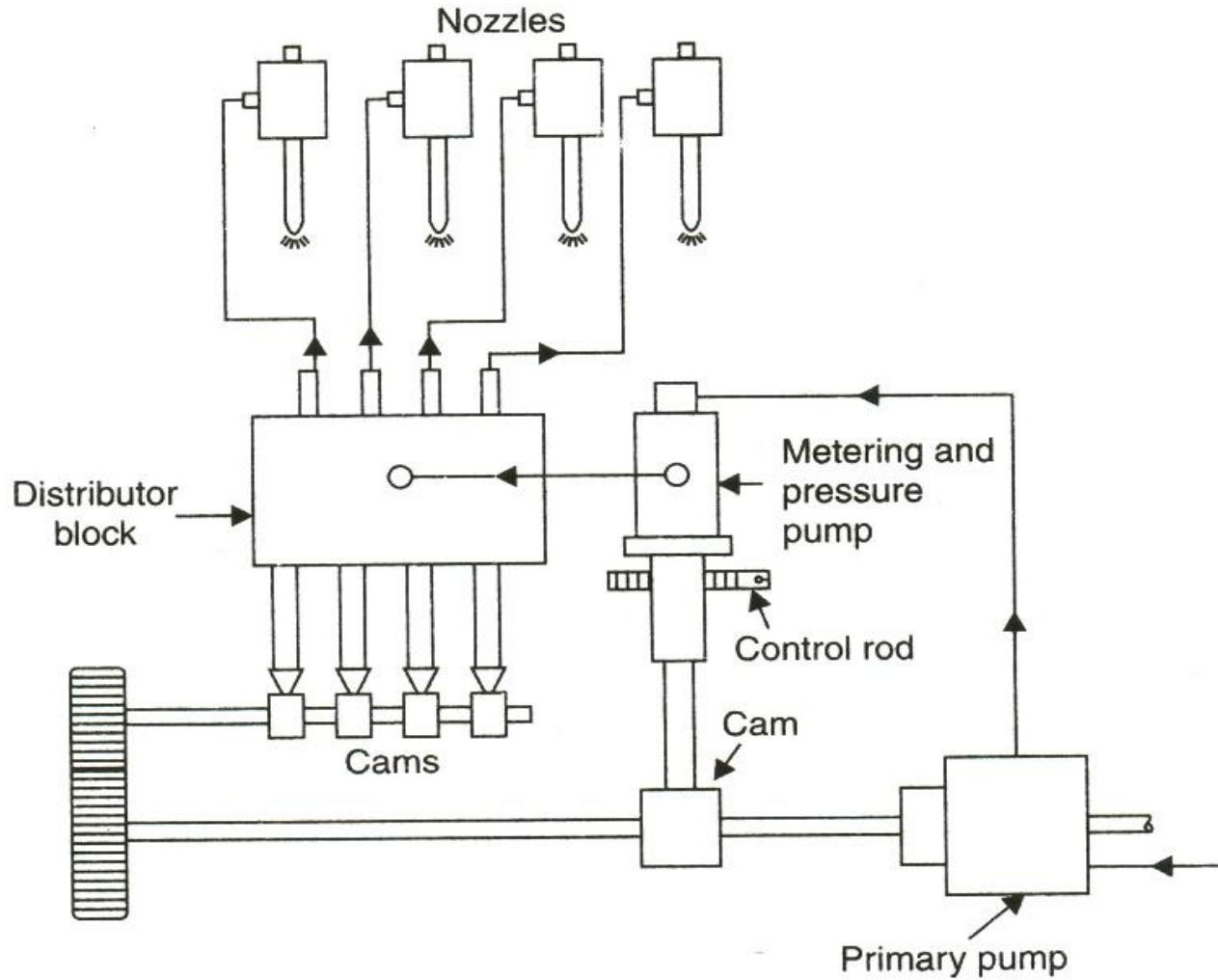


In this system an individual pump or pump cylinder connects directly to each fuel nozzle. Pump meters charge and control injection timing. Nozzles contain a delivery valve actuated by the fuel oil pressure.

Dis adv:

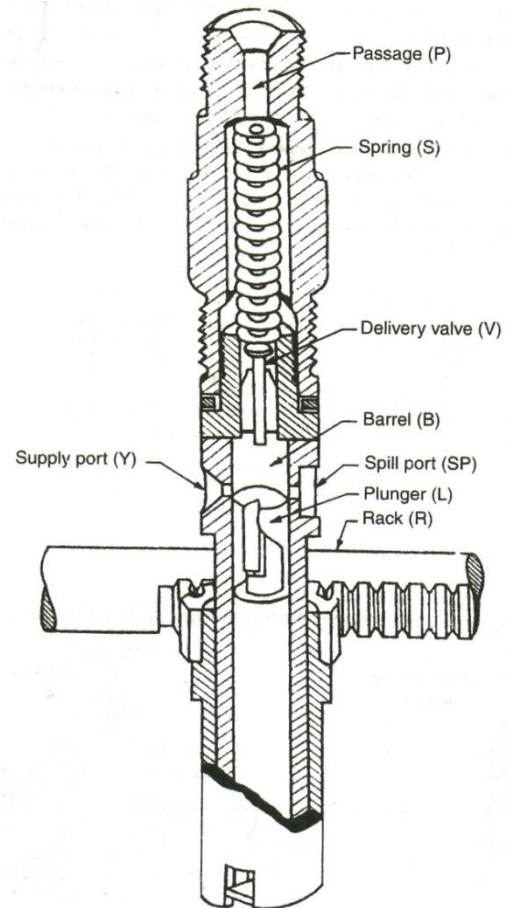
- This system has to be designed accurately to pump small quantity of fuel

# Distributor System



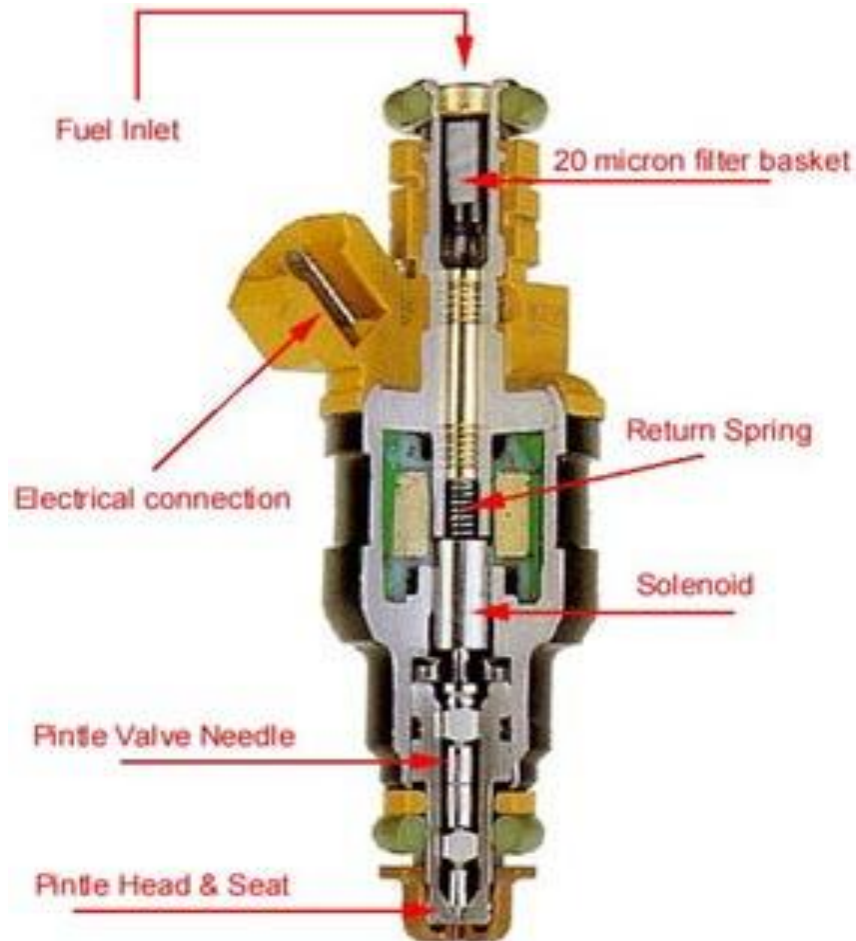
In this system the fuel metered at a central point; a pump pressurises, meters the fuel and times the injection. From here fuel is distributed to cylinders in correct firing order by cam operated poppet valves which open to admit fuel to nozzles.

# Fuel Pump



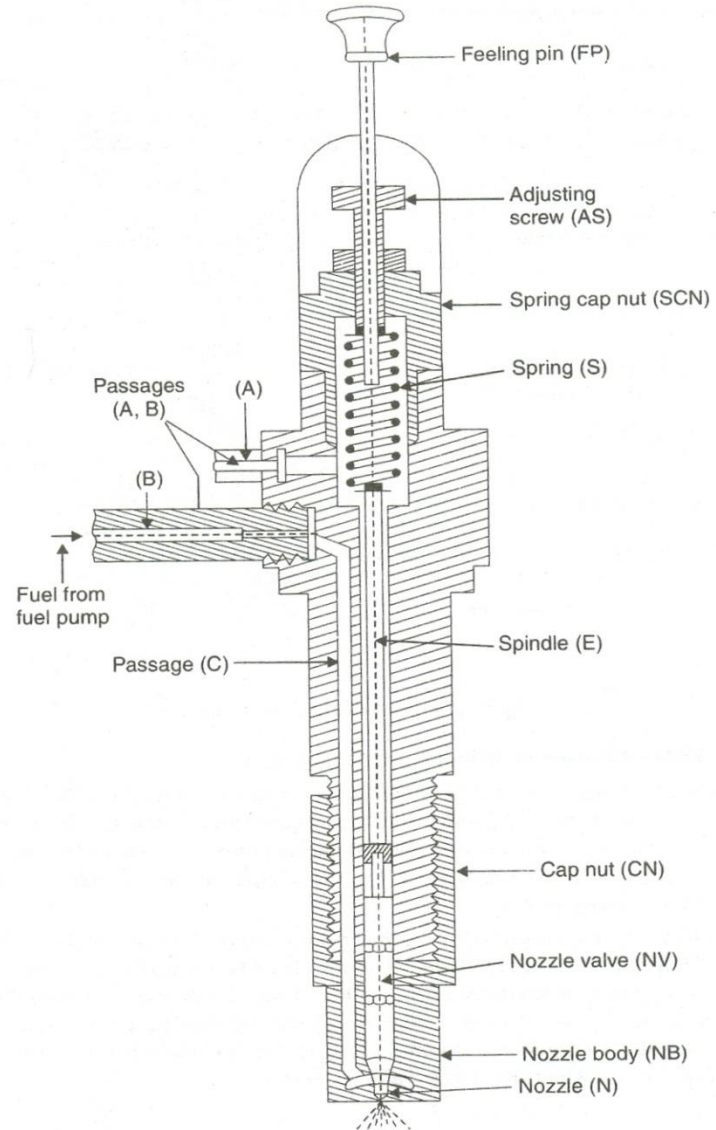
L is the plunger driven by a cam and tappet mechanism at the bottom . B is the barrel in which plunger reciprocates. There is a rectangular vertical groove in the plunger which extends from top to another helical groove. V is the delivery valve which lifts off its seat under the liquid fuel pressure and spring force. The fuel pump is connected to the fuel atomiser through passage P. SP and Y are the spill and the supply port respectively. When the plunger is at the bottom both ports SP and Y are uncovered by the plunger and fuel enters from the port SP into the barrel. On further upward movement of the plunger both the ports are closed and fuel is compressed and delivered through passage P to the atomiser as delivery valve lifts off from its seat. With further rise of the Plunger at certain moment, the port SP is connected to the fuel in the upper part of the plunger through rectangular vertical groove through helical groove , as a result of which sudden fall in pressure occurs and delivery valve occupies seat against the spring force. The plunger is rotated by the Rack R which is moved in or out by the governor. By changing the Angular position of the helical groove according to the load and speed of the vehicle amount of fuel delivered can be varied.

# Fuel Injector





# Fuel Injector



- It consists of a nozzle valve (NV) fitted in the nozzle body (NB). The nozzle valve is held on its seat by a spring 'S' which exerts pressure through spindle E. 'AS' is the adjusting screw by which nozzle valve lift can be adjusted. Usually the nozzle valve is set to lift at 135 to 175 bars pressure. FP is the feeling pin which indicates whether valve is working properly or not
- The fuel under pressure from the fuel pump enters the injector through the passages B and C and lifts the nozzle valve. The fuel travels down nozzle N and is injected into the engine cylinder in the form of fine spray. Then the pressure of the oil falls, the nozzle valve occupies its seat under the spring force and fuel supply is cut off. Any leakage of fuel accumulated above the valve is led to the fuel tank through passage A. The leakage occurs when the nozzle valve is worn out

# Petrol Injection

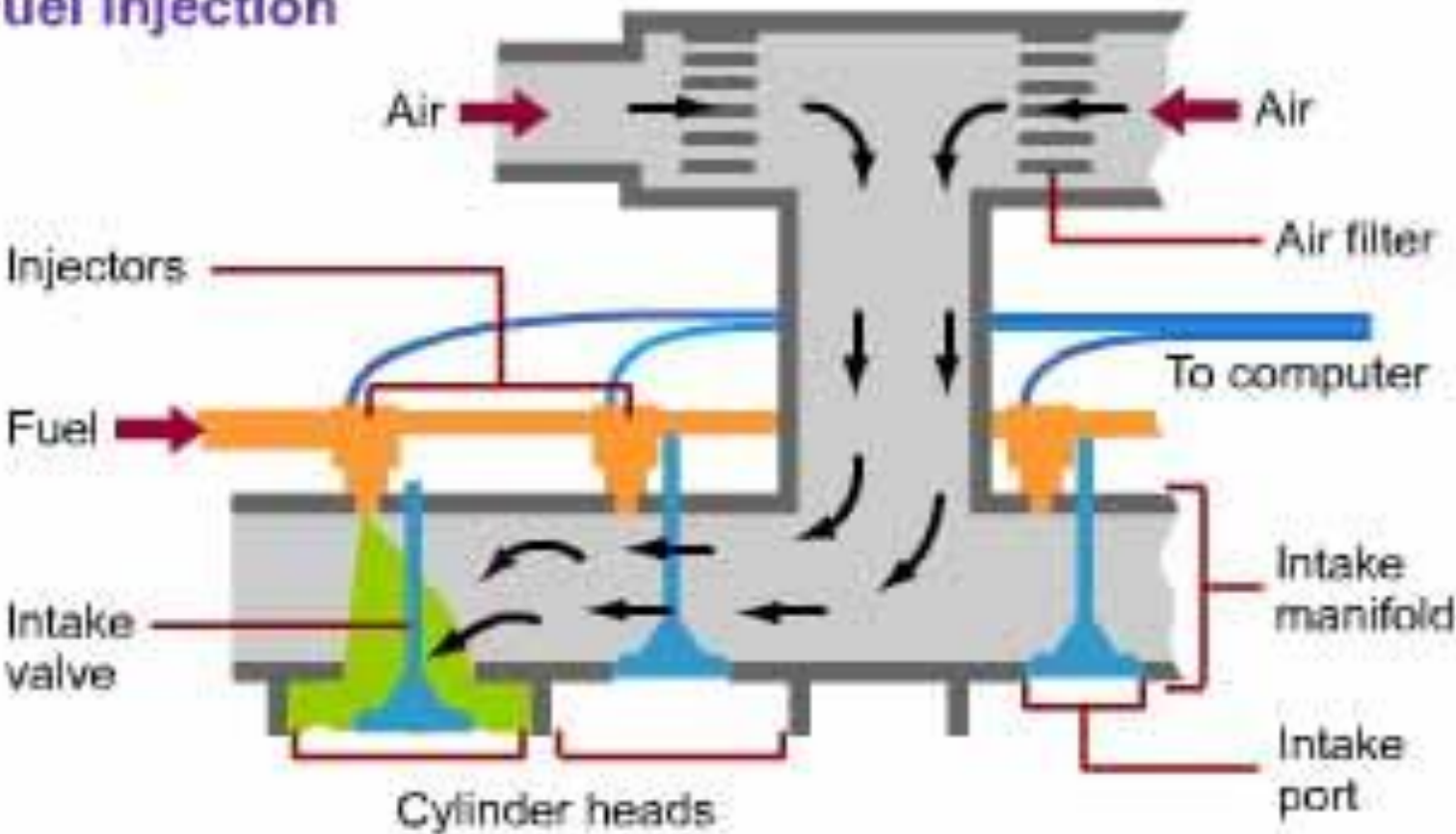
Petrol is supplied into intake manifold through petrol Injectors . This process is called the petrol injection. In this system the petrol is received by the injector from the pump and is sprayed into the air stream in atomized form.

Adv:

- High power
- Quick starting and warm up
- Low specific fuel consumption

# Multi-point fuel injection

## Multi-Point Fuel Injection



These systems are of two types

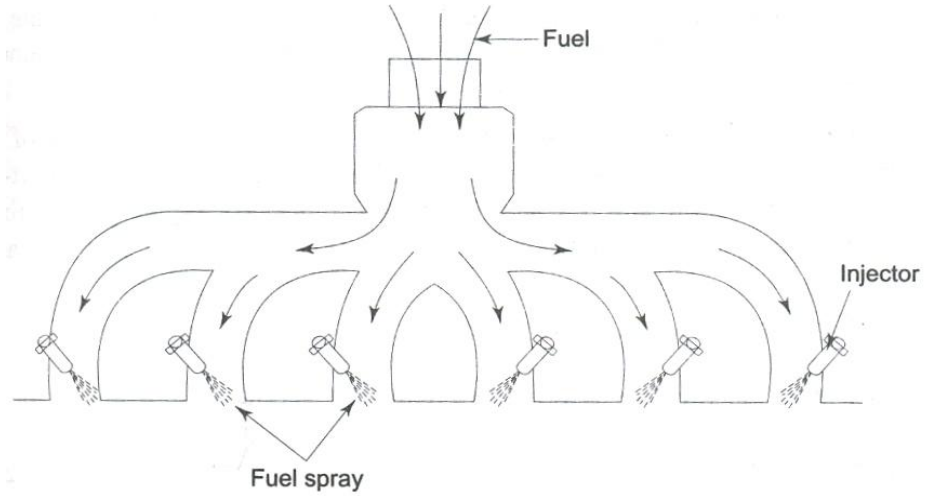
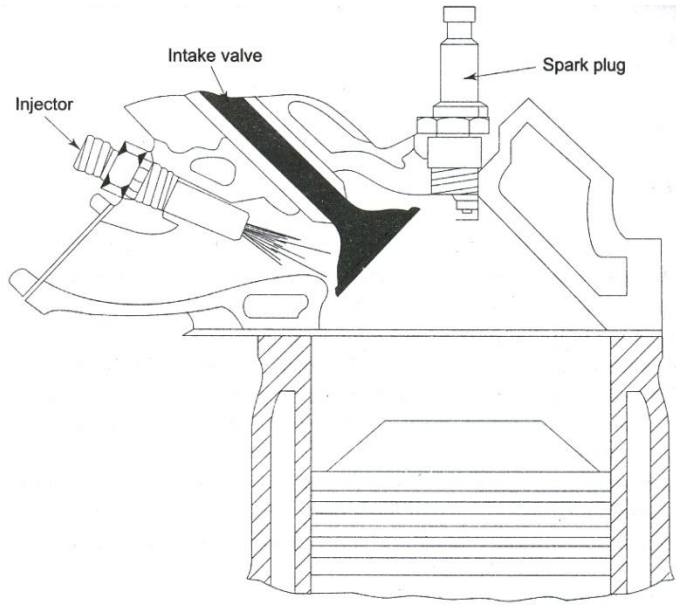
- ❖ Port Injection

- ❖ Throttle body Injection

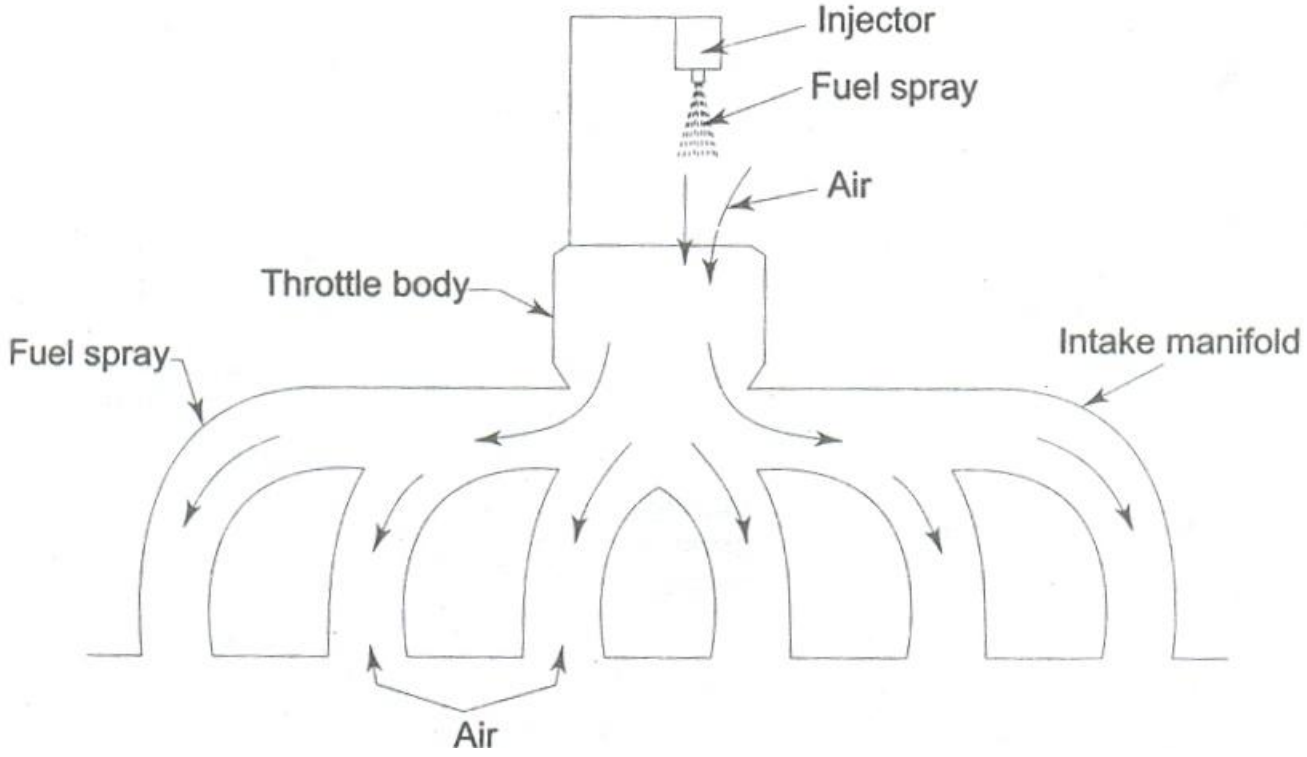
- In port injection the Injector is placed on the side of the intake manifold and sprays petrol into the air inside the intake manifold. The petrol mixes with air completely. This mixture of petrol and air then passes through the intake valve and enters into the cylinder.

- Throttle body injection is nothing but Single point fuel injection system. In this an Injector is placed slightly above throat of the throttle body. The Injector sprays petrol into the air in the intake manifold where petrol mixes with air. This mixture then passes through the throttle valve and enters the intake manifold.

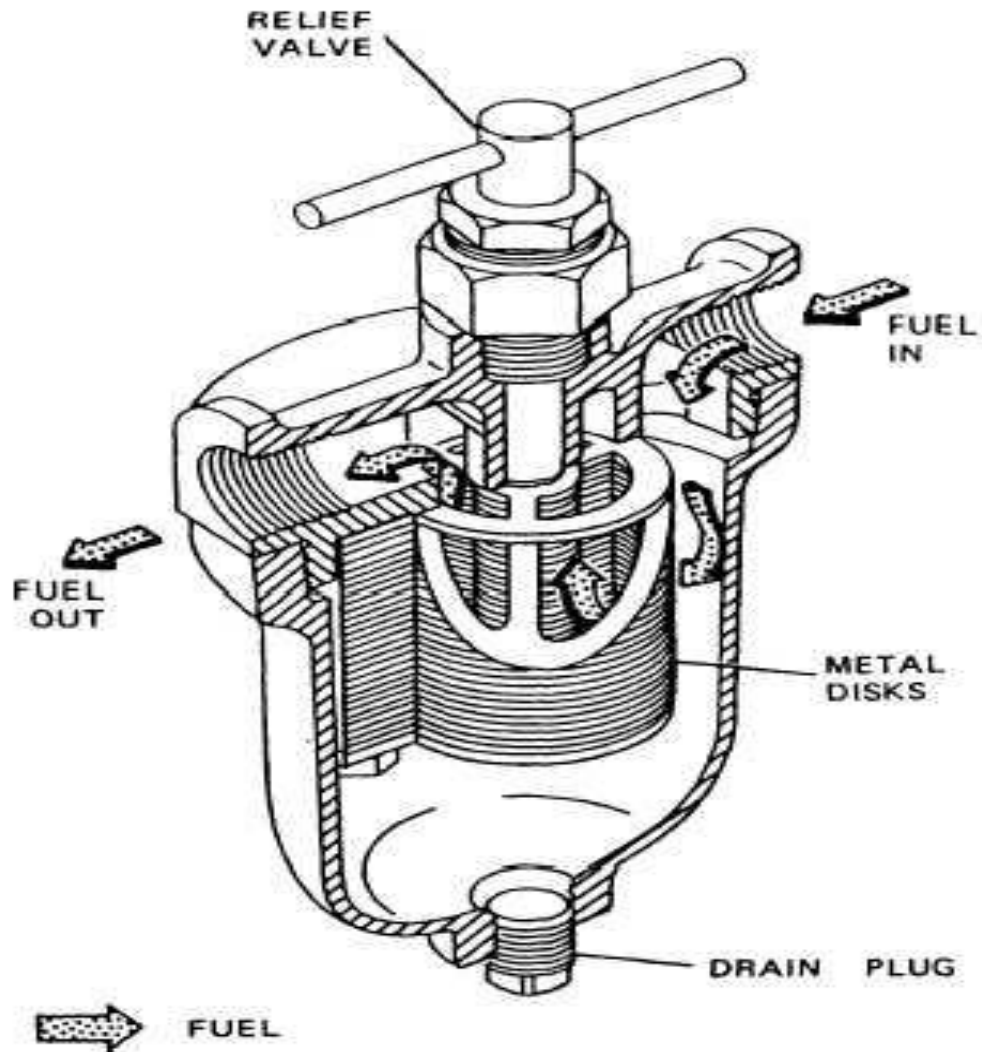
# Port Injection System



# Throttle body Injection



# Fuel Filters

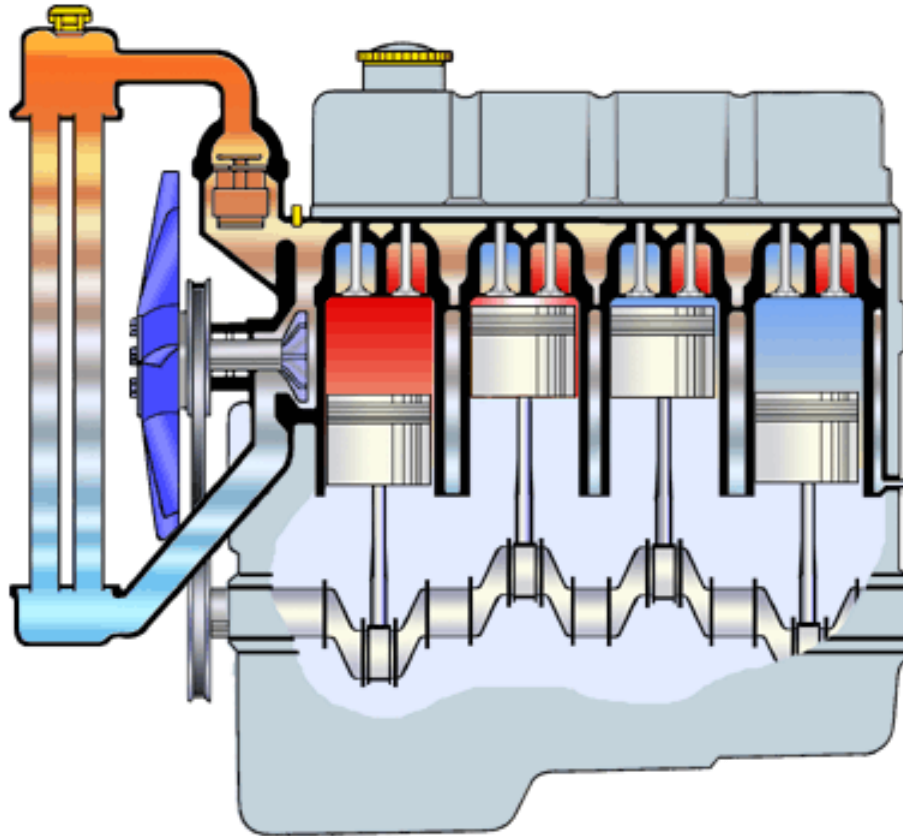




# **UNIT-2**

# Cooling System

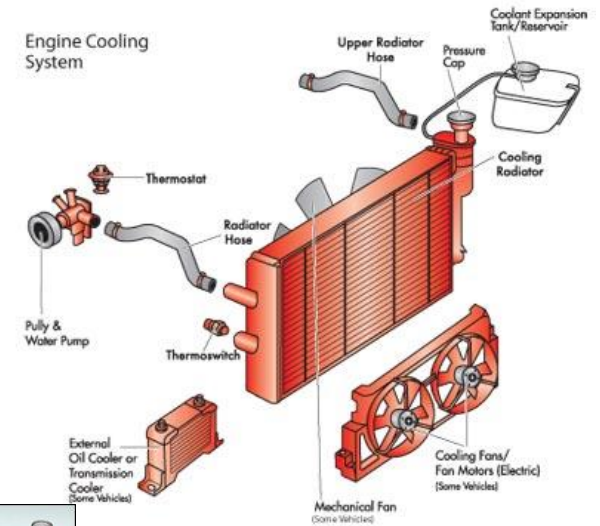
- Get the engine up to optimum operating Temperature as quickly as possible and maintains it at that temperature.
- Controls the heat produced in combustion chamber, so that the engine parts are not damaged & the oil does not break down.



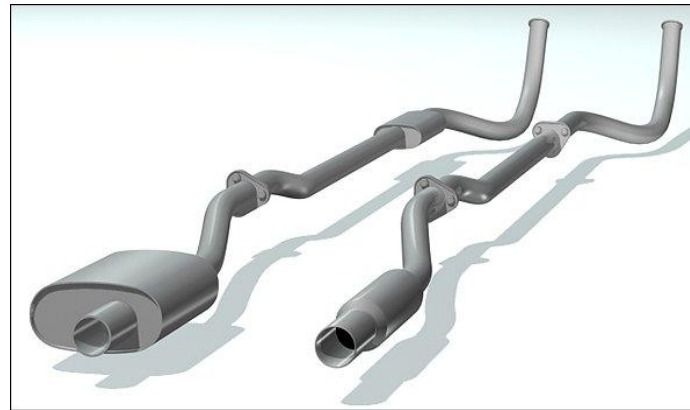
# Cooling System

## TOTAL FUEL BURNED

1/3 cooling system



1/3 Exhaust system



1/3 Propels the vehicle



# Cooling System

## AIR COOLED

- Have metal FINS on the outer perimeter of the engine.
- Heat is transferred from the engine, through these fins, into the atmosphere.



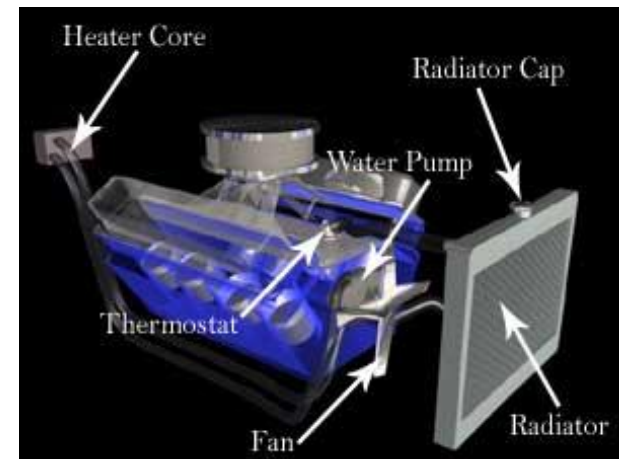
# Cooling System

## LIQUID COOLED

- A liquid (**coolant**) is circulated around the cylinders and absorb heat from the cylinder walls and cylinder head.

**COOLANT** is a mixture of antifreeze (*Ethylene Glycol*) and Water (*some Aluminum radiators have special antifreeze*)

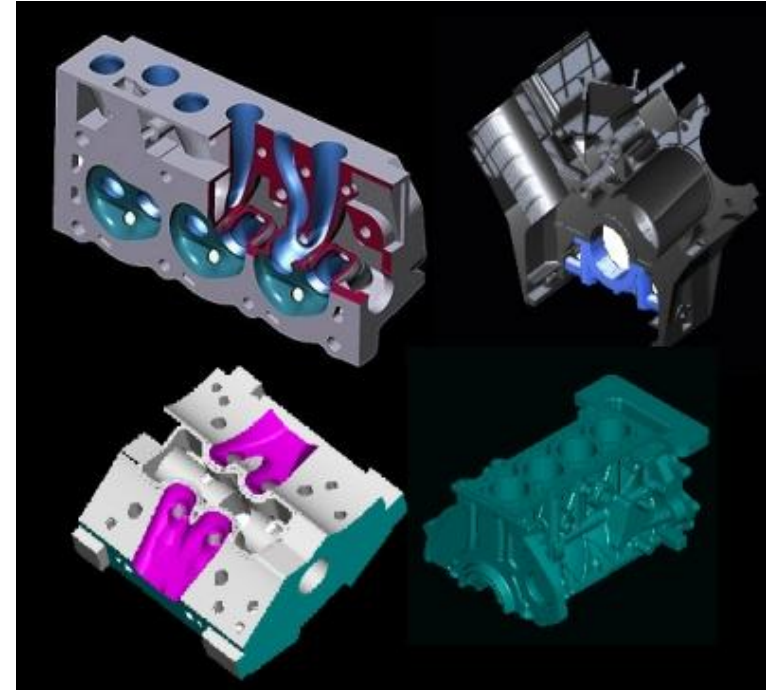
- Coolant absorbs heat as it passes through the engine and also lubricates the water pump.
- Hot coolant enters the radiator in which the heat is passed on to air that is flowing through the radiator.
- Prevents rust and corrosion from the water jackets.
- Cooling system flush is recommended every two years in order to remove any rust or contaminants.



# Cooling System

## Water Jackets

- Designed to keep engine block and cylinder head cool.
- Open spaces between the outside of cylinder and inside of cylinder block and head.
- When engine is running at normal operating temperature, the coolant is forced through the water jackets in the engine block, through the head gasket, into the head, and back to the radiator.



**Cylinder head gasket** sits between the short block and cylinder head.

- If damaged, the coolant enters the combustion chamber and the combustion into the cooling system. It will allow acids to form. (WHITE SMOKE)

# Cooling System

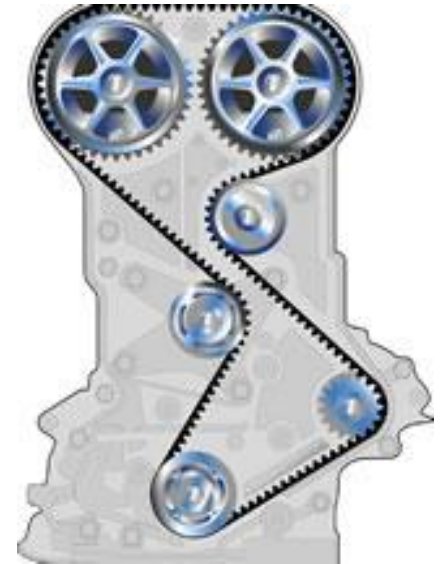
## Water Pump (Impeller Type)

- Draws the coolant from the radiator, through the lower radiator hose, and then forces it through the water jackets, back into the radiator.
- If the clutch fan can be wiggled up and down, most likely the water pump needs to be replaced.
- Water pumps gasket is placed between the water pump and the engine block to prevent leakage (if left loose it might leak and if tightened too much it might crack).



# Cooling System

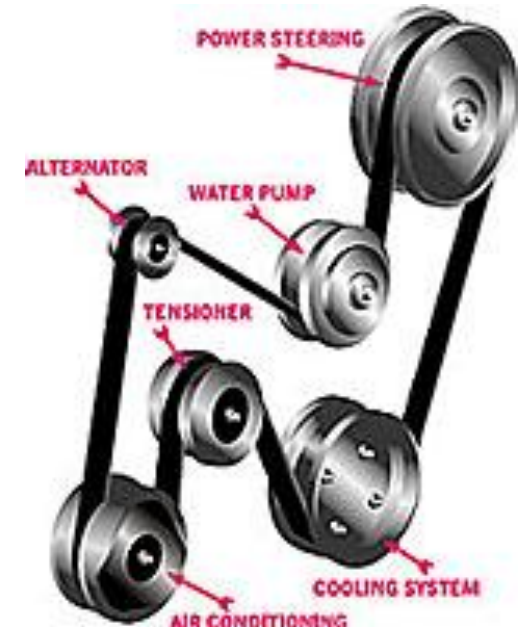
- **Water pump is driven by the crankshaft through**
- **Timing Belt** (*Keeps Cam and Crank shafts in time*)
- **Drive/accessory Belt** (Runs alternator, power-steering pump, AC, etc.)



V-Belt



Serpentine Belt





# Cooling System

**Engine Fan** draws air through the radiator at low speeds (i.e. Traffic)

**Clutch fan** is mounted on the water pump and is driven by the drive belt.

- It slips at higher speed, in turn slowing the fan speed down.
- It locks up at slow speeds, in turn speeding up the fan RPMs.
- Should be able to turn when the engine is turned off.



# Cooling System

**Electric fan** is mounted on the radiator and is operated by battery power.



- Is controlled by the thermostat switch.
- Is located on Thermostat housing, Block, or Radiator.
- Some modern cars have the range between 193° to 207° F (89 to 97° C)
- On AC equipped cars, a second fan is mounted, and it runs any time AC is turned on.

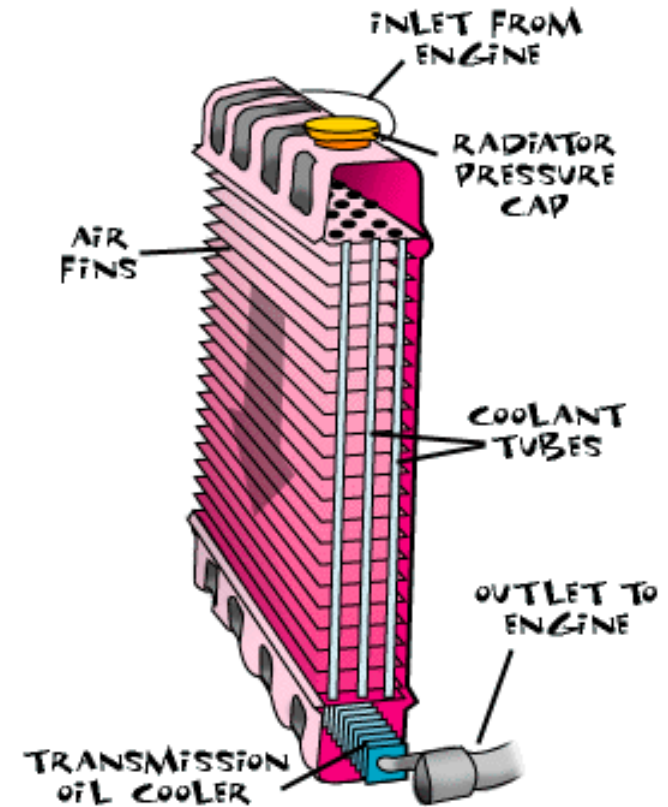
**CAUTION** Electric fan may run while the engine is turned off.



# Cooling System

**Radiator** is a heat exchanger that removes heat from the coolant passing through it.

- Vertical or Horizontal core
- Vehicles equipped with automatic transmission have transmission cooler build into the radiator.
- Some vehicles (towing purposes) have oil cooler mounted to “or” build into the radiator.

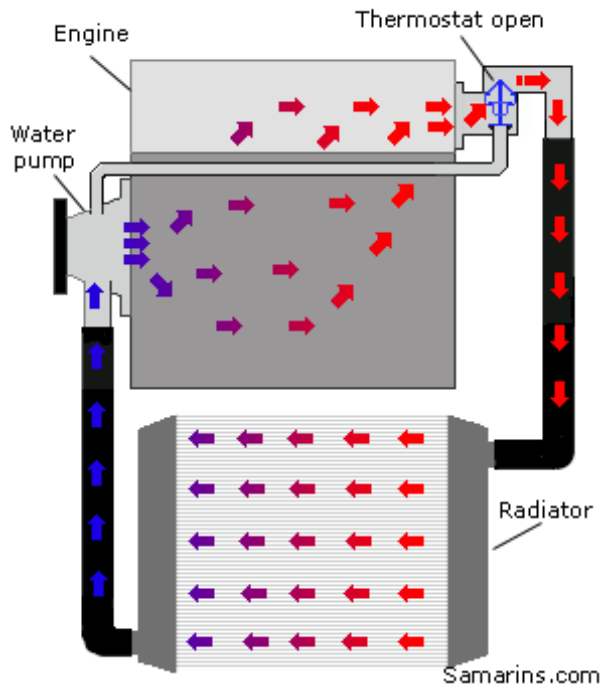


# Cooling System

**Thermostat** placed between the cylinder head and top radiator hose.

- Purpose is to close off this passage when engine is cold.

- The temperature that the thermostat opens is called ***thermostat rating***.



- Higher temperature thermostats are used on the modern vehicles.

- If thermostat is stuck open the engine will run cool, and if the thermostat is stuck closed the engine will Overheat.

- Can be checked by placing in the boiling water.



# Cooling System

**Radiator Pressure cap** seals the cooling system and pressurize it.

- Most caps insert 12-16 lbs of pressure.
- Each pound of pressure inserted increases the boiling point of coolant by 1.8° C (3° F).  
Boiling point of water is 100° C (212° F).
- Has a built in pressure relief valve to prevent excessive pressure build-up.
- Has a vacuum vent valve (when engine is shut off and it cools, the coolant volume is reduced)

Excess coolant goes to the expansion tank.

**CAUTION** never open the radiator cap if you can't squeeze the top radiator hose.



# Cooling System

## Hoses

Top Radiator hose brings the coolant back to the radiator and are molded specifically for individual make and model.



Lower radiator hose draws the coolant into the engine, from the radiator and is attached to the water pump. (sometimes a spring is inserted in order to prevent collapsing)



# Cooling System

## BLOCK HEATER

- Fitted into the block to keep the engine warm during extremely cold weather. (Diesel Engines)



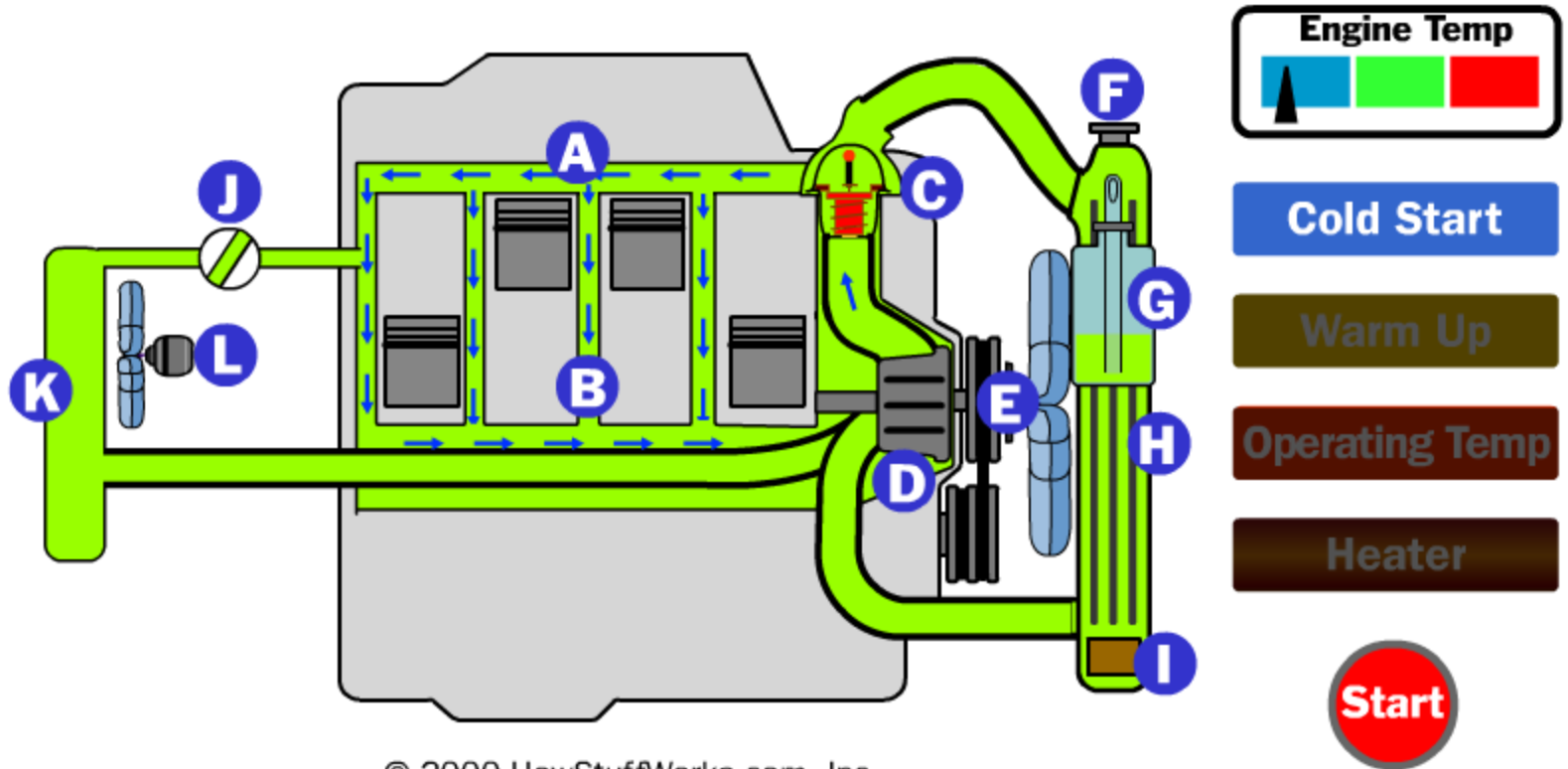
## FREEZE PLUG

- Prevents engine block cracking if water freezes inside.

- Common cause of freeze plug failure is rust.



# Cooling System



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# **IGNITION SYSTEMS**

# IGNITION FUNCTION

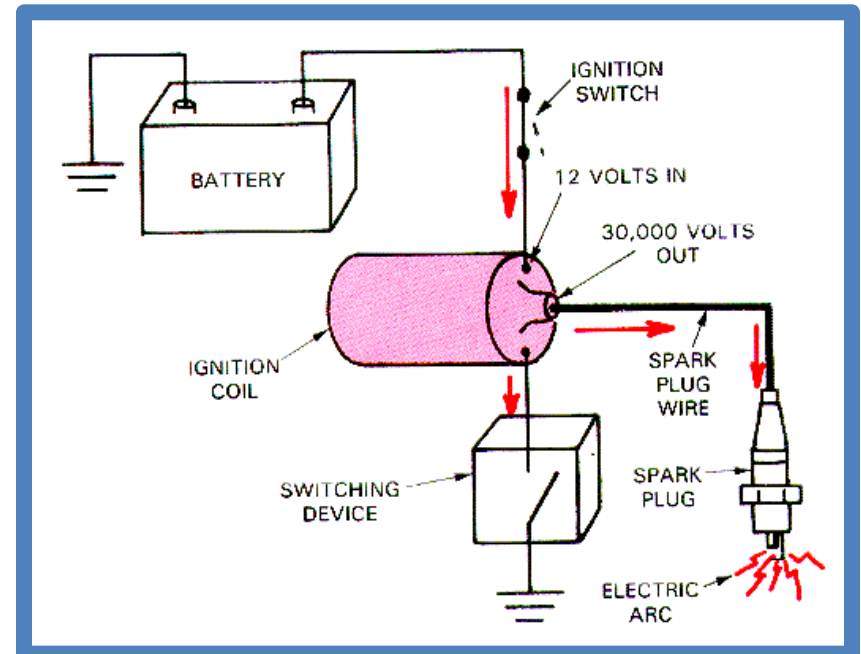
- **Produces 30,000 volt spark across spark plug**
- **Distributes high voltage spark to each spark plug in correct sequence**
- **Times the spark so it occurs as piston is nearing top dead center**
- **Varies spark timing with load, speed, and other conditions**

# **BASIC IGNITION SYSTEM COMPONENTS**

- **BATTERY**
- **IGNITION SWITCH**
- **IGNITION COIL**
- **SWITCHING DEVICE**
- **SPARK PLUG**
- **IGNITION SYSTEM WIRES**

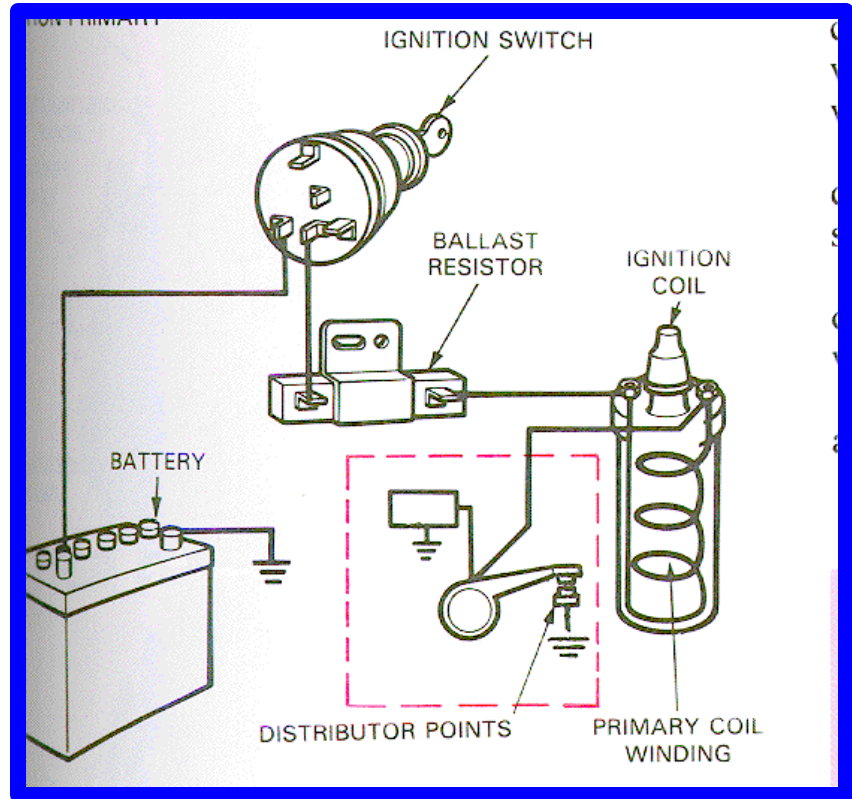
# BASIC IGNITION SYSTEM

- Battery supplies power to entire system
- Ignition Switch turns engine on or off
- Coil transforms volts
- Switching device triggers ignition coil
- Spark Plug and wires distribute spark



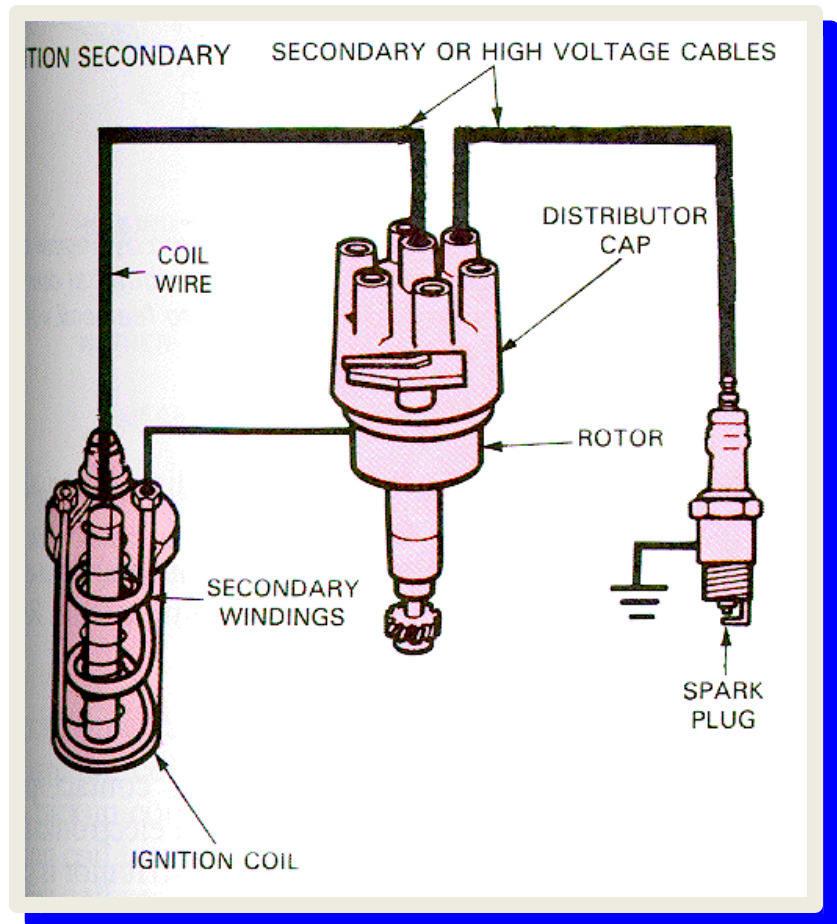
# PRIMARY CIRCUIT

- Consists of low voltage wiring and components
- Uses conventional type automotive primary wires
- Controls when ignition will take place. (When coil fires)



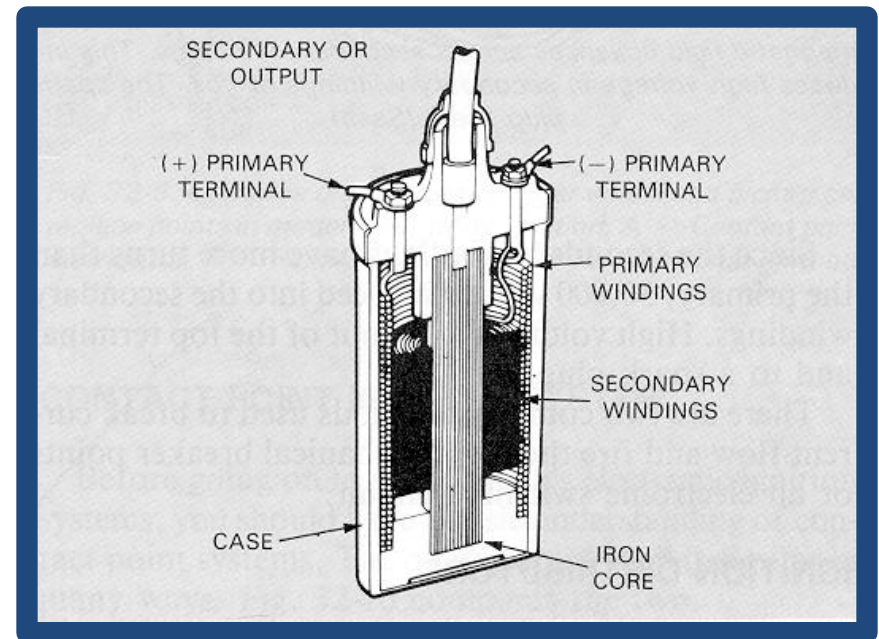
# SECONDARY CIRCUIT

- **Distributes current to individual cylinders to jump spark plug gap**
- **Must have thicker, heavier insulation on wires**
- **Typical voltage to jump gap - 10K Volts**



# IGNITION COIL

- **TRANSFORMER**
- **2 SETS OF WINDINGS**
  - Primary windings
  - Secondary windings
- **IRON CORE**
- **PRODUCES MAGNETIC FIELD**



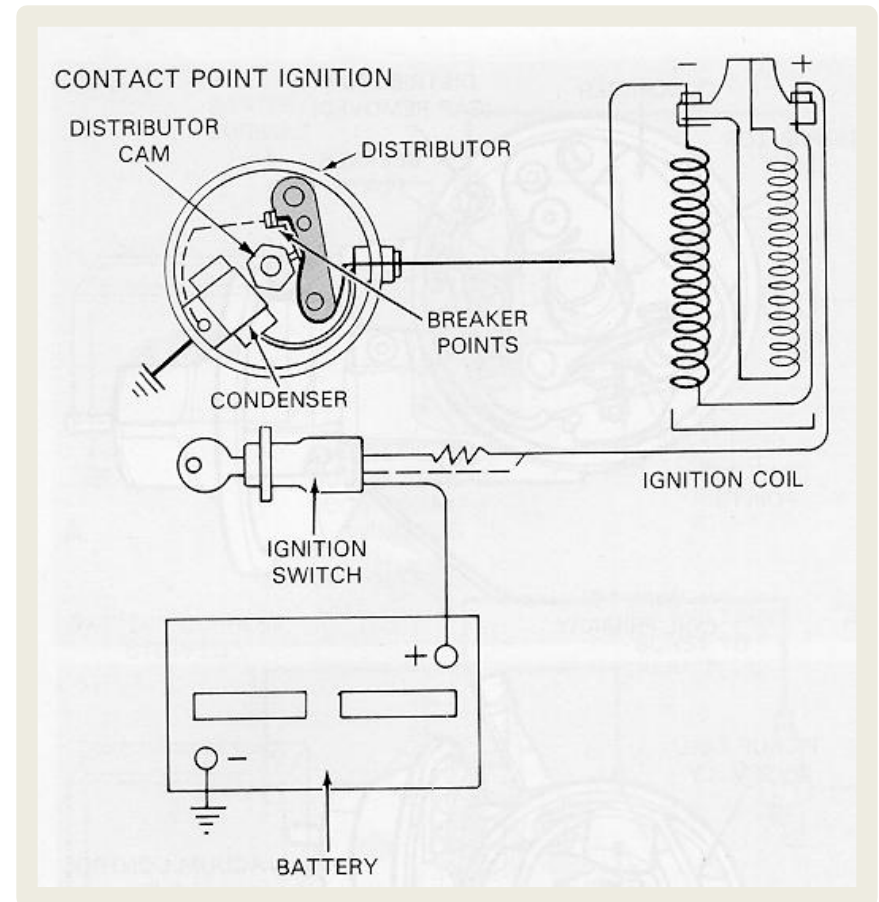
# **IGNITION SYSTEM TYPES**

- **CONTACT POINT IGNITION SYSTEM**
- **ELECTRONIC IGNITION SYSTEM**
- **DISTRIBUTORLESS IGNITION SYSTEM**

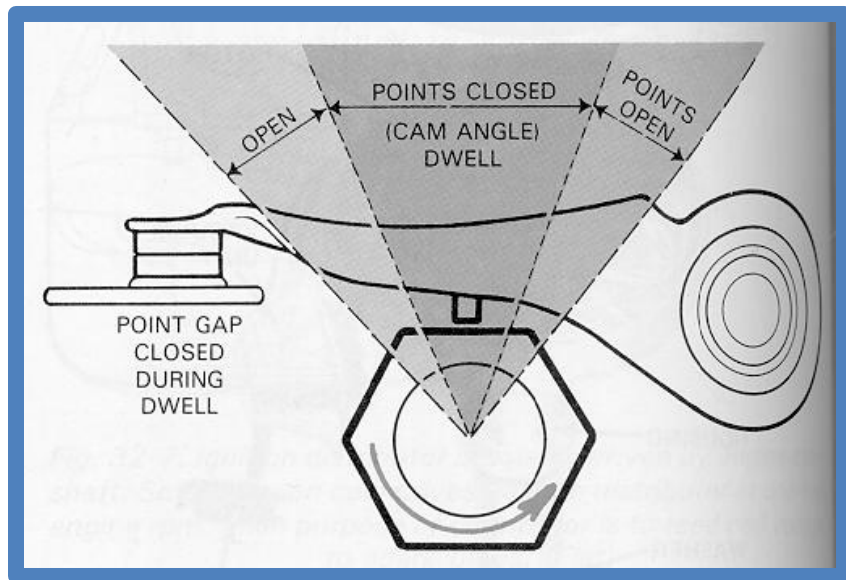


# CONTACT POINT SYSTEM

- **Distributor turns 1/2 engine rpm**
- **Distributor Cam**
- **Contact Points**
- **Condenser**
- **Point Dwell (Cam angle)**
- **Basis for all Systems**



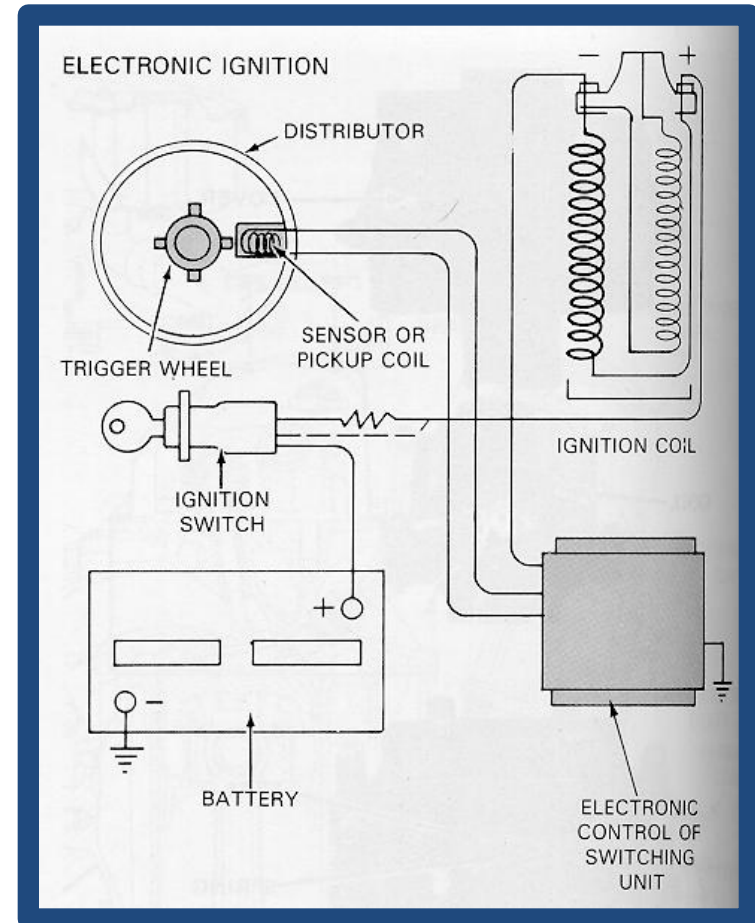
# DWELL (CAM ANGLE)



- Amount of time in distributor degrees that points remain closed between each opening
- Coil saturation time is controlled by amount of dwell

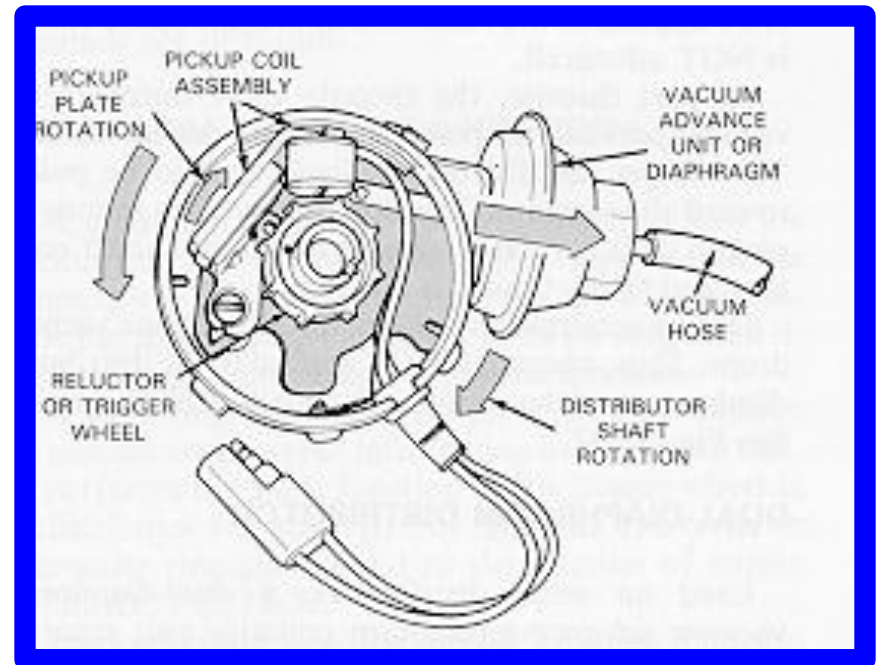
# ELECTRONIC IGNITION SYSTEM

- Uses electronic control circuit to operate the ignition coil
- More dependable than contact system
- Higher secondary Ignition voltages



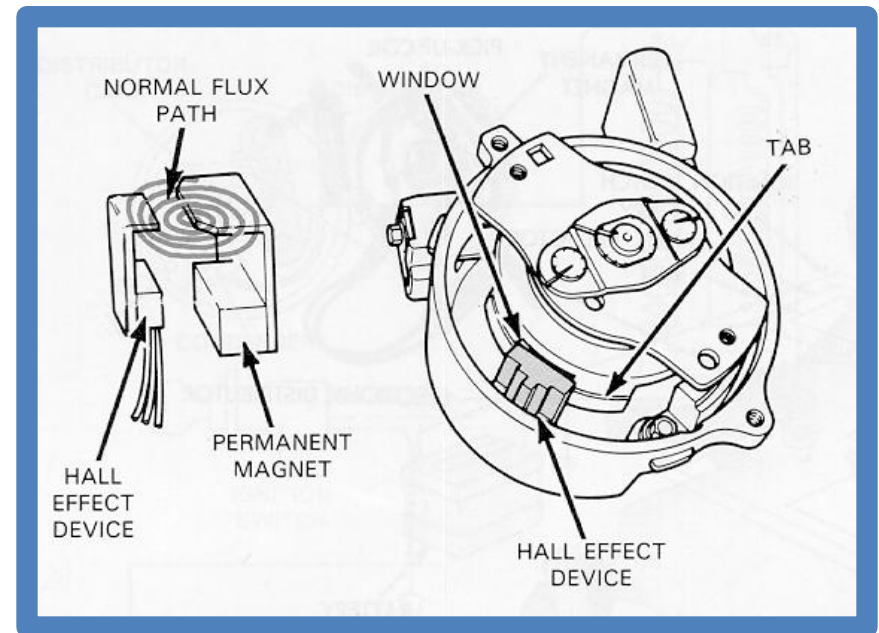
# MAGNETIC PICK UP COIL

- Produces tiny voltage pulses to create magnetic field changes
- Trigger Wheel interrupts magnetic field
- Tell control unit (amplifier) when to fire ignition coil

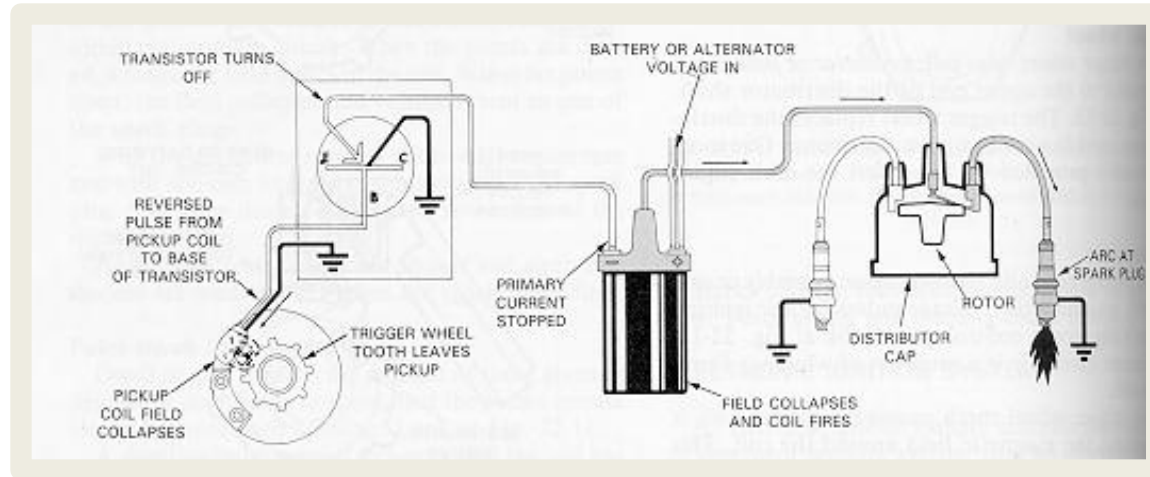


- Hall Effect element is a solid state device
- Contains a permanent magnet next to element
- A Tab shunts magnetic field to send signal to control unit
- Signal is On or Off

# HALL EFFECT DEVICE



# IGNITION CONTROL UNIT AMPLIFIER

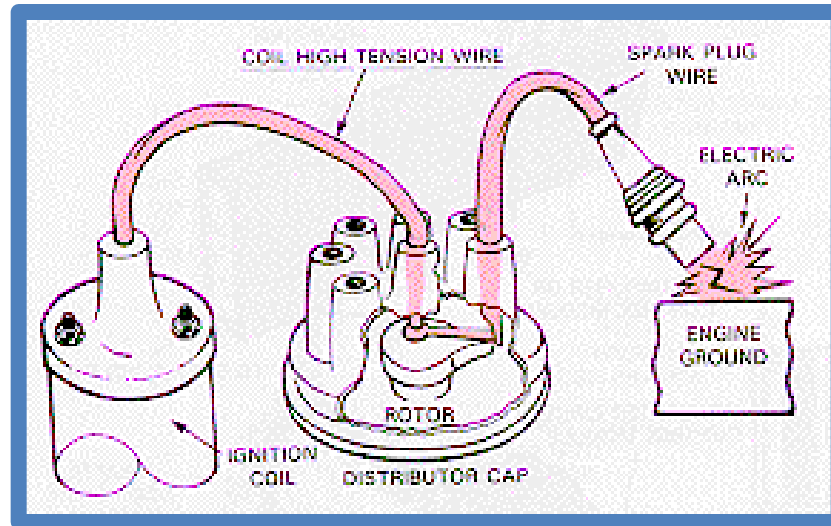


- **Controls Primary current to tell Ignition Coil when to fire spark plugs**

# **HIGH VOLTAGE SECONDARY COMPONENTS**

- **IGNITION COIL**
- **COIL WIRE**
- **DISTRIBUTOR**
- **DISTRIBUTOR CAP**
- **DISTRIBUTOR ROTOR**
- **SPARK PLUG WIRE**
- **SPARK PLUG**

# SECONDARY CIRCUIT

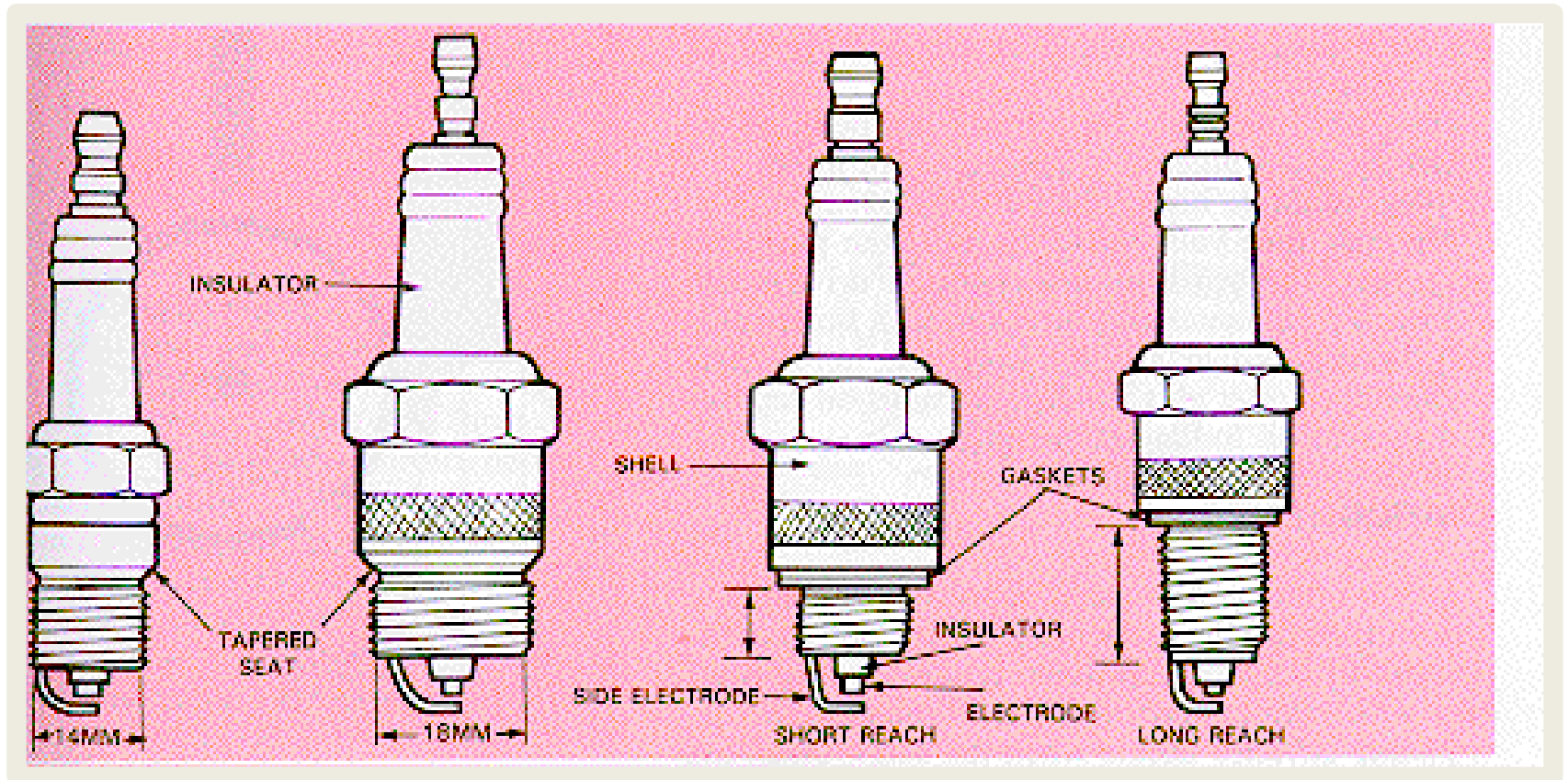


- **DISTRIBUTES SPARK TO RIGHT PLACE AT RIGHT TIME**
- **PARTS ARE DESIGNED TO CONTROL HIGH VOLTAGES**

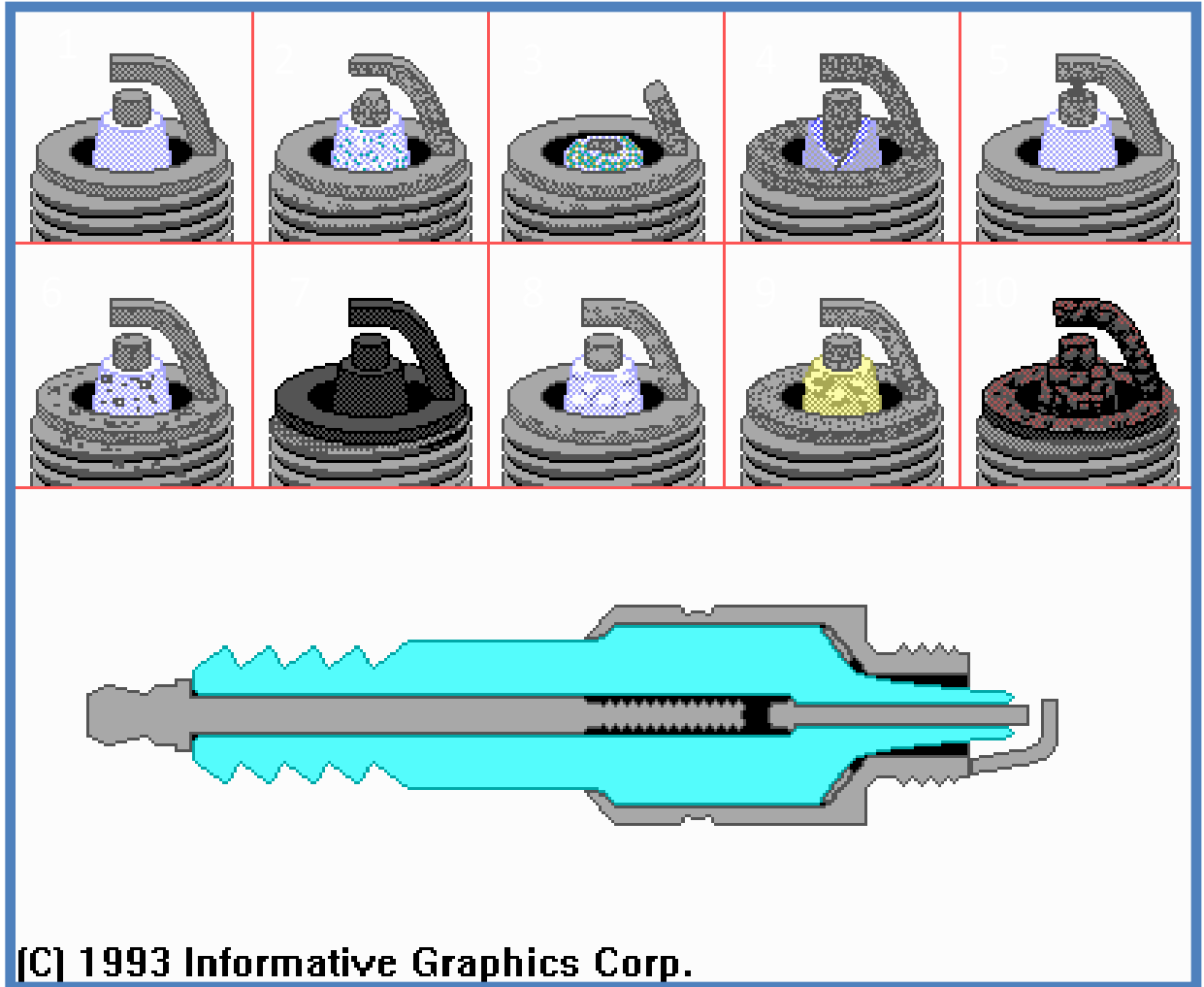


# SPARK PLUGS

Pg 121C

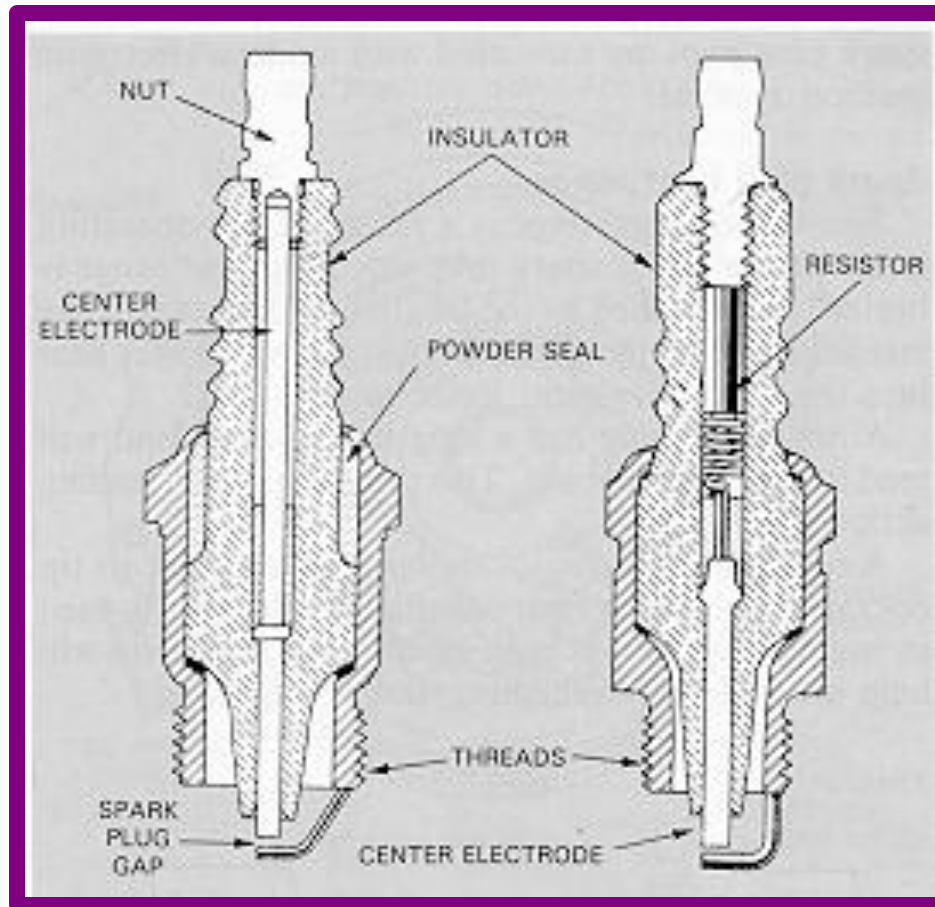


1. Normal
2. Overheated
3. Pre-ignition
4. Cracked insulator
5. Bridged gap
6. Deposit fouled
7. Carbon glazed
8. Splashed
9. Glazed
10. Oil fouled



**(C) 1993 Informative Graphics Corp.**

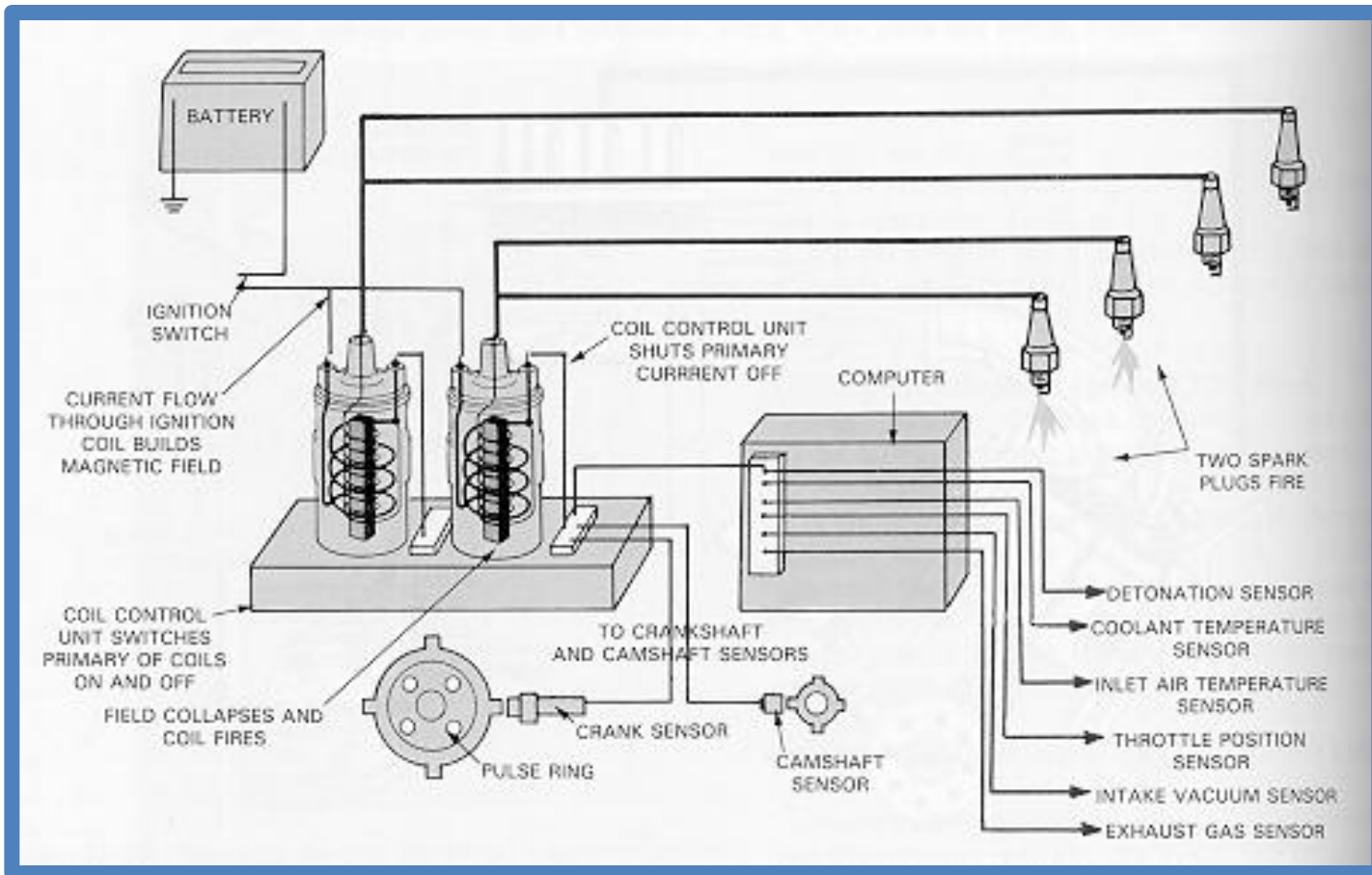
# SPARK PLUG TYPES



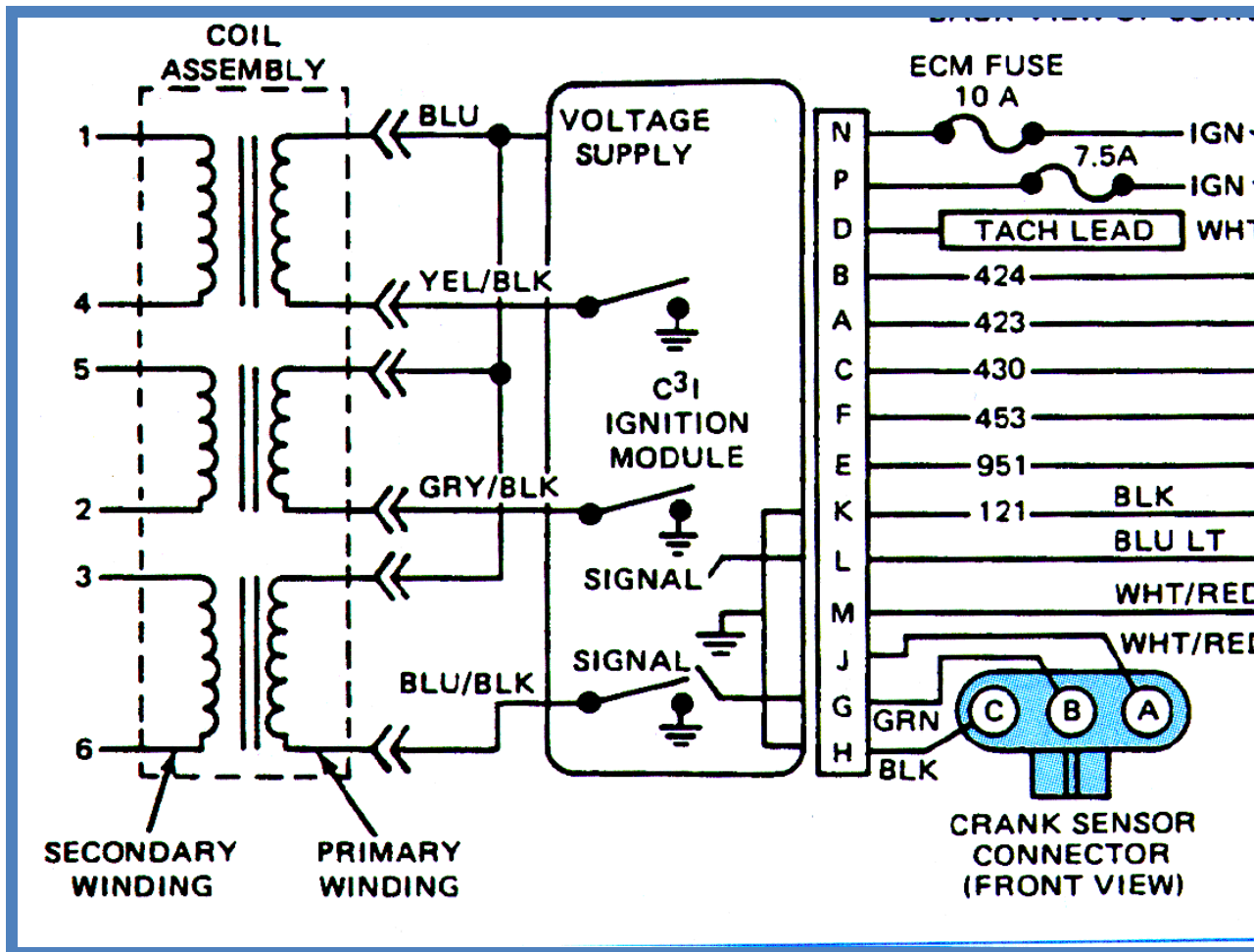
# **DISTRIBUTORLESS IGNITION**

- **Timing is very precise**
- **No mechanical parts to wear out**
- **Requires less maintenance**
- **Ignition timing is USUALLY not adjustable**
- **Computer relies on ignition sensors**
- **On-board computer controls ignition timing usually through a ignition module**

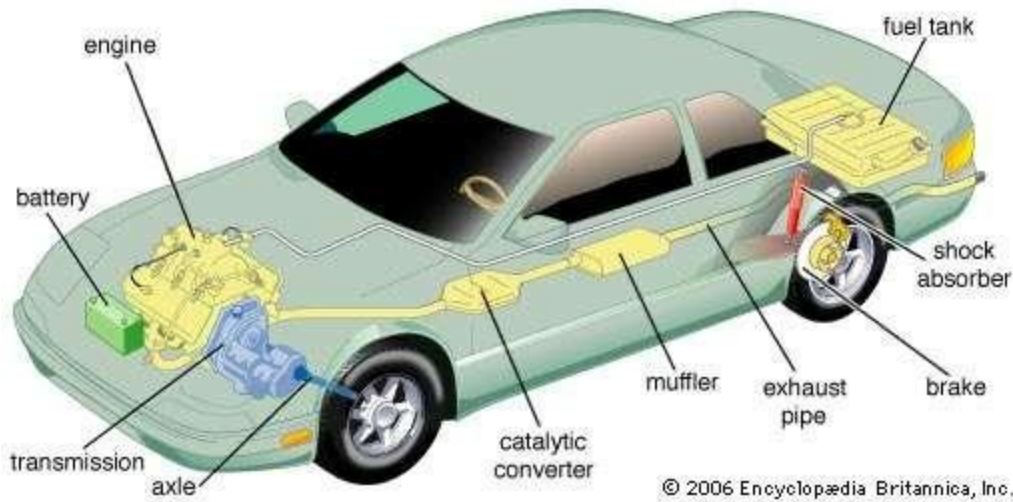
# DISTRIBUTORLESS IGNITION SYSTEM



# DIS System



# Electrical system in Automobile



# Introduction To Electrical system

➤ The electrical system comprises a storage battery, generator, starting (cranking) motor, lighting system, ignition system, and various accessories and controls. Originally, the electrical system of the automobile was limited to the ignition equipment.

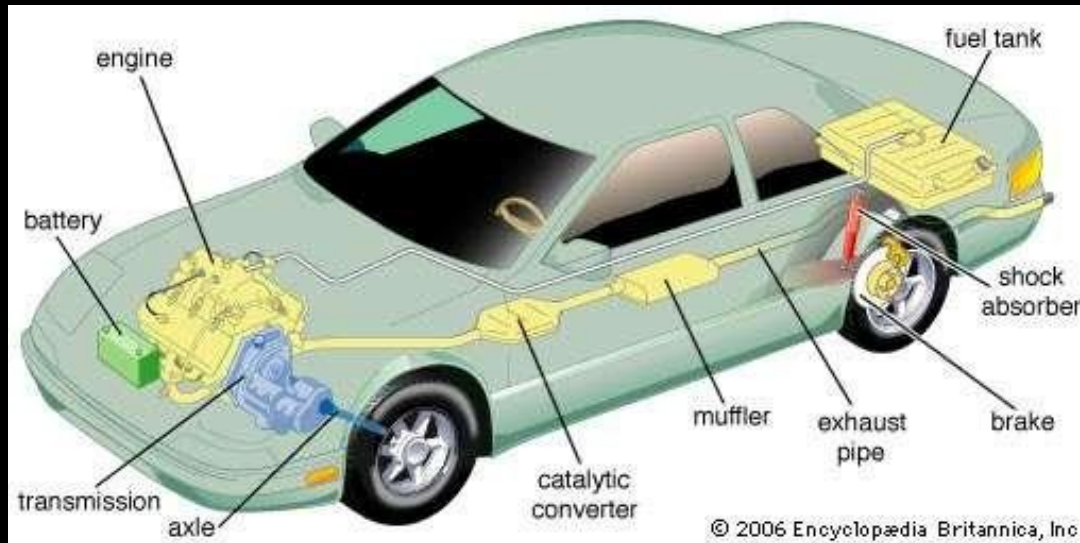
With the advent of the electric starter on a 1912 Cadillac model, electric lights and horns began to replace the kerosene and acetylene lights and the bulb horns. Electrification was rapid and complete, and, by 1930, 6-volt systems were standard everywhere.



# I. Battery System

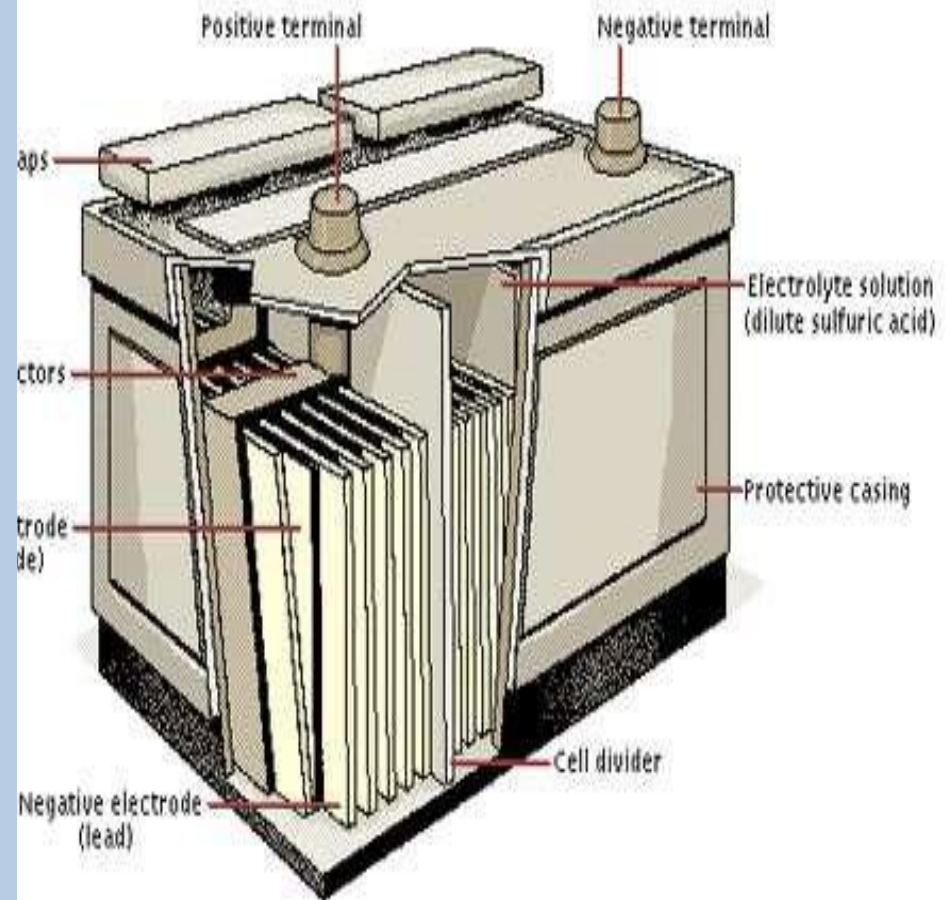
# II. Ignition System

# III. Alternato



# Battery System

Lead–acid batteries, invented in 1859 by French physicist Gaston Planté, are the oldest type of rechargeable battery. Despite having a very low energy-to-weight ratio and a low energy-to-volume ratio, their ability to supply high surge currents means that the cells maintain a relatively large power-to-weight ratio. These features, along with their low cost, make them attractive for use in motor vehicles to provide the high current required by automobile starter motors.

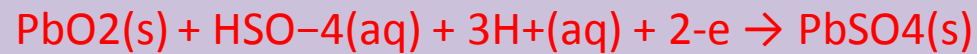


# Discharging

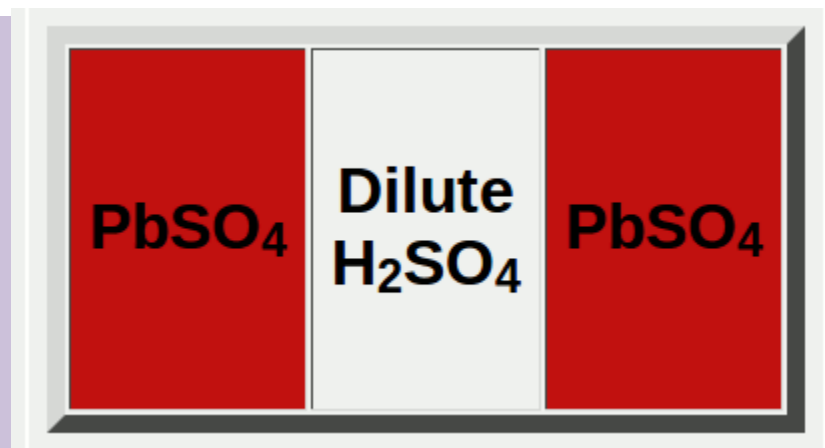
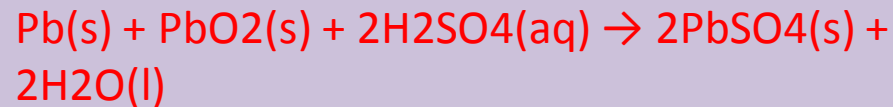
Negative plate reaction (Anode Reaction):



Positive plate reaction (Cathode Reaction):

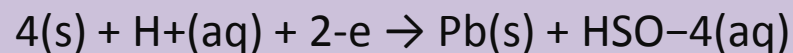


The total reaction can be written:

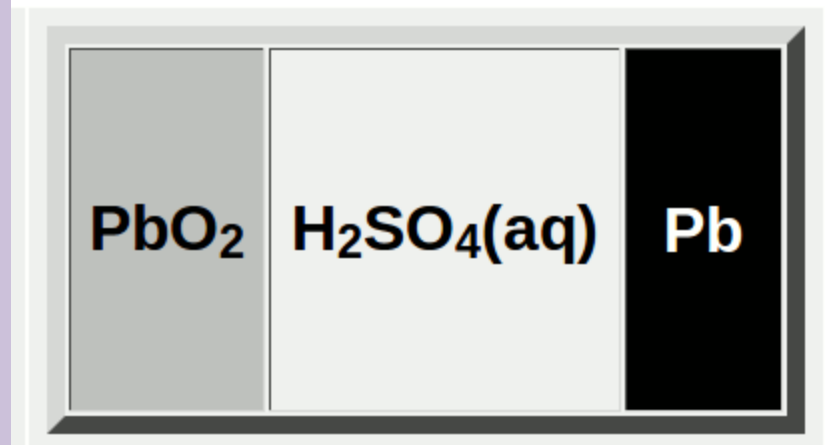
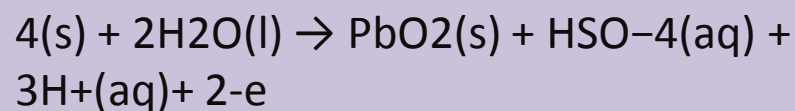


# Charging

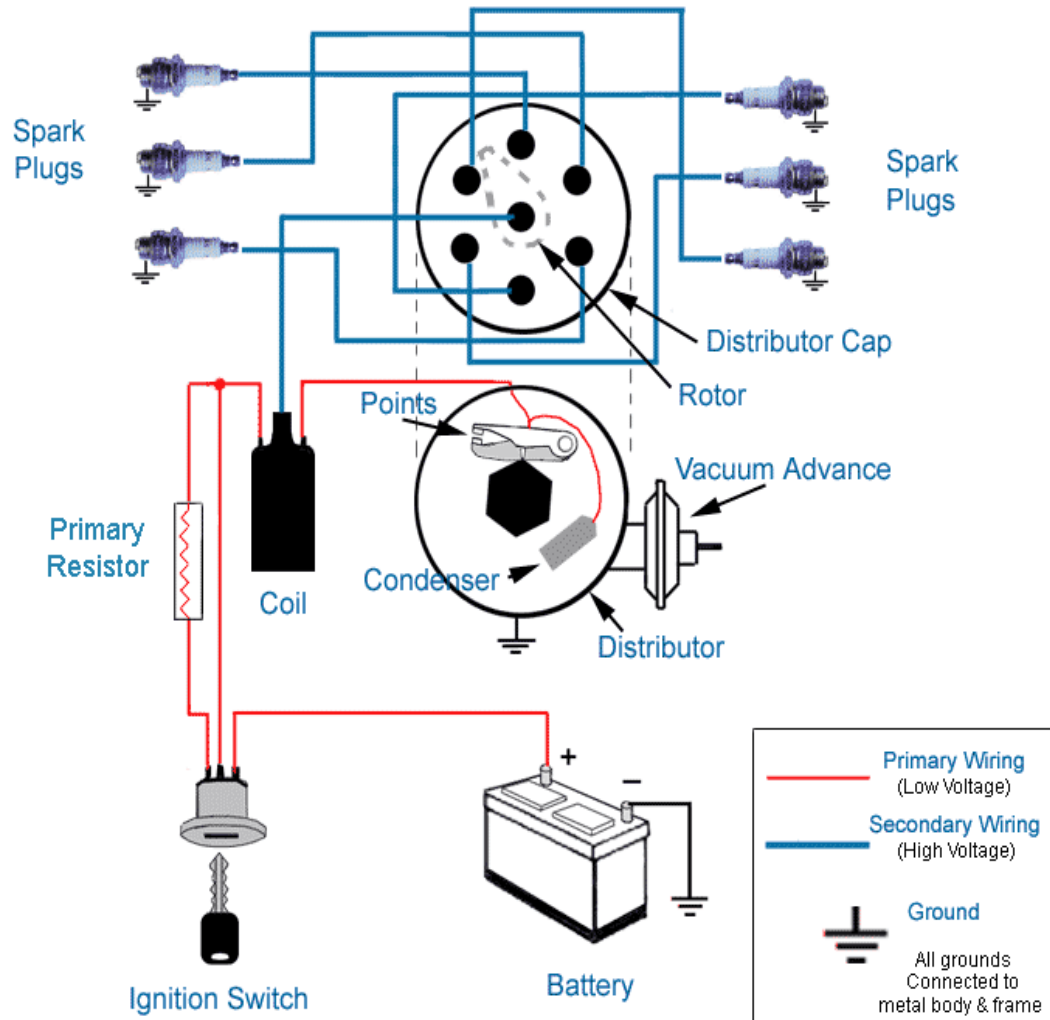
Negative plate reaction:  $\text{PbSO}_4$



Positive plate reaction:  $\text{PbSO}_4$



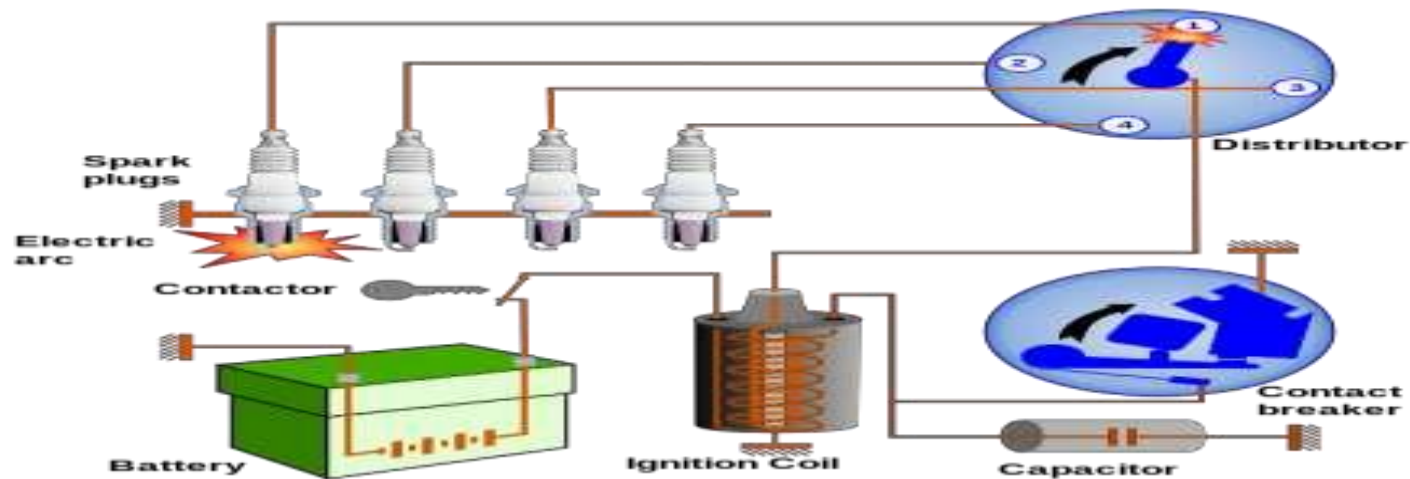
# Ignition System



An ignition system is a system for igniting a fuel-air mixture. Ignition systems are well known in the field of internal combustion engines such as those used in petrol (gasoline) engines used to power the majority of motor vehicles, but they are also used in many other applications such as in oil-fired and gas-fired boilers, rocket engines, etc.

The first ignition system to use an electric spark was probably Alessandro Volta's toy electric pistol from the 1780s. Virtually all petrol engines today use an electric spark for ignition.

# Battery and Coil-operated ignition



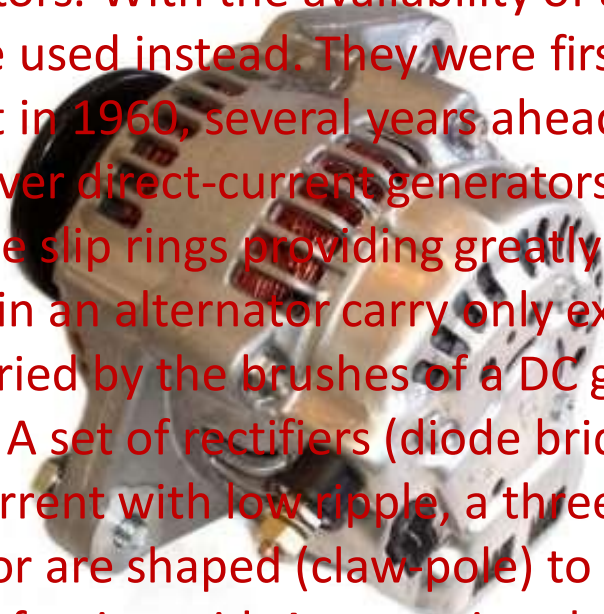
- With the universal adaptation of electrical starting for automobiles, and the concomitant availability of a large battery to provide a constant source of electricity, magneto systems were abandoned for systems which interrupted current at battery voltage, used an ignition coil (a transformer) to step the voltage up to the needs of the ignition, and a distributor to route the ensuing pulse to the correct spark plug at the correct time.

The first reliable battery operated ignition was developed by the Dayton Engineering Laboratories Co. (Delco) and introduced in the 1910 Cadillac. This ignition was developed by Charles Kettering and was a wonder in its day. It consisted of a single coil, points (the switch), a capacitor and a distributor set up to allocate the spark from the ignition coil timed to the correct cylinder. The coil was basically a transformer set up to step up the low (6 or 12 V) voltage supply to the high ignition voltage required to jump a spark plug gap.

The points allow the coil to charge magnetically and then, when they are opened by a cam arrangement, the magnetic field collapses and a large (20 kV or greater) voltage is produced. The capacitor has two functions: 1) it absorbs the back EMF from the magnetic field in the coil to minimize point contact burning and maximize point life; and 2) it forms a resonant circuit with the primary coil of the ignition coil

# . Alternators

are used in modern automobiles to charge the battery and to power the electrical system when its engine is running. Until the 1960s, automobiles used DC dynamo generators with commutators. With the availability of affordable silicon diode rectifiers, alternators were used instead. They were first introduced by the Chrysler Corporation on the Valiant in 1960, several years ahead of Ford and GM. Alternators have several advantages over direct-current generators. They are lighter, cheaper and more rugged. They use slip rings providing greatly extended brush life over a commutator. The brushes in an alternator carry only excitation current, a small fraction of the current carried by the brushes of a DC generator, which carry the generator's entire output. A set of rectifiers (diode bridge) is required to convert AC to DC. To provide direct current with low ripple, a three-phase winding is used and the pole-pieces of the rotor are shaped (claw-pole) to produce a waveform similar to a square wave instead of a sinusoid. Automotive alternators are usually belt driven at 2-3 times crankshaft speed. The alternator runs at various RPM (which varies the frequency) since it is driven by the engine. This is not a problem because the alternating current is rectified to direct current.



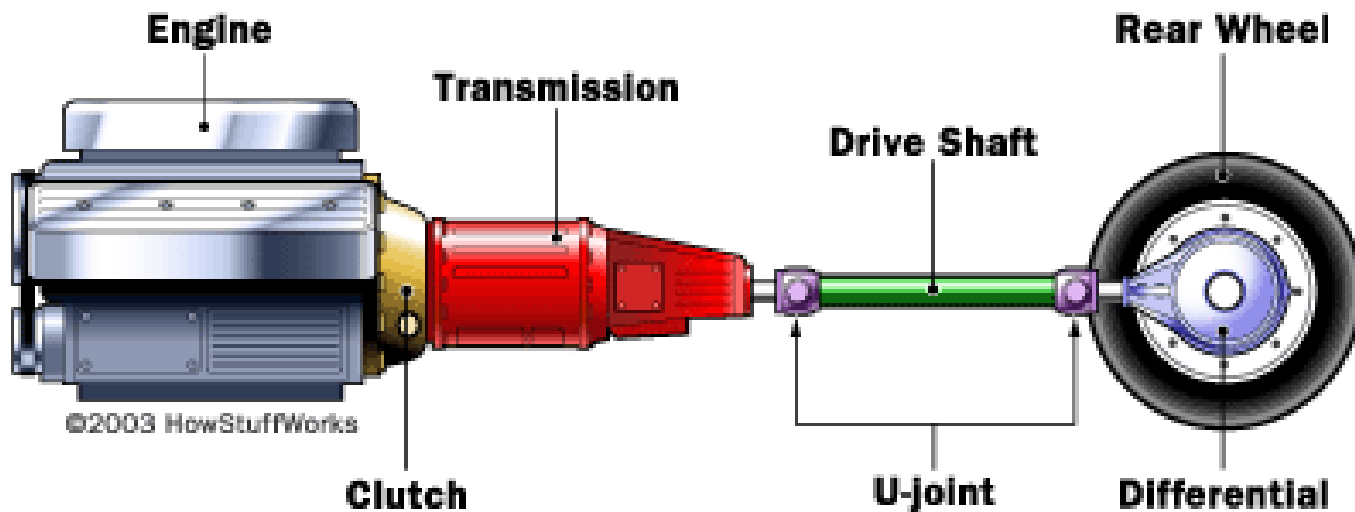
# **UNIT -3**



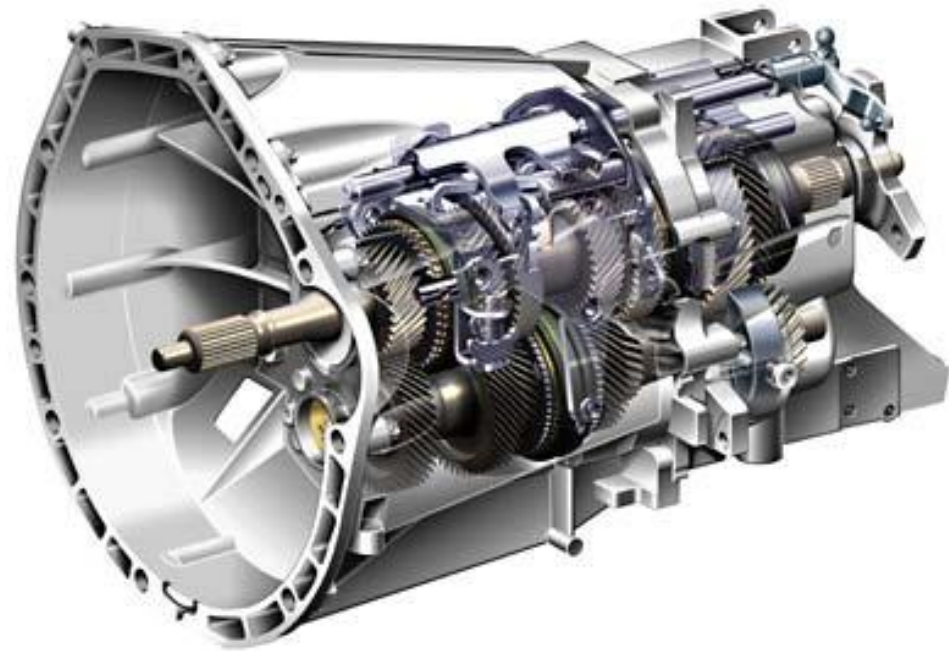
# **TRANSMISSION SYSTEM (GEAR BOX)**

- **Gear box:** Necessity for gear ratios in transmission, Synchronous gear boxes, 3, 4 and 5 speed gear boxes, Free Wheeling mechanism, Planetary gears systems, over drives, fluid coupling and torque converters, Epicyclic gear box, principle of automatic transmission, calculation of gear ratios

**Automotive Gears:** Gears play an important role in trucks, car, buses, motor bikes and even geared cycles. These gears control speed and include gears like ring and pinion, spiral gear, hypoid gear, hydraulic gears, reduction gearbox.



Depending on the size of the vehicles, the size of the gears also varies. There are low gears covering a shorter distance and are useful when speed is low. There are high gears also with larger number of teeth.



# Functions of Transmission

- To provide the high torque at the time of starting, hill climbing, accelerating and pulling a load since high tractive effort is needed
- It permits engine crankshaft to revolve at high speed, while the wheels turn at slower speeds
- Variable torque by set of gears
- Vehicle speed can be changed keeping engine speed same with certain limit

- The transmission also provides a neutral position so that the engine and the road wheels are disconnected even with the clutch in the engaged position
- A means to back the car by reversing the direction of rotation of the drive is also provided by the transmission

# Necessity of transmission

- Variation of resistance to the vehicle motion at various speeds
- Variation of tractive effort of the vehicle available at various speeds

# Types of Transmission

## □ Manual Transmission

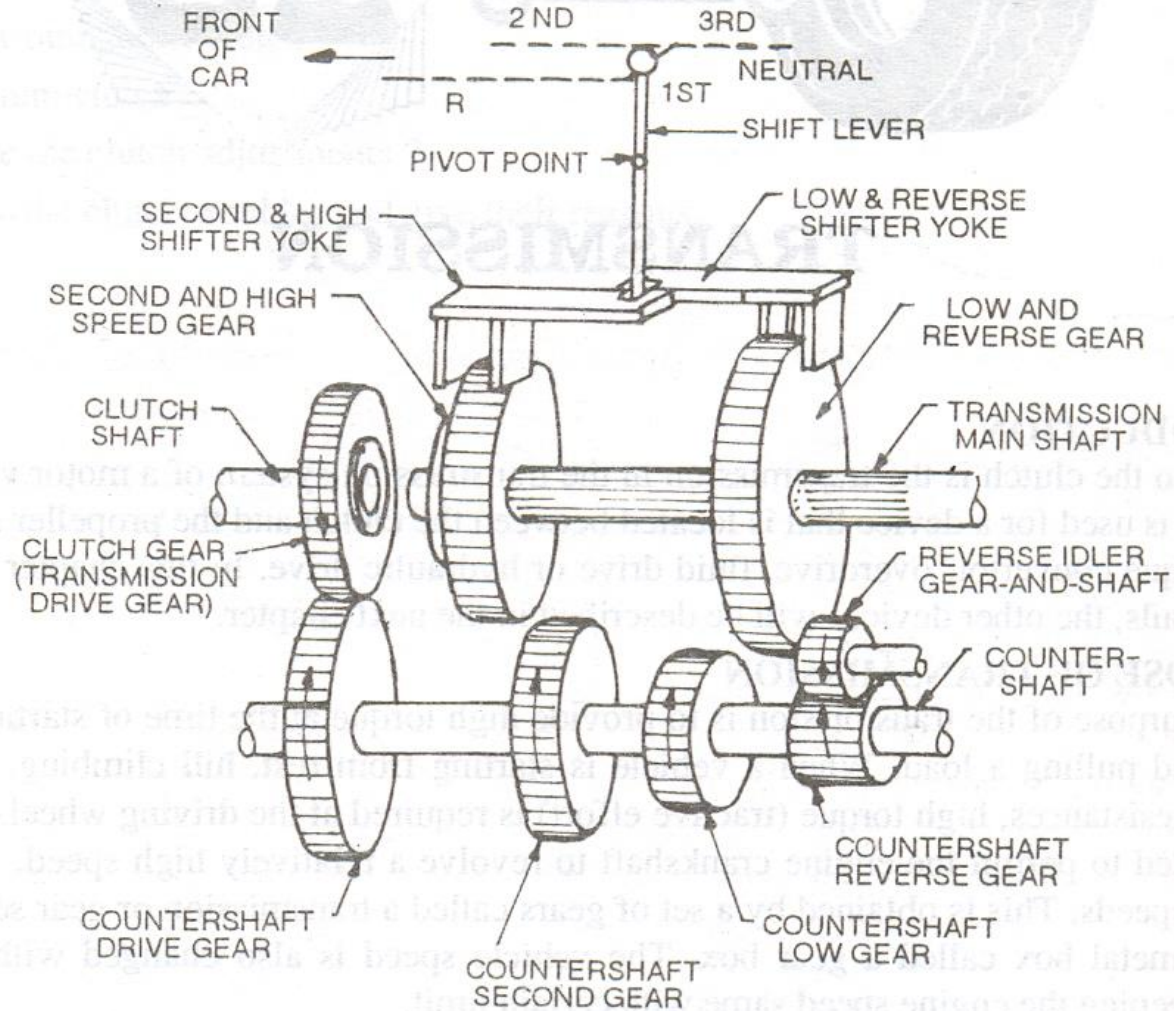
- Sliding Mesh Gear box
- Constant Mesh Gear box
- Synchromesh Gear box

## □ Automatic Transmission

- **Over drive (semi-automatic)**
  - Fluid drive or Fluid coupling
- **Fully automatic**
  - Epicyclic gear box
  - Free Wheeling unit
  - Torque Convertor

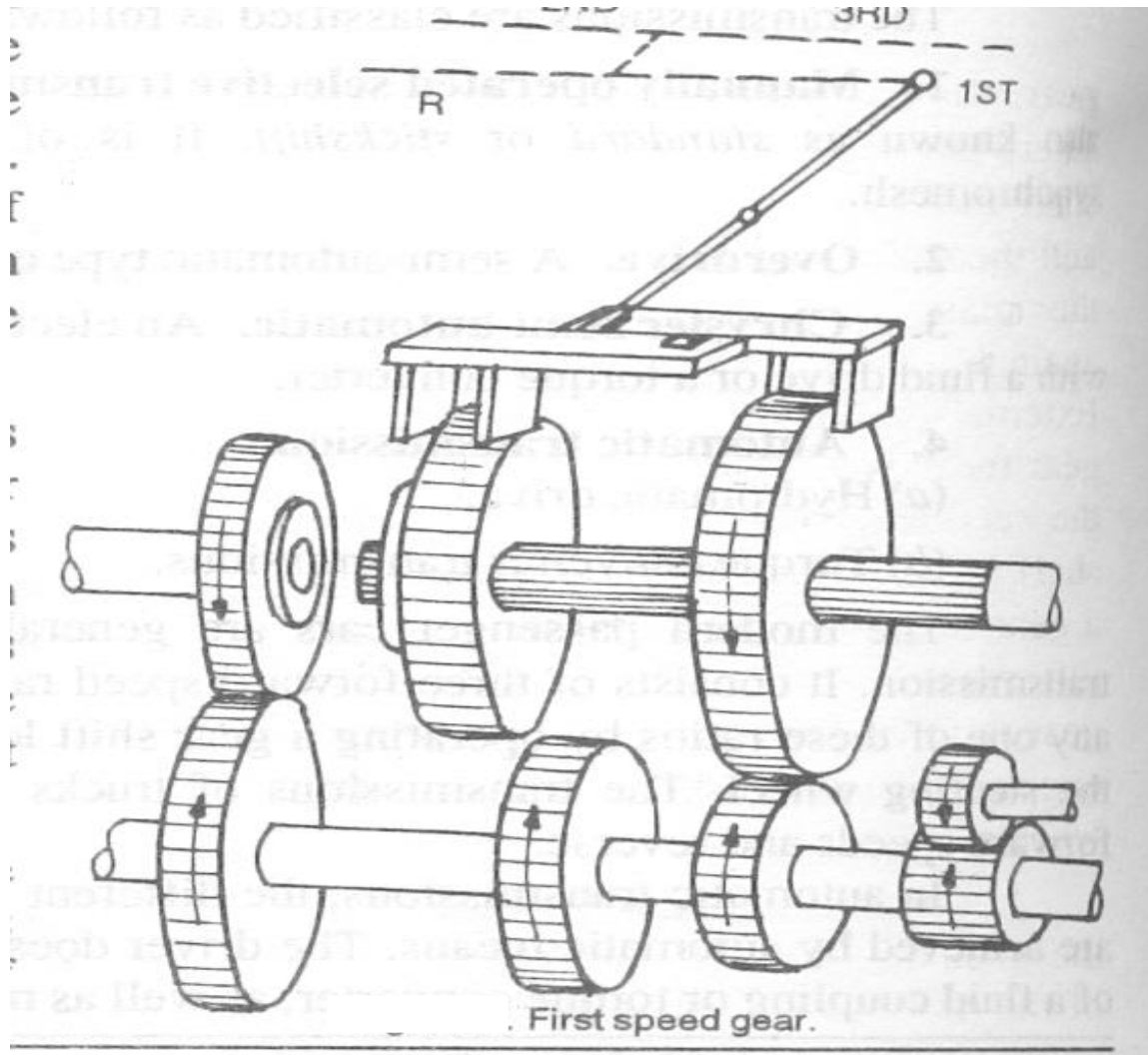


# Sliding mesh type of gear box

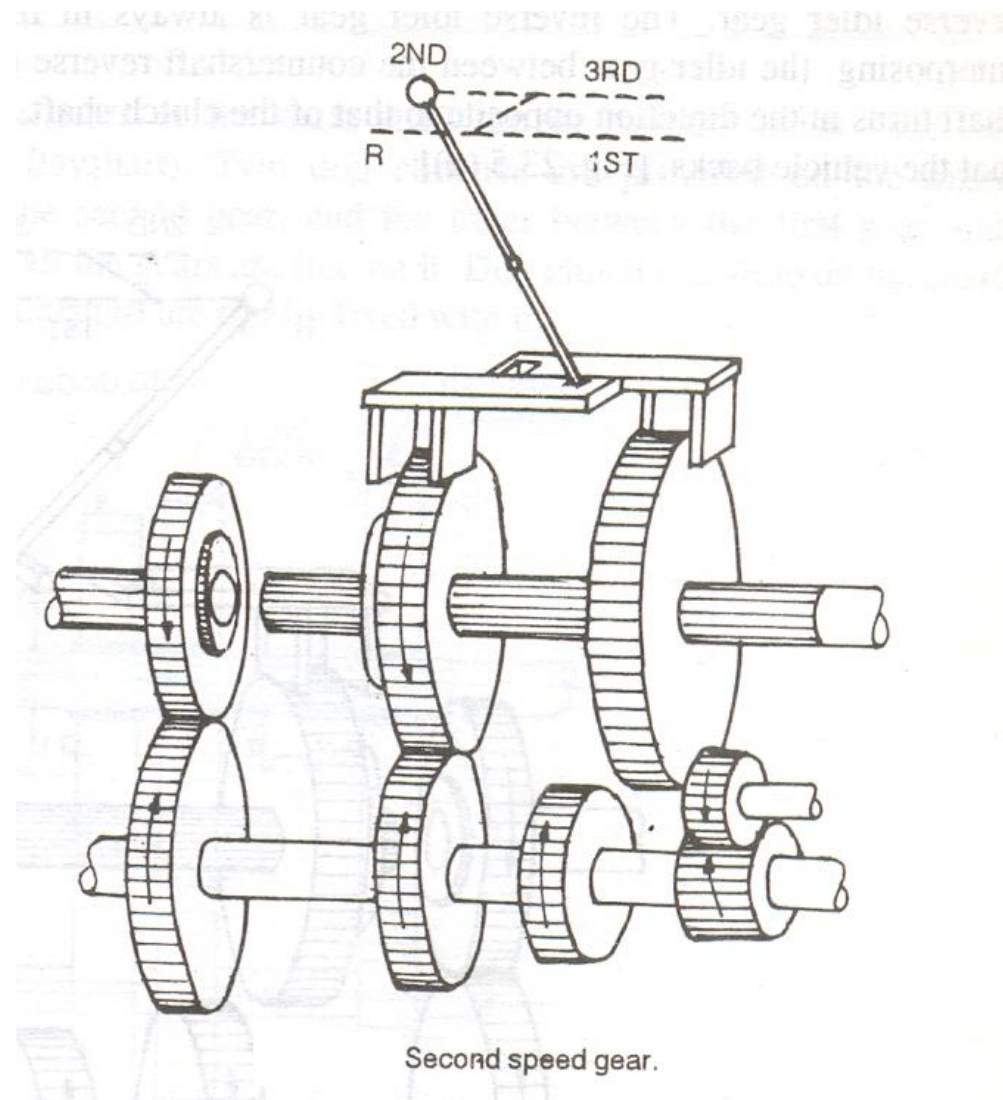


Sliding mesh gear box. (Gears in neutral).

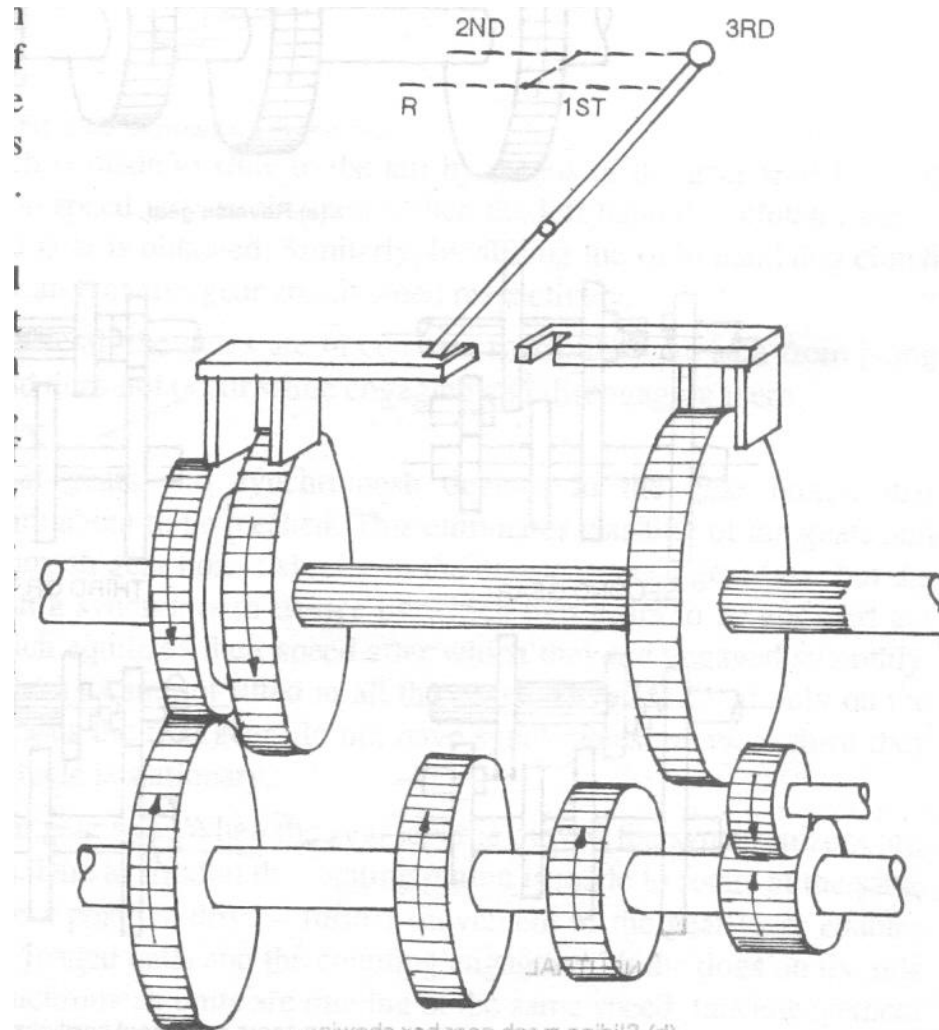
# Sliding mesh type of gear box



# Sliding mesh type of gear box



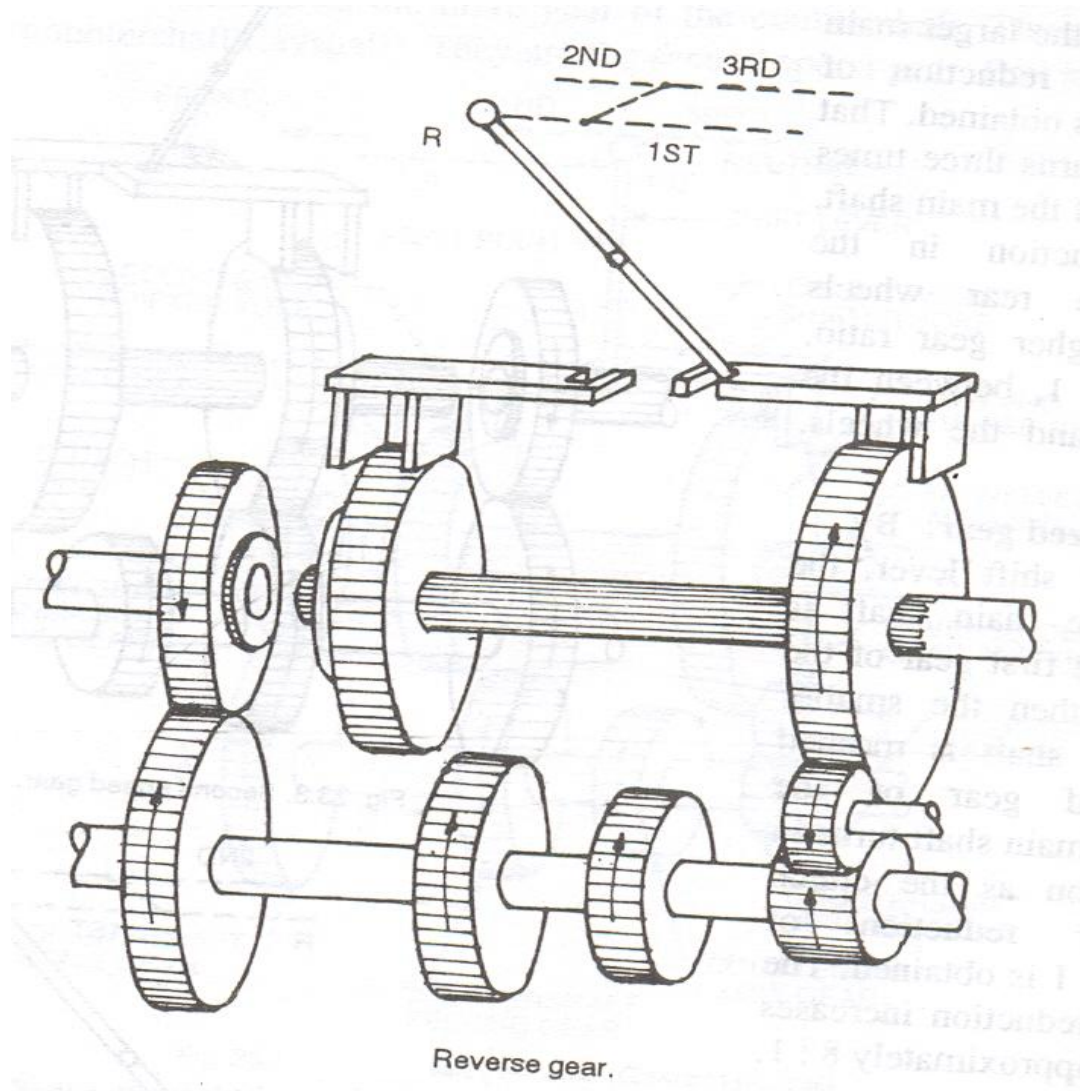
# Sliding mesh type of gear box



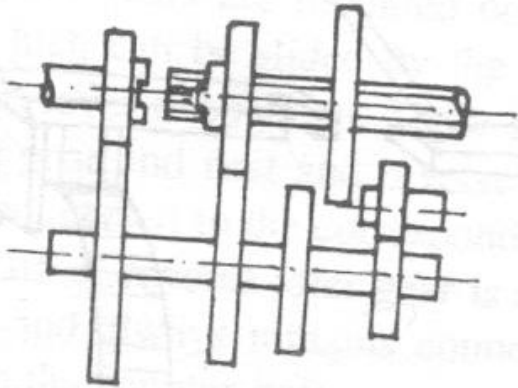
(b) Sliding mesh gear box showing gear  
Fig. 23.3

Third Speed gear.

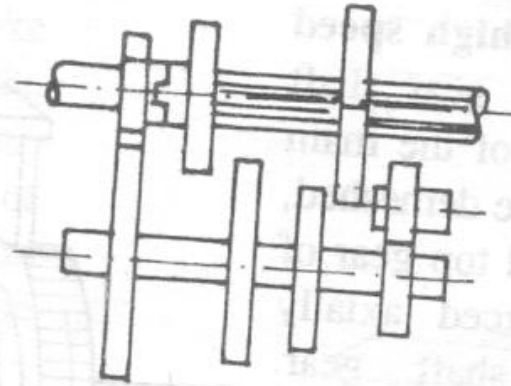
# Sliding mesh type of gear box



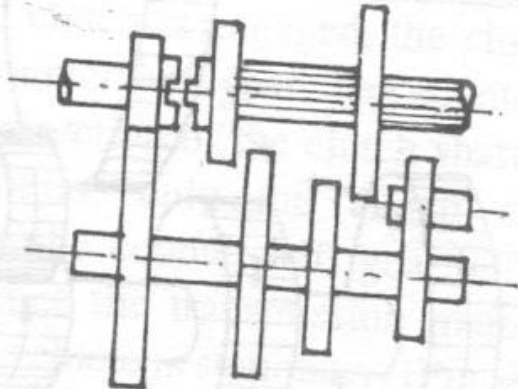
# Sliding mesh type of gear box



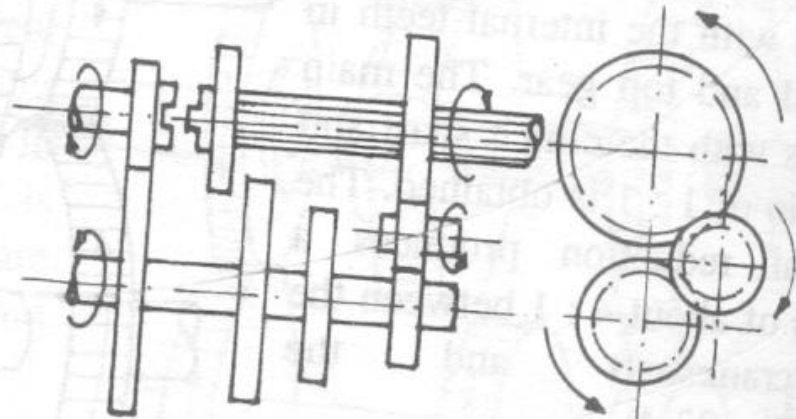
SECOND GEAR



THIRD OR TOP GEAR

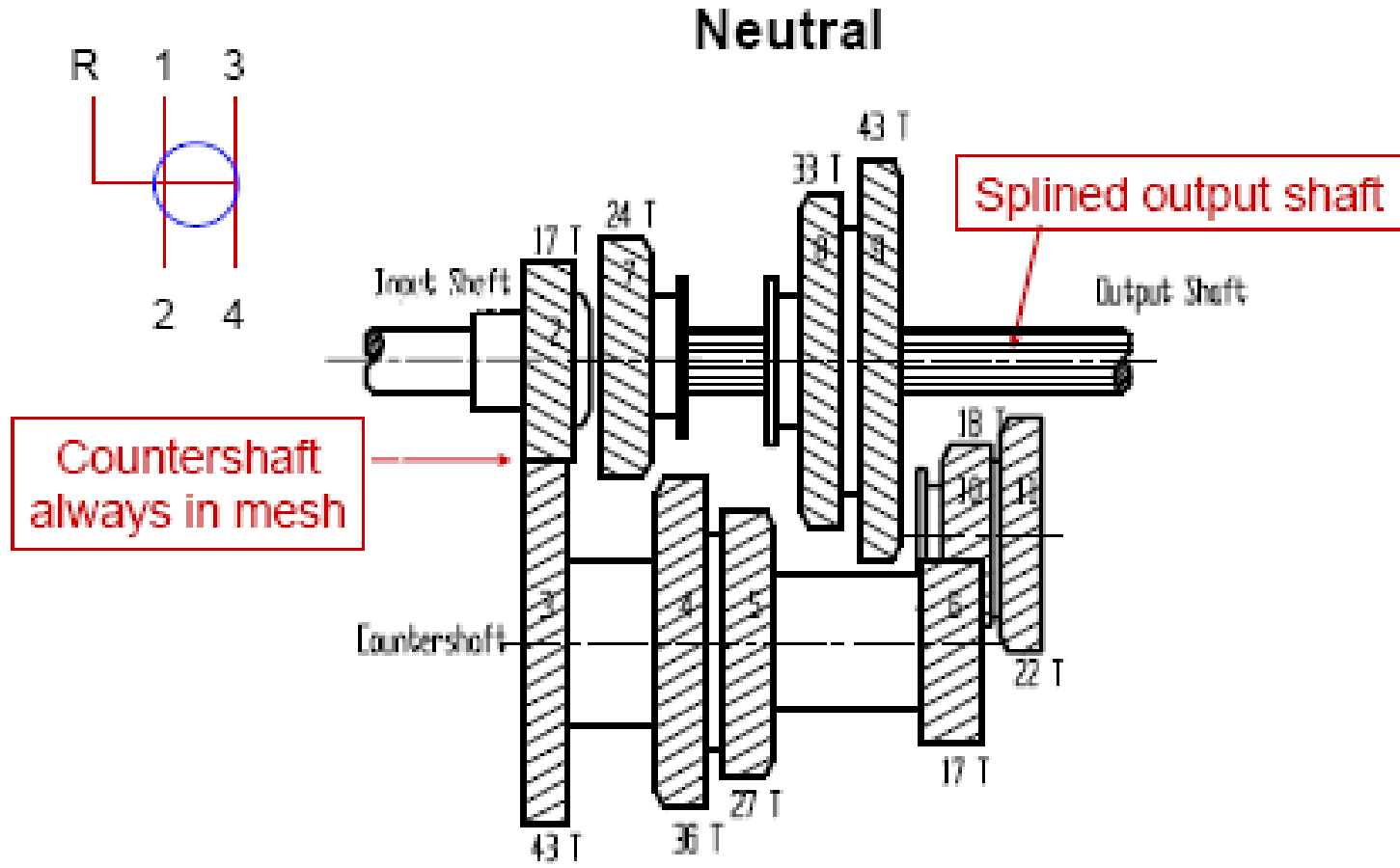


NEUTRAL

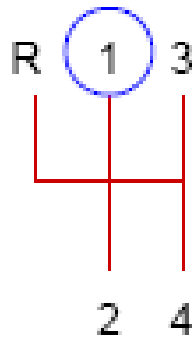


REVERSE

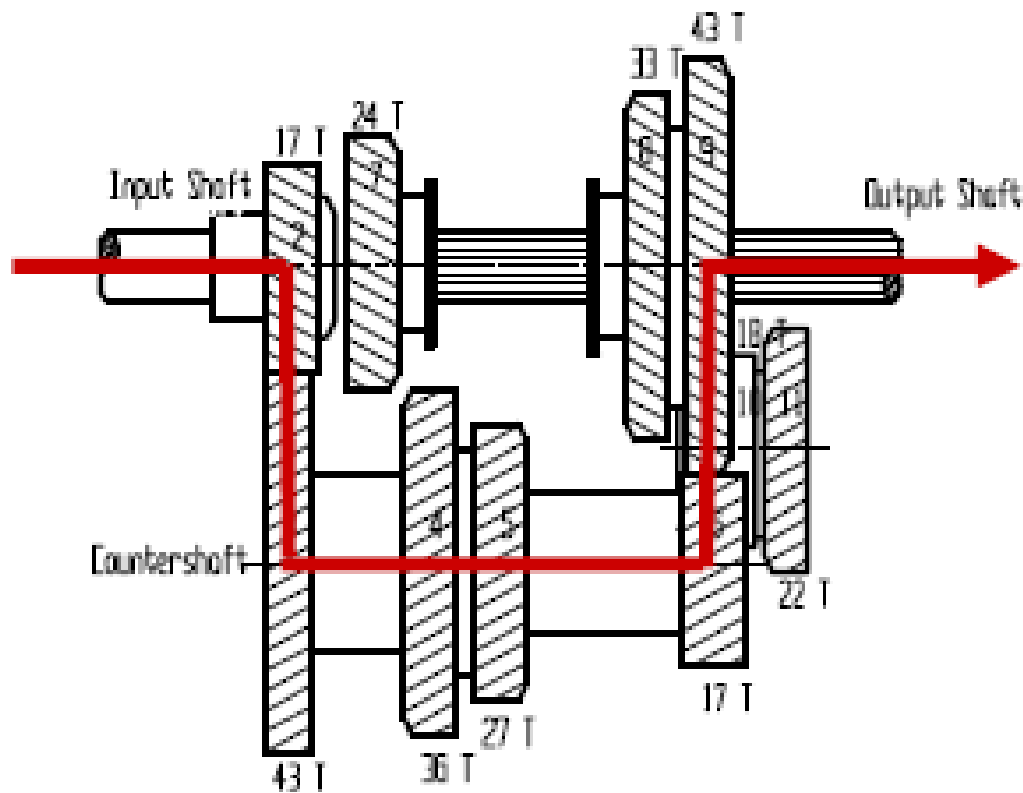
# Sliding mesh type of gear box



# Sliding mesh type of gear box

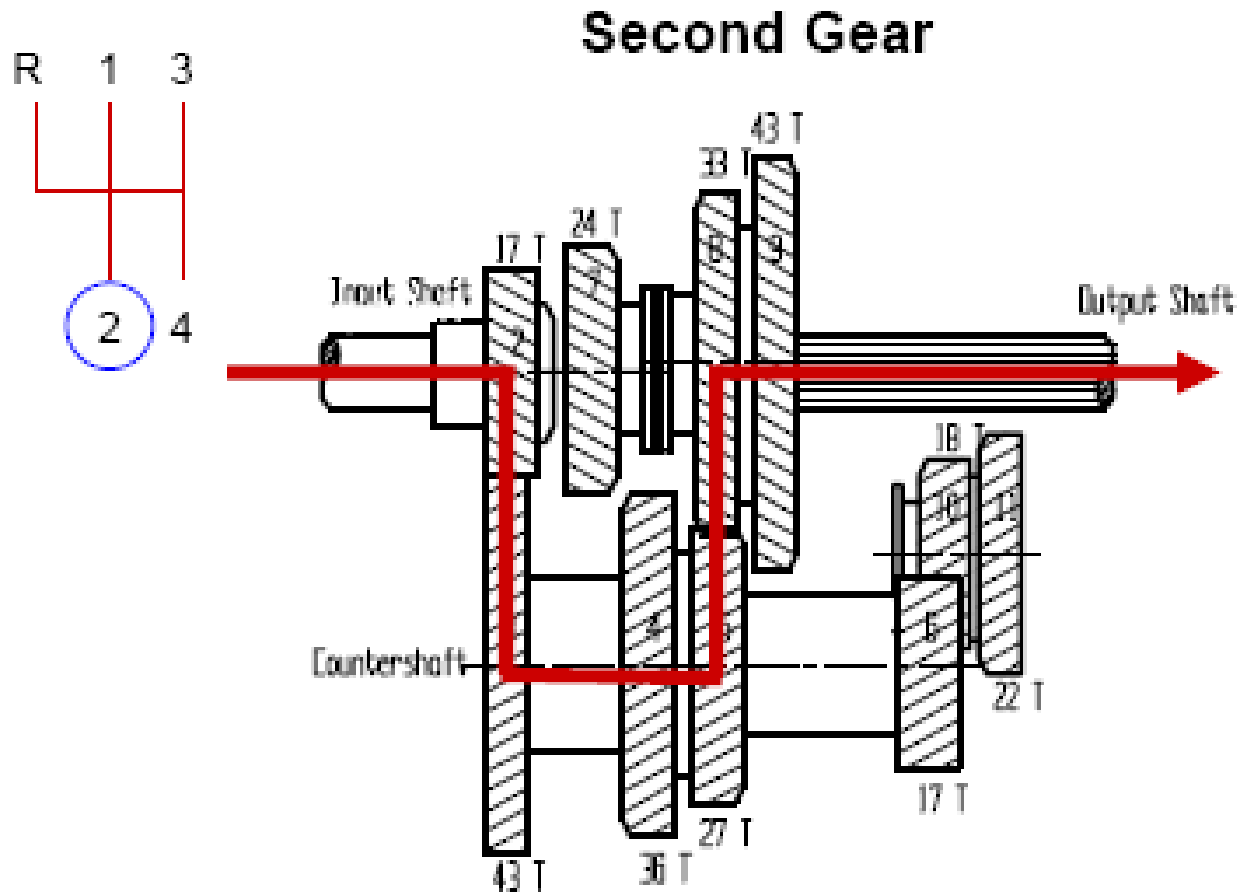


## First Gear

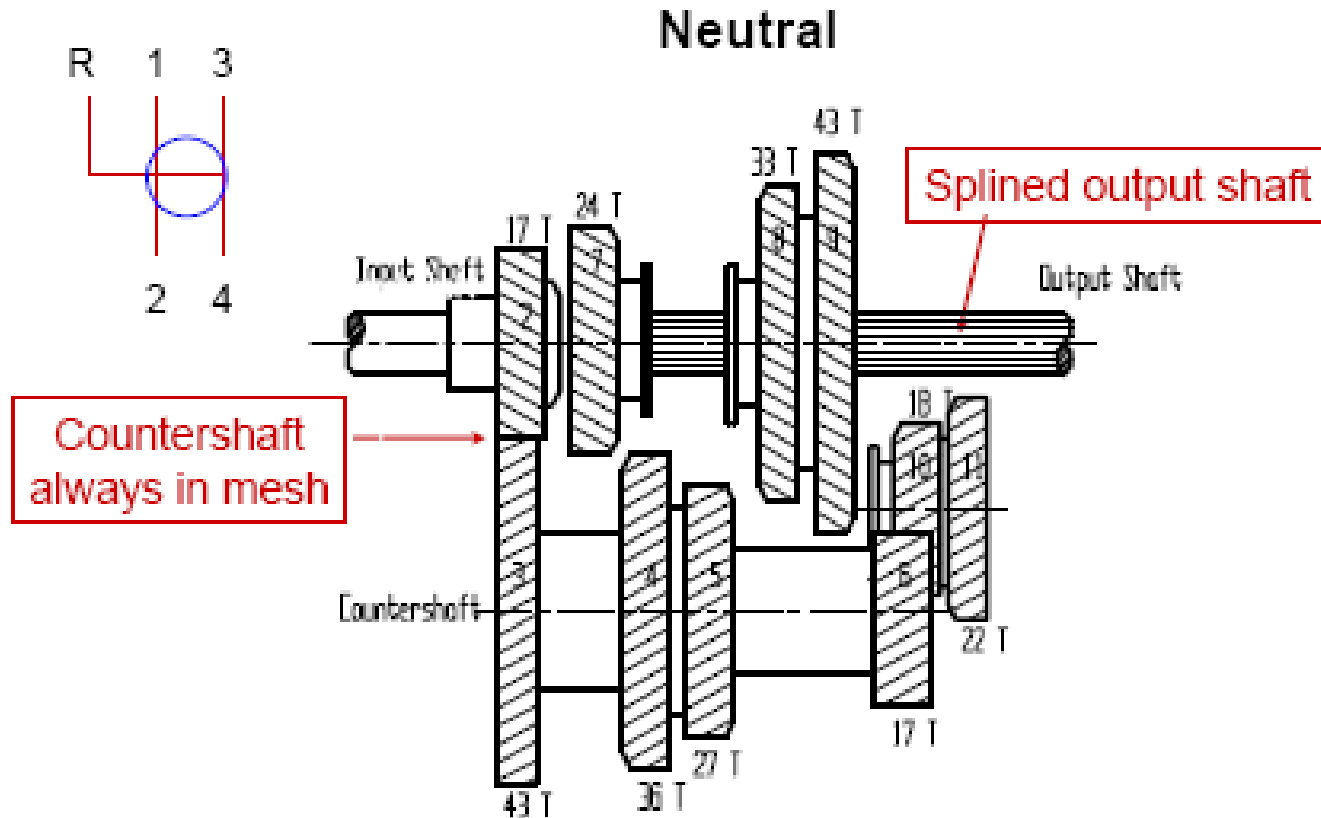




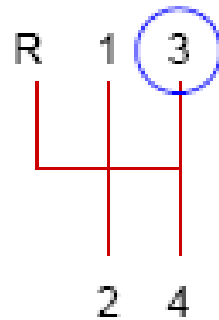
# Sliding mesh type of gear box



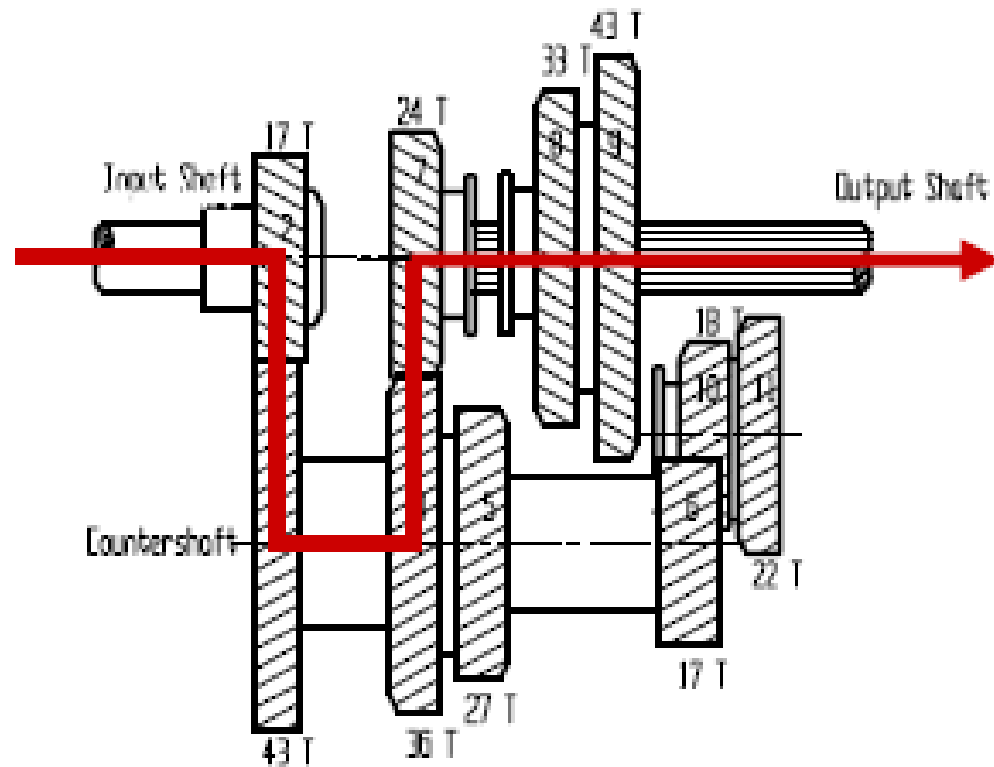
# Sliding mesh type of gear box



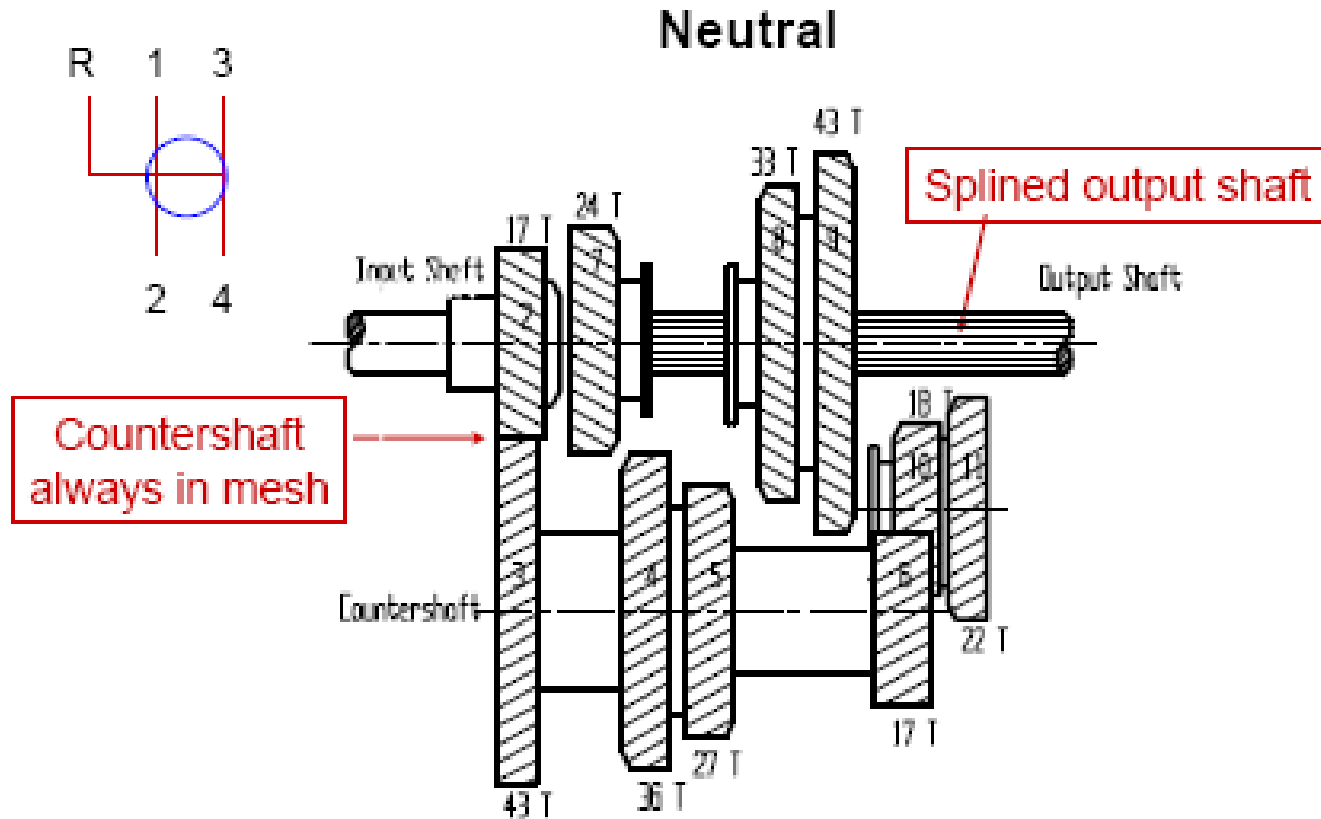
# Sliding mesh type of gear box



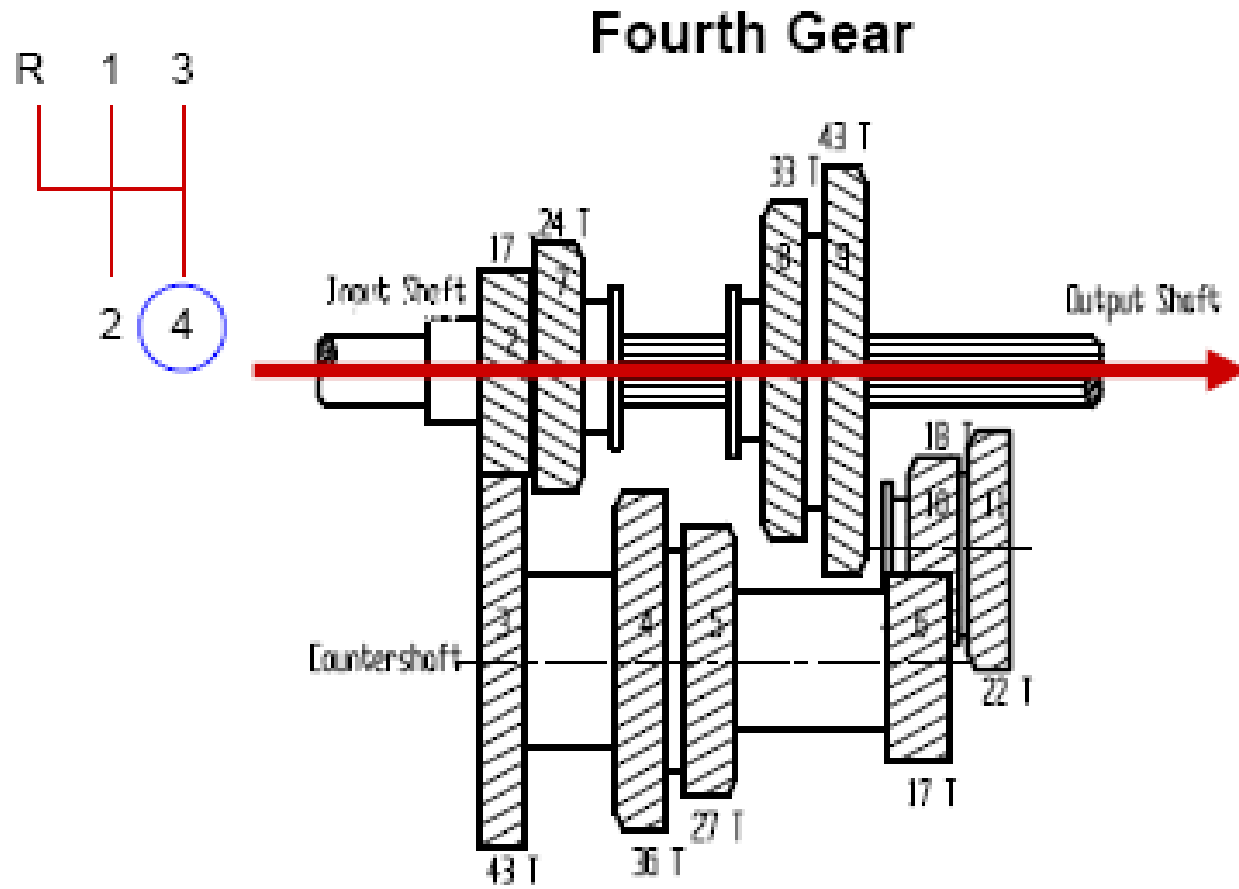
## Third Gear



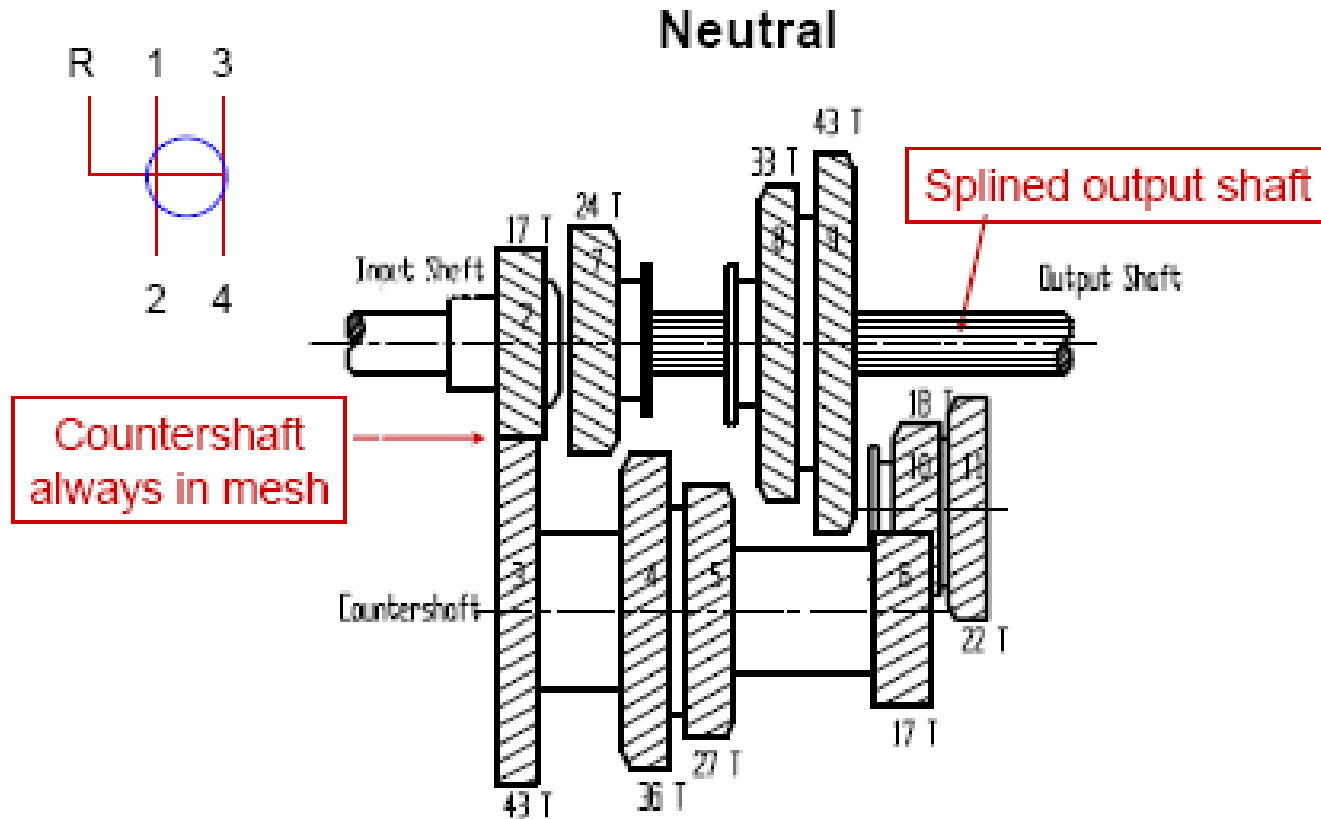
# Sliding mesh type of gear box



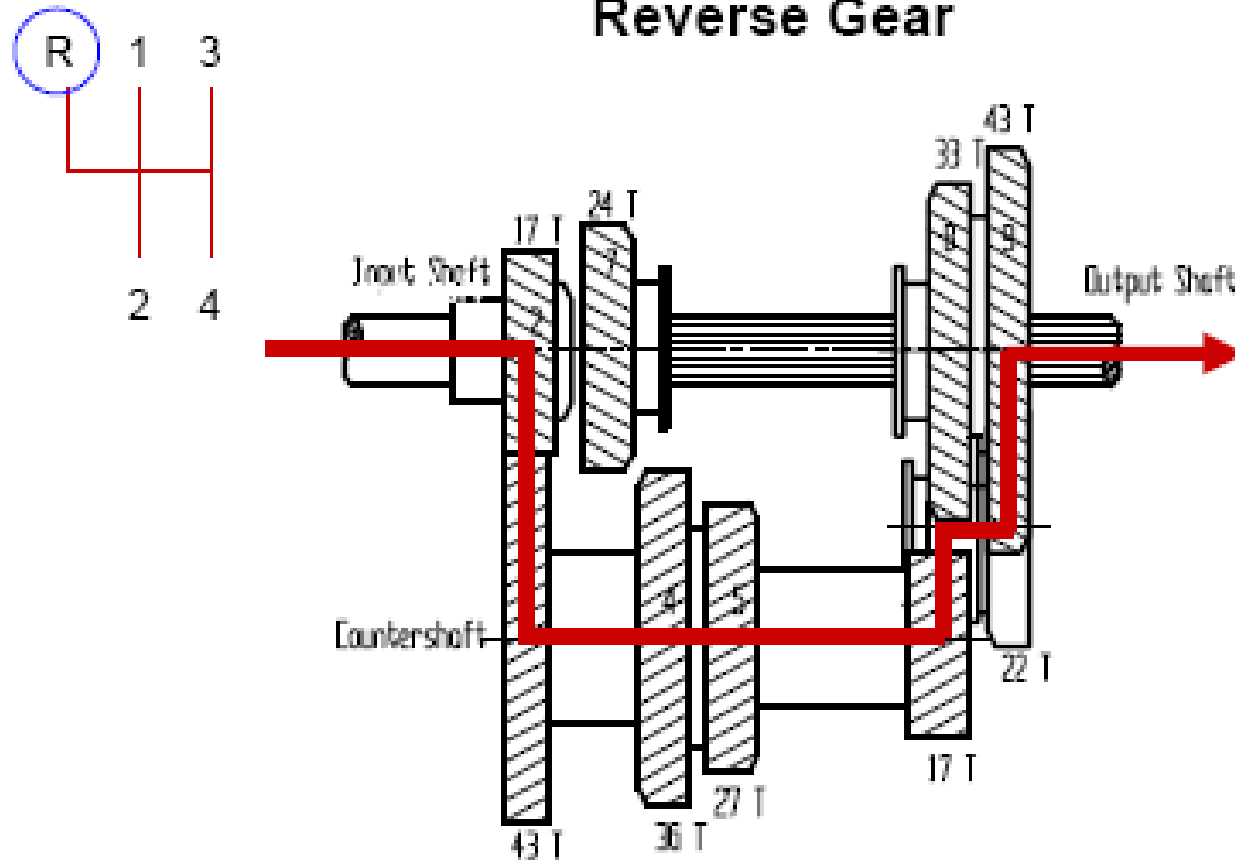
# Sliding mesh type of gear box



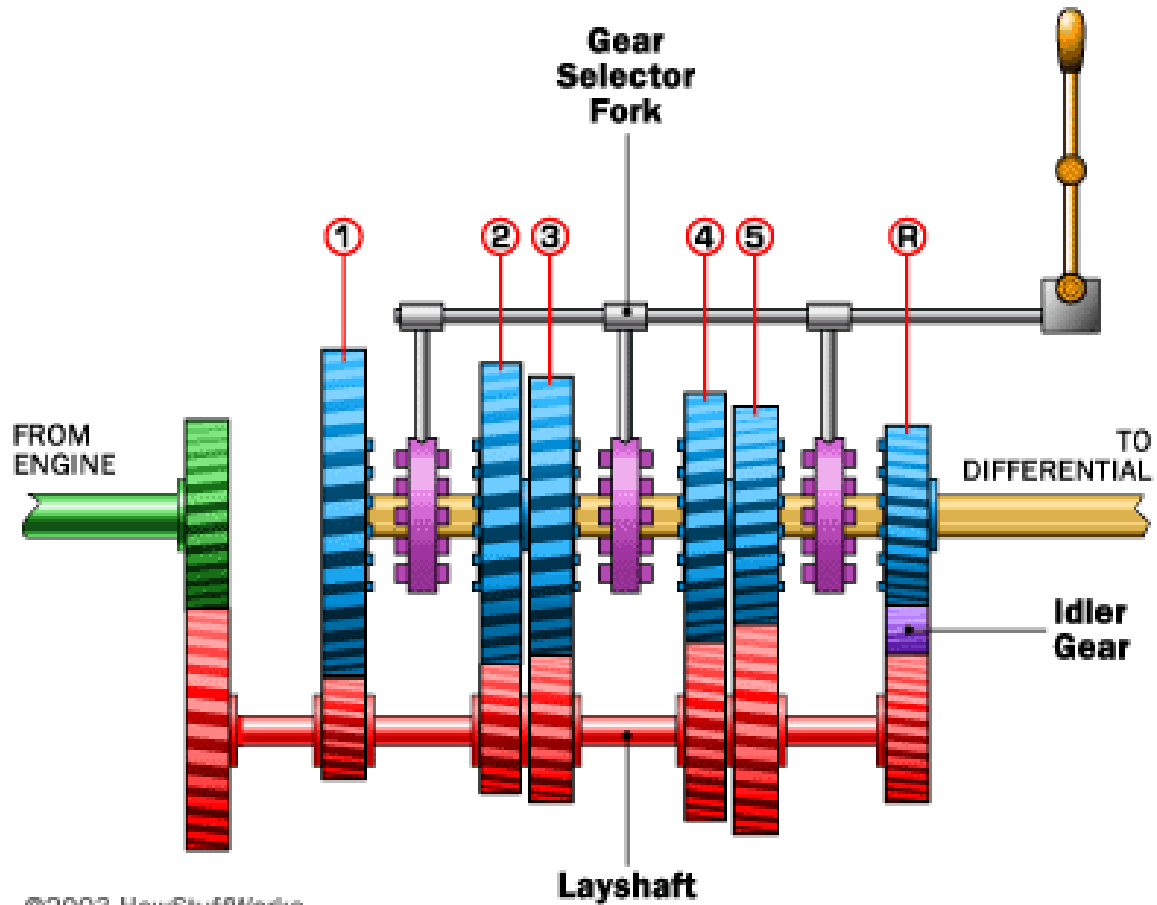
# Sliding mesh type of gear box



# Sliding mesh type of gear box

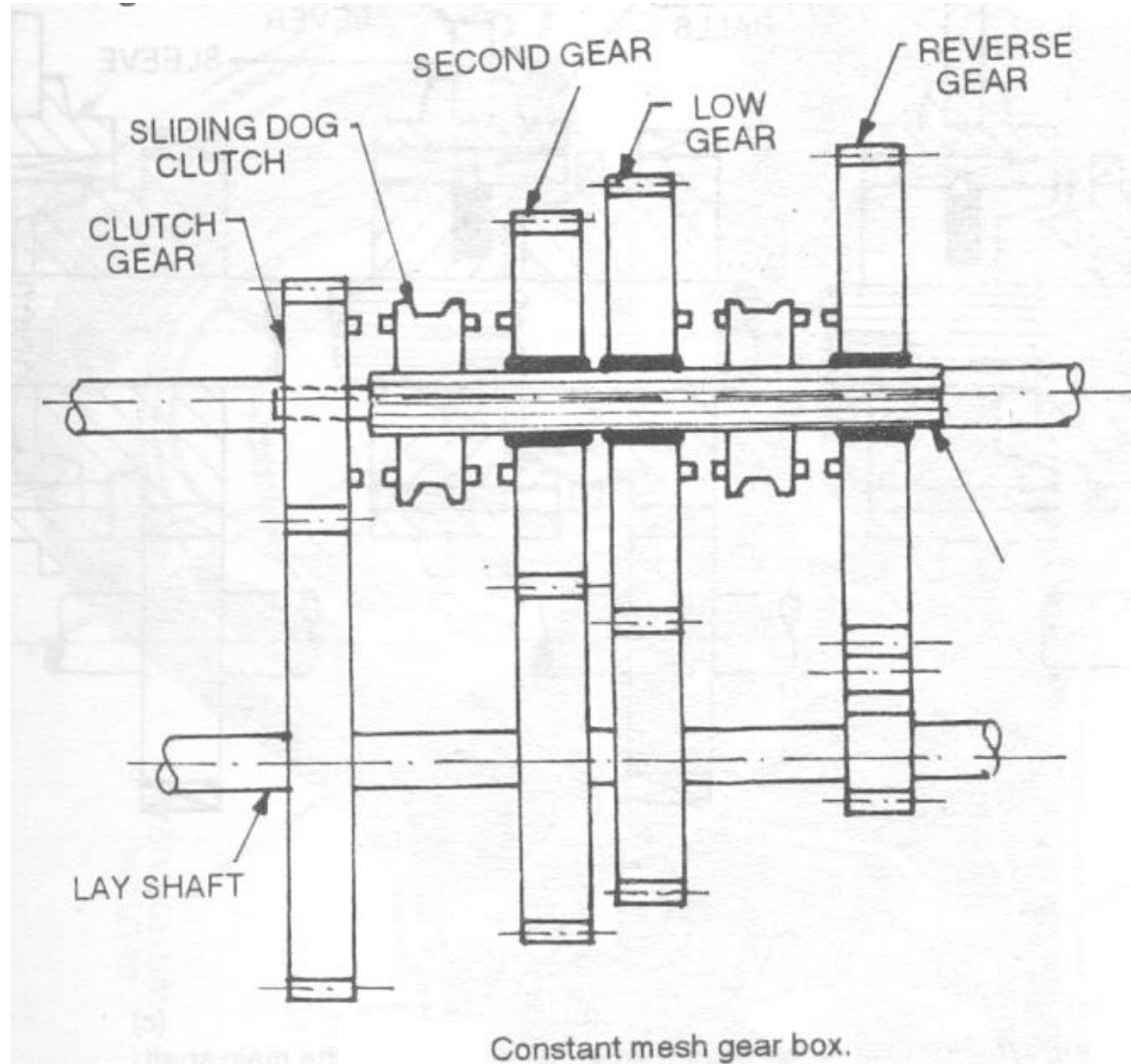


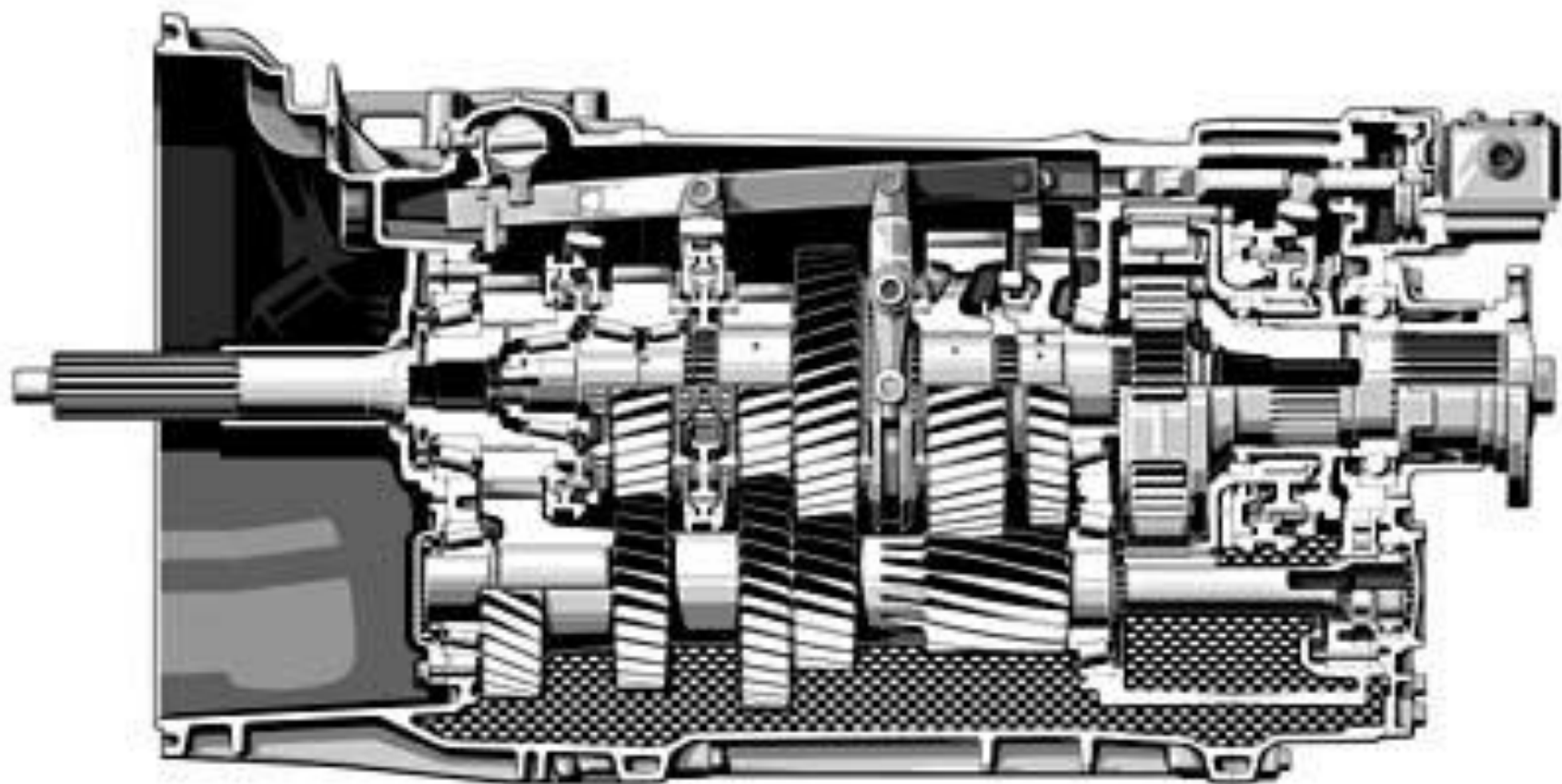
# Constant mesh gear box



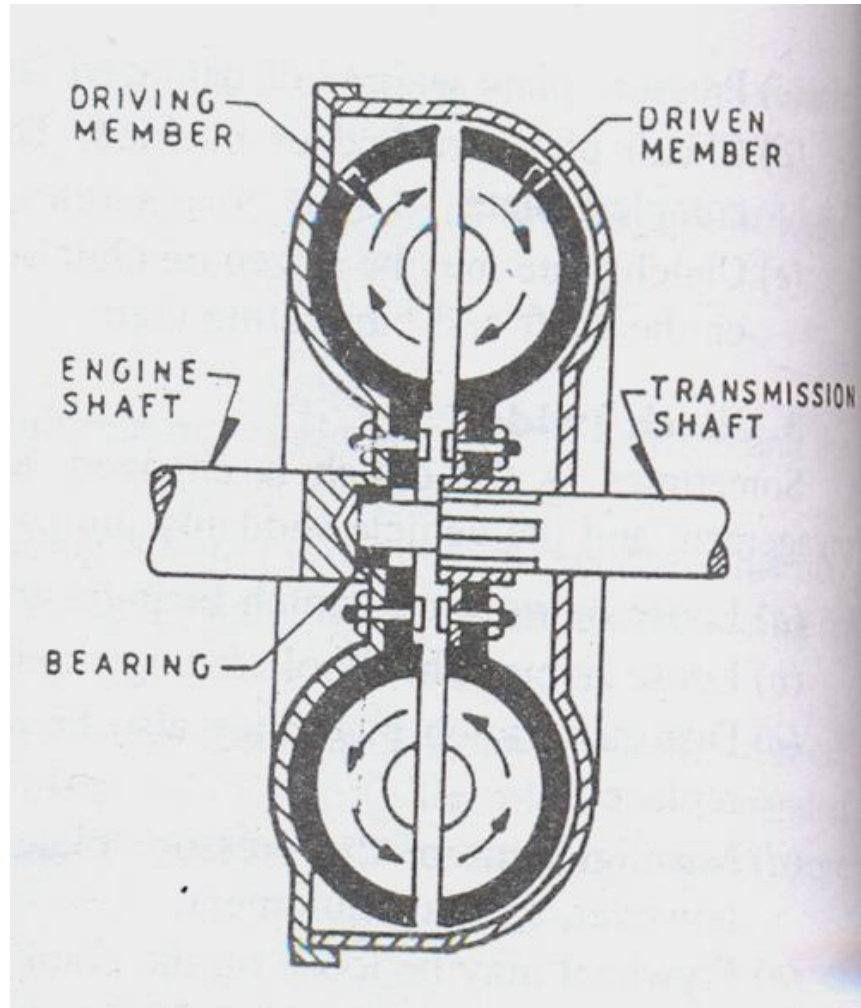


# Constant mesh gear box



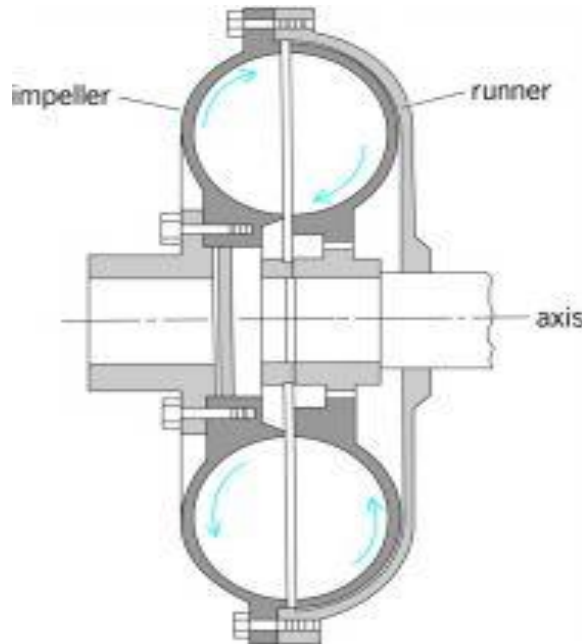


# Fluid flywheel or Hydraulic Coupling



# Fluid Coupling or Torque Converter

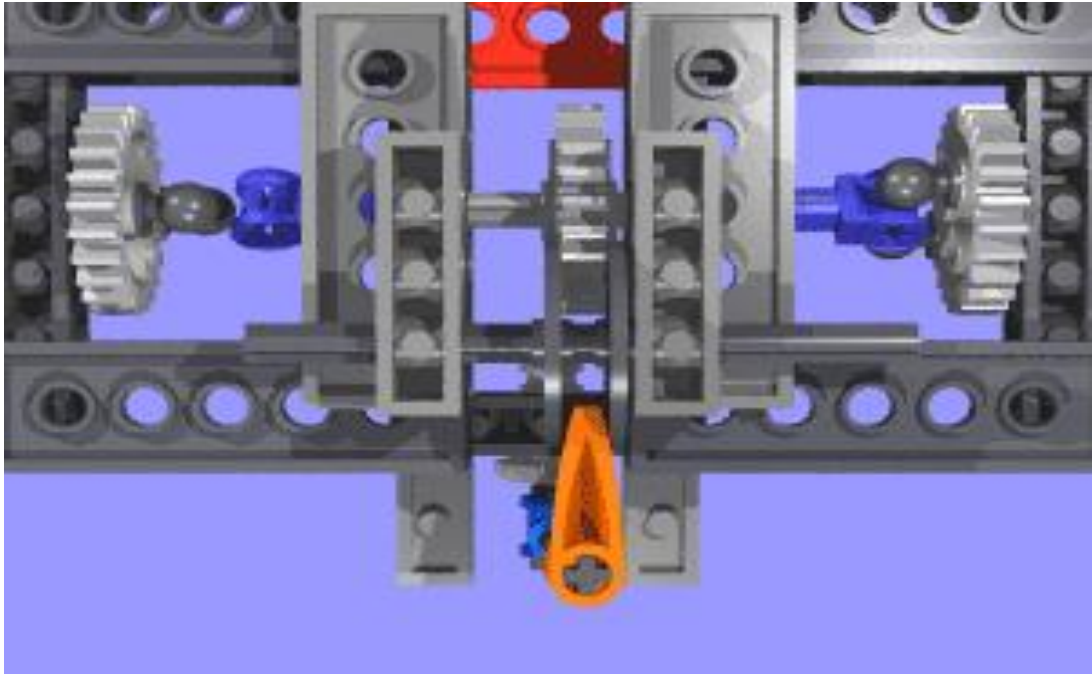
A **fluid coupling** is a hydrodynamic device used to transmit rotating mechanical power. It has been used in automobile transmission as an alternative to a mechanical clutch

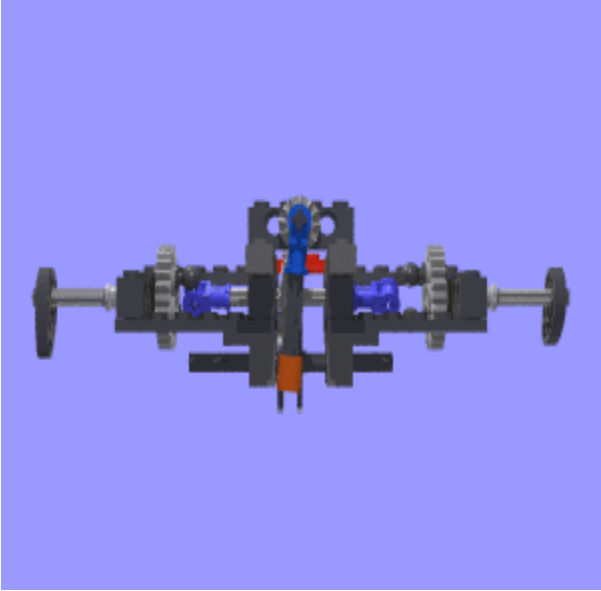


Fluid coupling consists of three components, plus the hydraulic fluid:

- The housing, also known as the *shell* (which must have an oil tight seal around the drive shafts), contains the fluid and turbines.
- Two turbines:
  - One connected to the input shaft; known as the *pump* or *impellor, primary wheel, input turbine, driving member*
  - The other connected to the output shaft, known as the *turbine, output turbine, secondary wheel or runner or driven member*

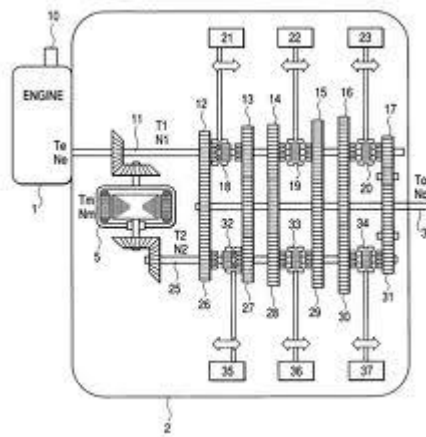
- The driving turbine, known as the 'pump', (or *driving torus*) is rotated by the [prime mover](#), which is typically an [internal combustion engine](#) or [electric motor](#). The impellor's motion imparts both outwards linear and rotational motion to the fluid.
- The hydraulic fluid is directed by the 'pump' whose shape forces the flow in the direction of the 'output turbine' (or *driven torus*). Here, any difference in the angular velocities of 'input stage' and 'output stage' result in a net force on the 'output turbine' causing a torque; thus causing it to rotate in the same direction as the pump.
- The motion of the fluid is effectively [toroidal](#) - travelling in one direction on paths that can be visualised as being on the surface of a [torus](#):
- If there is a difference between input and output angular velocities the motion has a component which is circular (i.e. round the rings formed by sections of the torus)
- If the input and output stages have identical angular velocities there is no net centripetal force - and the motion of the fluid is circular and co-axial with the axis of rotation (i.e. round the edges of a torus), there is no flow of fluid from one turbine to the other.

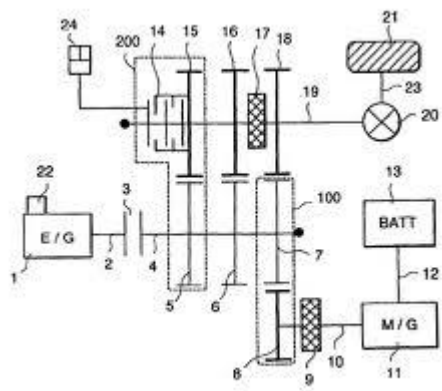




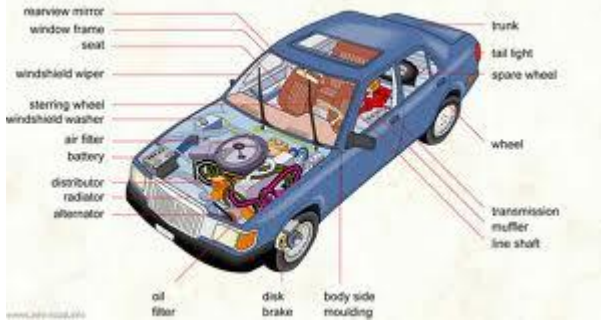


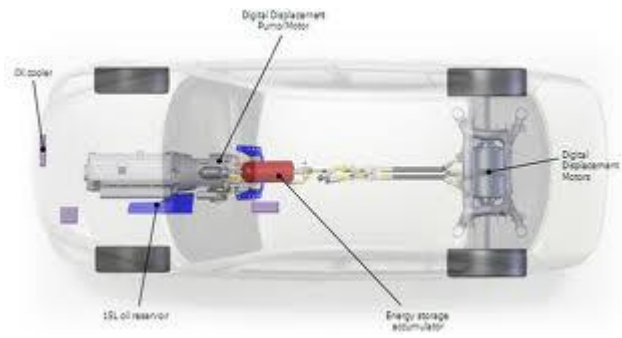
The figure shows the power transmission system of an automobile. The motion of the crank shaft is transmitted through the clutch to the gear box. From the gear box the motion is transmitted to the propeller shaft through the universal joint and then to differential through another universal joint. Finally power transmitted to the rear wheels through the rear axle.

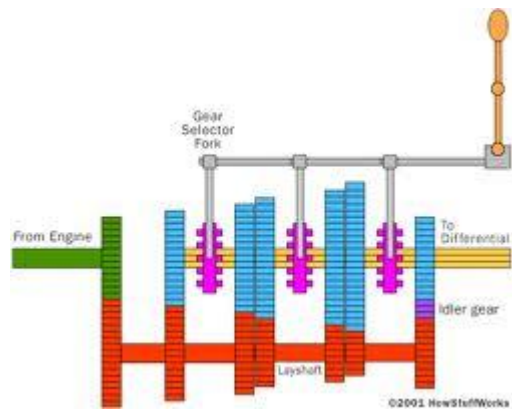




**ANATOMY OF AN AUTOMOBILE**

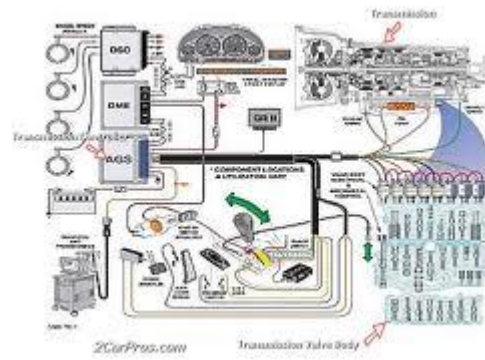






automobile systems: main parts







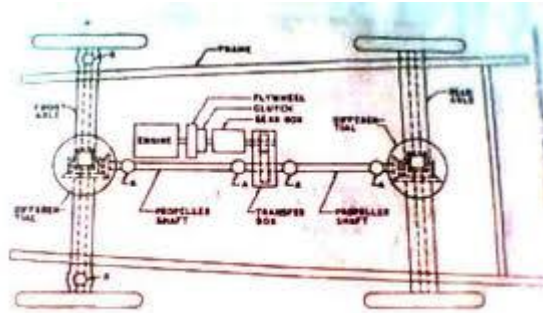
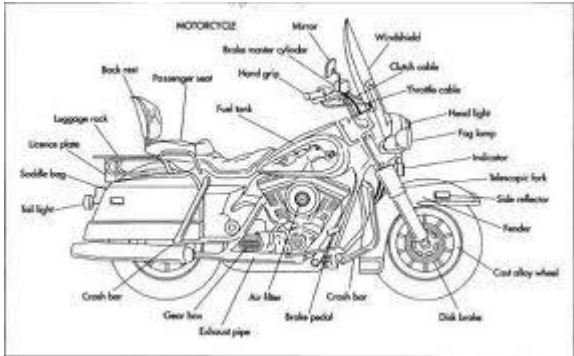
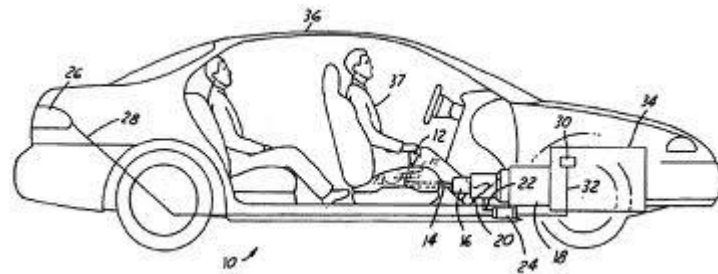
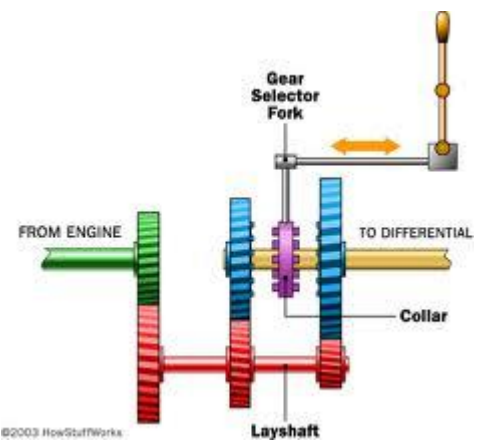
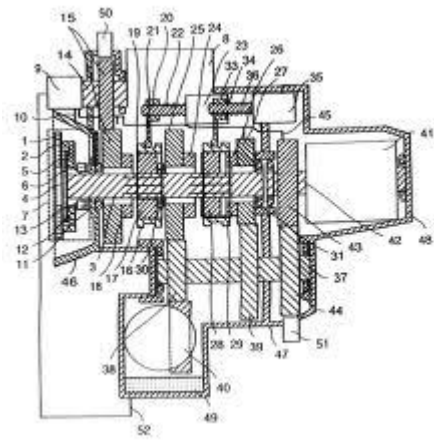


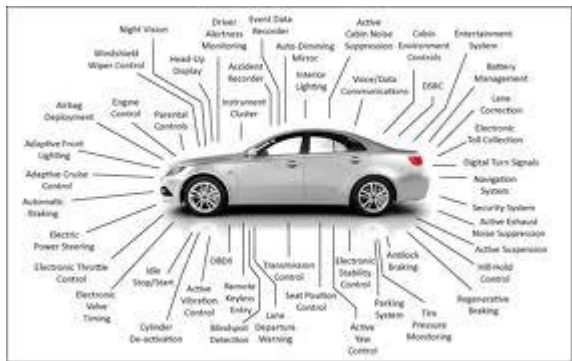
Fig. Layout of the transmission system of a four wheel drive automobile.

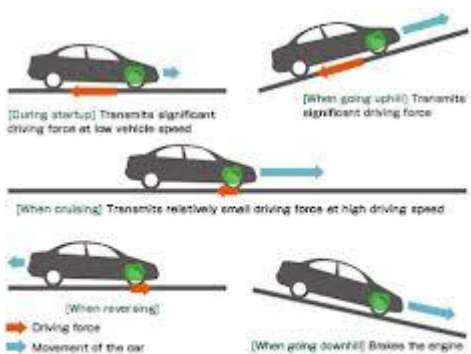






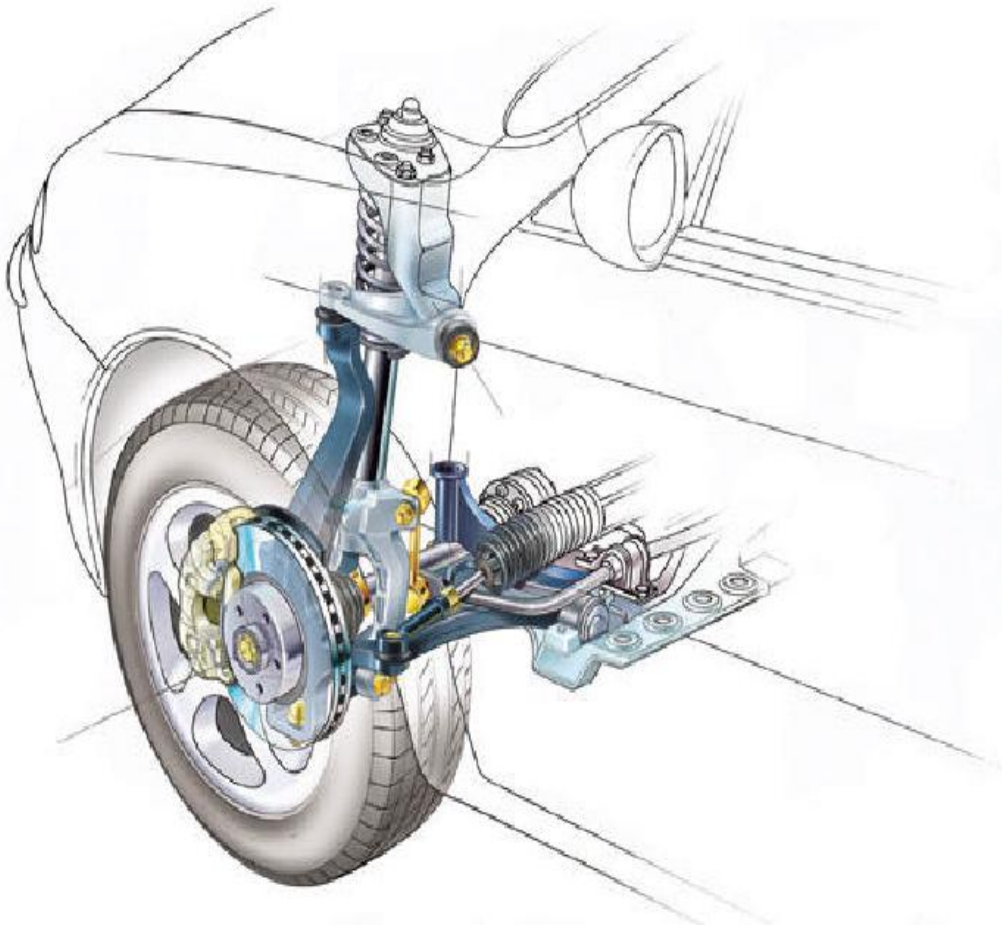






Since the torque (power) and speed of the engine are limited, the transmission ensures that the necessary torque and number of revolutions are achieved in order for the car to travel comfortably. It aids the vehicle in traveling powerfully during startup, when going uphill, accelerating quickly on highways and traveling at cruising speeds. It is also effective in helping the vehicle reverse and in braking the engine when the vehicle goes downhill.

# Suspension system in automobiles

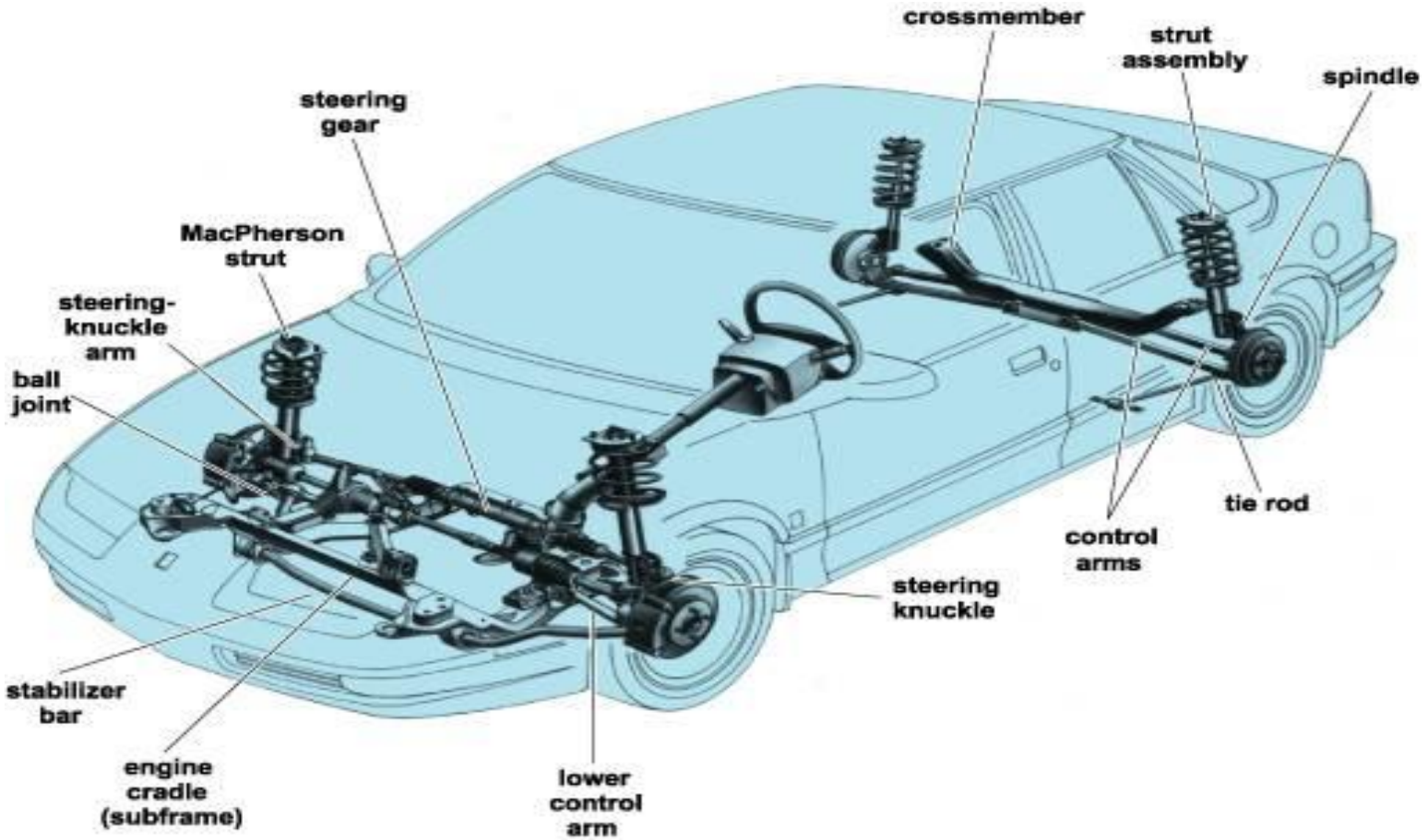




# What is suspension system

- **Suspension** is the term given to the system of springs, shock absorbers and linkages that connects a vehicle to its wheels
- Serve a dual purpose – contributing to the car's handling and braking.
- Protects the vehicle itself and any cargo or luggage from damage and wear

# SUSPENSION SYSTEM – LAY OUT



# Different suspension systems

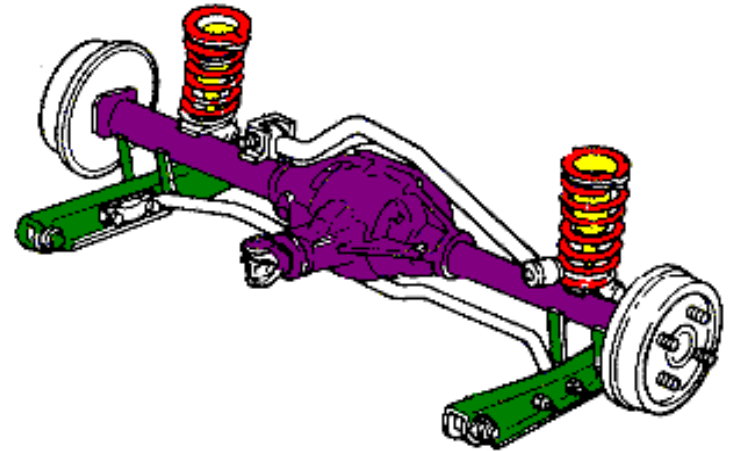
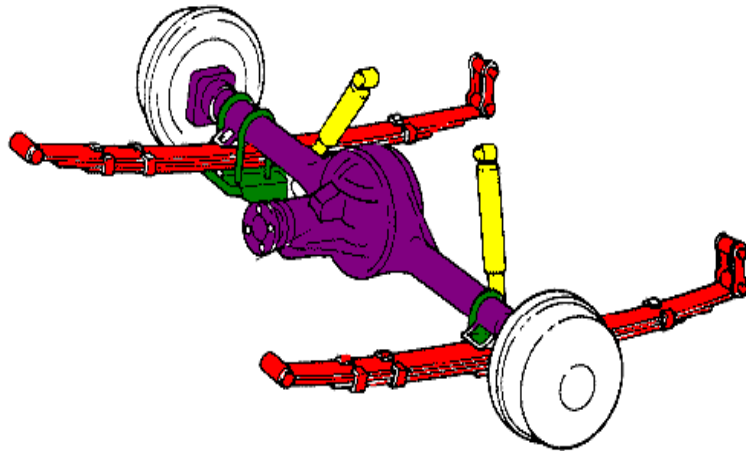
- Conventional suspension system
- Independent suspension system
- Air suspension system
- Hydro elastic suspension system

# Conventional suspension system

- Two wheels are mounted on either side of the rigid axle
- When one wheel encounters the bump, both the wheel do not execute parallel up and down motion
- So it gives rise to gyroscopic effect and wheel wobble
- Rear driving wheels mounted on live axle suspended by laminated leaf springs and shock absorbers



D97/6991



# Independent suspension system

- Both the front and the rear wheel are utilized
- Design incorporated in the front wheels
- One wheel goes down ,the other wheel does not have much effect
- Basic classification of the design
  - 1. MacPherson Strut**
  - 2. Double Wishbone**
  - 3. Multi link**

## MACPHERSON STRUT

- the most widely used front suspension system in cars
- comprises of a strut-type spring and shock absorber combo, which pivots on a ball joint on the single, lower arm.
- The steering gear is either connected directly to the lower shock absorber housing, or to an arm from the front or back of the spindle (in this case
- When you steer, it physically twists the strut and shock absorber housing (and consequently the spring) to turn the wheel



# DOUBLE WISHBONE SUSPENSION

Type of *double-A* or *double wishbone* suspension

Wheel spindles are supported by an upper and lower 'A' shaped arm.

The lower arm carries most of the load.

If you look head-on at this type of system, parallelogram system that allows the spindles to travel vertically up and down.

This side-to-side motion is known as scrub



- Type of *double-A arm* suspension although the lower arm in these systems can sometimes be replaced with a single solid arm (as in my picture).
- The spring/shock combo is moved from between the arms to above the upper arm.
- This transfers the load-bearing capability of the suspension almost entirely to the upper arm and the spring mounts.
- The lower arm in this instance becomes a control arm.

# Multi-link suspension

- It's currently being used in the Audi A8 and A4 amongst other cars.
- The basic principle of it is the same, but instead of solid upper and lower wishbones, each 'arm' of the wishbone is a separate item.
- These are joined at the top and bottom of the spindle thus forming the wishbone shape.
- The super-weird thing about this is that as the spindle turns for steering, it alters the geometry of the suspension by torquing all four suspension arms.
- Spring is separate from the shock absorber.



# Advantages ( independent front )

- Bigger deflection of front wheels, no reaction on steering
- Greater distance for resisting rolling action
- Front axle (small-stub), improves road holding tendency of tyres.
- Minimum vibrations

## DISADVANTAGES

- Better shock absorber required.
- Expensive
- Tyre wear increases due to transmission of torque.

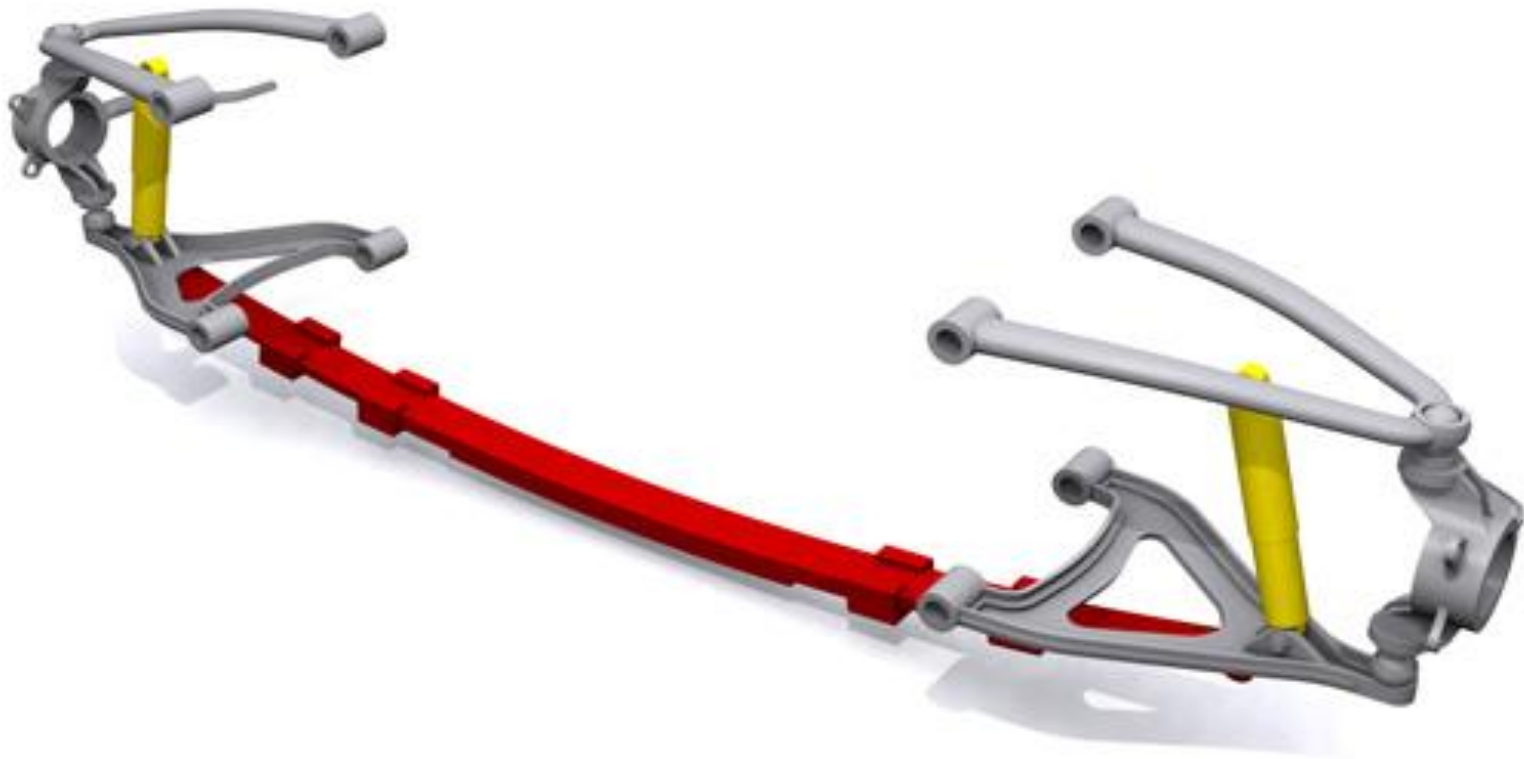
## Advantages ( independent rear suspension)

- Lesser unsprung weight – improves ride , reduces tyre wear.
- Increased passenger space
- Rear wheels remain stable ..

## DISADVANTAGES

- Increased cost
- Complicated design
- Steering action is not proper

# Traverse suspension system

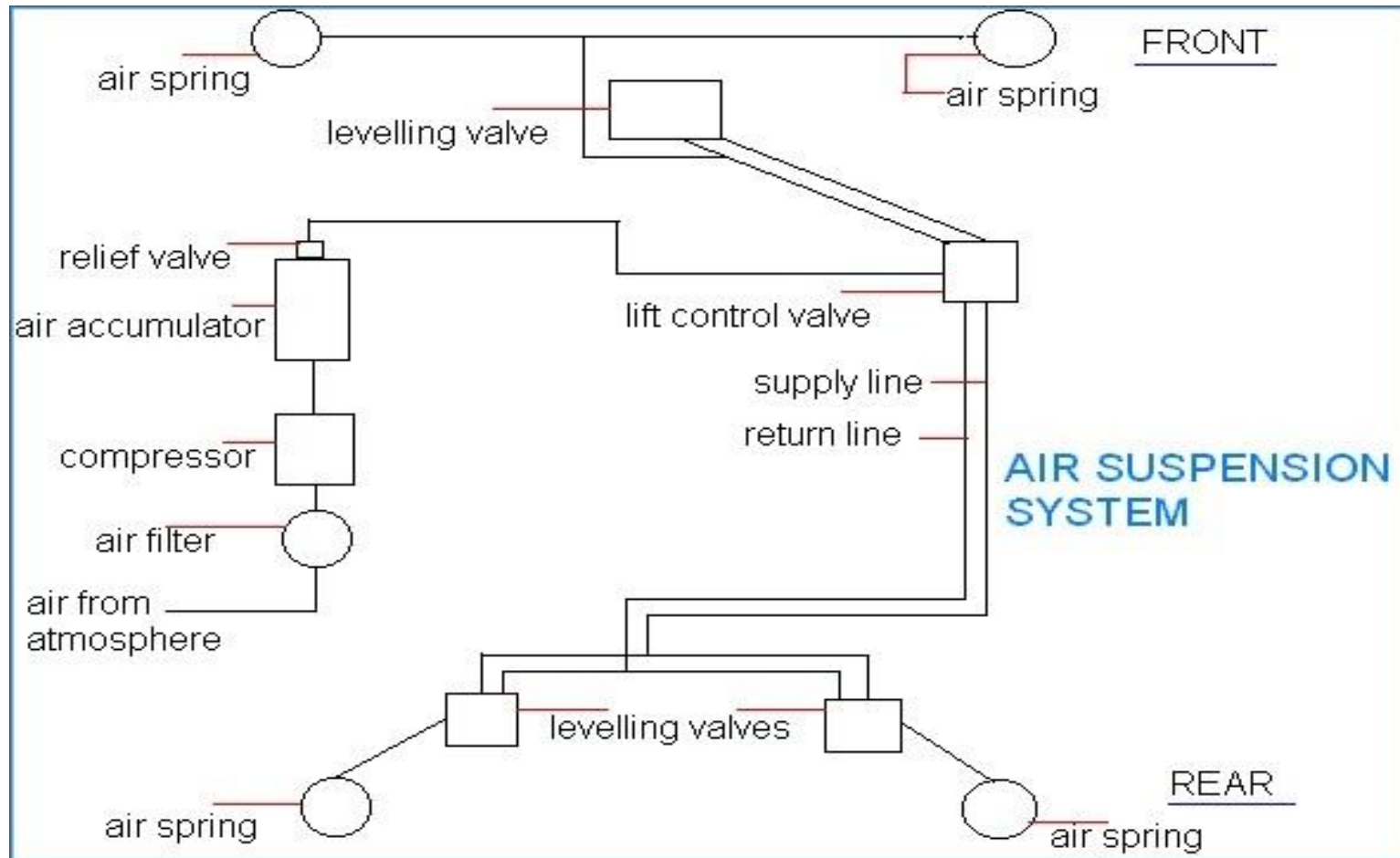


- Normally find on the rear suspension
- Combines independent double wishbone suspension with a leaf spring.
- It involves one leaf spring mounted *across* the vehicle, connected at each end to the lower wishbone.
- The centre of the spring is connected to the front subframe in the middle of the car.
- There are still two shock absorbers, mounted one to each side on the lower wishbones.

# Air suspension

- Comprises of compressor , supplying air to air tank
- Pressure maintained – 5.6 to 7 kg/sq.m
- Air bags – on each wheel
- As load applied , air bags compressed actuating the levelling valve .
- Air from the tank fills the compressed air bag & hence raise the level of the frame.
- Air from air bag gets released as load on chassis decreases .

# Air suspension layout





# Advantages of air suspension

- These maintain a constant frequency of vibration whether the vehicle is laden or unladen.
- Constant frame height is maintained.
- It helps to reduce the load while the vehicle in motion i.e. the dynamic loading as the spring rate variation between laden and unladen weight is much less.
- It gives smooth and comfort ride of the vehicle.
- The stiffness of the system increases with the increase of the deflection.

# Common Air Suspension Problems

## ❑ Air bag or air strut failure

- due to old age, or moisture within the air system that damages them from the inside.

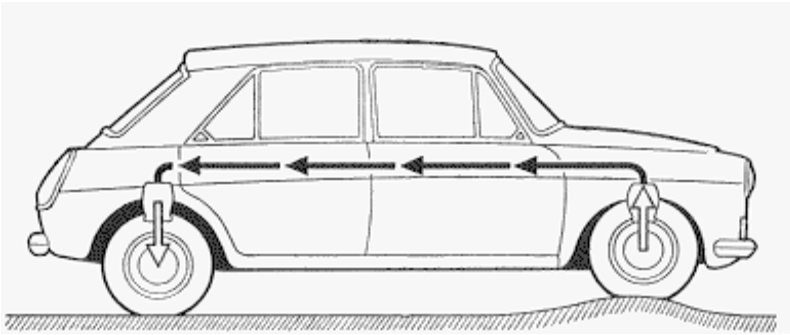
## ❑ Compressor failure

- Primarily due to leaking air springs or air struts
- Compressor burnout may also be caused by moisture from within the air system coming into contact with its electronic parts.

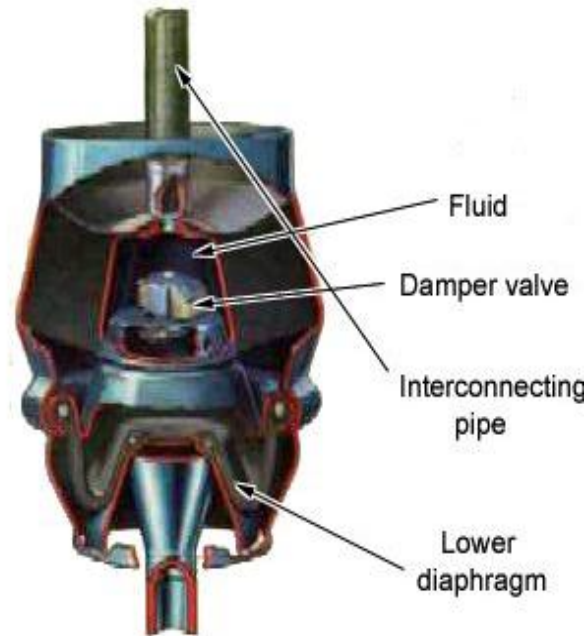
## ❑ Dryer failure

- which functions to remove moisture from the air system eventually becomes saturated and unable to perform that function

# Hydrolastic Suspension



- a system where the front and rear suspension systems were connected together in order to better level the car when driving.
- The front and rear suspension units have Hydrolastic displacers, one per side.
- These are interconnected by a small bore pipe. Each displacer incorporates a rubber spring
- Damping of the system is achieved by rubber valves.



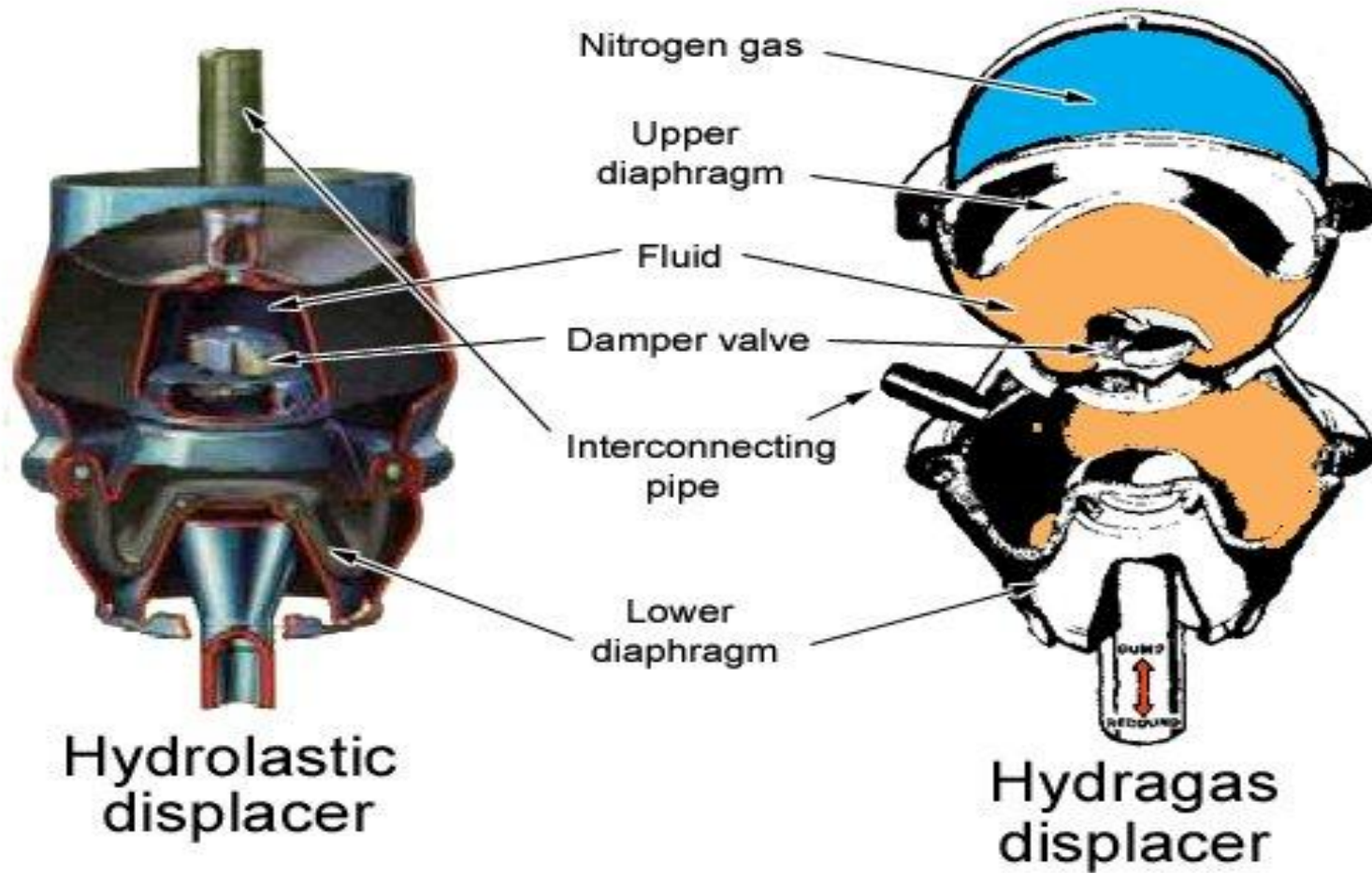
Hydrolastic  
displacer

- when the front wheel encounter bumps ,the piston moves upwards pressurising the fluid to enter into the rear unit.
- Hydroelastic was eventually refined into Hydragas suspension.....

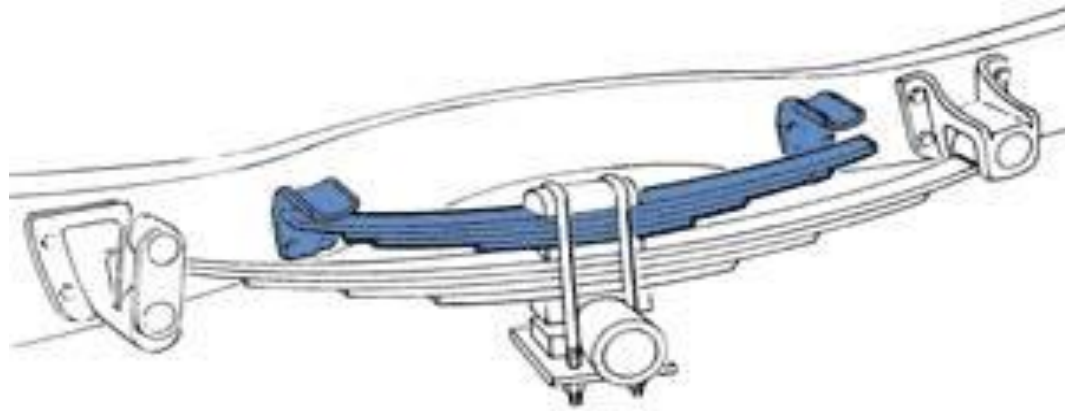
# Hydrogas suspension

- Known as hydro-pneumatic suspension.
- The difference is in the displacer unit itself.
- In the older systems, fluid was used in the displacer units with a rubber spring cushion built-in.
- With Hydragas, the rubber spring is removed completely.
- The fluid still exists but above the fluid there is now a separating membrane or diaphragm, and above that is a cylinder or sphere which is charged with nitrogen gas.
- The nitrogen section is what has become the spring and damping unit whilst the fluid is still free to run from the front to the rear units and back.

# Difference ...

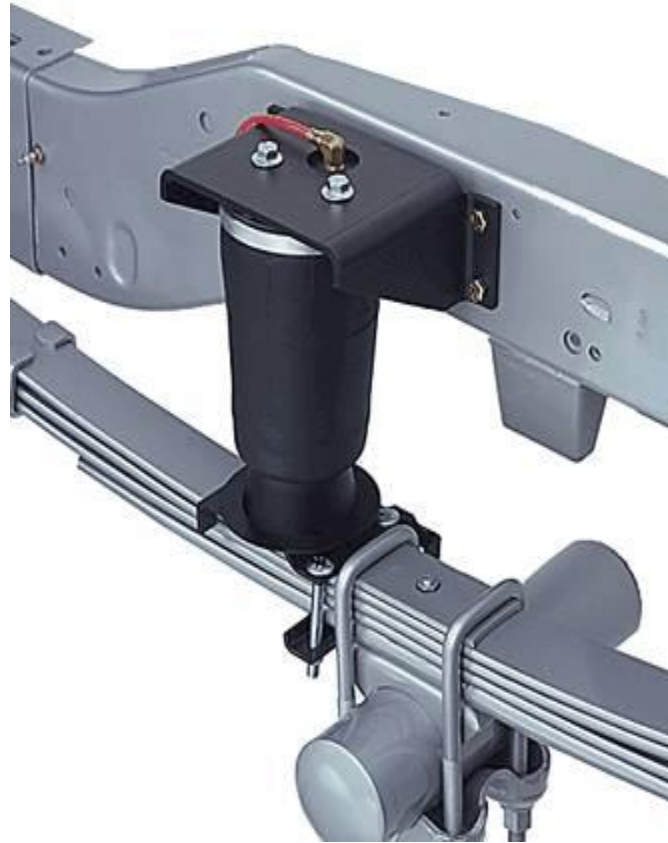


# HELPER SPRING

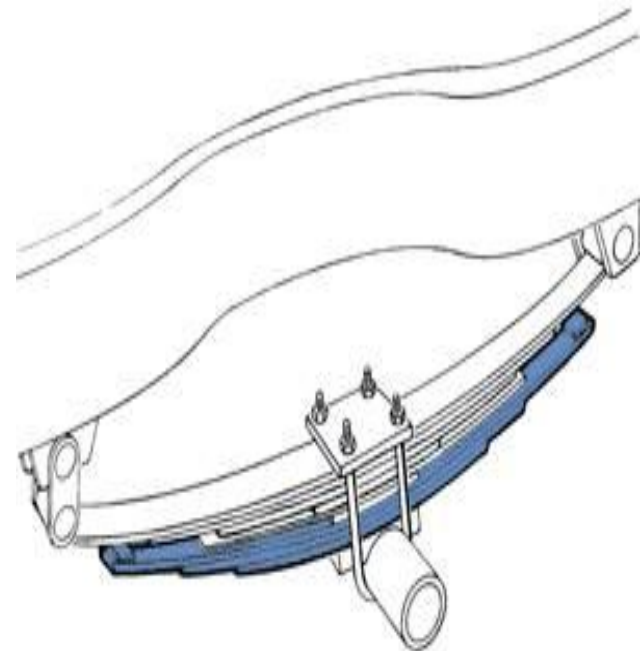


- DIRECTLY MOUNTED ON MAIN SPRINGS
- TAKE CARE OF LARGE VARIATION IN SPRING LOAD
- DURING LIGHT LOADS , ONLY MAIN SPIRNG IS ACTIVE , AS LOAD INCREASE TO A PARTICULAR FIXED VALUE , BOTH THE SPRINGS ARE ACTIVE

## AIR ASSISTED HELPER SPRING



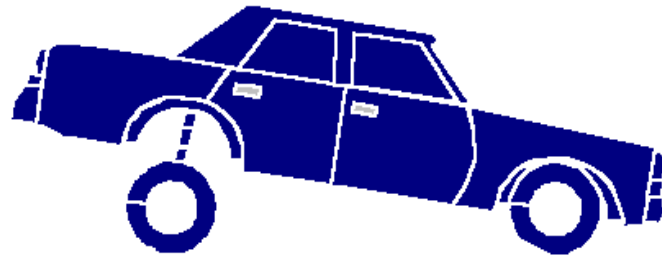
## LEAF HELPER SPRING





# **UNIT-IV**

# BRAKE SYSTEMS



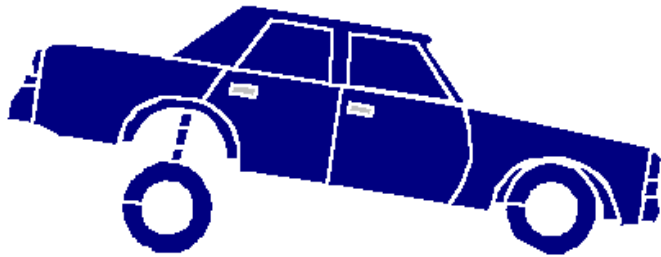
# Topics To Be Presented

- ◆ The Basic Concepts
- ◆ Hydraulic layouts
- ◆ Component functions
- ◆ Brake Balance
- ◆ Stopping Distance and Fade
- ◆ Formula SAE vs. Mini Baja
- ◆ Lessons Learned
- ◆ The Rules
- ◆ Questions

# The Basic Concepts

- Kinetic energy = heat
- $F = ma$
- Newton is always right!
- Do the calculations first
- When all else fails see rule 3.

# Energy Conversion



The brake system converts the kinetic energy of vehicle motion into *heat*

# Energy Conversion

A vehicle weighing 290 kg. (639 lbs.)

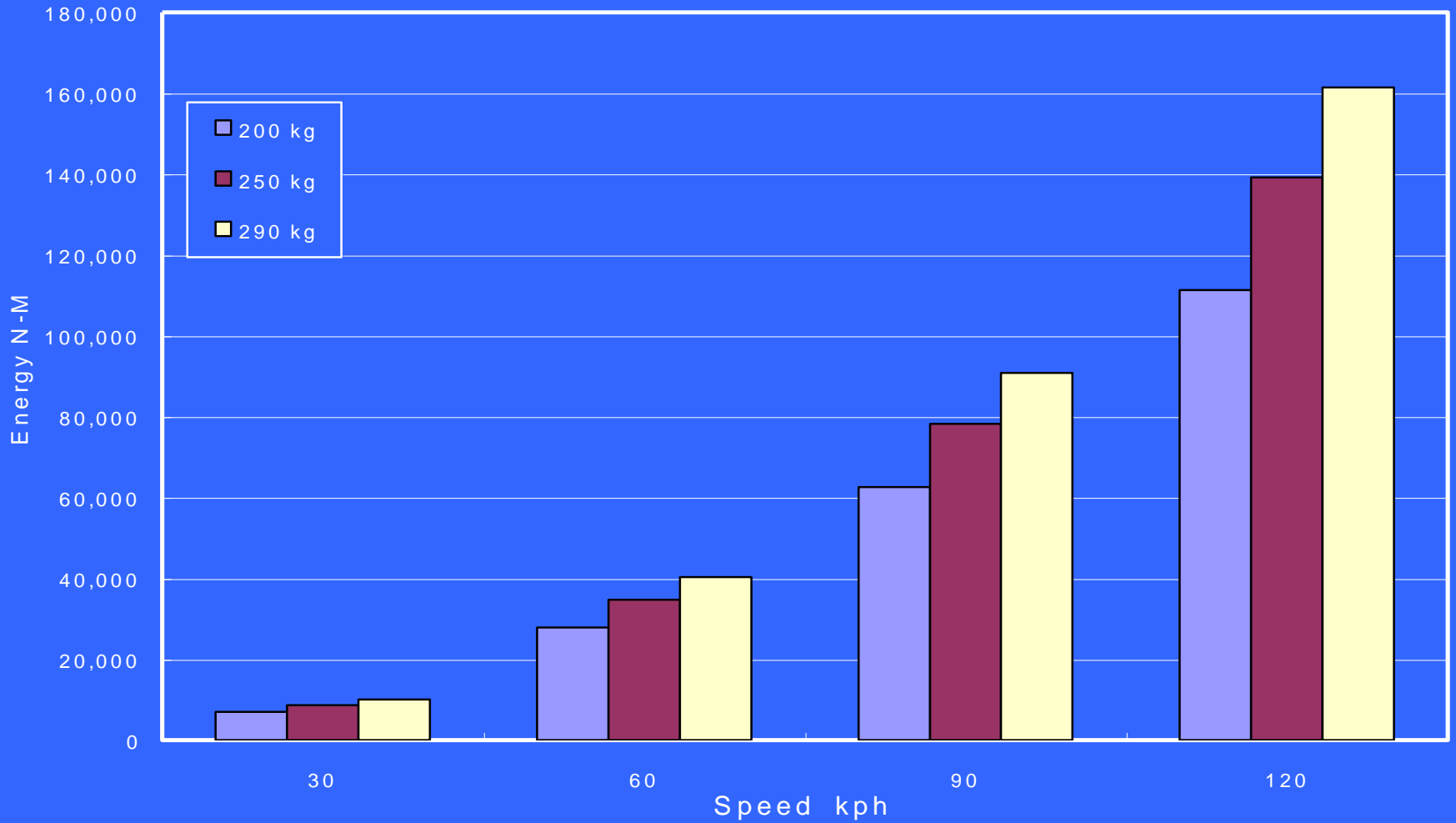
At 90 kph (55.9 mph) has kinetic energy of:

OR 90,770 N-M.

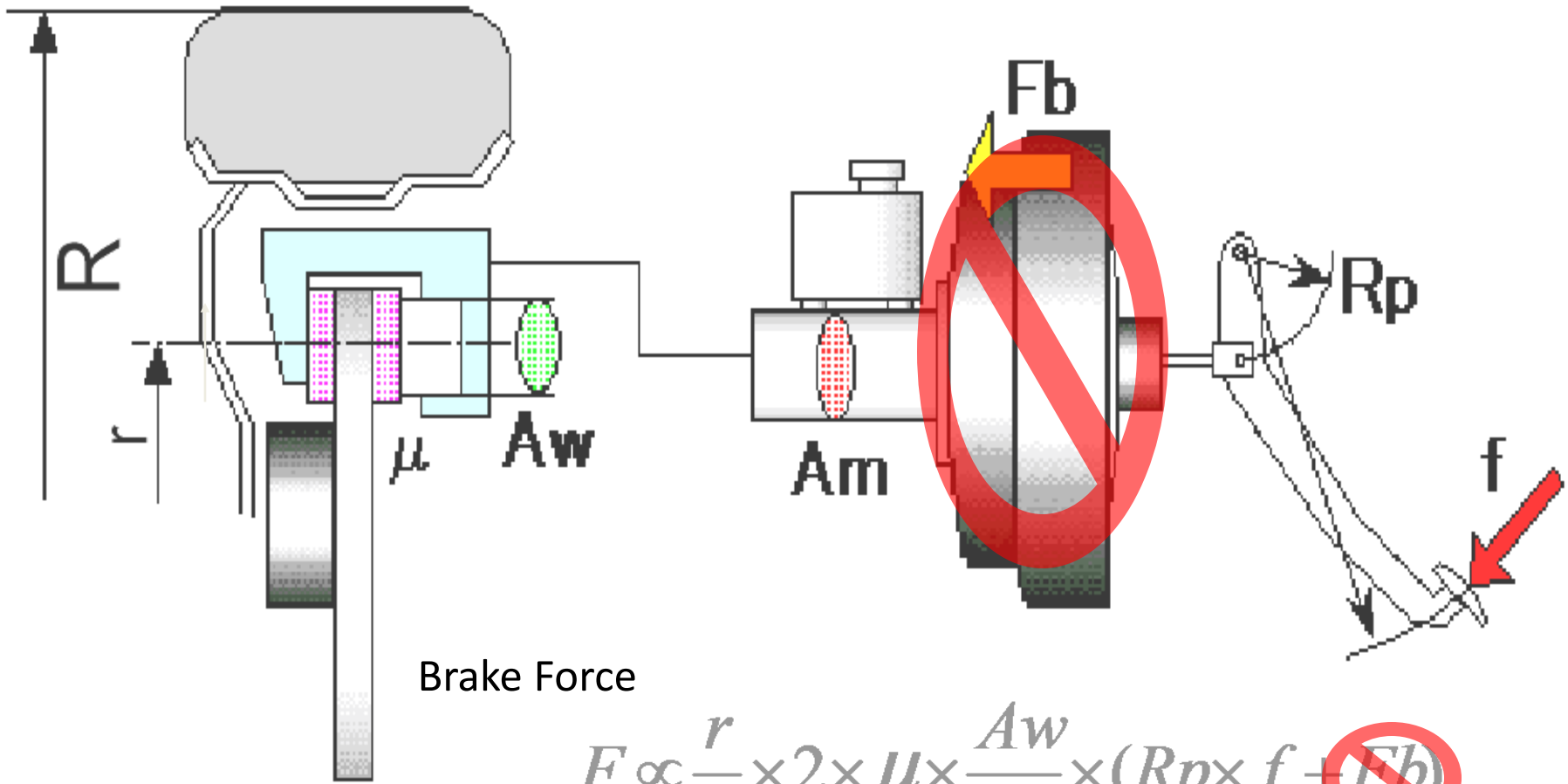
Stopping the vehicle at .9G takes 2.9 Seconds

This is equal to 31 kilowatts (42 HP).

## Kinetic Energy as a Function of Speed and Mass



 **F Basic System Model**



Brake Force

$$F \propto \frac{r}{R} \times 2 \times \mu \times \frac{A_w}{A_m} \times (R_p \times f + \cancel{F_b})$$



# Hydraulic System Configurations

There are two layouts of hydraulic brake systems used in cars and light trucks.

Front/Rear hydraulic split:

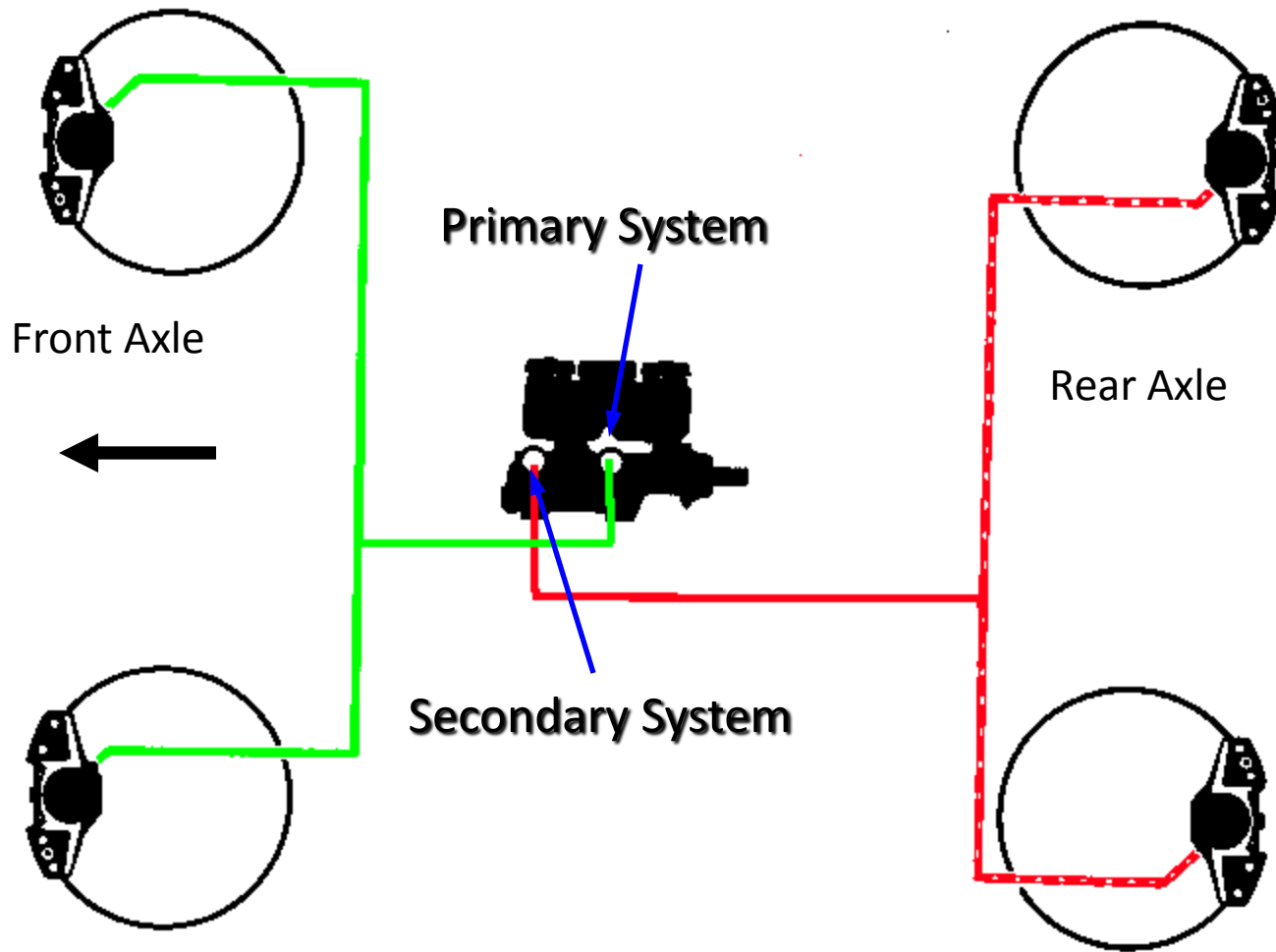
Also called axle by axle, vertical, and some times “black and white”.

Diagonal Split:

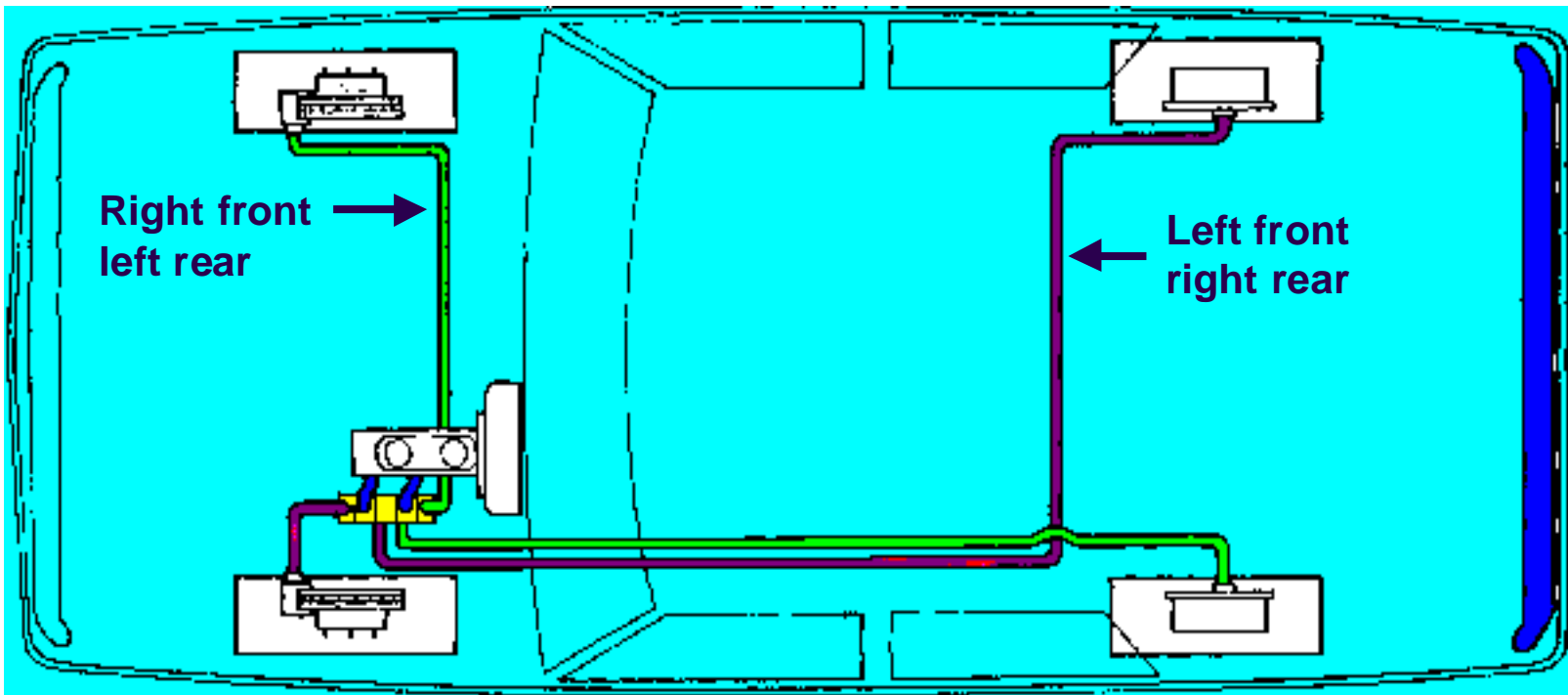
Also called criss-cross.

*The type of split is only significant in the event of a hydraulic system failure.*

# Front/rear Hydraulic Split



# Typical Diagonal Split System



# ***Brake Component Function***

# Four Sub-systems

## ◆ Actuation sub-system

- ◆ Foundation sub-system
- ◆ Parking brake sub-system
- ◆ ABS & ESP (electronic stability program) sub-system

# Actuation Sub-system

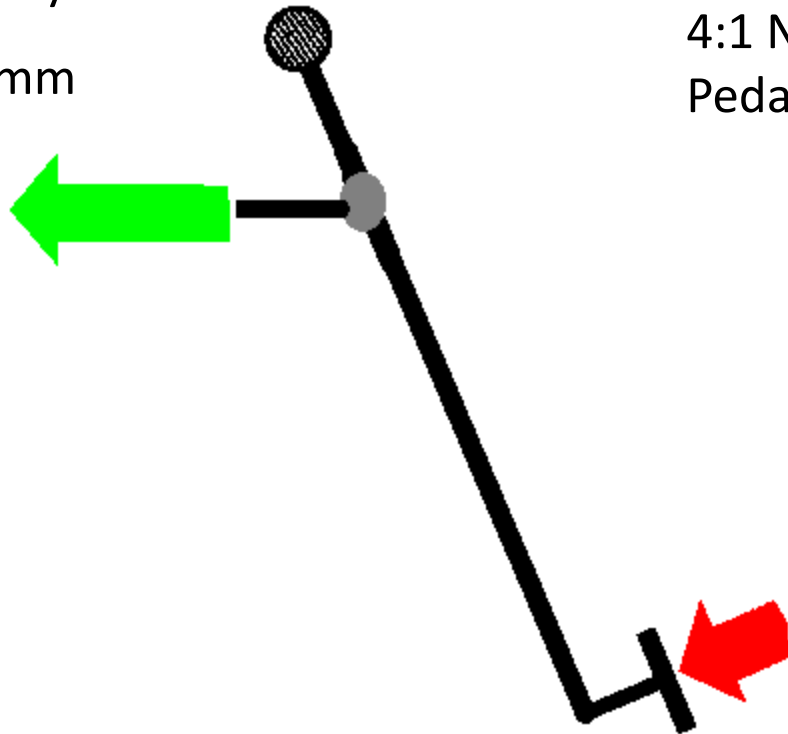
- ★ Brake Pedal
- ★ Master Cylinder
- ★ Proportioning Valves
- ★ Brake Lines

# The Brake Pedal

Output to master cylinder

400 N and 36 mm

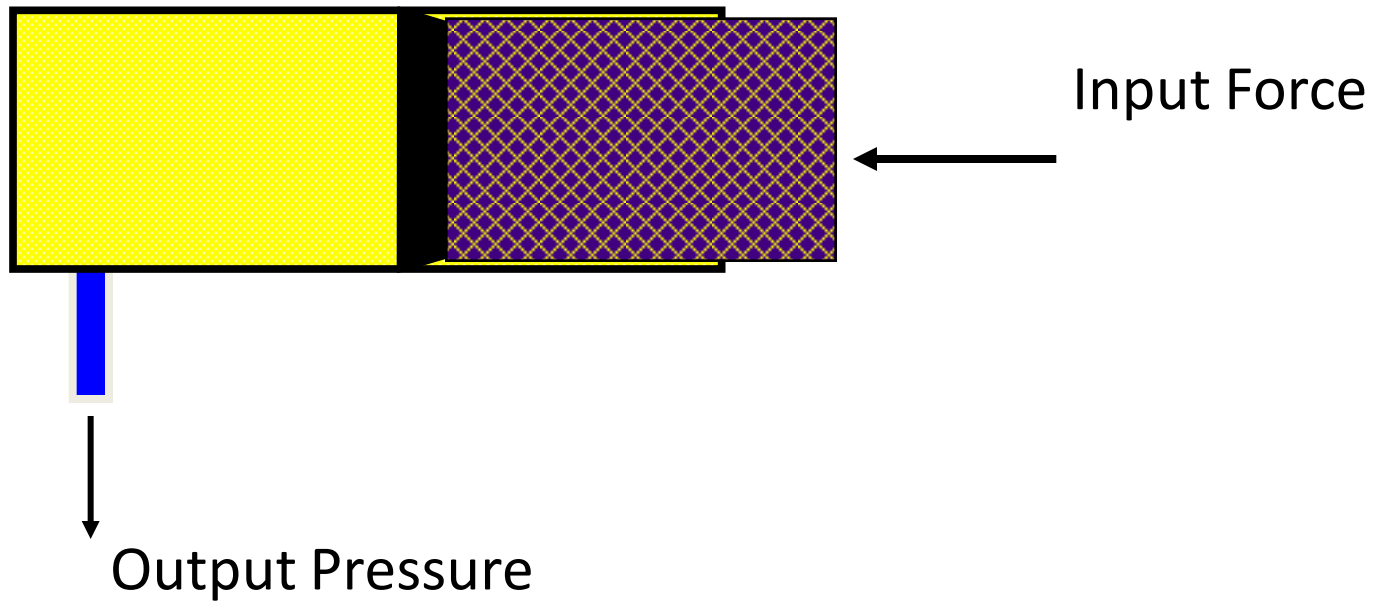
4:1 Nominal  
Pedal Ratio



Driver Input  
100 N and 144 mm

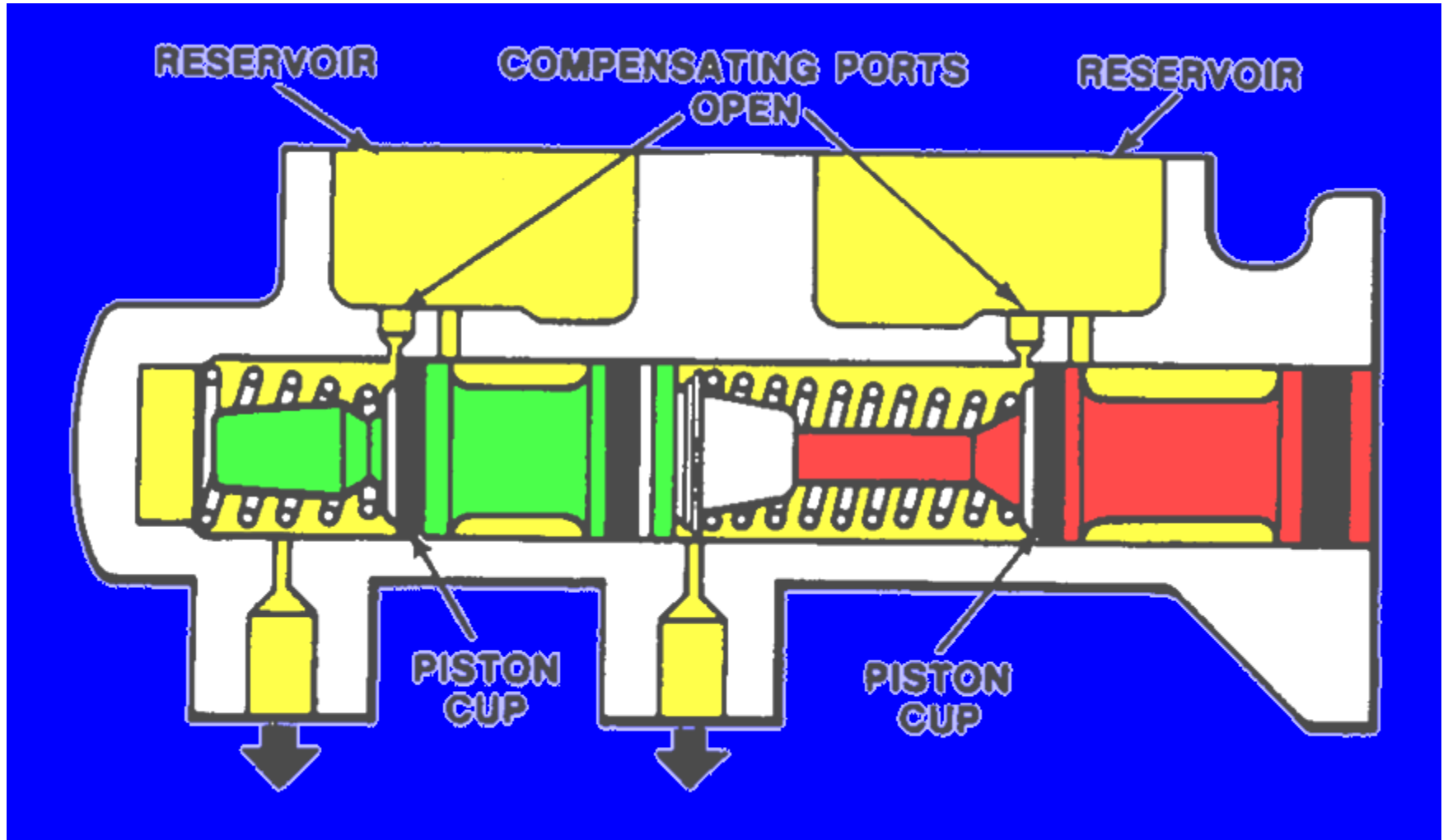
# Master Cylinders

A master cylinder is just a simple piston inside a cylinder

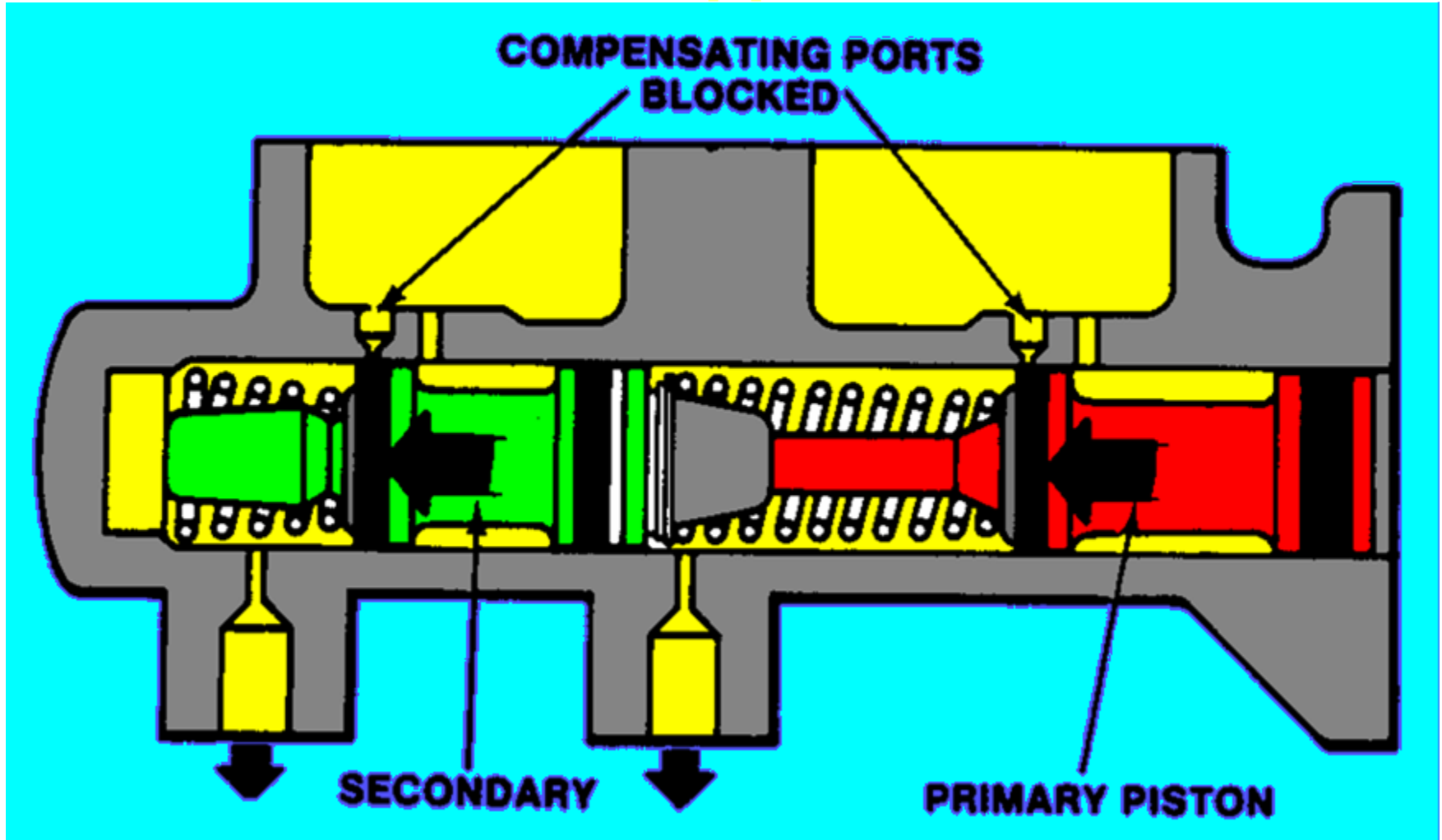




# M/C Unapplied

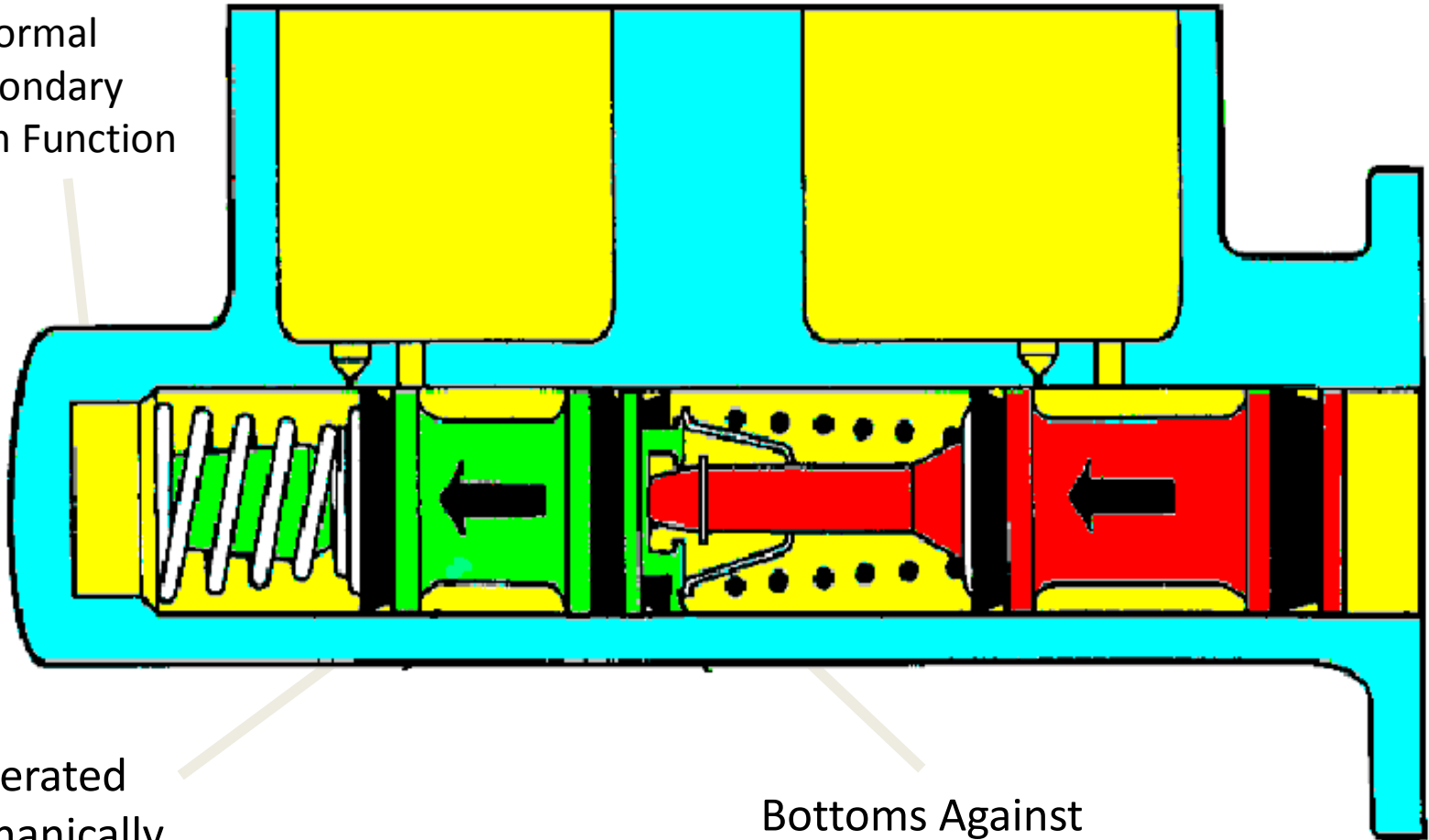


# M/C Applied



# Primary System Failure

Pressure for  
Normal  
Secondary  
System Function

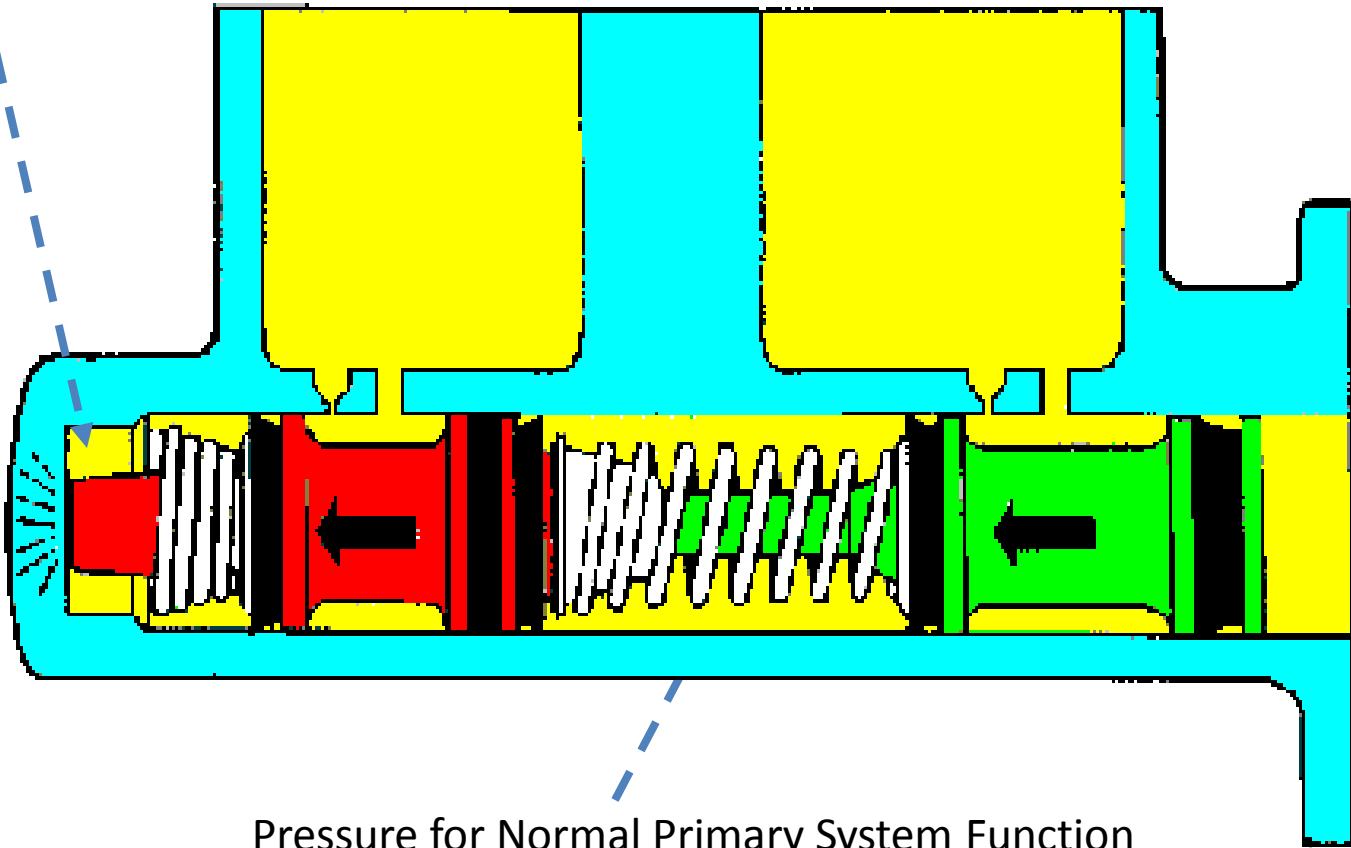


Operated  
Mechanically

Bottoms Against  
Secondary Piston

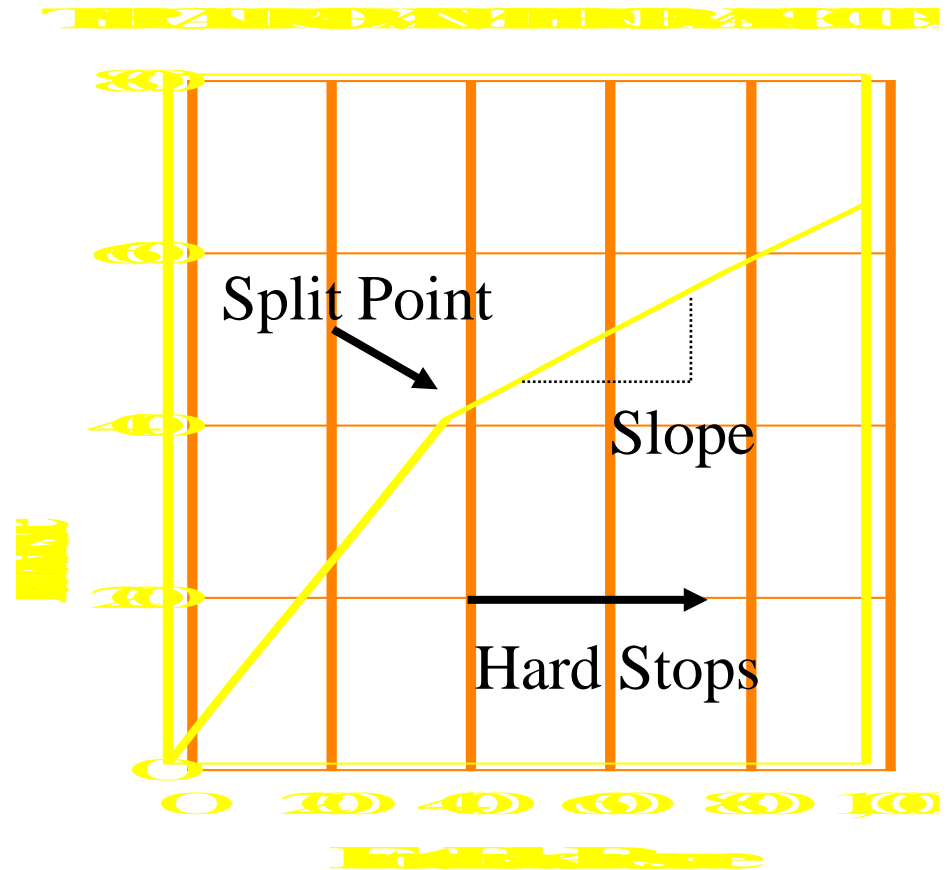
# Secondary System Failure

Bottoms at End of Cylinder Bore

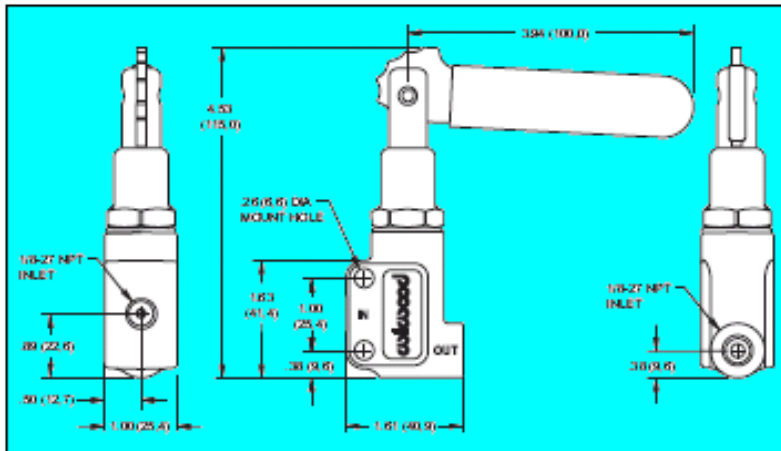


# Proportioning Valves

- ◆ Reduce the pressure to the rear brakes
- ◆ Diagonal systems require two
- ◆ Split and slope are changed to create proper balance



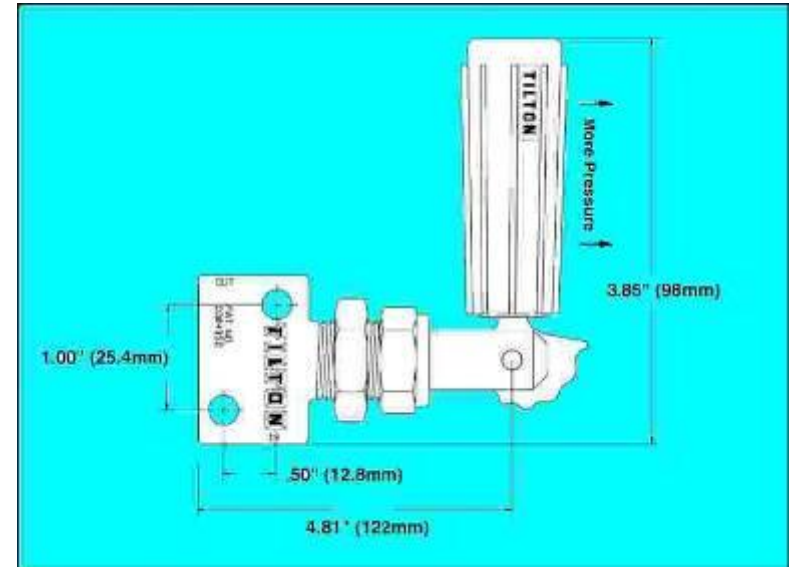
# Adjustable Proportioning valves



**DESCRIPTION**  
Lever style proportioning valve

**PART NO.**  
260-8420

Wilwood



Tilton

Only the split points are adjustable

- Brake Lines

- ◆ Double wall steel tubing (Bundy Tubing) is industry standard.
- ◆ 3/16" o.d. is standard size.
- ◆ Very robust, can take a lot of abuse
- ◆ Use SAE 45° inverted flare (J533 and J512) joints if you can.

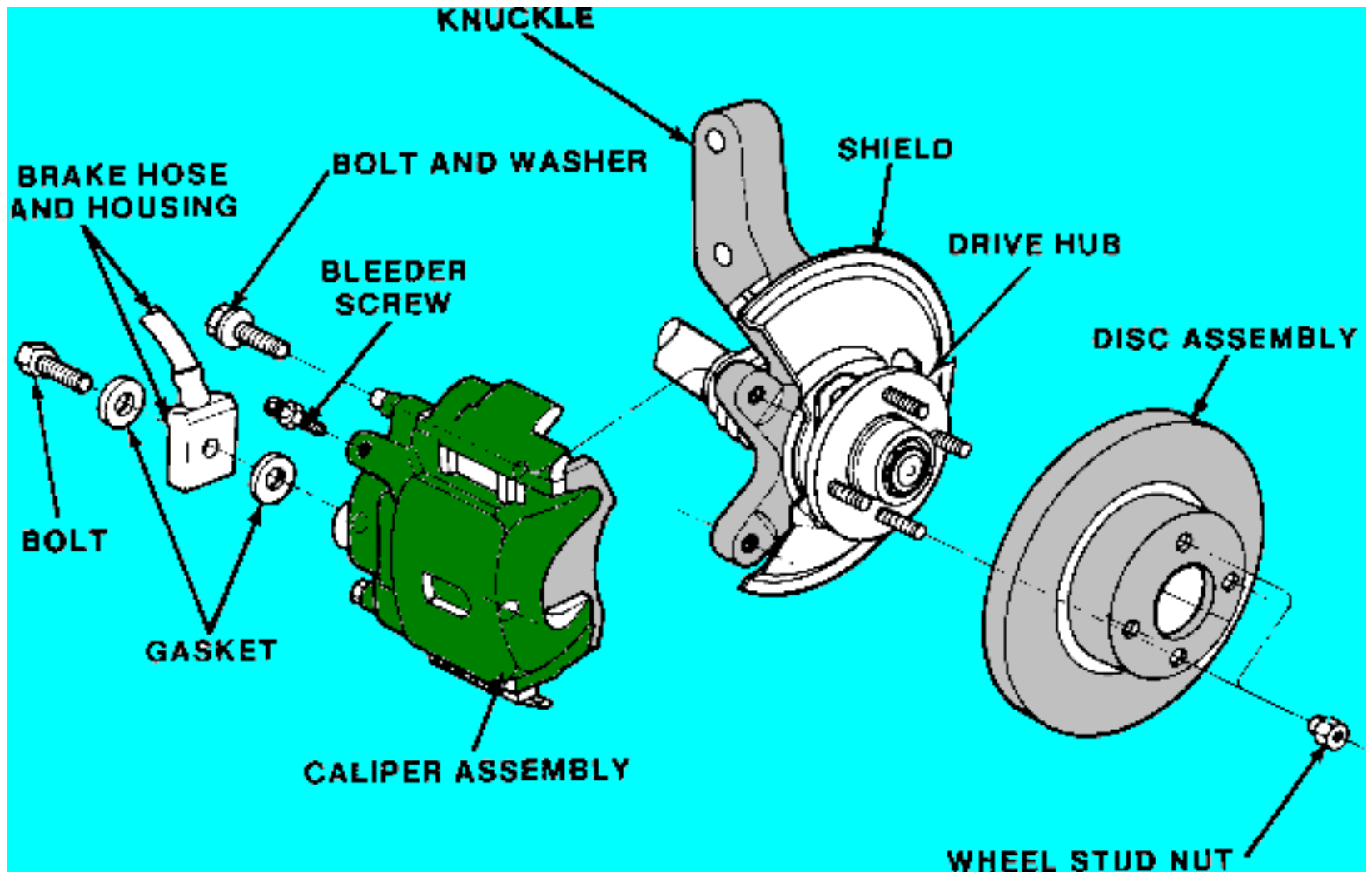


# Foundation Brake Sub-system

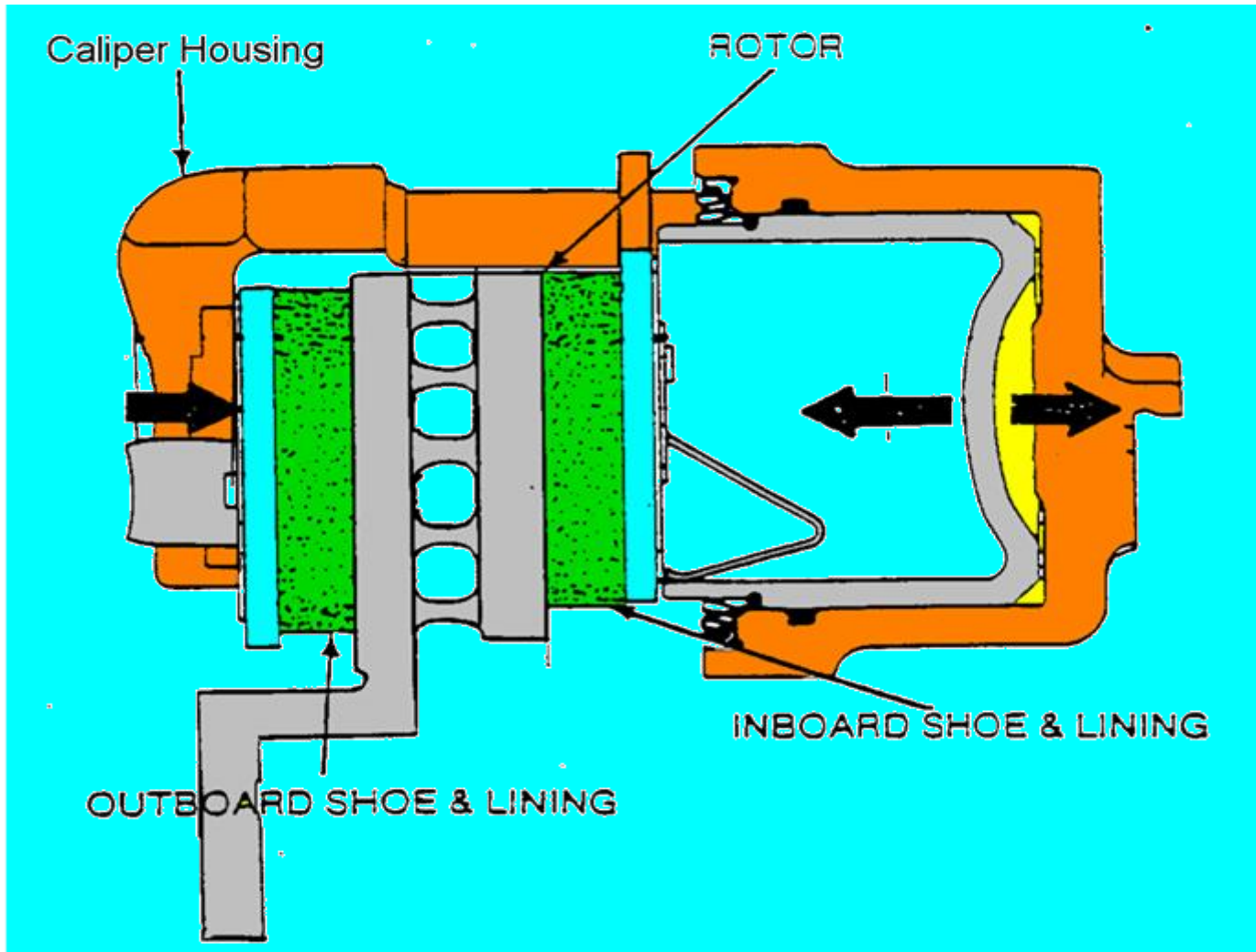
- ◆ Disc Brakes
- ◆ Linings



# Front Disc Brake



# Front Disc Brake



# Brake Linings

- Brake linings are probably the most mis-understood part of a brake system.
- The output of any brake is directly related to the coefficient of friction ( $\mu$ ) between the lining and the disc or drum.
- The challenge is knowing what the instantaneous value of  $\mu$  is during any given stop.
- Any design calculations you do, go right out the window if the lining you use does not have the  $\mu$  value you assumed.

# Brake Linings

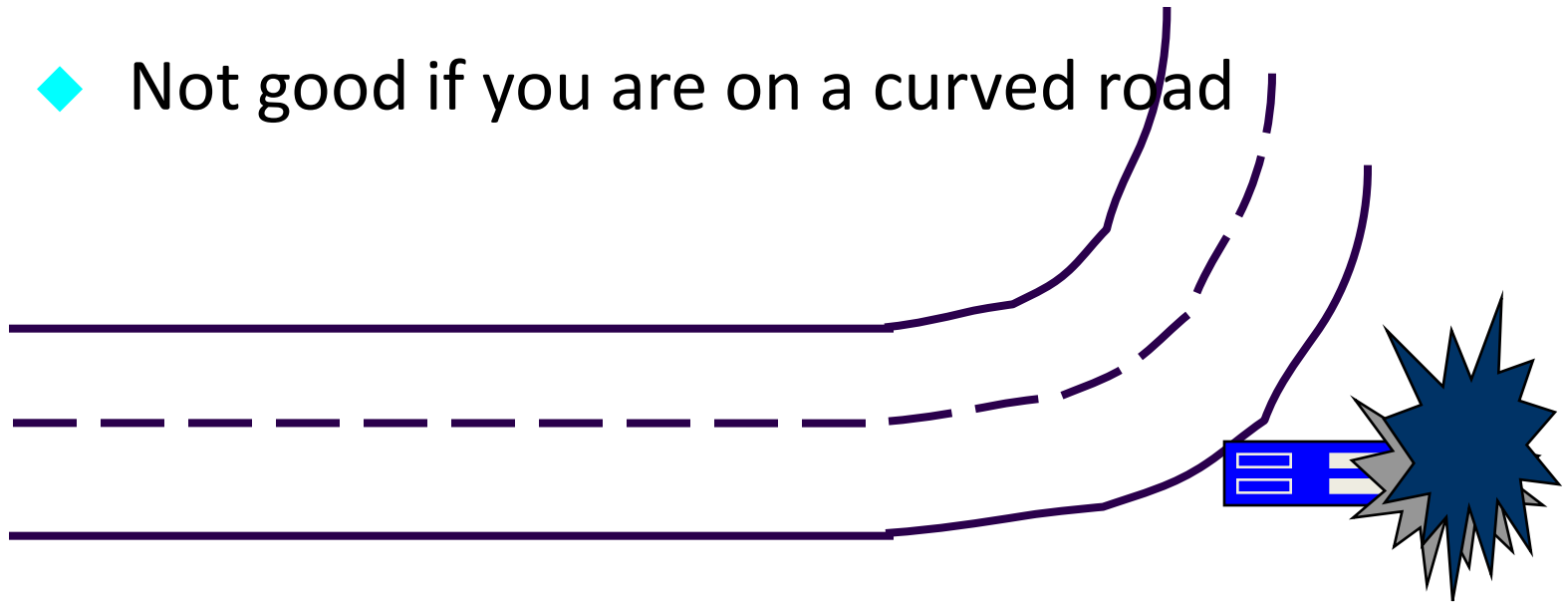
Remember the equation for a disc brake

$$T = \frac{F \times R}{2} \times \mu \times \frac{A_w}{A_m} \times (2 \times \theta)$$

The best method for determining the actual value of  $\mu$  for a given lining is from a dynamometer test.

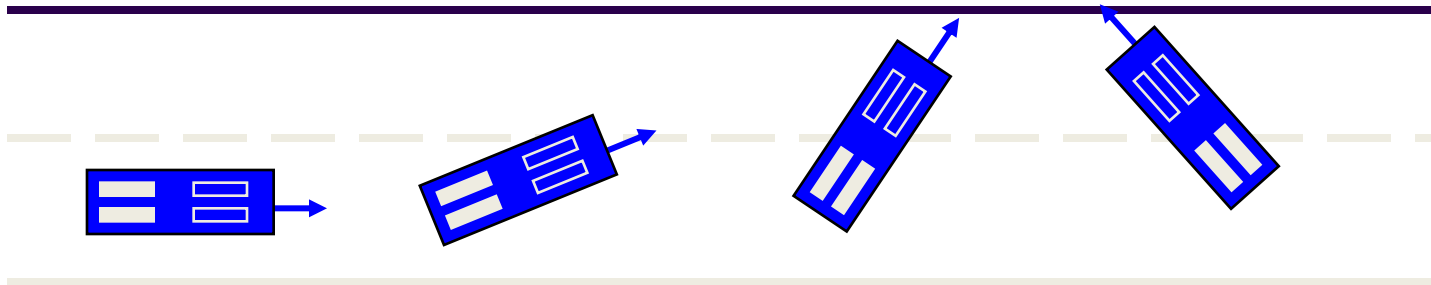
## Both Front Wheels Locked:

- ◆ You can't steer
- ◆ The vehicle goes straight
- ◆ OK, if you must hit something
- ◆ Not good if you are on a curved road



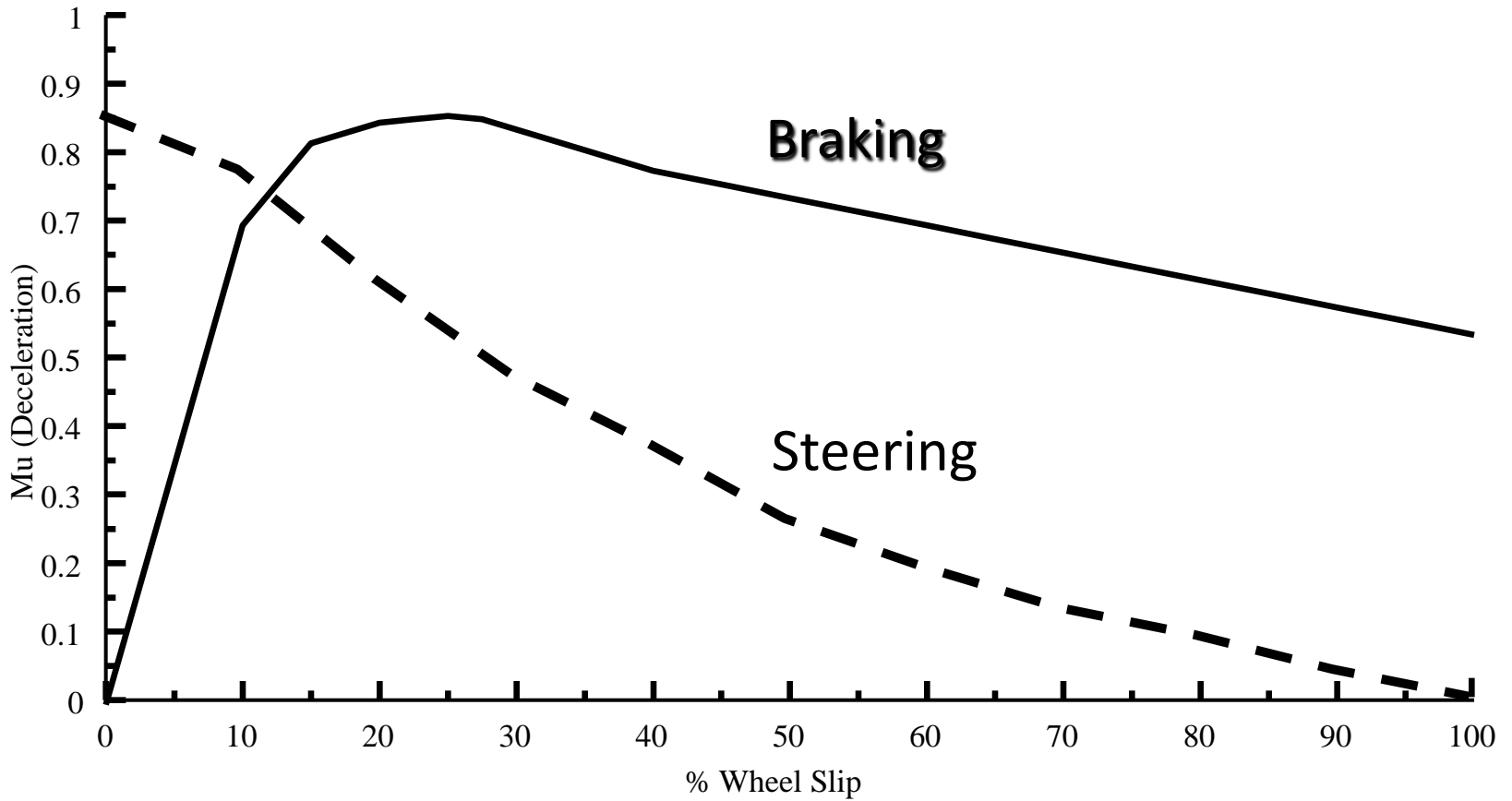
## Both Rear Wheels Locked:

- ◆ The front wheels track straight ahead
- ◆ Then the rear wheels deviate to the side
- ◆ Until the vehicle can't track straight any longer and the rear starts to spin around the front



# $\mu$ vs. % Wheel Slip

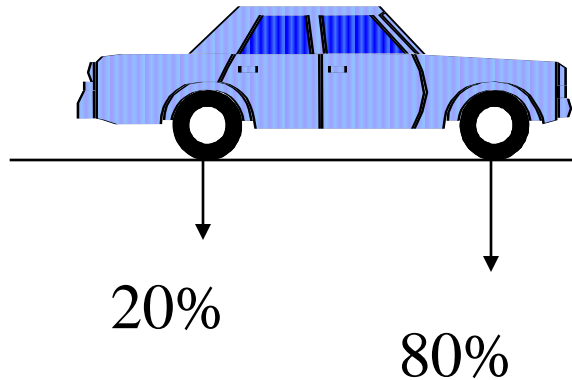
Typical Dry Surface



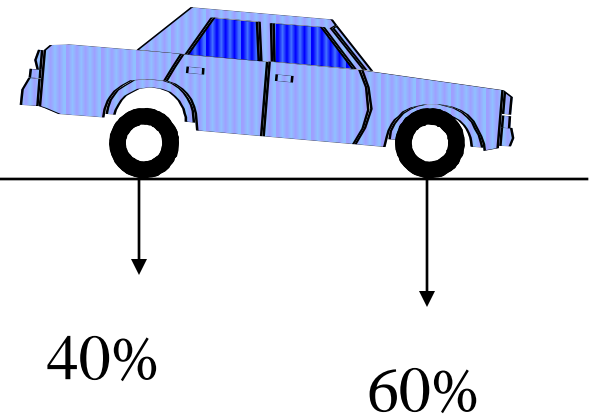
# Front Lock

If there is more front brake torque than dynamic front weight

Brake torque  
distribution



Dynamic weight  
distribution



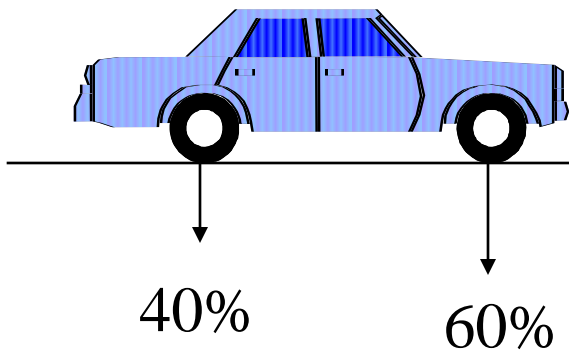
The front wheels will lock up before the rears



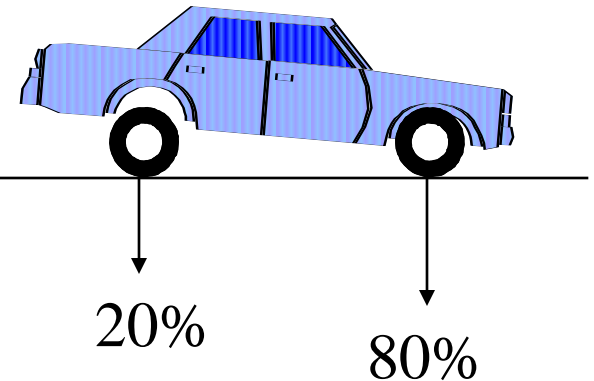
# Rear Lock

If there is more rear brake torque than dynamic rear weight;

Brake torque  
distribution



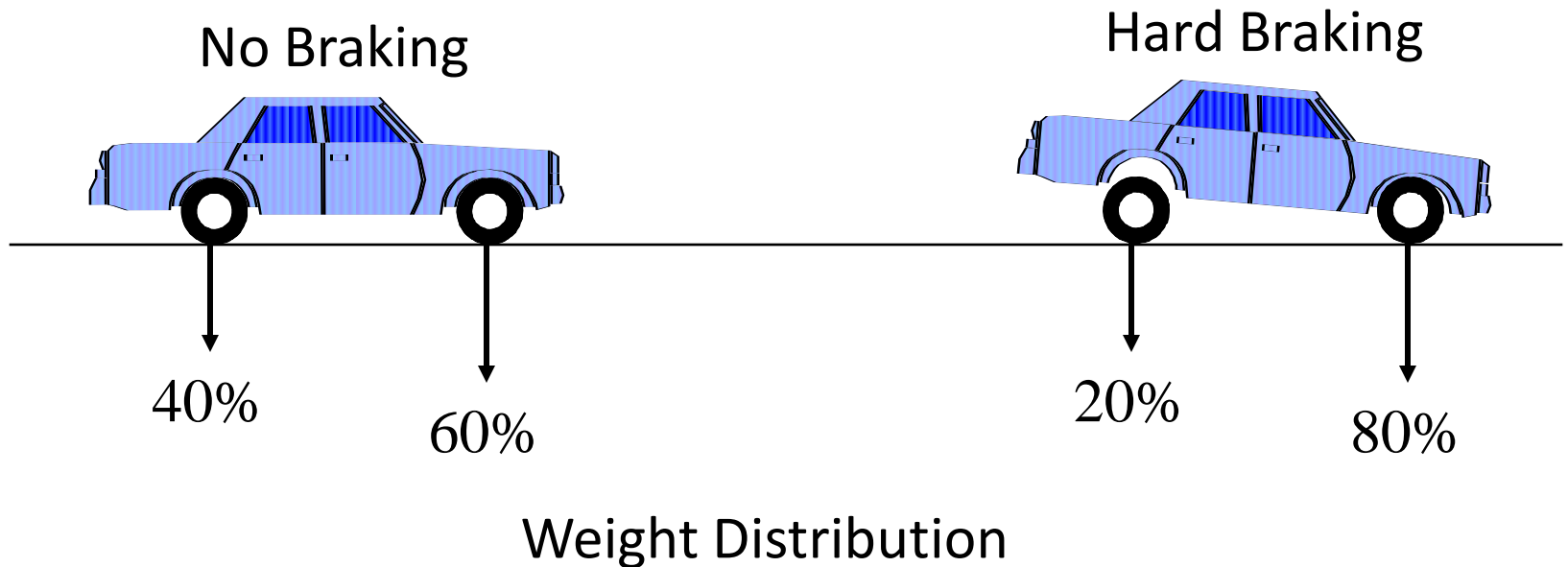
Dynamic weight  
distribution



The rear wheels will lock up before the fronts

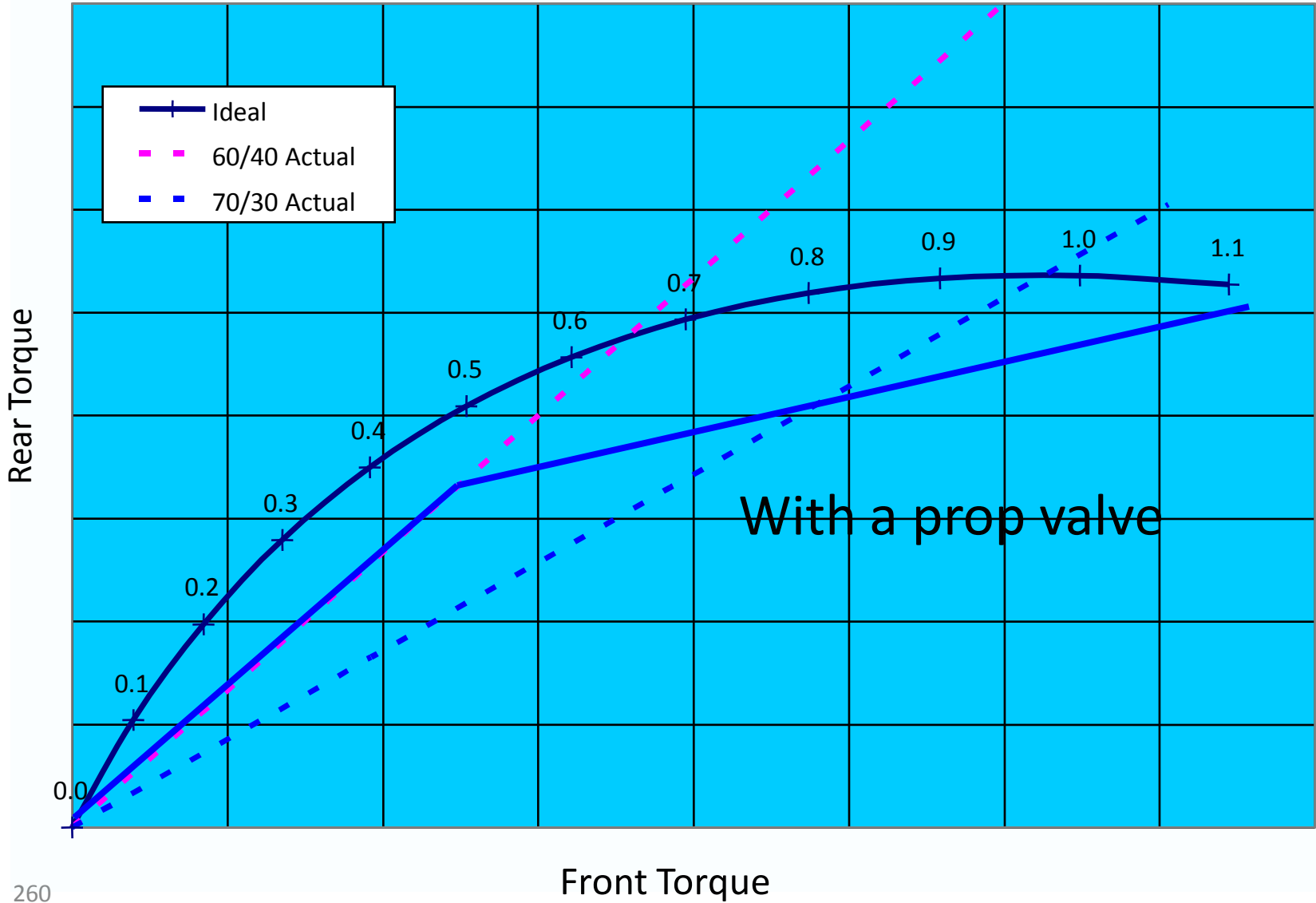
# Optimum Braking

Optimum braking is achieved when brake torque distribution matches dynamic weight distribution



# Calculating Dynamic Weight Transfer

# Ideal Vs Actual Torque



# Stopping Distance

*Does **not** Depend on:*

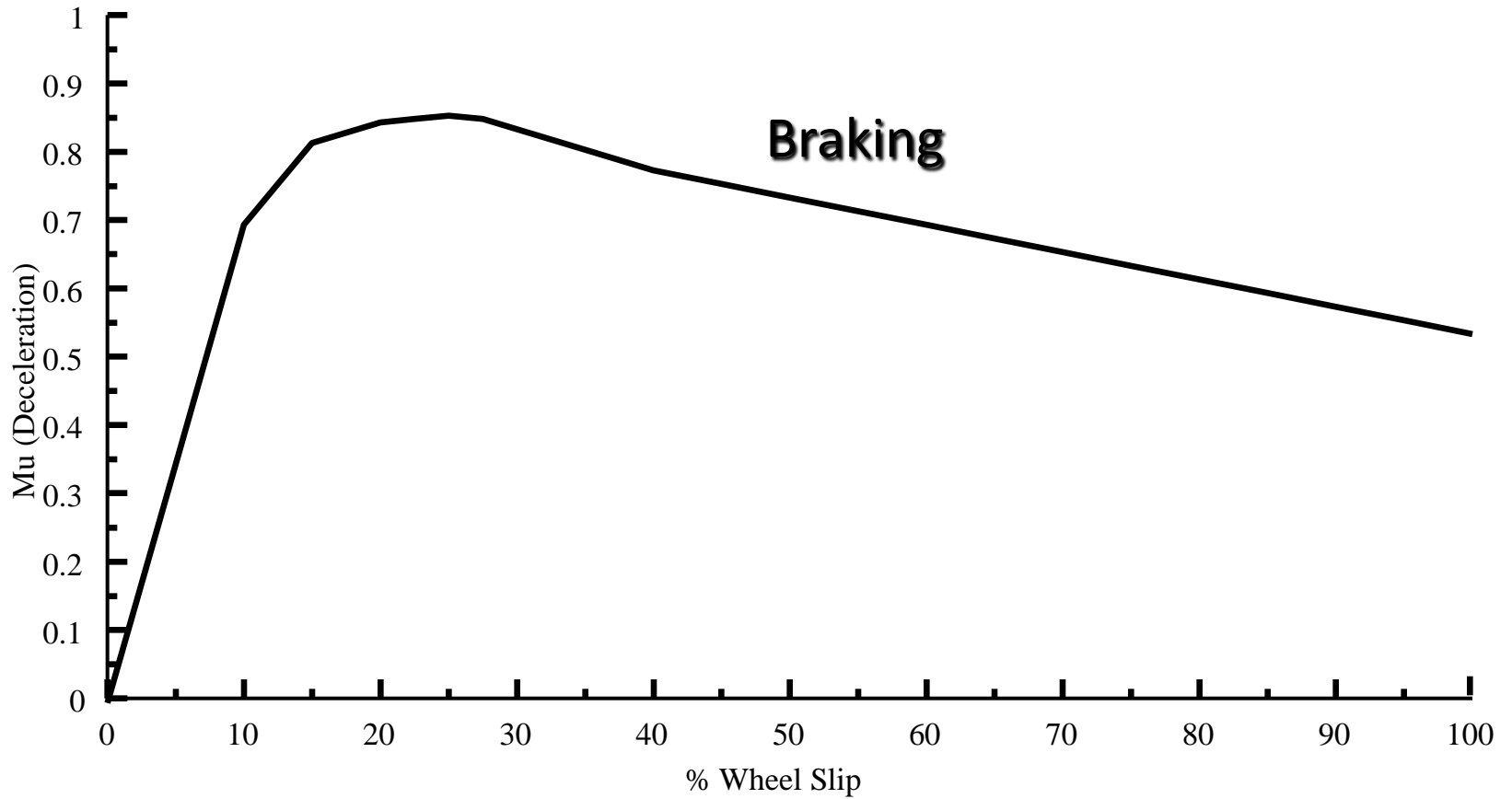
- Type of brakes
- Size of brakes

*Does Depend on:*

- Tire to road friction
- Vehicle balance
- Skill of driver
- System Reaction Time

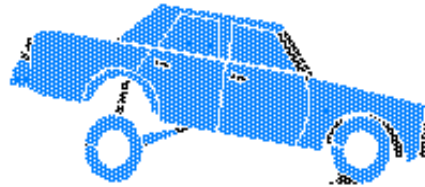
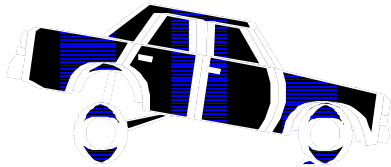
# $\mu$ vs. % Wheel Slip

Typical Dry Surface



# Brake Fade

Brake fade is the loss of performance resulting from the lining friction decreasing as the lining and rotor or drum rises in temperature



# UNIT-5



# Emission Control System Fundamentals

# Objectives

- Describe the different types of air pollution caused by motor vehicles
- Explain the fundamentals of the major emission control systems
- Label the parts of emission control systems
- Explain the operation of electronically controlled emission systems

# Introduction

- Emission controls
  - Began to be included on cars in the 1960s
  - Complicated specialty area
  - Most states: emission specialists are required to be licensed to perform repairs

# Air Pollution

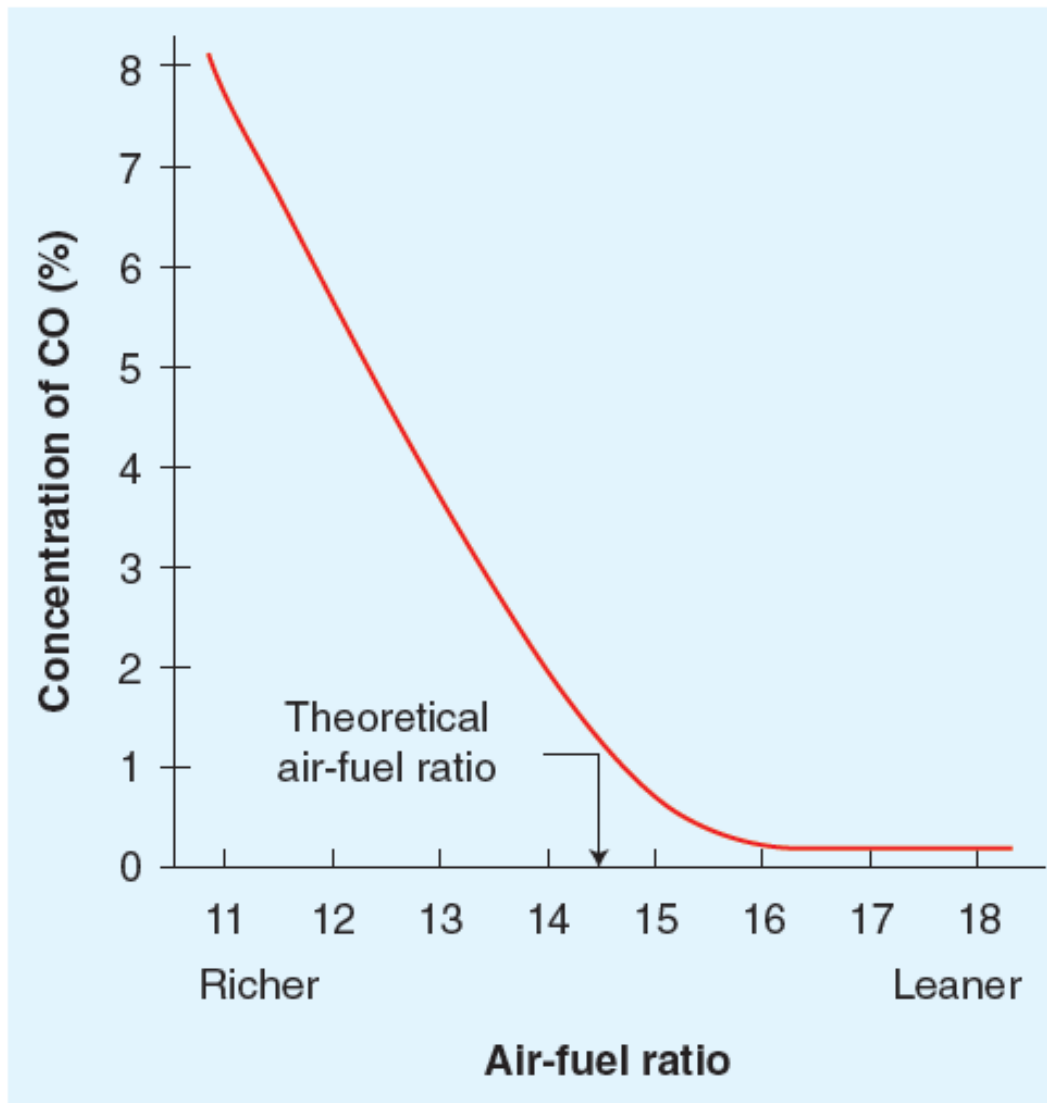
- Photochemical smog
  - Hydrocarbons and oxides of nitrogen react with sunlight
  - Warm air inversion layer traps smog
- Pollution laws
  - Administered by the EPA
  - Vehicles manufactured today produce less than 5% of the air pollution of 1960s models

# Automotive Emissions

- Sources of emissions
  - Exhaust pipe, crank-case, and vapors
- Hydrocarbon sources
  - Blowby gases
  - Skin effect
  - Raw gas in exhaust
  - Insufficient compression
  - Inadequate ignition spark

# Automotive Emissions (cont'd.)

- Carbon monoxide emissions
  - Result when gasoline not completely burned
- Oxides of nitrogen
  - Produced when combustion temperatures are too high
- Particulates
  - Are airborne microscopic particles
- Carbon dioxide and oxygen
  - Used to diagnose combustion problems
  - Carbon dioxide is a greenhouse gas



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**Figure 43.4** The amount of carbon monoxide (CO) in the exhaust varies with the air-fuel ratio.

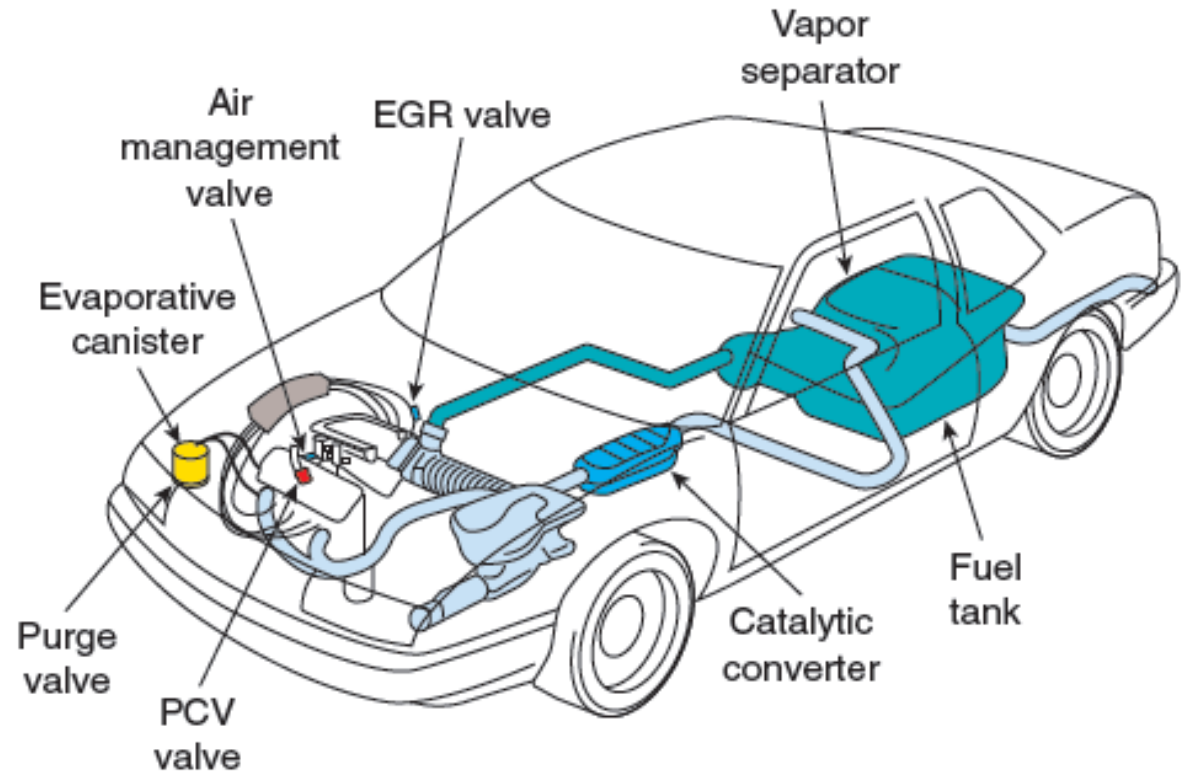
# Pollution Control

- Early 1960s: California led emission control legislation
  - 1961: crankcase emission system required on all new cars in California
- 1963: crankcase emission system required on all new cars in U.S.
- 1966: exhaust emission systems required on new cars in California
- 1970: U.S. Congress passed Clean Air Act



# Automobile Emission Control Systems

- Lower exhaust emissions
  - Engine design
  - Fuel and ignition system controls
  - Devices designed to control emissions
- Computers manage emission devices
  - Engine load
  - Engine temperature
  - O<sub>2</sub> sensor



**Figure 43.5** Typical emission control system.

# Crankcase Ventilation

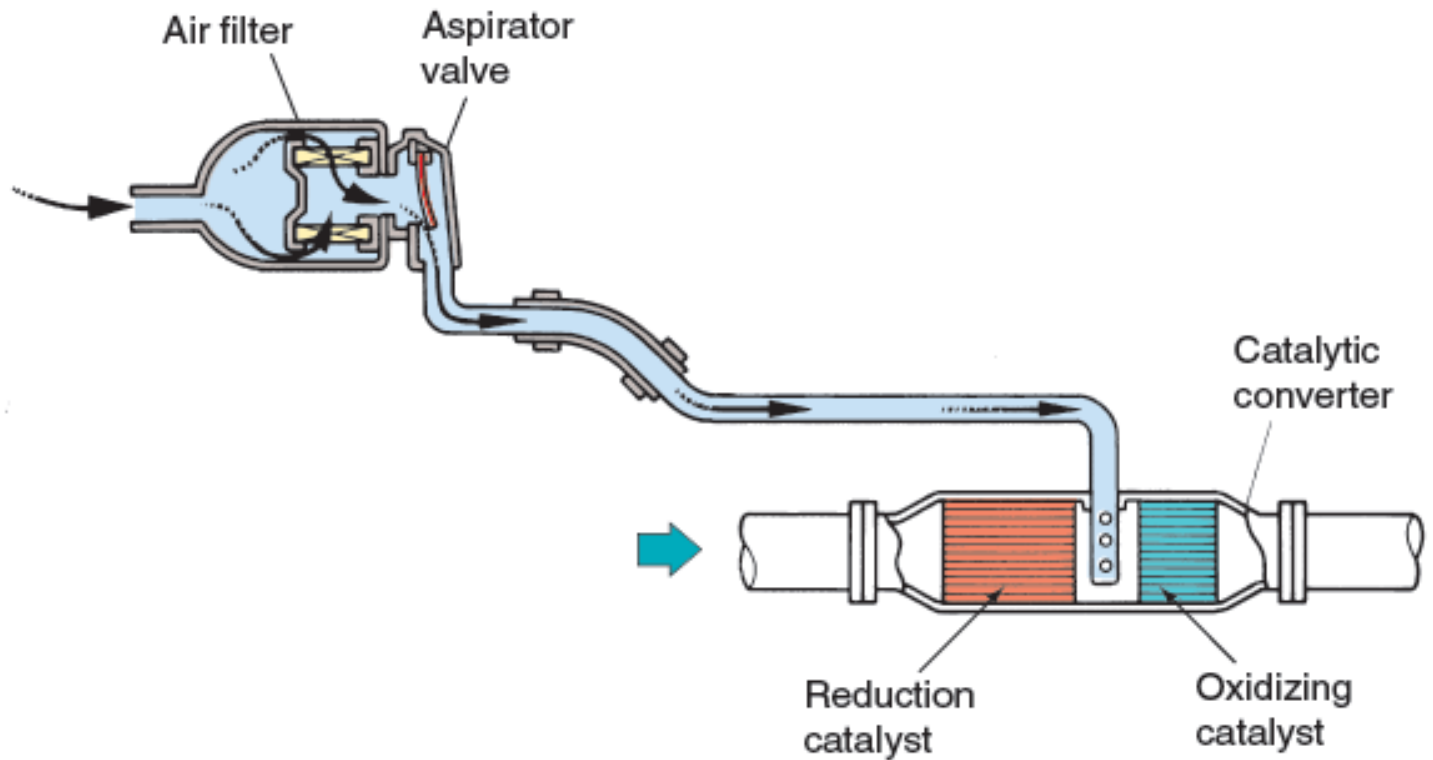
- PCV system
  - Reintroduces blowby gases into combustion chambers
- Benefits of PCV system
  - Prevents emissions of HCs
  - Reduces sludge
  - Reduces oil leakage
- Closed ventilation system
  - Filtered intake air is supplied through hose from air cleaner

# Air Injection System

- Feeds hot gases to keep them burning
  - Air is provided by belt-driven air pump, electric motor-driven pump, or non-pump pulse air system
- Functions
  - Provides low-pressure air supply
  - Provides air to catalytic converter
- Air injection system uses an air pump, control valves, and lines to manifolds
  - Some vehicles have electric air pumps

# Aspirator Valve or Pulse Air System

- Momentary low-pressure condition (pulse) occurs at end of exhaust stroke
  - Aspirator valve or pulse air system uses pulses to blow fresh air into exhaust
    - Not efficient at high speeds
  - One-way check valve (i.e., aspirator valve) allows fresh air from cleaner
    - Flows when vacuum created by exhaust pulse
    - Closes when exhaust pressure builds



**Figure 43.14** An aspirator valve system providing air to a catalytic converter.

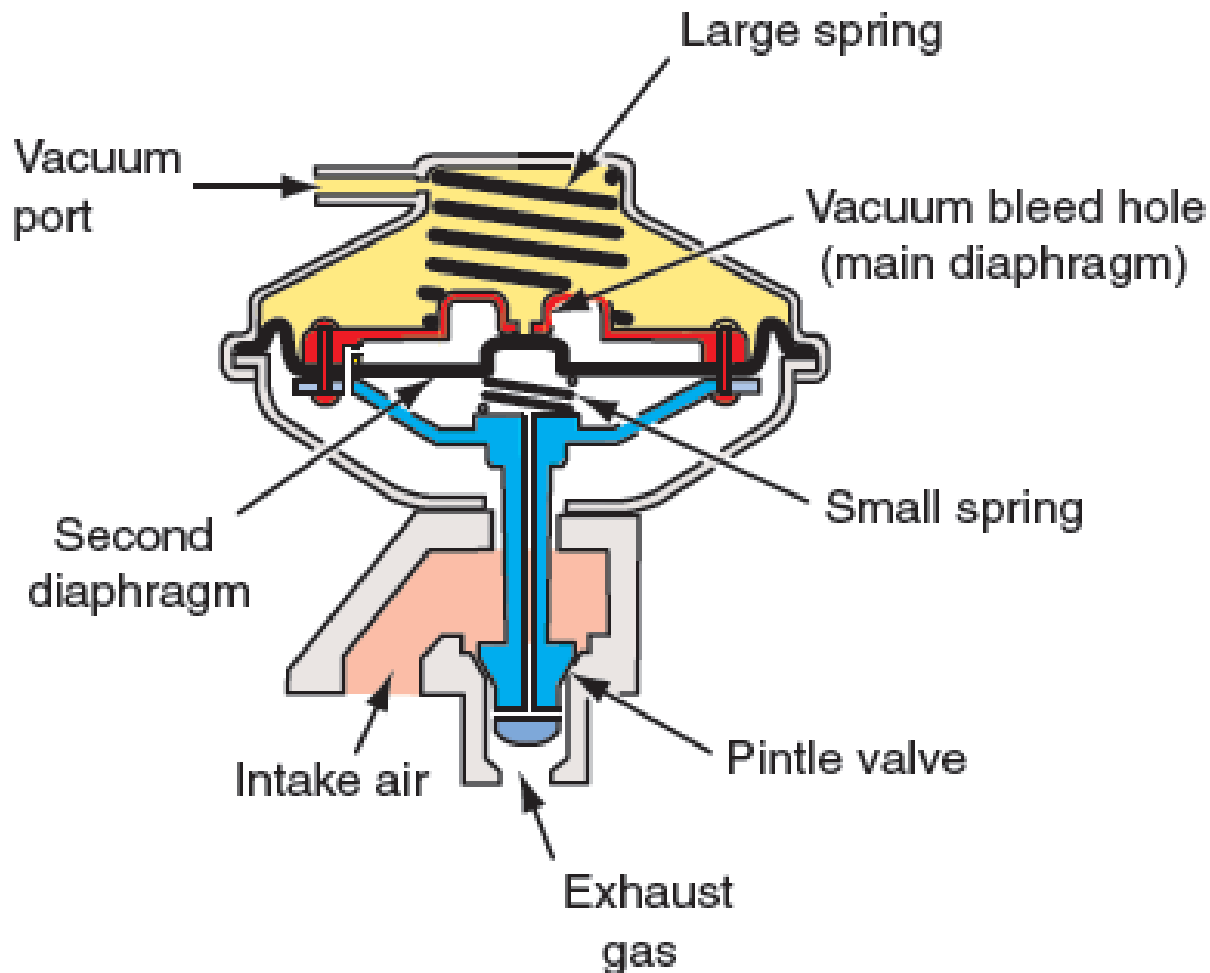
# Exhaust Gas Recirculation

- Lean air-fuel mixtures and higher operating temperatures raise  $\text{NO}_x$ 
  - Exhaust gas recirculation (EGR) system allows exhaust gas into air-fuel mixture
    - Diluting air-fuel mixture with exhaust gas lowers combustion temperature by  $300^\circ\text{F}$
  - EGR improves fuel economy
    - Early EGR systems were often disabled to improve fuel economy

# EGR System Operation

- Simple EGR system has an EGR valve operated by engine vacuum
  - Located on intake manifold
- Little NOX is formed at idle
  - EGR valve is closed at these times
- Exhaust backpressure is a good indicator of engine load
  - More EGR flow needed under load
- Thermal vacuum valve (TVV)
  - Prevents vacuum operation before engine is warm





**Figure 43.16** A mechanical EGR valve allows a small amount of exhaust gas to leak into the intake stream. This EGR valve is in the *closed* position.

# Computer-Controlled EGR Systems

- Today's cars have computer-controlled EGR systems
  - EGR valve is controlled by input signals of engine temperature and load
    - Vehicle speed signal or PRNDL switch
  - Position sensors on EGR valves: included in late-model engines
  - Digital EGR valves: EGR flow regulated by computer using a series of solenoids
  - Linear EGR valves: include a stepper motor

# Catalytic Converter

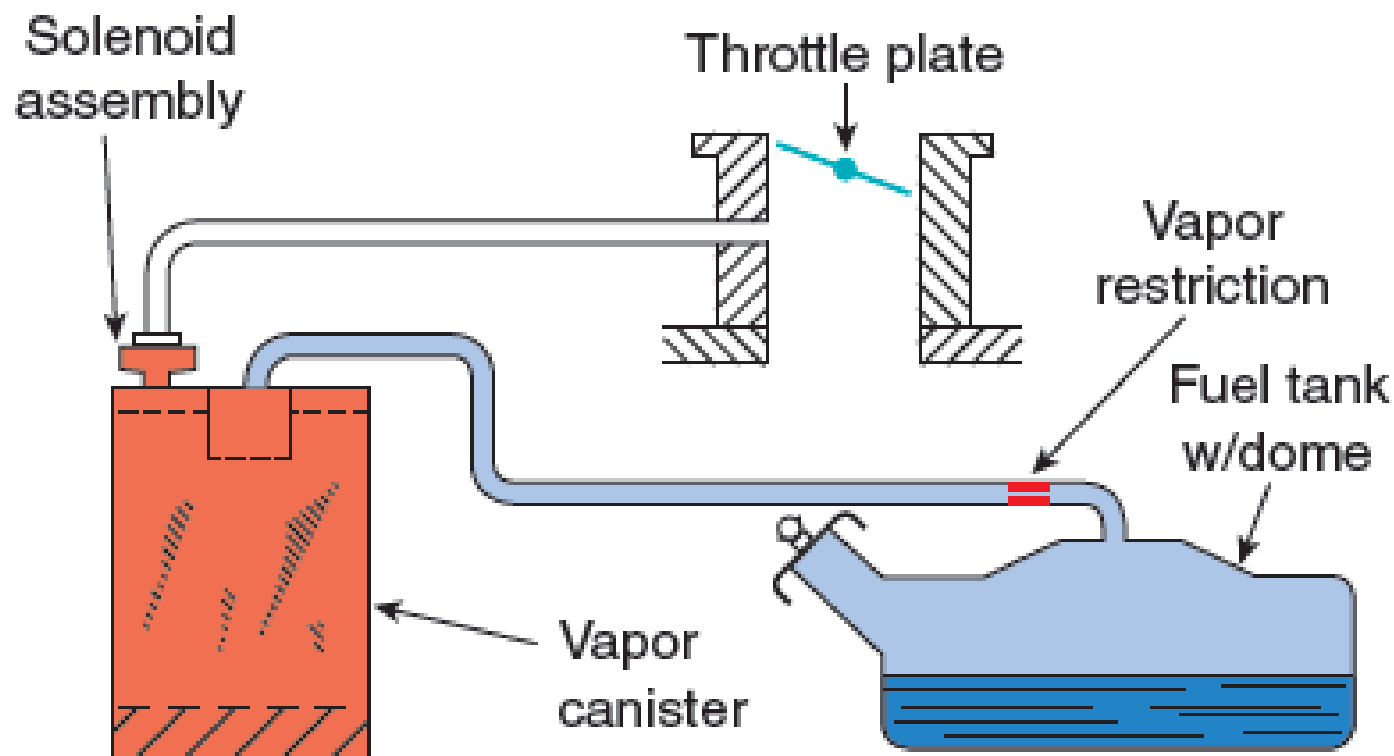
- Catalyst
  - Causes chemical reaction without changing itself
    - Chemical reaction only occurs in presence of catalyst or occurs faster because of one
- Catalytic converters
  - Must be hot to operate
  - Monolithic catalyst has thin coating of platinum applied to ceramic coated with alumina
  - Late-model vehicles have pre-catalysis which begin operating earlier

# Types of Catalytic Converters

- Two-way catalyst; changes HC and CO into CO<sub>2</sub> and H<sub>2</sub>O
- Three-way catalytic converter: used with oxygen sensor
  - Reduces NO<sub>x</sub> and oxidizes HC and CO
  - Single or dual bed design
    - Dual bed catalytic converters include air switching valve and diverter
  - Use rhodium as a catalyst
  - Needs heat and regulated air-fuel mixture

# Evaporative Controls

- Control emission of gasoline vapors from tank
  - Activated charcoal store gasoline vapors until they are drawn into the engine and burned
  - Emission of fuel vapors is controlled by sealing the fuel system
- Gasoline tanks allow for fuel expansion of 10%
  - Expansion dome and liquid/vapor separator
  - Expansion tank
  - Filler neck design
- Gas caps sealed or have pressure vacuum valve



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**Figure 43.31** A simplified evaporative emission control system.

# Other Parts of the Fuel Tank System

- Include:
  - Liquid vapor separator keeps liquid fuel from being drawn into charcoal canister
  - Charcoal canister stores vapors from fuel tank
  - Thermostatic air cleaner (TAC) maintain consistent air-fuel mixture
  - Manifold heat control valves were used to reduce exhaust emissions and improve drivability during engine warmup

# On-Board Diagnostics

- 1988: on-board diagnostics regulations became law
  - Require computer to monitor engine's O2 sensor, EGR valve, and charcoal canister purge solenoid
  - Malfunction indicator light was also required
- Names of emission parts and connections for test equipment were standardized
  - Part of the OBD II regulations



# Engine Emission Modifications

- Common modifications
  - As little as possible exposed surface area on the combustion chamber and top of piston
  - Engines run with higher cooling system temperatures
  - Advancing ignition timing can increase fuel economy
  - Changing cam design specifications results in different emissions
  - Domestic diesel light trucks and vans are now using urea selective catalyst reduction