AUTOMOBILE ENGINEERING

UNIT-2

Lecture – 01

Clutch-1

CLUTCHES

- It is a device used to connect & disconnect engine power flow to the transmission at the will of the driver
- When the clutch pedal is depressed, the three major clutch assembly components viz. flywheel, friction disc & pressure plate are disengaged

- **Remember this simple rule:-**
  - The pressure plate & flywheel are bolted to the engine's crankshaft & rotate at engine speed
  - The clutch disc is splined to the transmission input shaft & rotates at transmission speed
  - Parts splined together rotate as a unit, but the parts are free to move somewhat along the shaft's centerline

Principle of Operation of Clutch

- Clutch works on the principle of **friction**
  - when the two rough surface clutch plates are comes in contact with each other then they become rotating as a single unit
- This is possible due to the friction between the two plates
- One surface is connected to engine and other to the transmission system of automobile

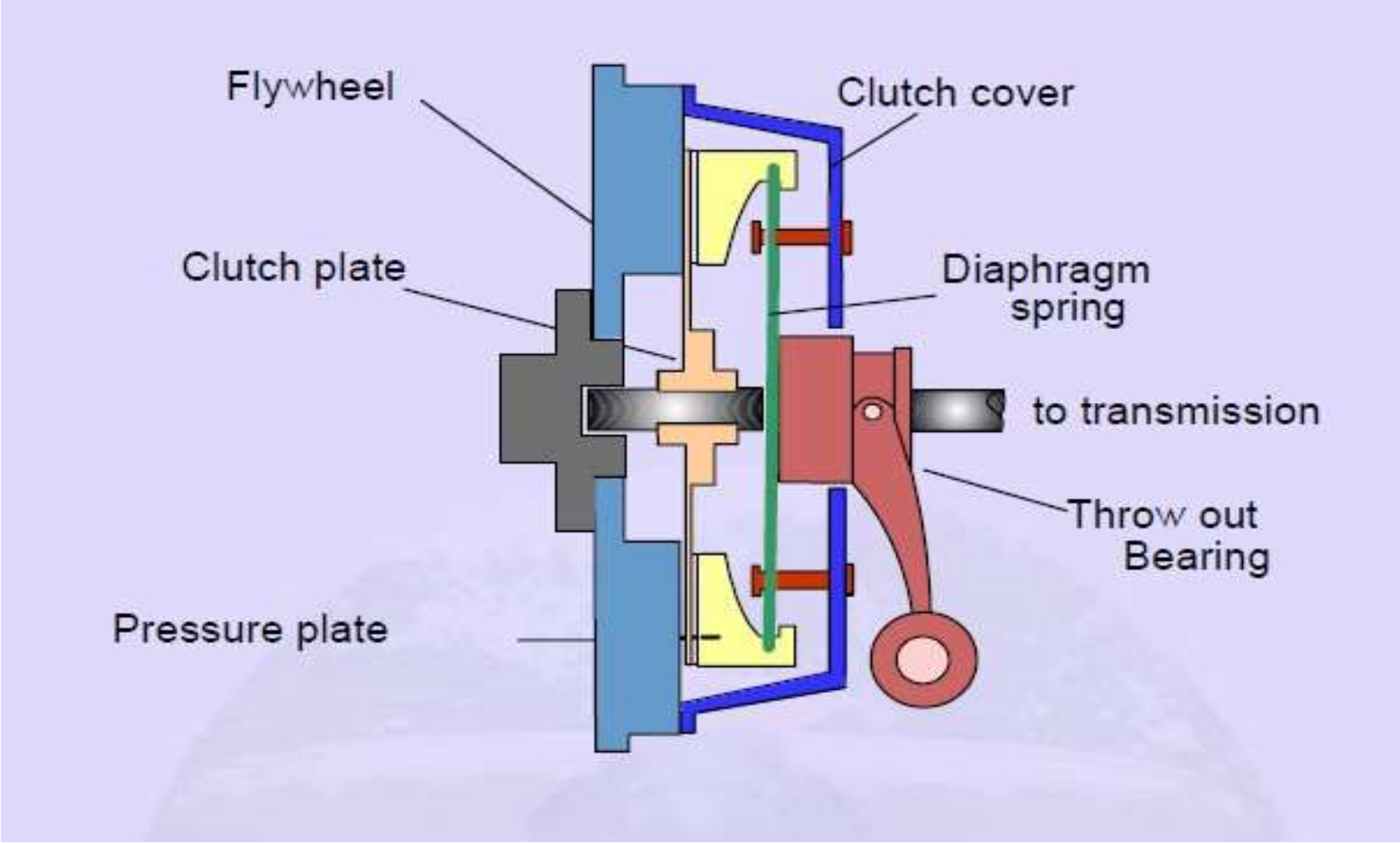
Requirements of a Good Clutch

- It should be able to transmit maximum torque of the engine
- It should engage gradually to avoid sudden jerks
- It should be able to dissipate large amount of heat generated during clutch operation
- It should be dynamically balanced, particularly in the case of high speed engine clutches
- It should have suitable mechanism to damp vibrations and to eliminate noise produced during power transmission

Requirements Contd...

- It should be as small as possible so that it will occupy minimum space
- It should be easy to operate requiring as little exertion as possible on the part of the driver
- It should be made as light as possible so that it will continue to rotate for any length of time after the clutch has been disengaged
- It must be trouble free and have longer life
- It must be easy to inspect, adjust and repair

Clutch Parts



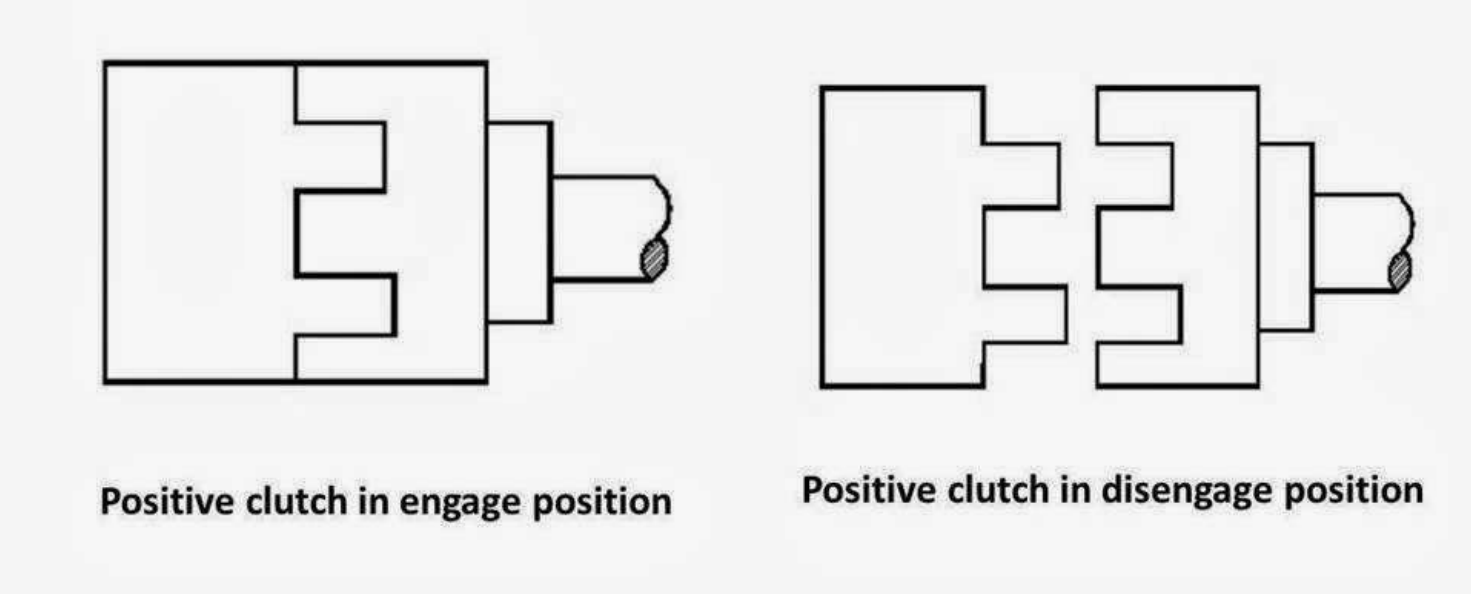
TYPES OF CLUTCH

- **Friction Clutch**
  - single plate clutch
  - multi-plate clutch
  - cone clutch
  - diaphragm Clutch
- **Centrifugal clutch**
- **Semi-centrifugal clutch**
- **Hydraulic clutch**
- **Positive clutch**
- **Vacuum clutch**
- **Electromagnetic clutch**

According to the method of transmitting torque:

1. Positive clutch (Dog clutch)

– Grooves are cut either into the driving member or into the driven member and some extracted parts are situated into both driving and driven member



Positive clutch in engage position

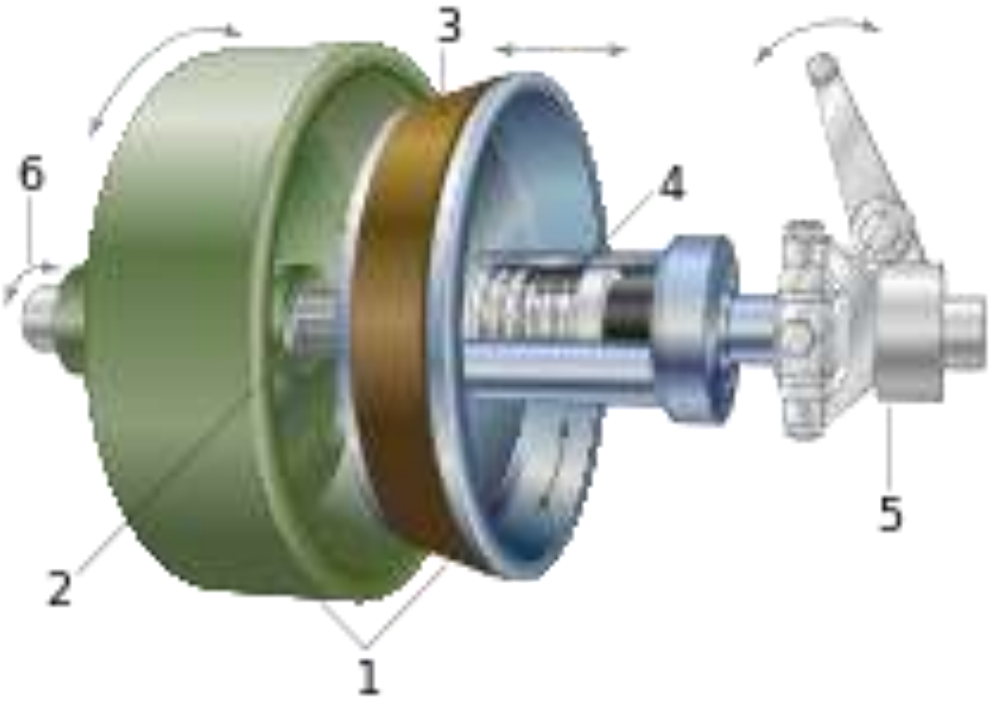
Positive clutch in disengage position

2. Friction clutch

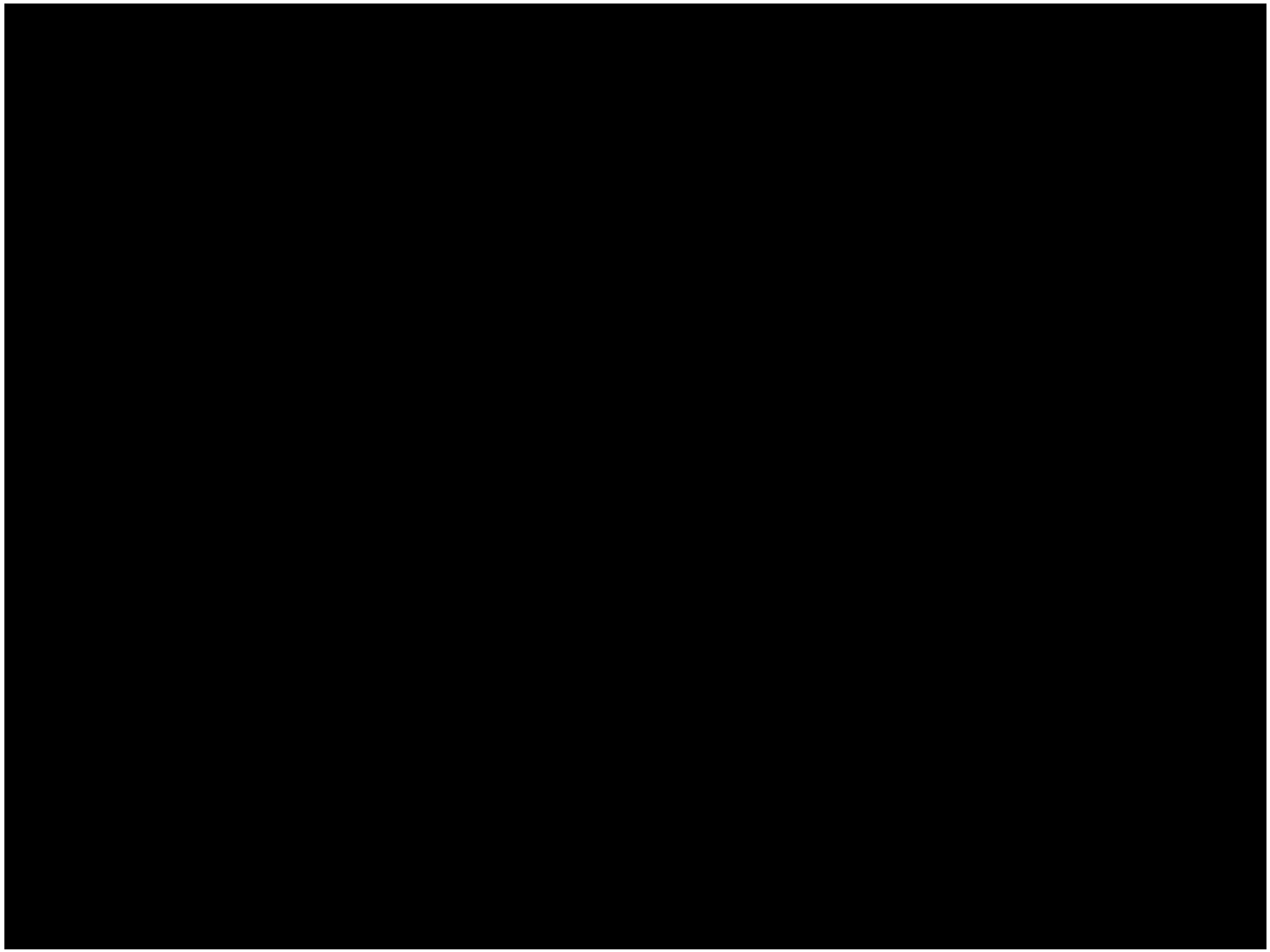
- Friction force is used to engage and disengage the clutch
- A friction plate is inserted between the driving member and the driven member of the clutch
- This type of clutch is subdivided into four types according to the design of the clutch

A) Cone Clutch

- This type of clutch consist a cone mounted on the driven member and the shape of the sides of the flywheel is also shaped as the conical
- The surfaces of contact are lined with the friction lining



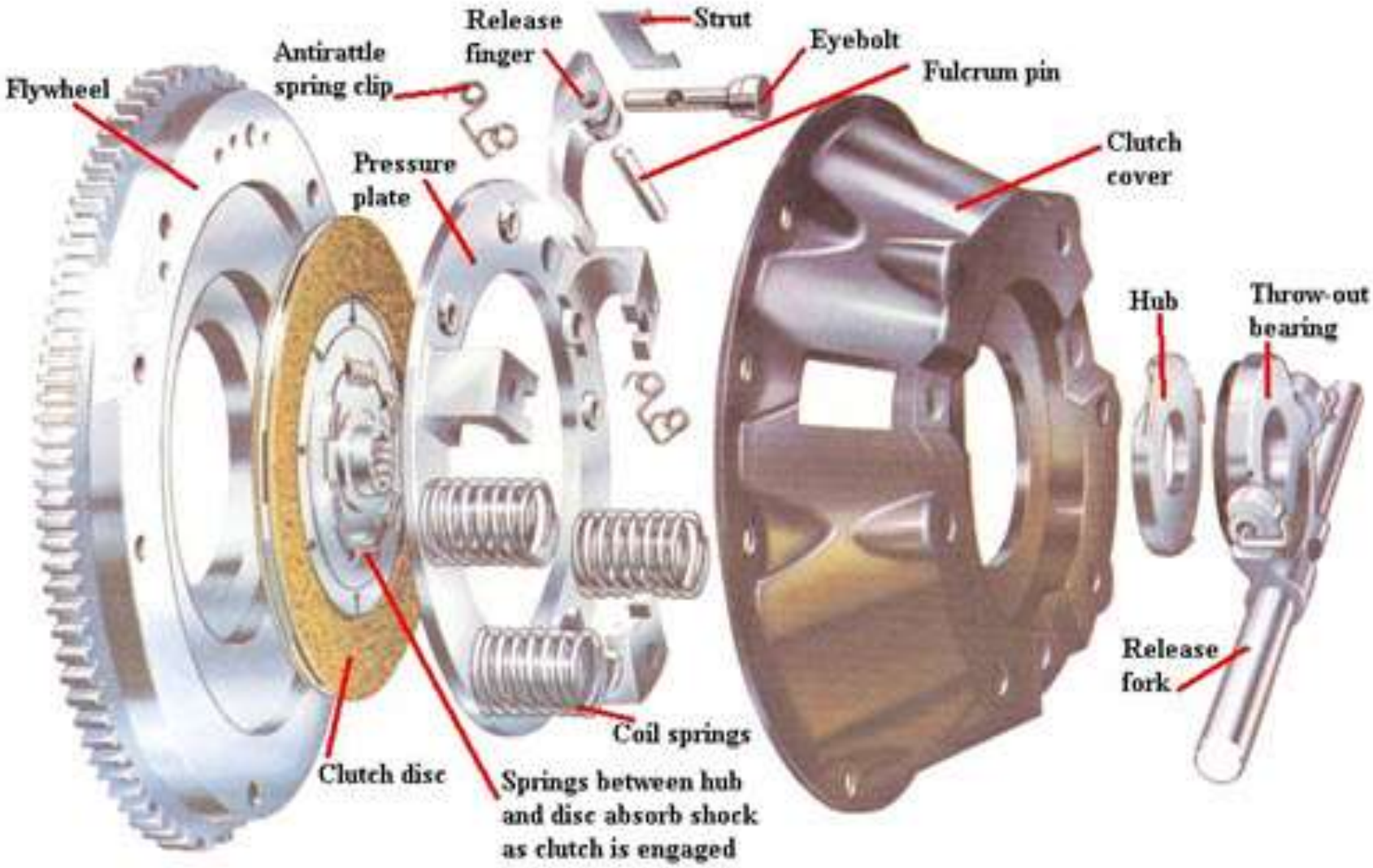
Animation of Cone Clutch



B) Single Plate Clutch

- Flywheel is **fixed to the engine shaft** and a pressure plate is attached to the gear box shaft
- This pressure plate is free to move on the spindle of the shaft
- A friction plate is situated between the flywheel and pressure plate

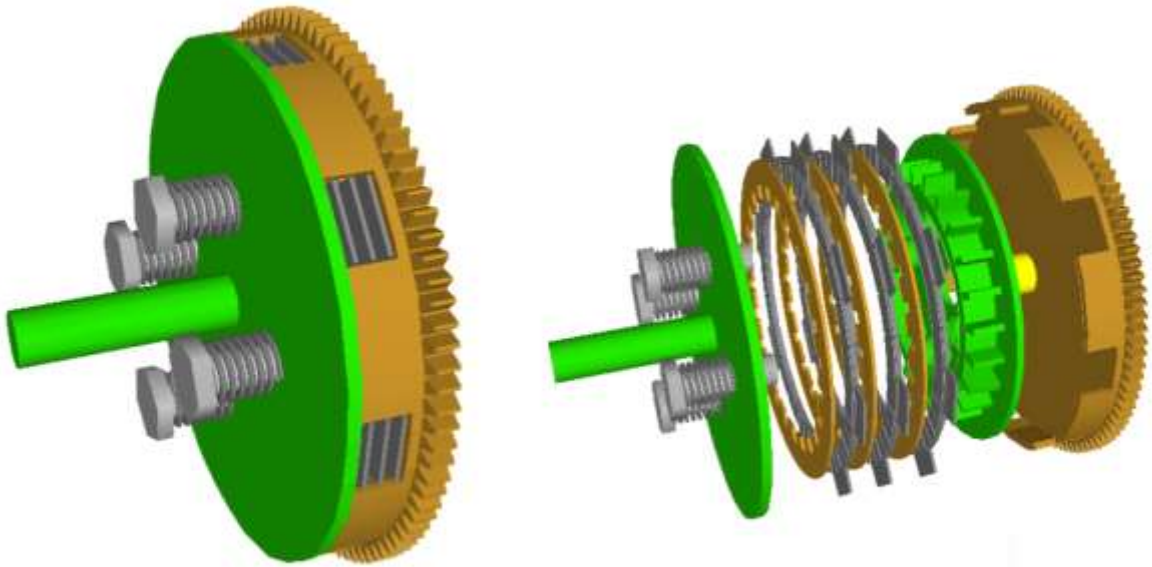
Main components of a Single Plate Axial Spring type friction clutch



Animation of Single Plate Clutch

C) Multi-plate Clutch

- Multi-plate clutch is same as the single plate clutch but there is two or more clutch plates inserted between the flywheel and pressure plate
- This clutch is compact then single plate clutch for same transmission of torque



Animation of Multiple Plate Clutch

D) Diaphragm Clutch:

- Similar to the single plate clutch except diaphragm spring is used instead of coil springs for exert pressure on the pressure plate
- In the coil springs, one big problem occur that these springs do not distribute the spring force uniformly

Diaphragm spring

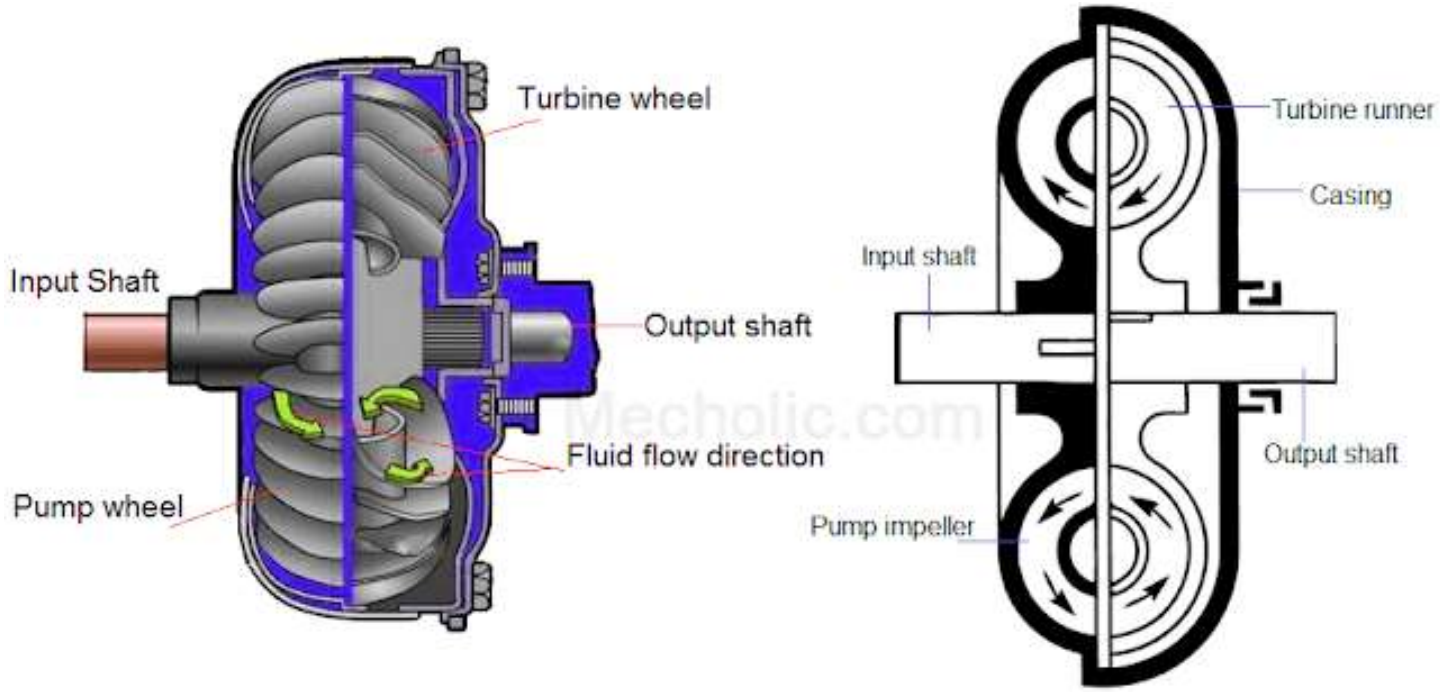
3. Hydraulic Clutch

- This clutch uses hydraulic fluid to transmit the torque
- There is no mechanical connection between driving member and driven member
- According to their design, this clutch is sub- divided into two types
  - Fluid coupling
  - Hydraulic torque converter

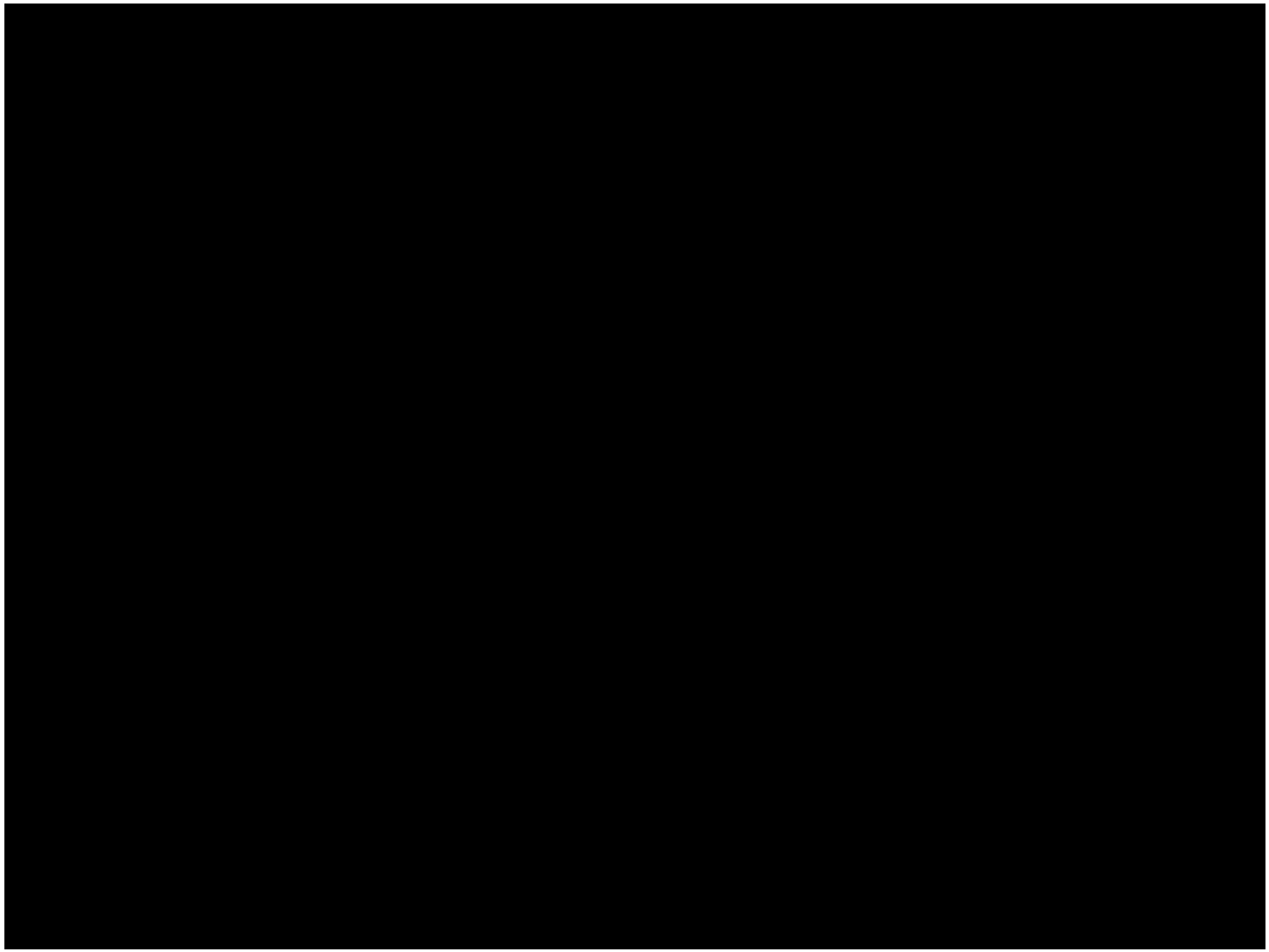
3.1 Fluid Coupling

- A pump impeller is boltted on a driving member (Engine) and a turbine runner is bolted on the driven member (Gearbox)
- Both the above unit is enclosed into single housing filled with a liquid
- This liquid serve as the torque transmitter from the impeller to the turbine
- When the driving member starts rotating then the impeller also rotates and through the liquid outward by centrifugal action
- This liquid then enters the turbine runner and exerts a force on the runner blade

- This make the runner as well as the driven member rotate
- The liquid flows to the runner then flows back into the pump impeller, thus complete the circuit
- **It is not possible to disconnect to the driving member to the driven member when the engine is running**
- **So the fluid coupling is not suitable for ordinary gear box**
- It is used with **automatic or semi-automatic gear** box



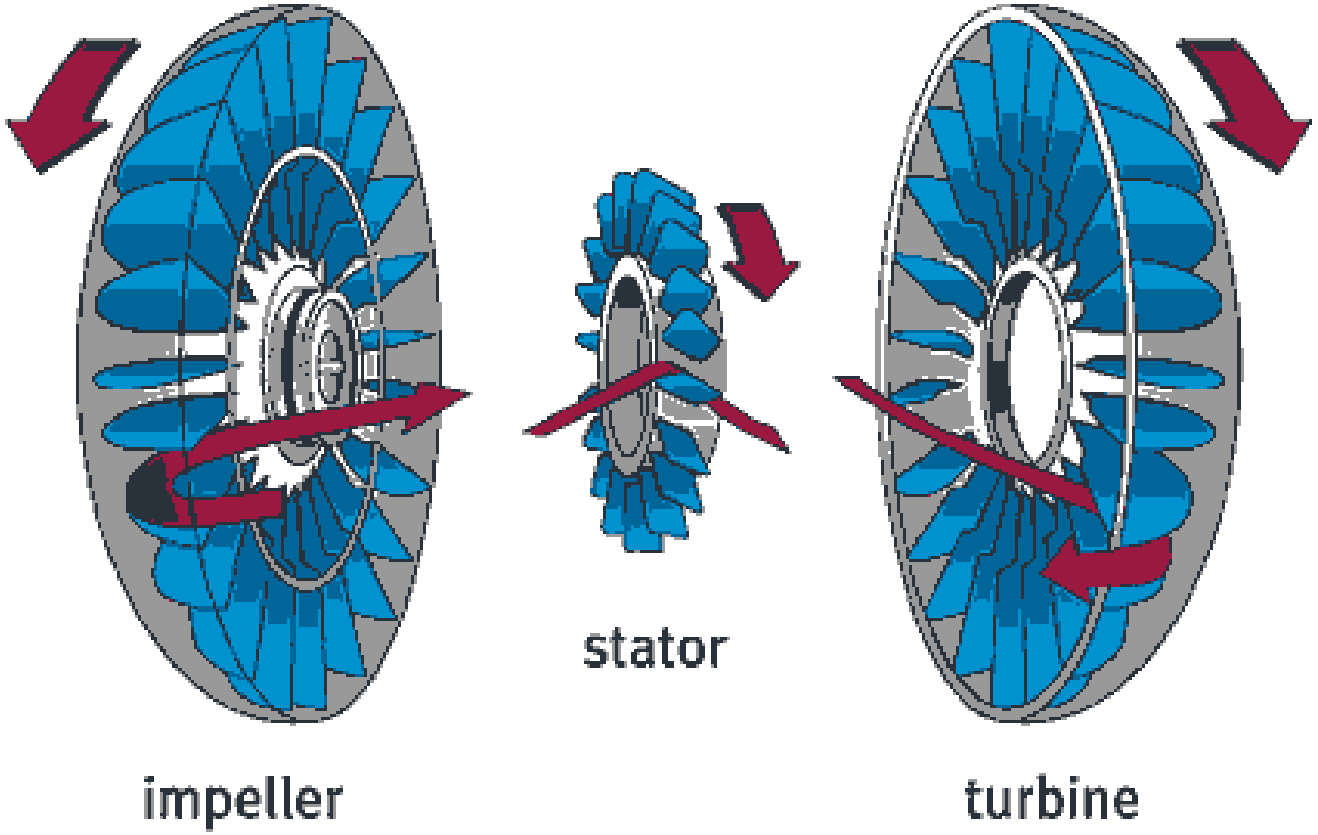
Animation of Fluid Coupling



3.2 Hydraulic torque converter

- Same as the electric transformer
- The main purpose is to engage the driving member to driven member and increase the torque of driven member
- An impeller is bolted on the driving member, a turbine is bolted on the driven member and **a stationary guide vanes are placed between these two members**
- This all parts are enclosed into single housing which filled with hydraulic liquid
- This liquid flowing from the impeller to turbine runner exerts a torque on the stationary guide vanes **which changes the direction of liquid,** thereby making possible the transformation of torque and speed

– The difference of torque between impeller and turbine **depends upon these stationary guide vanes**
– The hydraulics torque converter serves the function of clutch as well as the automatic gear box



Animation of Hydraulic Torque Converter

- **Advantages**
  - It produces the maximum torque as compared with the vehicle equipped with clutch
  - It removes the clutch pedal
  - It makes the job of driving a vehicle easier
- **Disadvantages**
  - Its fuel efficiency is low as compared with the vehicle with manual transmission

AUTOMOBILE ENGINEERING

UNIT-2

Lecture – 02

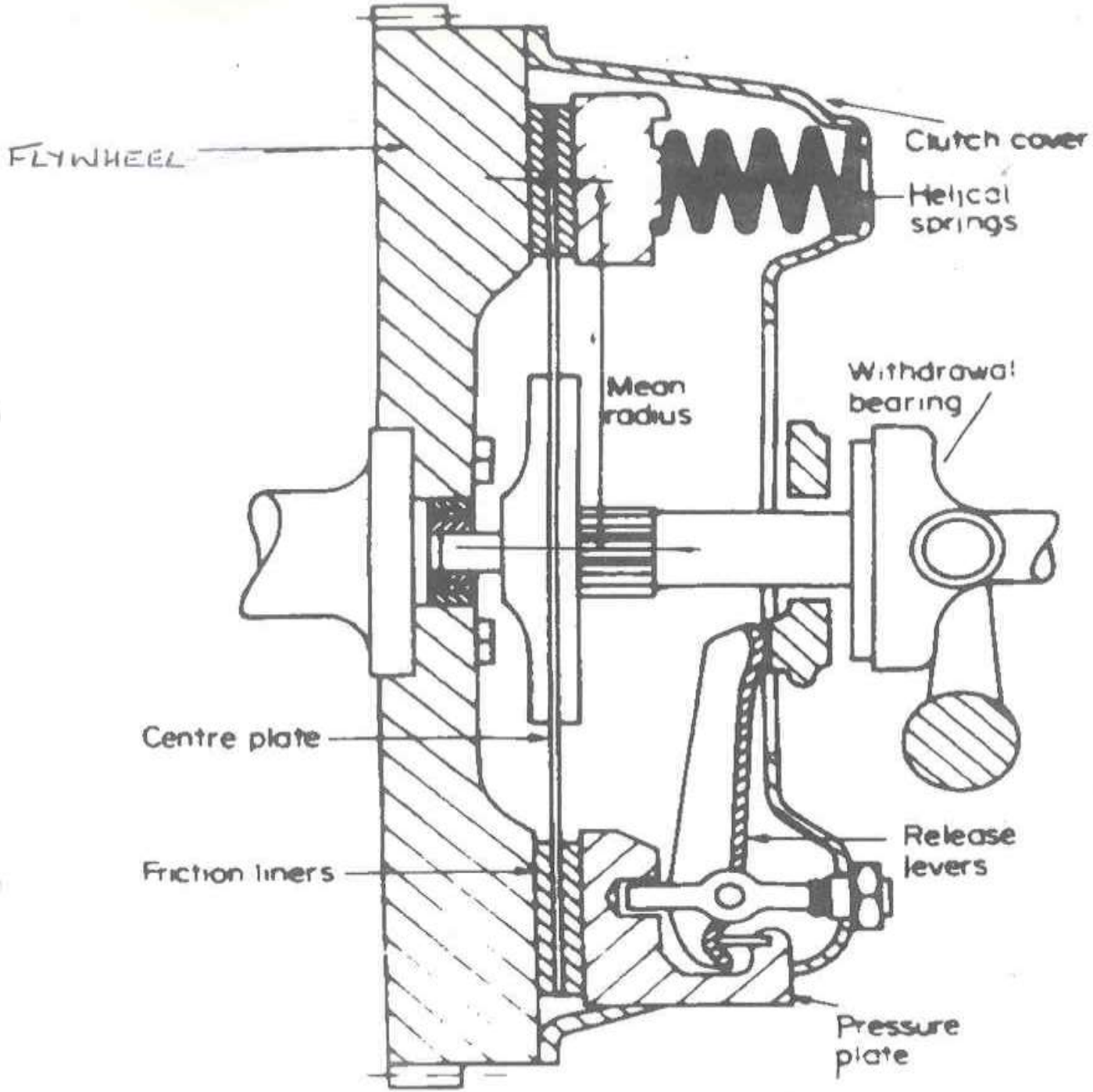
Clutch-2

According to the method of engaging force

- Spring types clutch
- Centrifugal clutch
- Semi-centrifugal clutch
- Electro-magnetic clutch

1. Spring types clutch

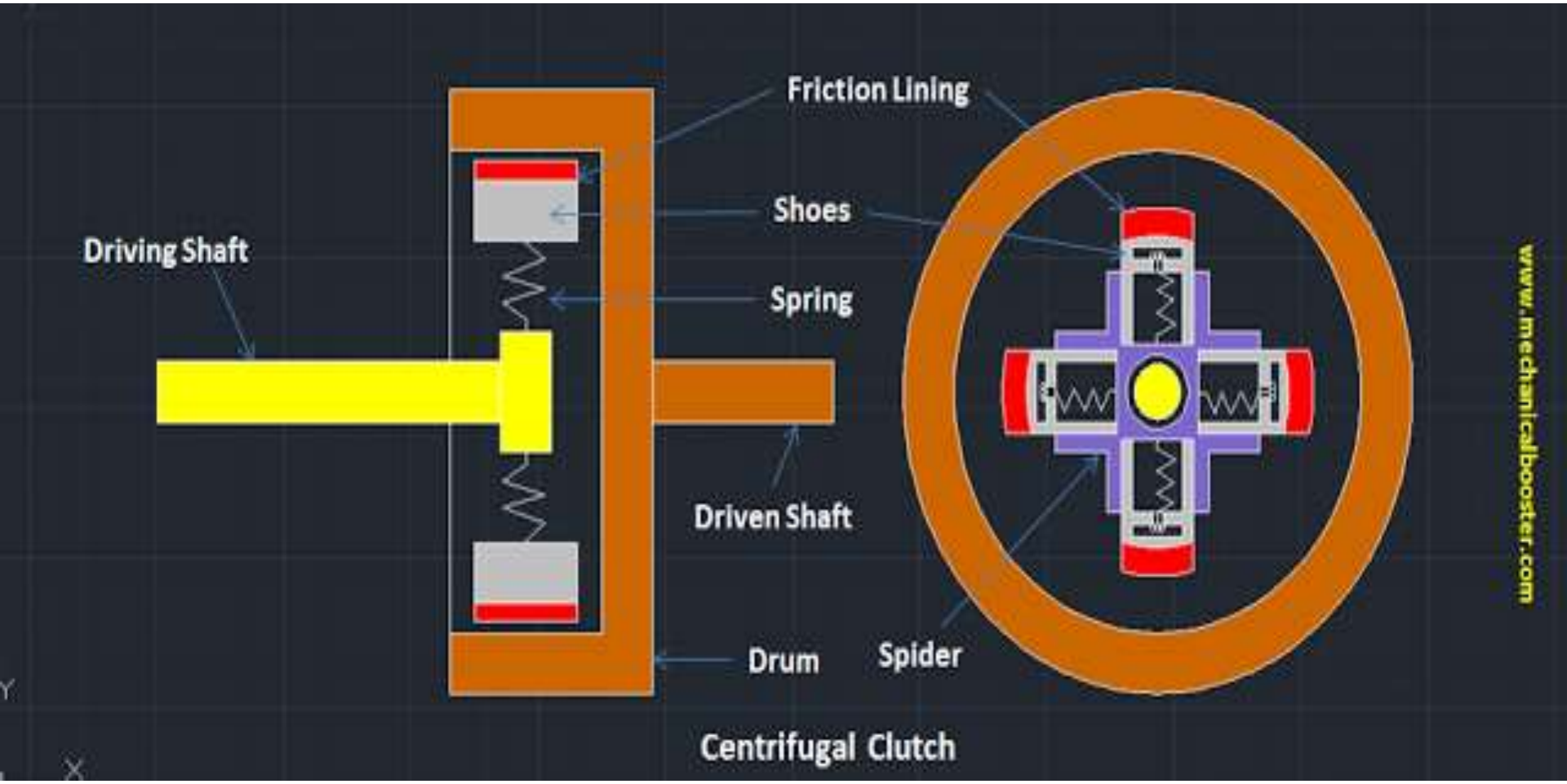
- In this types of clutches, helical or diaphragm springs are used to exert a pressure force on the pressure plate to engage the clutch
- These springs are situated between pressure plate and the cover
- These springs are inserted into compact position into the clutch, so when it is free to move between these two members, it tends to expand
- It exert a pressure force on the pressure plate thus it brings the clutch in engage position

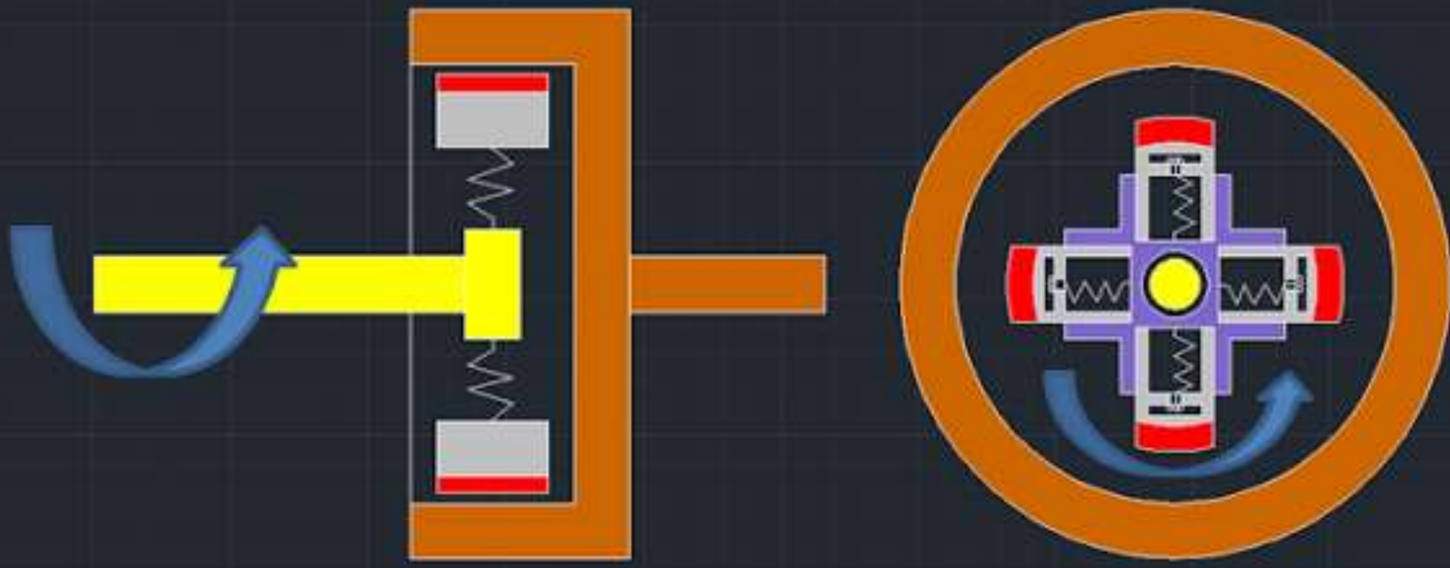

FLYWHEEL
Clutch cover
Helical springs
Mean radius
Withdrawal bearing
Centre plate
Friction liners
Release levers
Pressure plate

2. Centrifugal Clutch

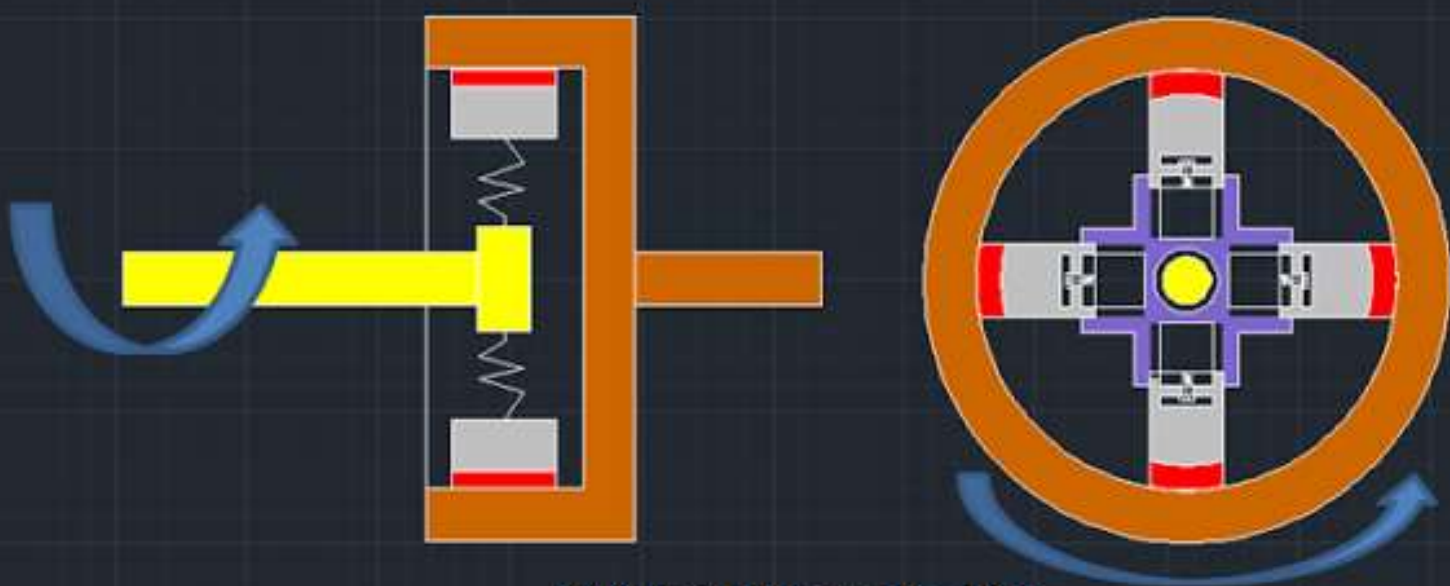
- Centrifugal force is used to engage the clutch
- It does not require any clutch pedal for operating the clutch
- The clutch is operated automatically depending upon the engine speed
- It consist a weight pivoted on the fix member of clutch
- When the engine speed increase the weight fly of due to the centrifugal force, operating the bell crank lever, which press the pressure plate

Centrifugal Clutch





Clutch in Disengage Position

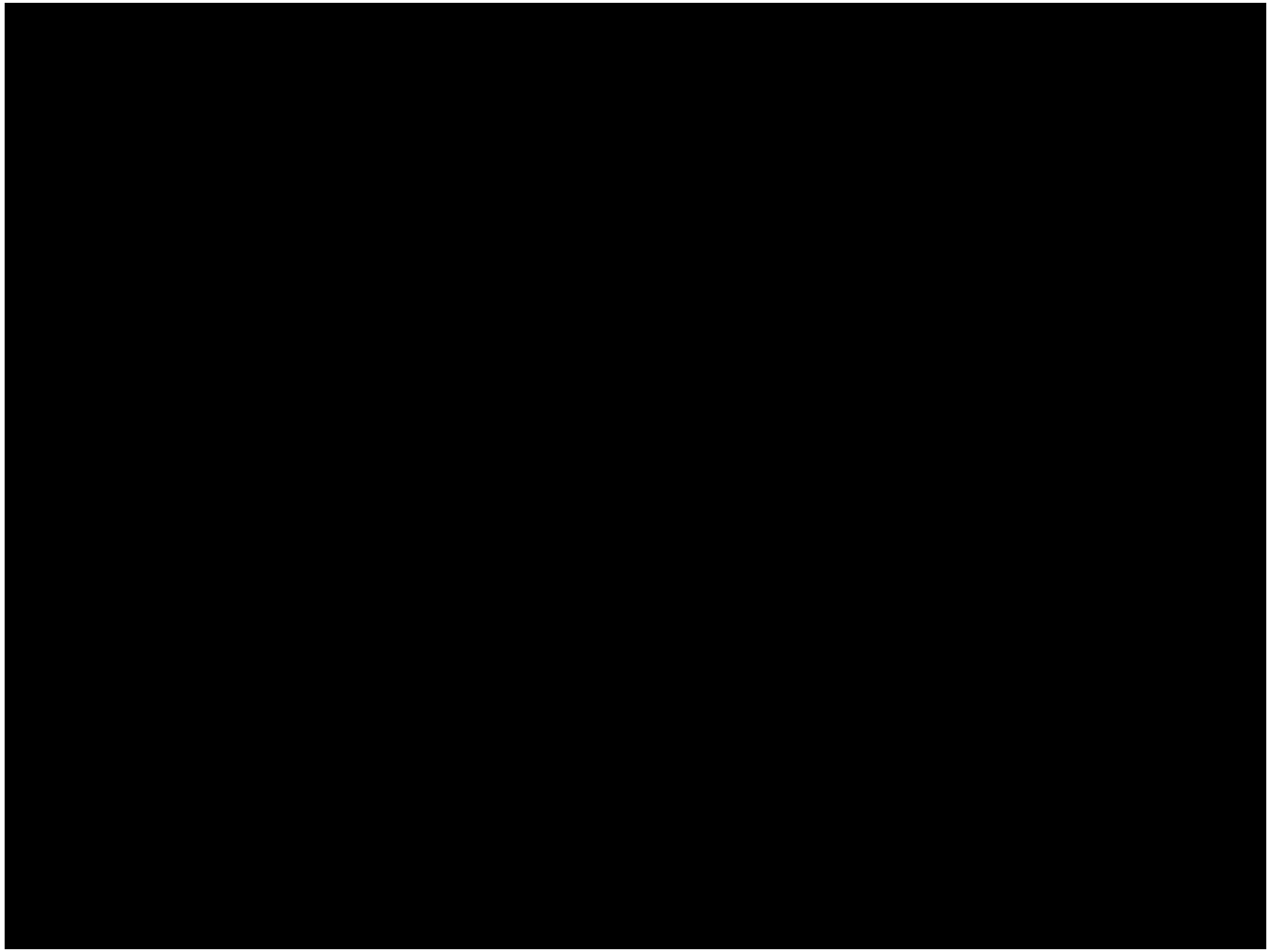


Clutch in Engage Position

- **Advantages**
  - It is simple and requires less maintenance
  - It is inexpensive
  - Since it is automatic, so it does not need necessary control mechanism
  - Its engagement speed can be controlled by selecting appropriate spring
  - It helps to prevent the engine from stalling

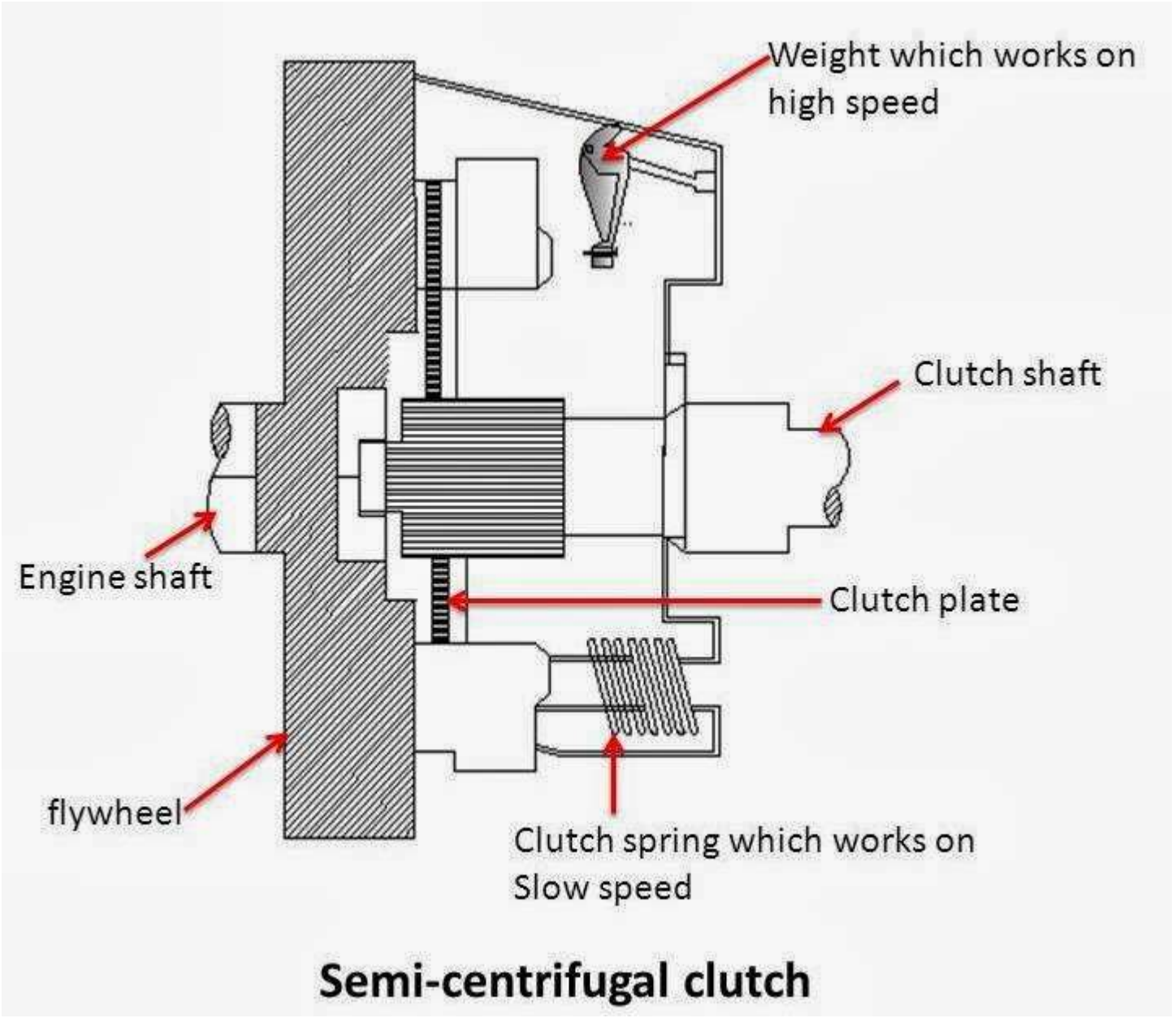
- **Disadvantages**
  - There is a loss of power in it due to slipping and friction
  - It is not capable of transferring high amount of power and it shoes slip in heavy load condition
  - It experiences overheating problem
  - Its engagement depends upon the speed of the driving shaft

Animation of Centrifugal Clutch



3. Semi-Centrifugal Clutch

- One big problem occur in centrifugal clutch is that at **lower speed they don't do their work sufficiently**
- This type of clutch uses centrifugal force as well as spring force for keeping it in engaged position
- The springs are designed to transmit the torque at normal speed, while the centrifugal force assists in torque transmission at higher speeds



Semi-centrifugal clutch

Working of Semi centrifugal clutch

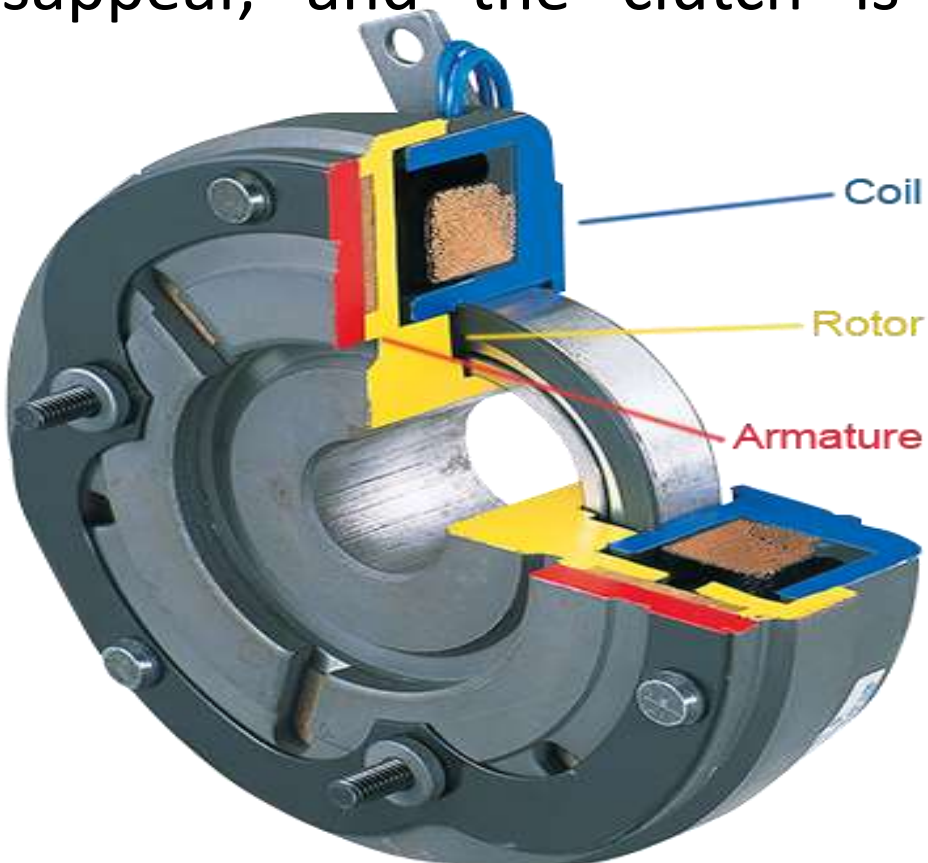
Clutch engaged

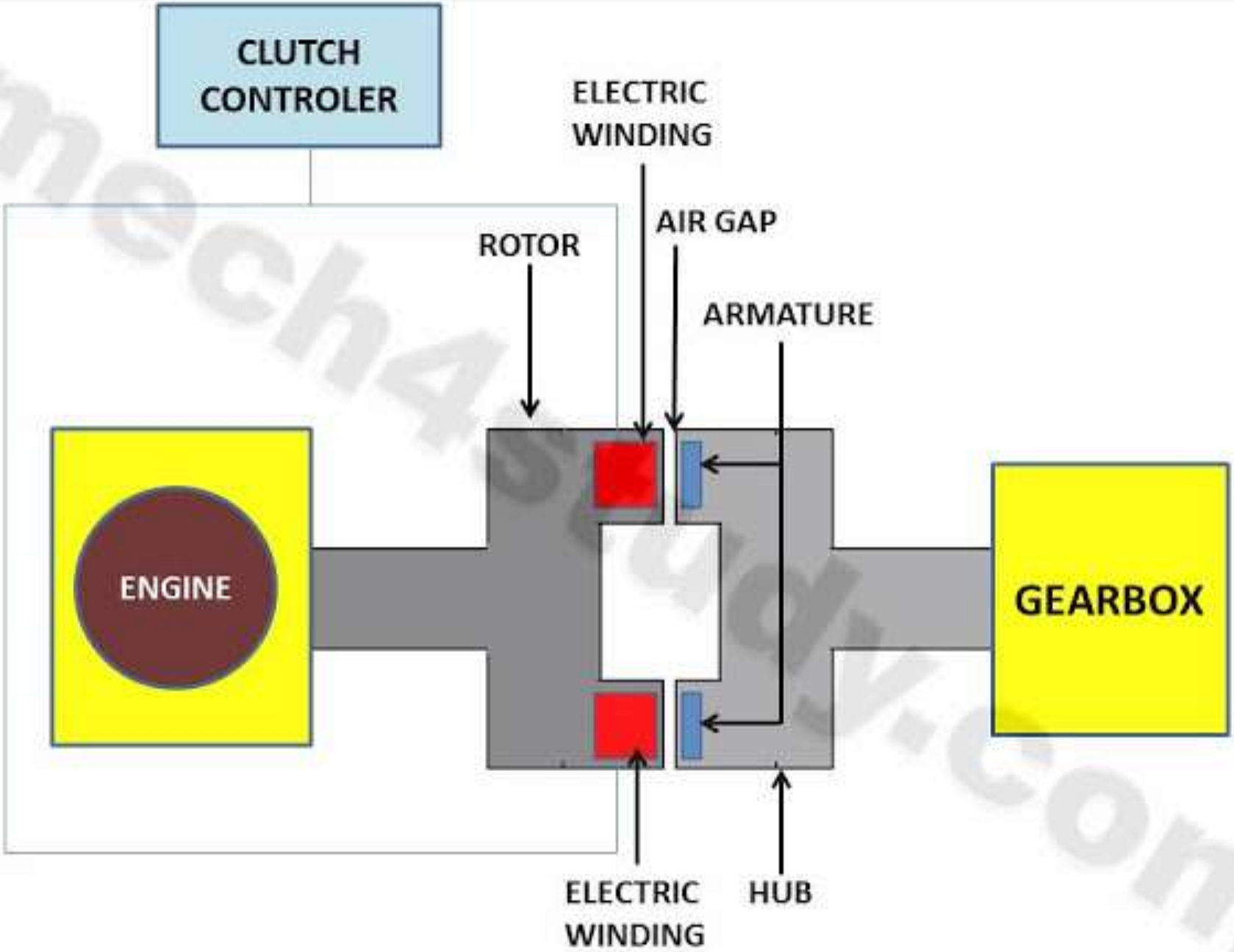
- Clutch springs exerts pressure on pressure plate at low engine speeds
- At high speeds the centrifugal force developed by rotation of weighted levers exerts pressure on pressure plate

4. Electro-Magnetic Clutch

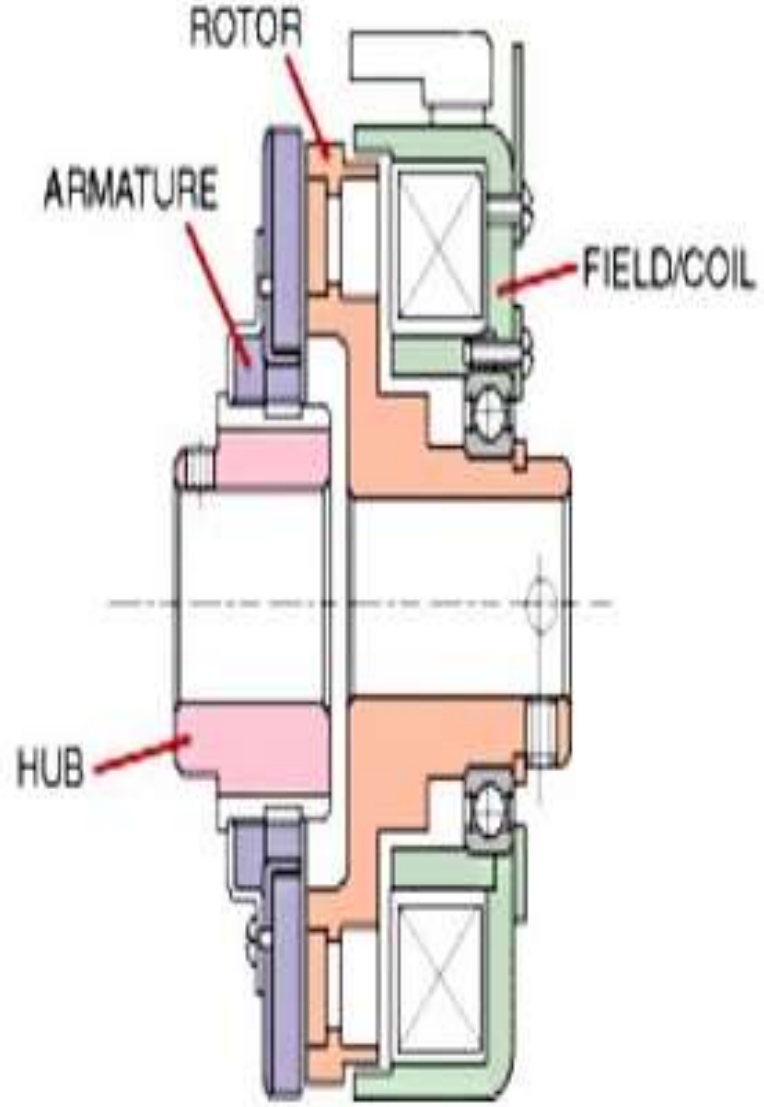
- An electromagnetic clutch is also a friction clutch but it uses magnetic force in place of spring force to engage and disengage
- It consist two clutch plates (Rotor and Hub)
- One of them is connected with the electric circuit
- When the electricity passes through this plate, it converts it into electromagnet which attract the other plate towards it
- There is a friction plate between them

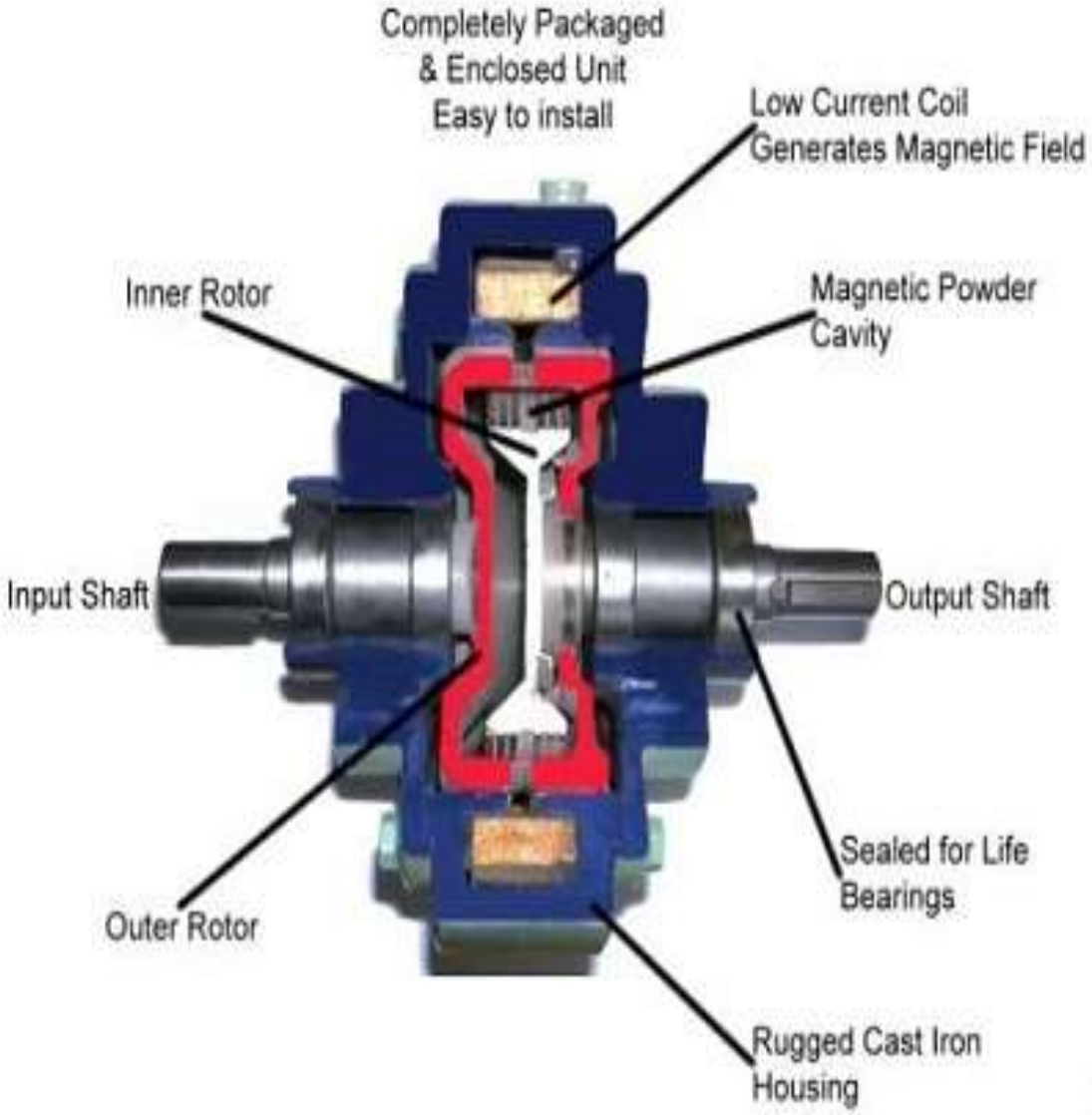
- The magnetic field apply force to connect both these plates and friction plate transmit torque between them
- When the driver cut the electricity, this attraction force disappear, and the clutch is in disengage position





ELECTROMAGNETIC CLUTCH IN DISENGAGE POSITION


ROTOR
ARMATURE
FIELD/COIL
HUB


Completely Packaged
& Enclosed Unit
Easy to install
Low Current Coil
Generates Magnetic Field
Inner Rotor
Magnetic Powder
Cavity
Input Shaft
Output Shaft
Sealed for Life
Bearings
Outer Rotor
Rugged Cast Iron
Housing

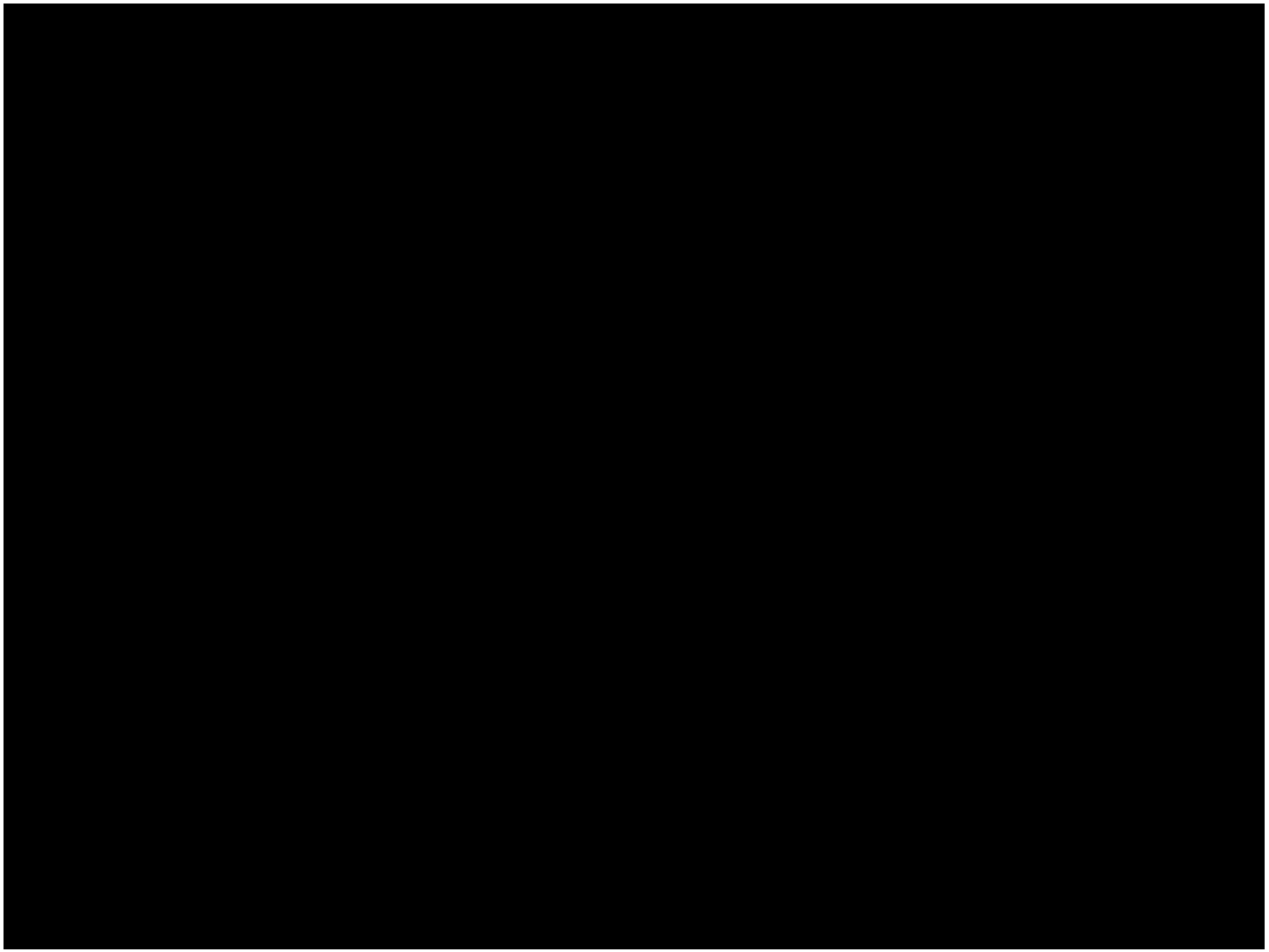
- **Rotor**
  - Major part of this clutch which is connected directly to the driving shaft or engine shaft
  - It continuously rotate along with the driving shaft
- **Winding or Coil**
  - It is situated behind the rotor and remains in stationary position during clutch working
  - It is connected with a high voltage DC supply which transfer a high voltage current into this winding and convert it into electromagnet
- **Armature**
  - It is situated at front of the rotor
  - It is connected to the hub or pressure plated with the help or rivet or bolted joint

- **Hub**
  - Hub or pressure plate is bolted with the gear shaft or driven shaft and rotates with it
  - It is situated after the armature
- **Friction Plate**
  - Friction plate is inserted between armature and rotor according to the requirement
- **Supply unit**
  - Supply unit consist clutch switch, battery, wire etc.

Working of Electromagnetic Clutch

- In the disengage position there is an air gap between rotor and hub
- First the engine starts which rotate the rotor connected with the engine shaft
- A DC battery supplies DC current into the clutch winding
- This high voltage DC current converts this winding into an electromagnet which attract armature towards it
- This armature forces friction plate towards the rotor and rotate the hub
- When the clutch pedal is pressed, the battery stops the supply in winding which remove the electromagnetic force, thus the clutch is in disengage position

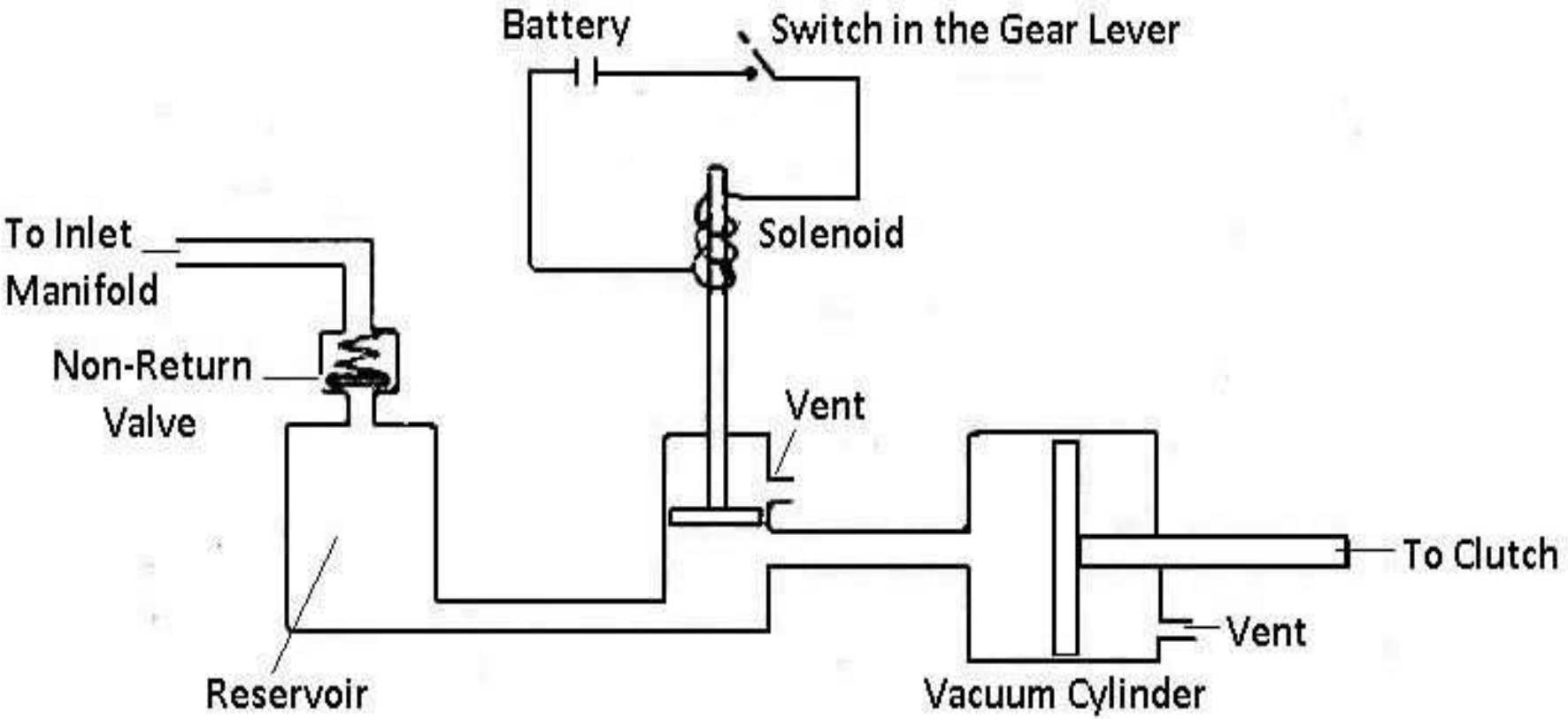
Animation of electromagnetic Clutch



- **Advantages**
  - No linkage is required to operate the clutch. So it can be installed any remote location
  - It can be used to achieve automatic transmission
  - Easy to operate
  - Less wear and tear at contact point
- **Disadvantages**
  - This clutch operating temperature is limited by the temperature rating of the insulating material
  - High initial Cost

5. Vacuum Clutch

- This type of clutches uses existing vacuum in the engine manifold to operate the clutch
- The vacuum clutch consists of a reservoir, non-return valve, vacuum cylinder with piston and solenoid valve



Vacuum Clutch

Construction

- The reservoir is connected to the inlet manifold through a non-return valve
- A vacuum cylinder is connected to a reservoir through a solenoid operated valve
- The solenoid is operated from the battery and the circuit has a switch which is attached on the gear lever
- The switch is operated when the driver changes the gear by holding the gear lever

Working

- When the throttle is opened the pressure increases in the inlet manifold due to this the valve of the non-return valve closes
- It separates the reservoir and manifold thus the vacuum exists all the time in the reservoir
- In the normal operation, the solenoid valve rod is in the bottom position of the valve and the switch in the gear lever remains open

- At this stage, the atmospheric pressure acts on both the side of the piston of the vacuum cylinder, because the vacuum cylinder is open to the atmosphere through the vent
- When the driver changes the gear by holding gear lever the switch gets closed
- The solenoid energizes and pulls the valve up this connects one side of vacuum cylinder to the reservoir
- This action opens the passage between the vacuum cylinder and the reservoir
- Due to the difference in the pressure, the vacuum cylinder piston moves forward and backwards.

AUTOMOBILE ENGINEERING

UNIT-2

Lecture – 03

Overdrive

OVERDRIVE

- Overdrive is the operation of an automobile cruising at sustained speed with reduced engine revolutions per minute (RPM), leading to better fuel consumption, lower noise, and lower wear
- **Overdrive** is the highest gear in the transmission
- **Overdrive** allows the engine to operate at a lower RPM for a given road speed

- It is an arrangement of sun and planetary gear which are arranged in such a fashion that :
  - when overdrive is enabled, it provides high rotation per minute to the output shaft with reduced engine rotation per minute

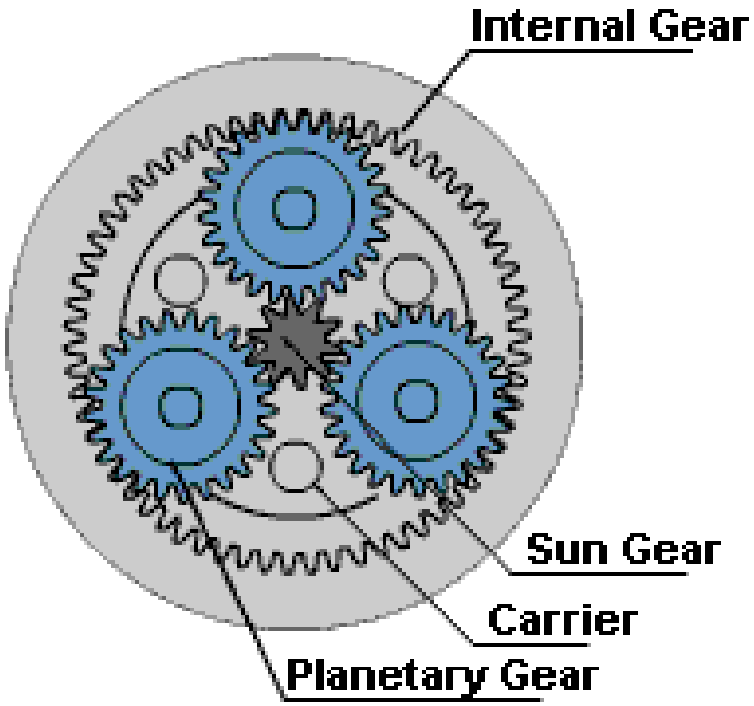
Need of An Overdrive

- On a long drive we shift our drive to the top gear (direct drive)
  - Means the final output shaft is rotating at the engine's rpm which in turn increase the load on the engine's shaft
- So an overdrive can be used with the transmission box which can reduce engine's load and provides high speed (higher than engine's rpm) during a long run

Need of An Overdrive contd..

- Fuel economy is the first priority
  - As overdrive reduces the engine's load we get better fuel economy
- Overdrive reduces the maintenance of the automobile vehicle
  - As the engine's load is reduced which reduces the wear and tear of the engine as well as transmission box

Planetary Gear



Construction

- It consists of 3 types of gears that are meshed together
  - **1. Ring gear-** It is in a shape of ring having internal teeth
    - Responsible for transmitting the final output through the connected output shaft
  - **2. Sun gear- It** is the centre most gear of an overdrive around which the number of planetary gears revolves in a direction guided by the ring gear or annulus
  - **3. Planetary gears-** which revolve in between the sun gear and ring gear through the teeth which are made to be in meshed with both sun and ring gear

- **Shafts**
  - **1. Input shaft-** solid cylindrical having splines cut over its surface is used as a input shaft which carries input from the transmission box
  - The splines of the input shaft are made to be in constant mesh with the sun gear's inner splines or in other words, sun gear is mounted over the splined input shaft
  - **2. Output shaft-** a solid cylinder shaft which is responsible for the transfer of final output from the overdrive to the differential through a propeller shaft
  - **3. Carrier –**over which the planetary gears are mounted
    - The carrier is itself mounted over the splined input shaft same as the sun gear

Working of an Overdrive

- Fixing of any of the sun or planetary or annulus changes the output
- Overdrive in cars can be enabled or disabled using any of the electrical, magnetic, pneumatic actuation method through button

- **Overdrive Disabled** – When overdrive is disabled the input shaft passing through the sun gear rotates the sun gear which in turn rotates the constantly meshed planetary gears and then these planetary gears rotates the annulus and direct drive (same as input shaft rpm) is obtained

- **Overdrive enabled-** When driver enabled the overdrive, the sun gear becomes fixed which mean the annulus is now rotated by the planetary gears due to which overdrive is obtained, which means now the output shaft rotates with the higher rpm than input shaft due to the higher reduction ratio of planetary gears and annulus

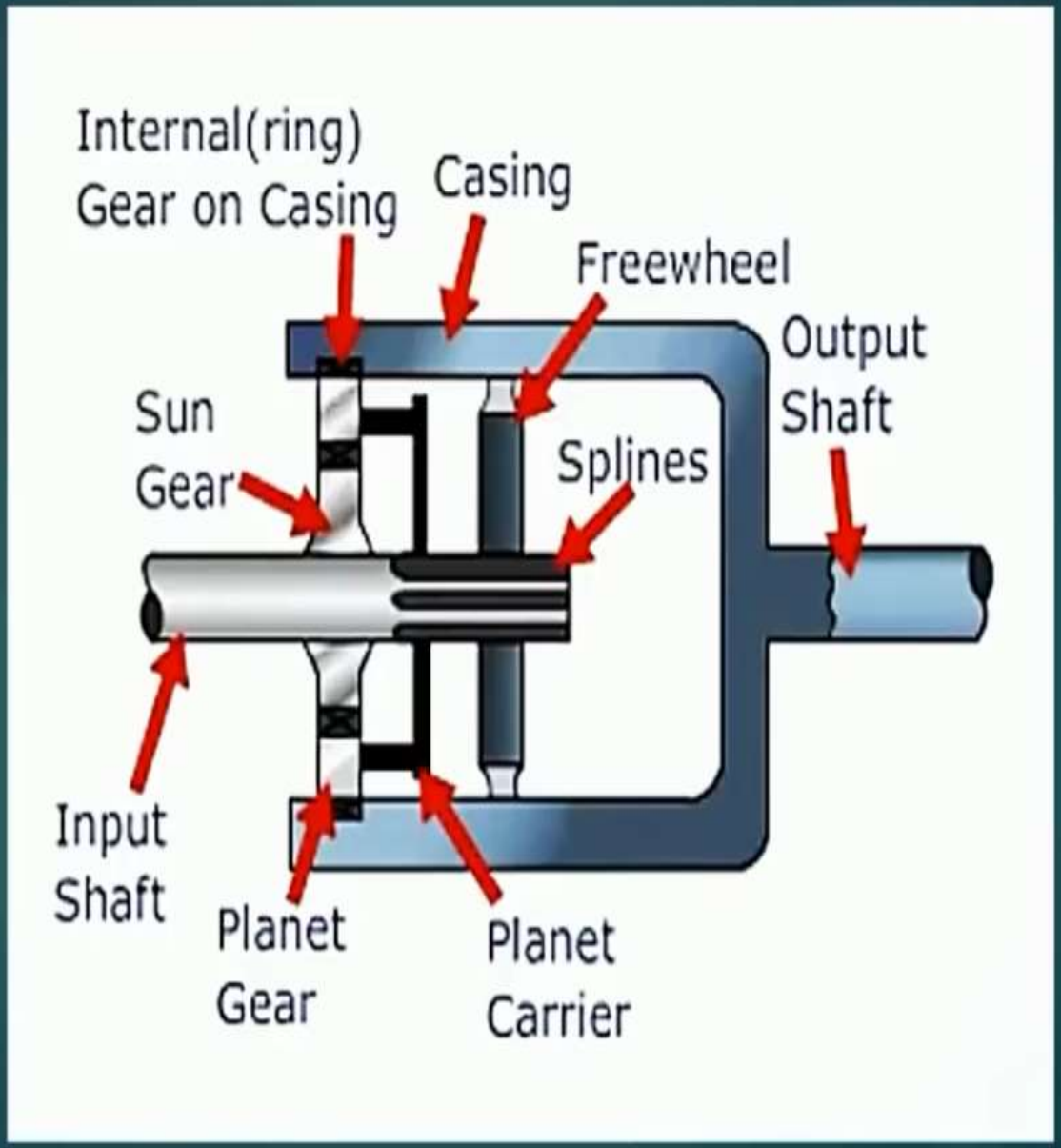
Points to Remember

- You should leave the Over-Drive **switch on** all the time for regular driving
- Your car will automatically shift into top gear if necessary, regardless of your selection
- Don’t use it when you are speeding at less than 50mph or during city driving because the speed tends to be inconsistent there

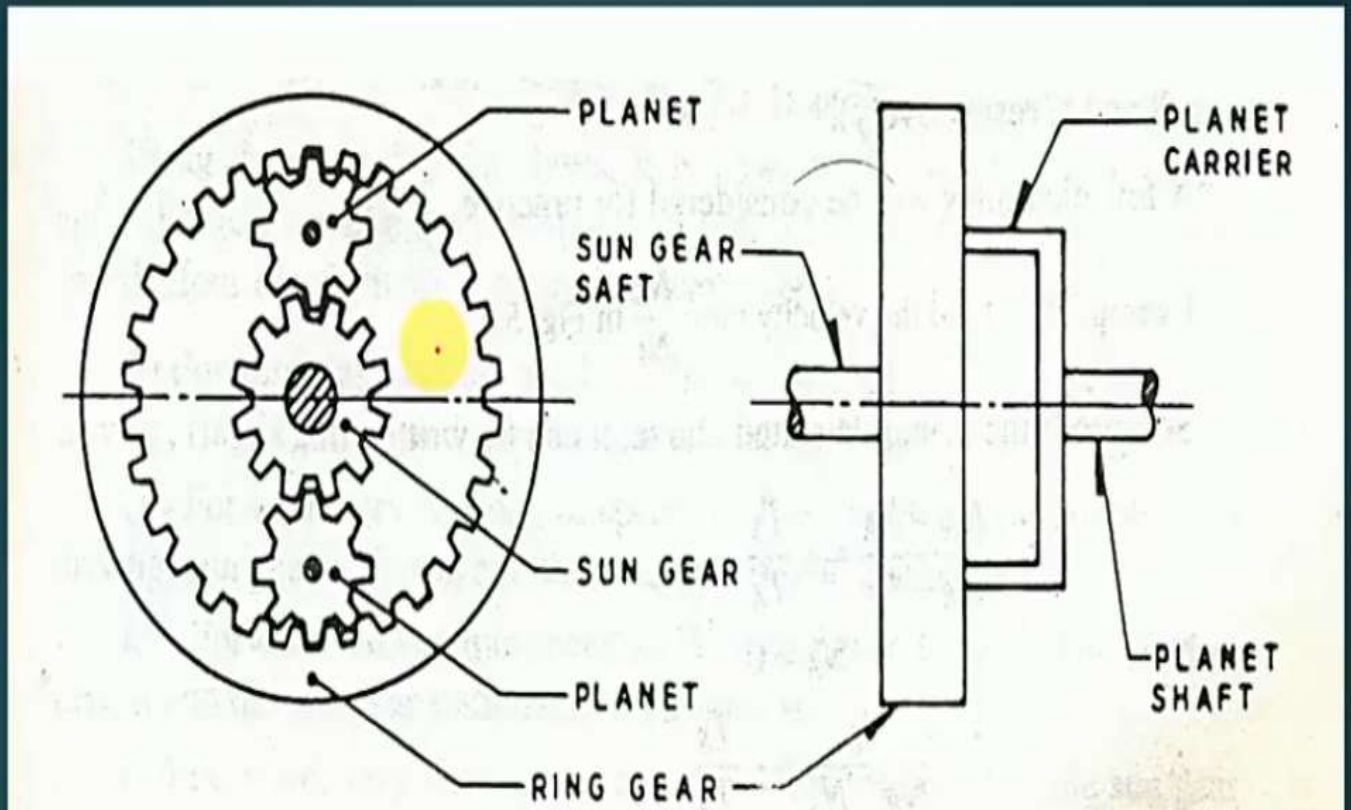
Precautions

- If you use it incorrectly such as while towing a trailer, driving uphill, or speeding at less than 50mph, it will cause irreparable damage
- It will burn out the transmission real fast which is a costly fix for the repair and reinstallation

OVERDRIVE


Internal(ring)
Gear on Casing
Casing
Freewheel
Output
Shaft
Sun
Gear
Splines
Input
Shaft
Planet
Gear
Planet
Carrier

EPICYCLIC GEAR BOX

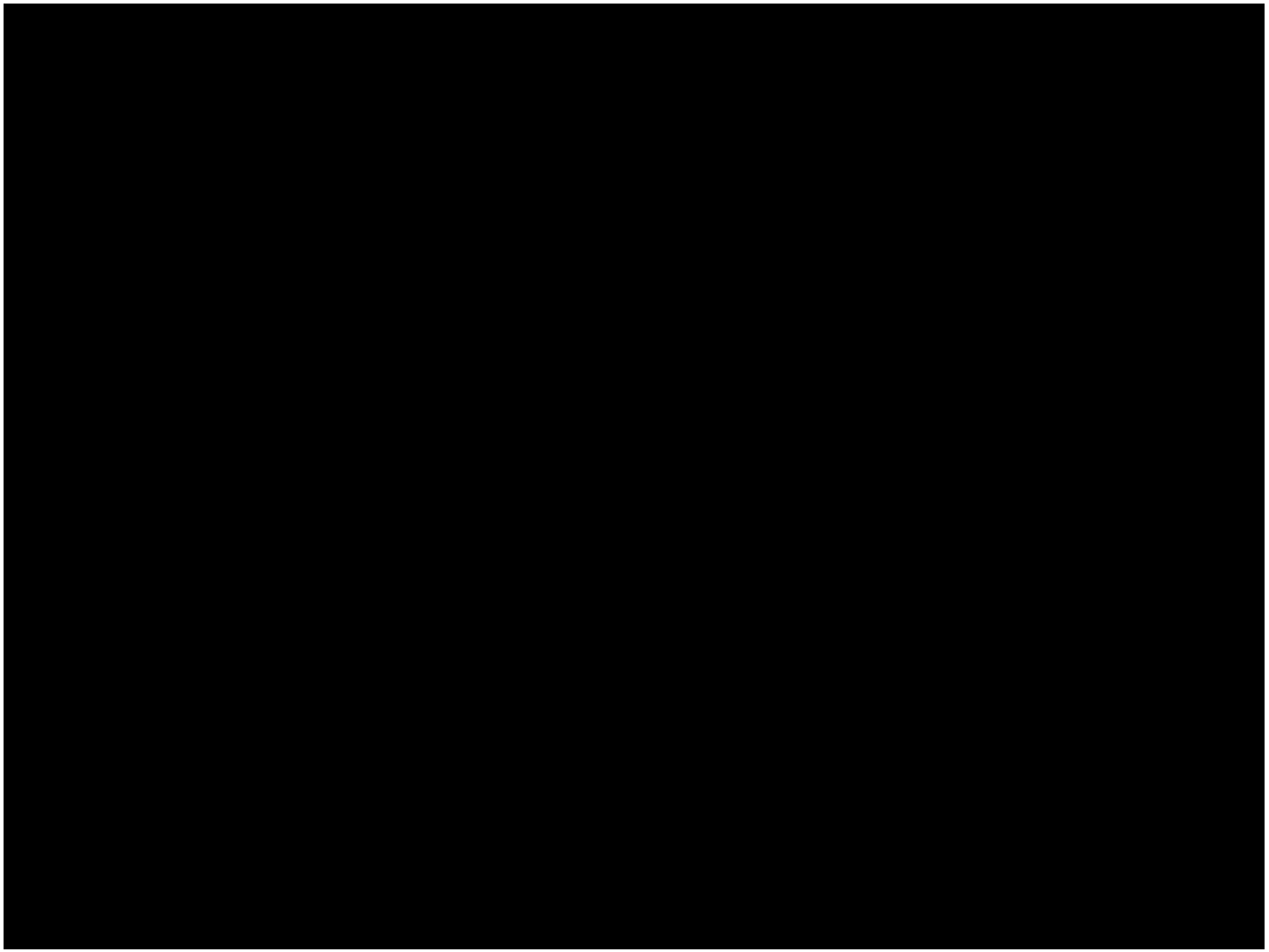


Simple epicyclic gear set.

- First gear ratio listed below is a **reduction**
- The second is an **overdrive**
- The last is a reduction again, but the output **direction is reversed**

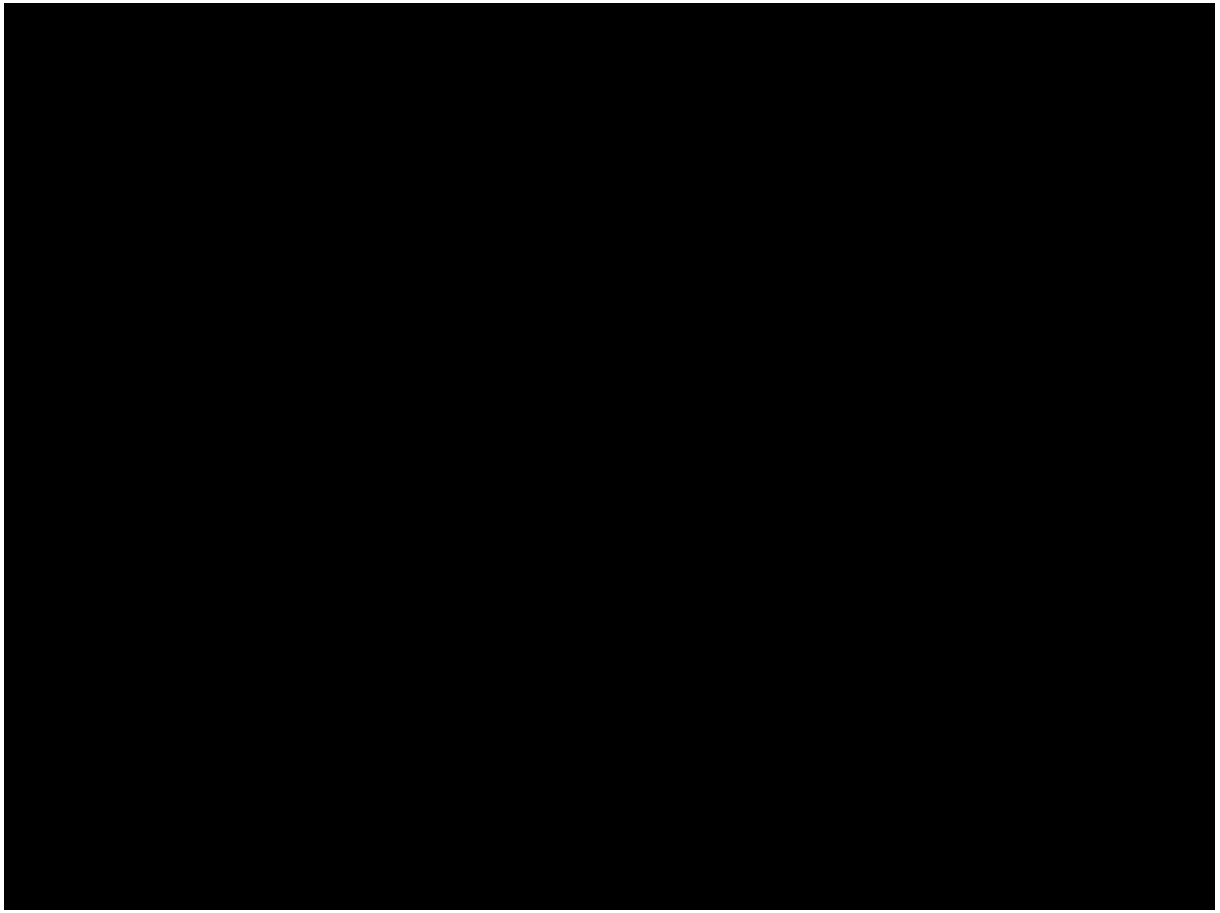
	Input	**Output**	**Stationary**
A	Sun (**S**)	Planet Carrier (**C**)	Ring (**R**)
B	Planet Carrier (**C**)	Ring (**R**)	Sun (**S**)
C	Sun (**S**)	Ring (**R**)	Planet Carrier (**C**)

Animation of Overdrive Gear

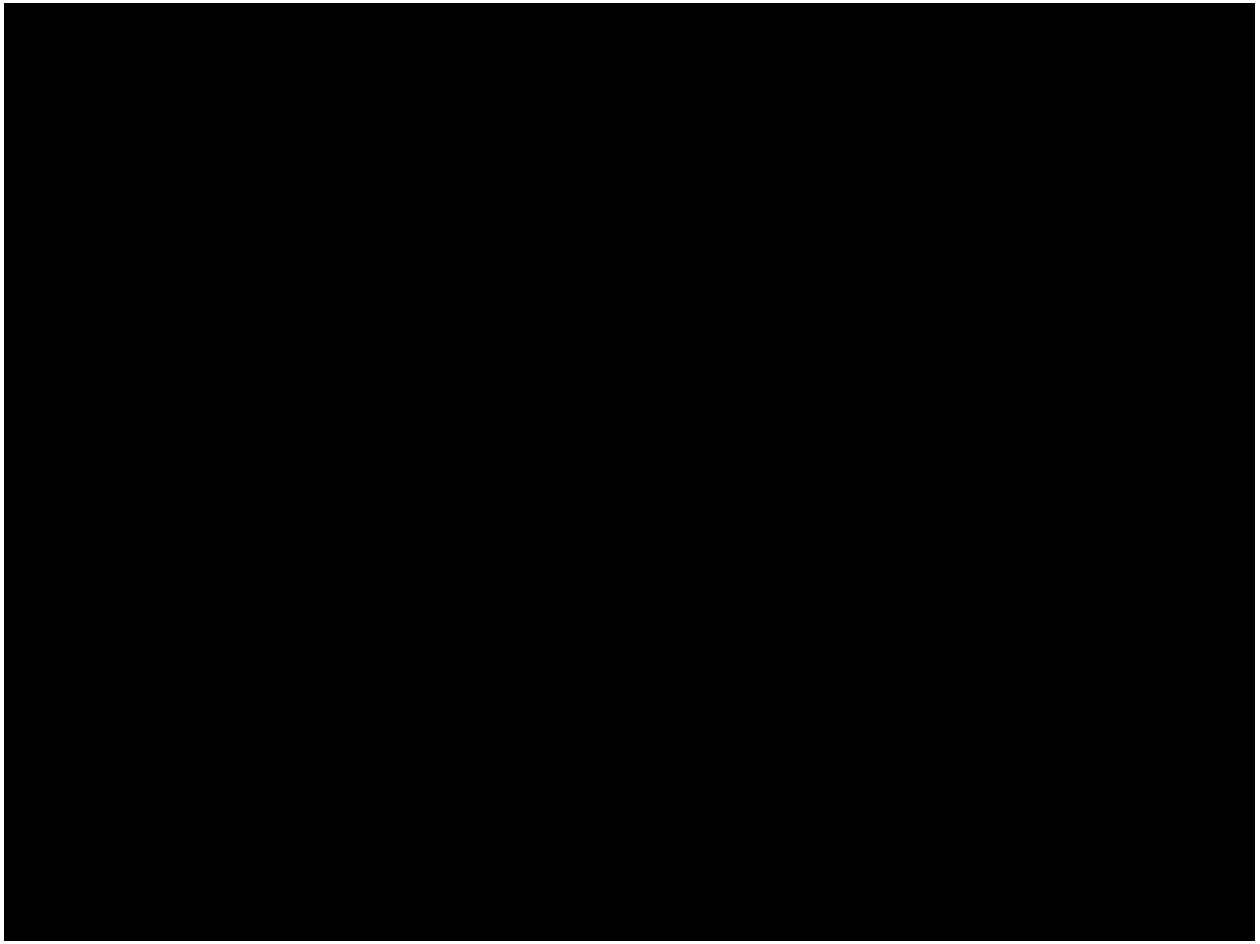


Variation in speed

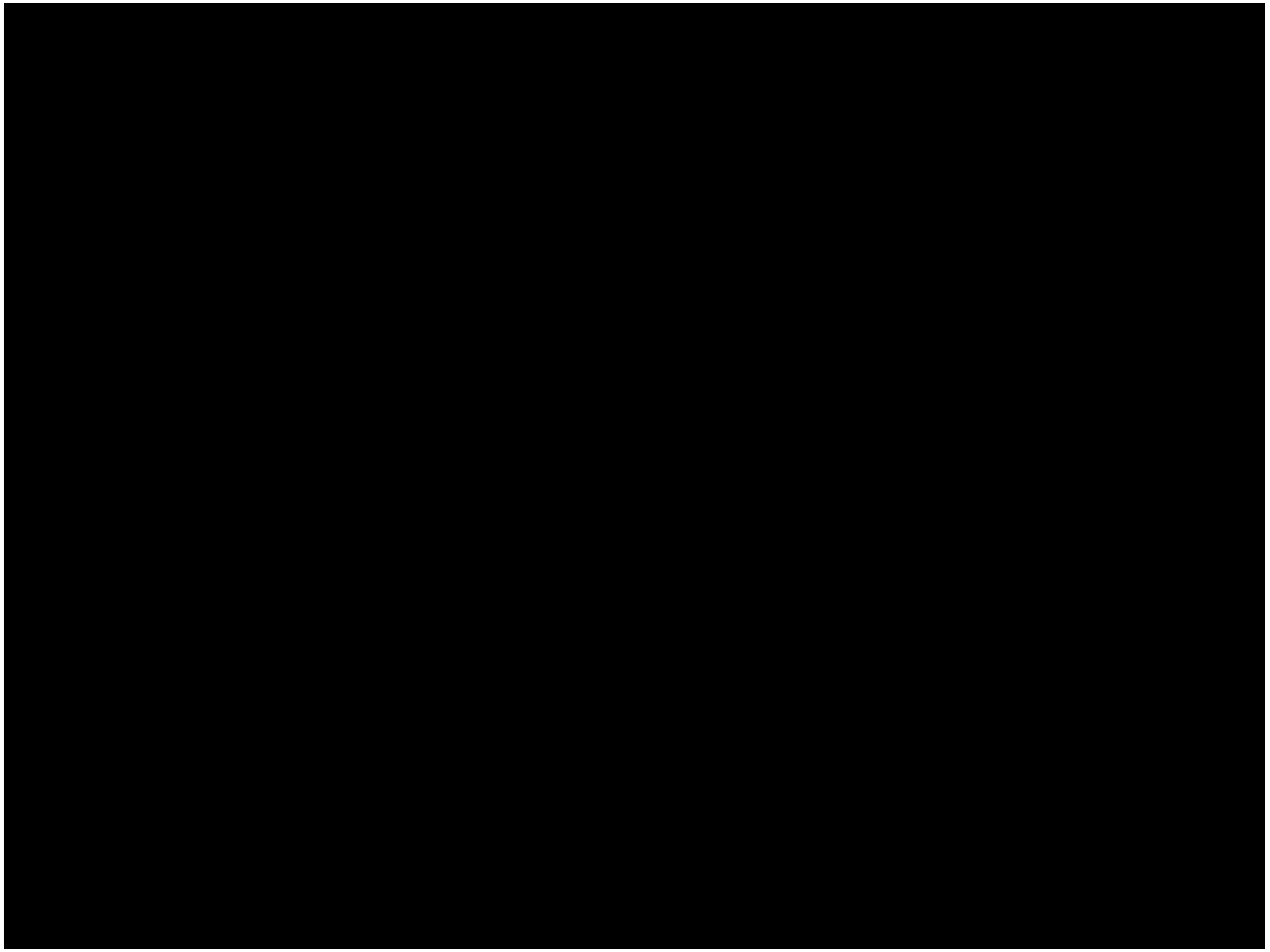
Fixed ring gear



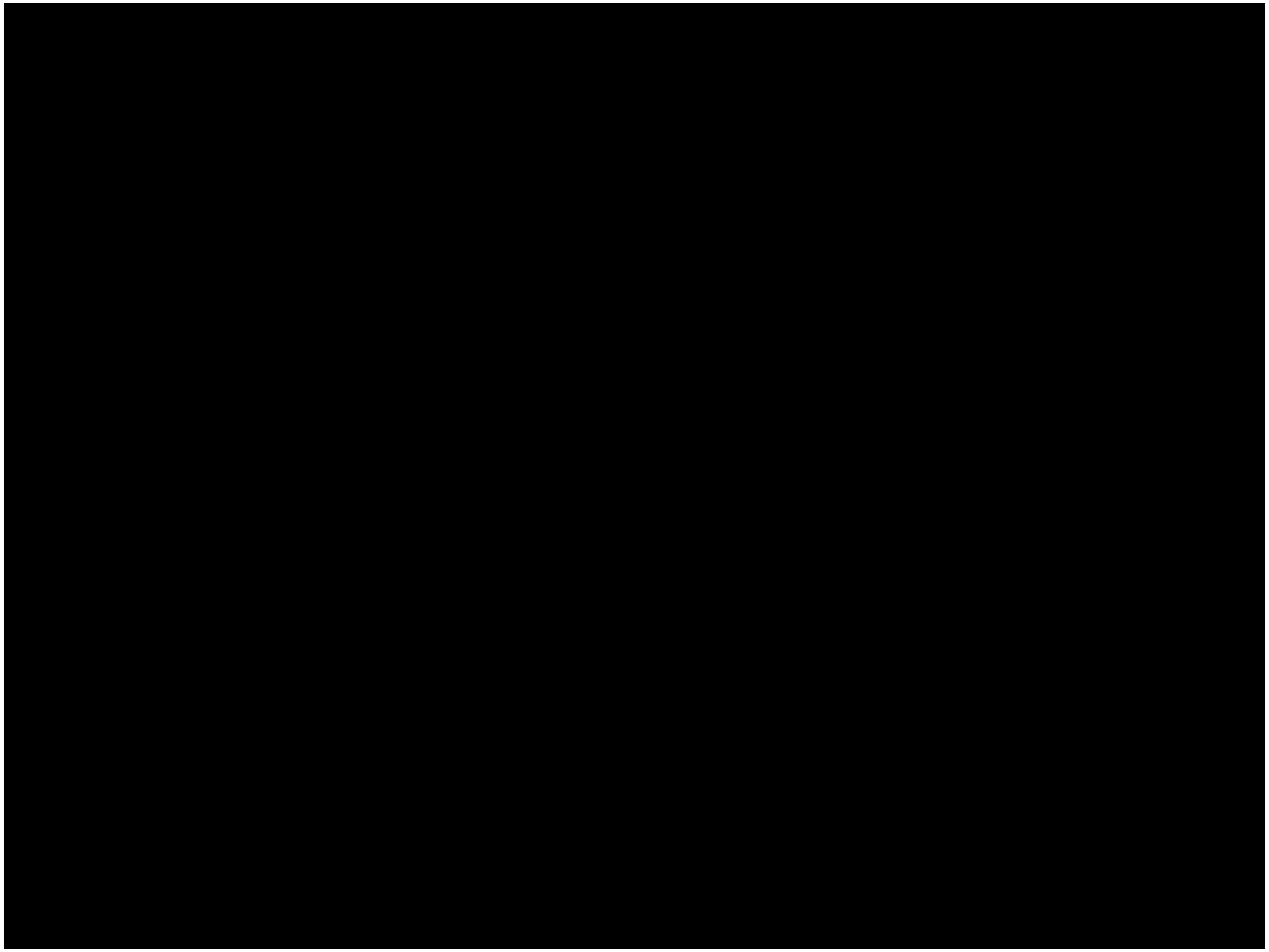
Fixed carrier



Fixed sun gear



Direct drive



AUTOMOBILE ENGINEERING

UNIT-2

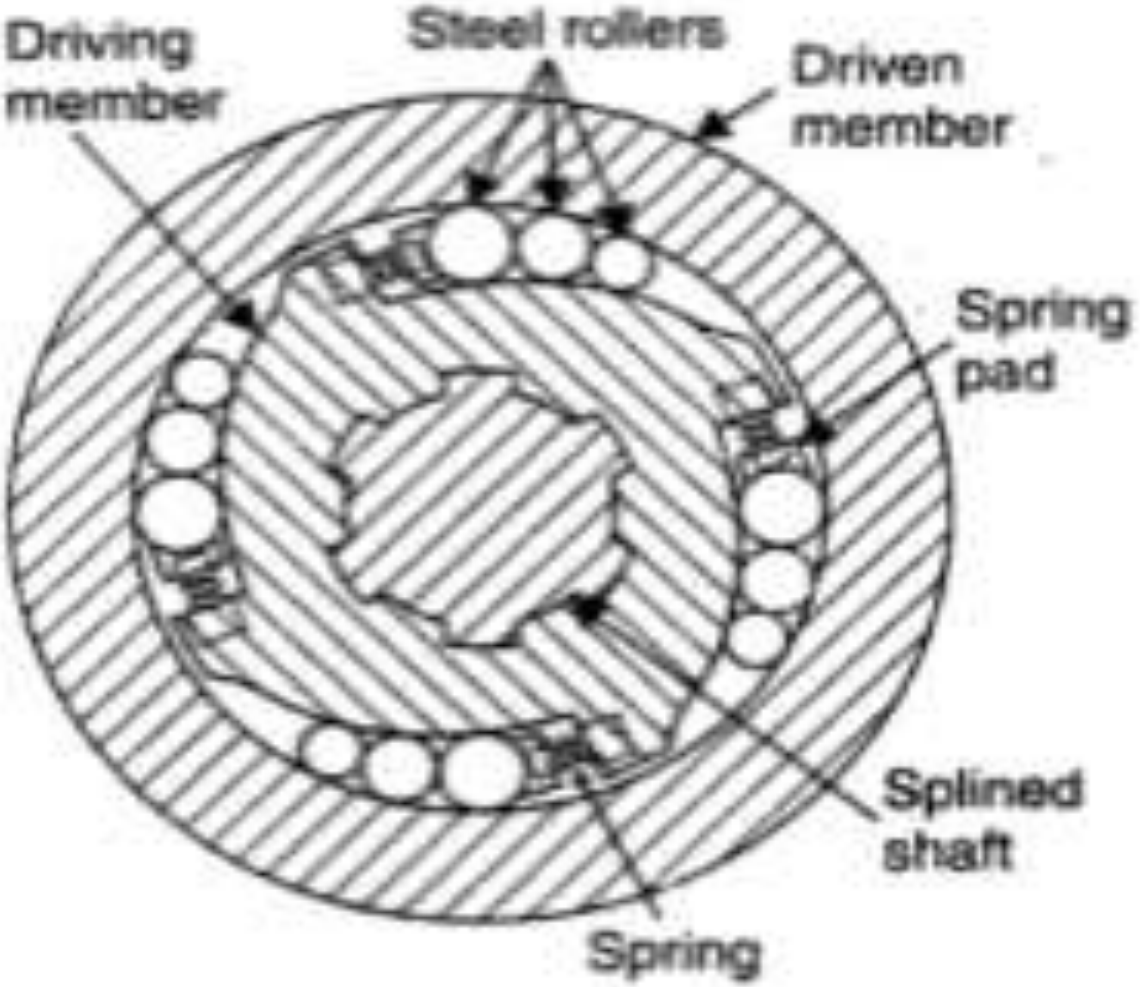
Lecture – 04

Freewheels and Joints

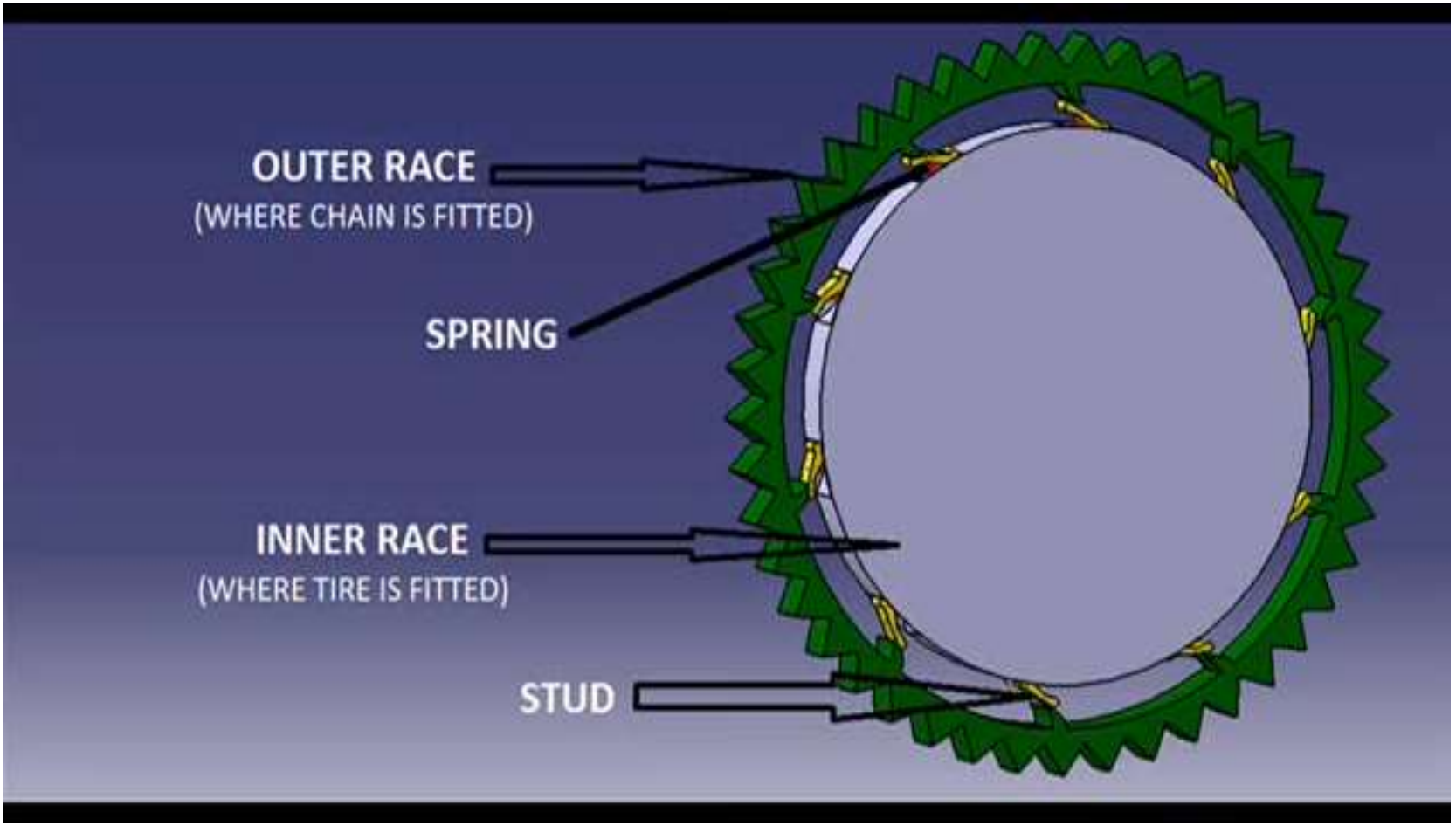
Freewheels

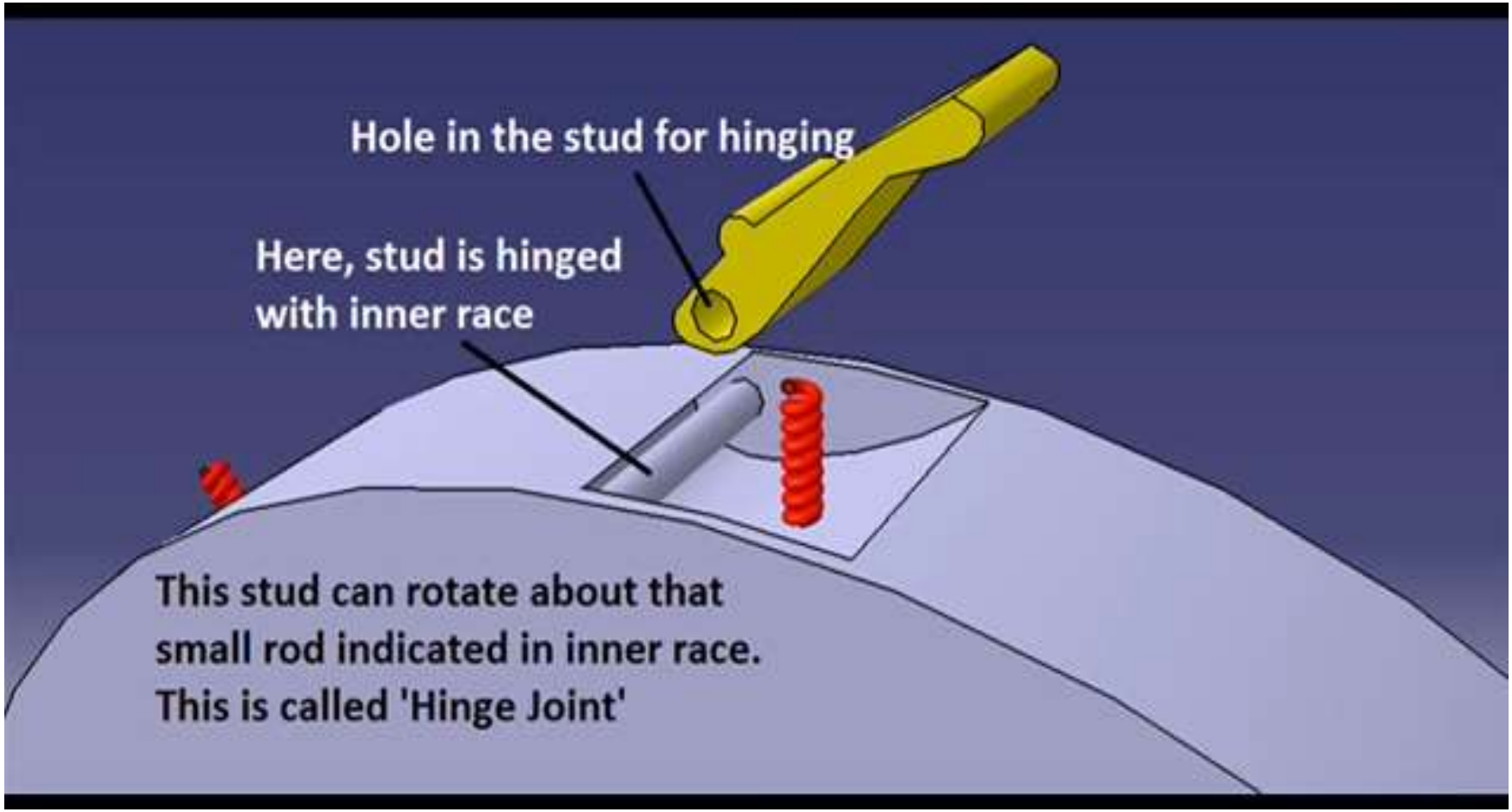
- A freewheel or overrunning clutch is a device in a transmission that disengages the driveshaft from the driven shaft when the driven shaft rotates faster than the driveshaft
- When a vehicle going downhill or any situation where the driver takes his or her foot off the accelerator pedal, closing the throttle; the wheels want to drive the engine, possibly at a higher RPM
- **To avoid this from happening we use a freewheel unit which disengages the driven shaft from the driveshaft**

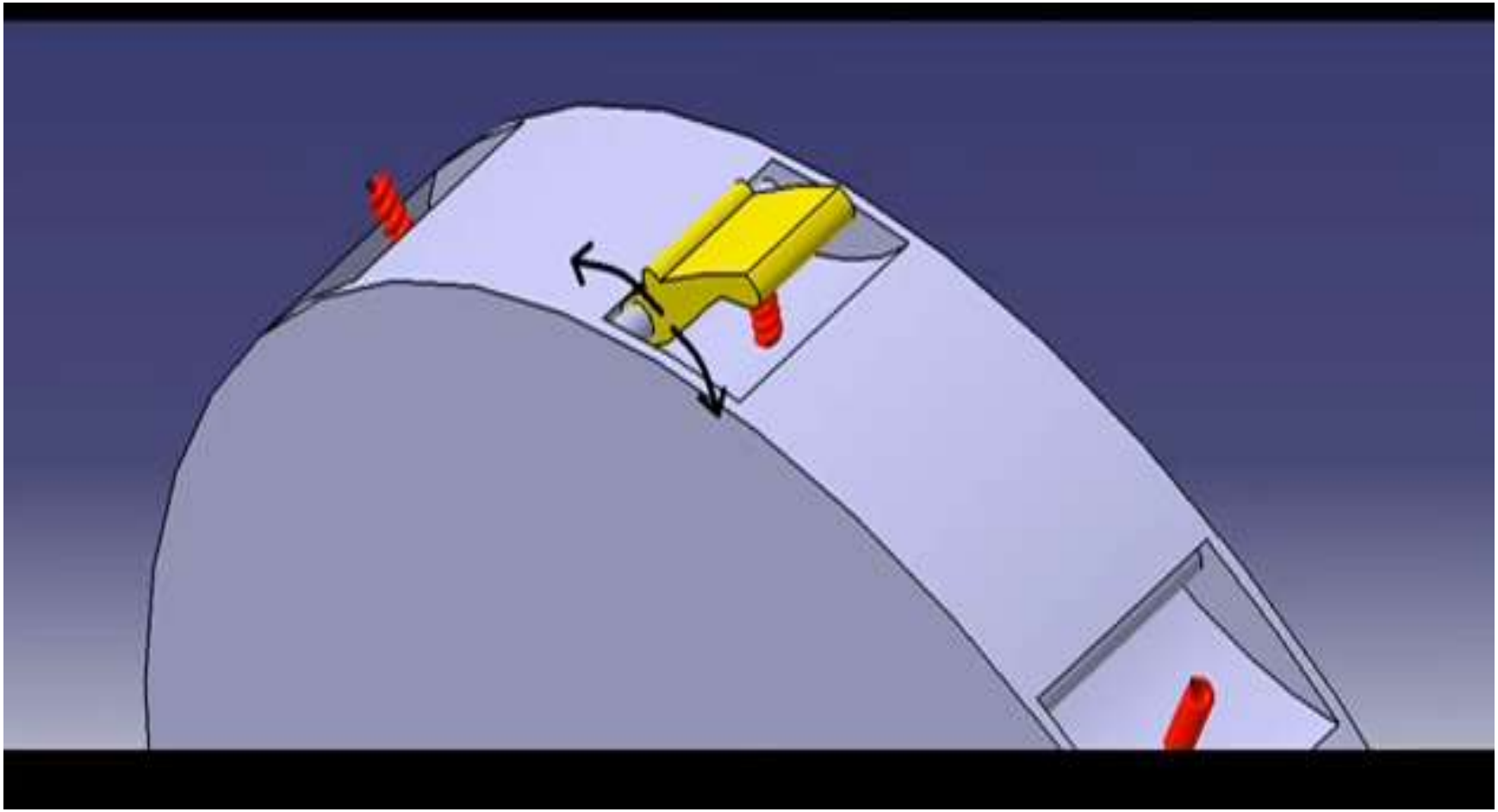
- It consists of an outer shell, pinion and collar assembly
- The outer shell has five notches containing five steel rollers fitted in it
- The notches are smaller at one end

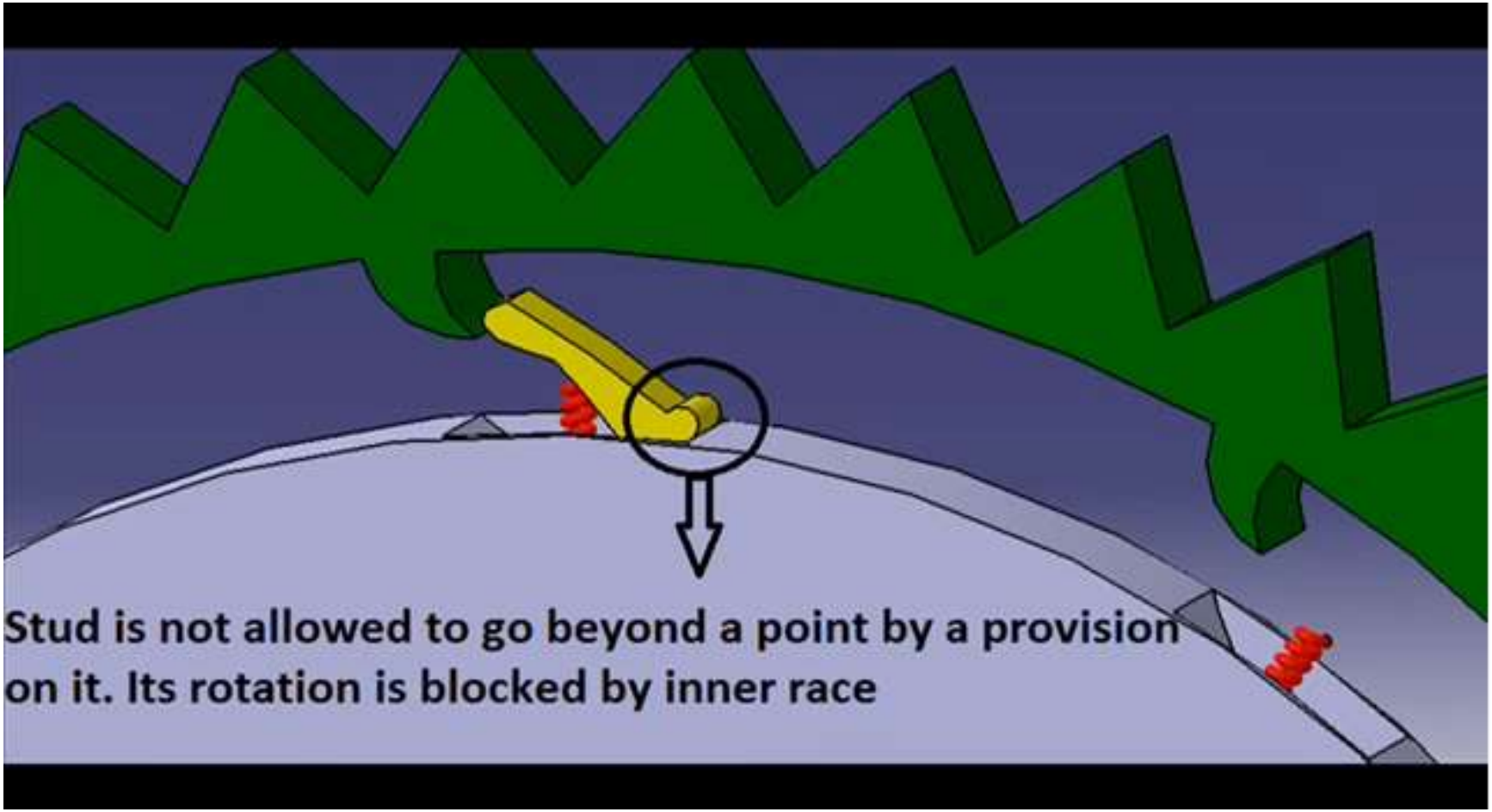

Driving member
Steel rollers
Driven member
Spring pad
Splined shaft
Spring

Freewheel


OUTER RACE
(WHERE CHAIN IS FITTED)
SPRING
INNER RACE
(WHERE TIRE IS FITTED)
STUD


Hole in the stud for hinging
Here, stud is hinged
with inner race
This stud can rotate about that
small rod indicated in inner race.
This is called 'Hinge Joint'




Stud is not allowed to go beyond a point by a provision on it. Its rotation is blocked by inner race

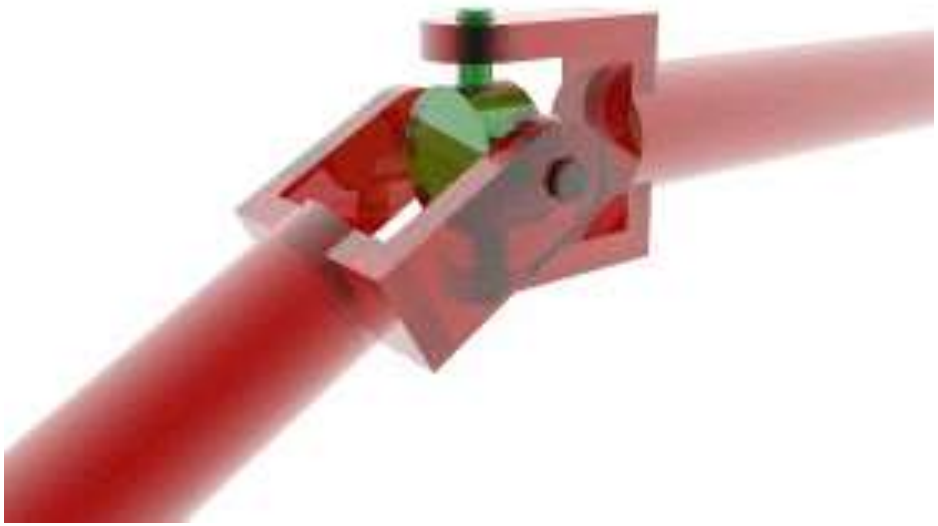
Working of Freewheel

- When the drive shaft starts to rotate, the rollers roll into the smaller end of the notch jamming between the shell and the pinion collar
- This forces the pinion to turn and the power is transmitted to the driven shaft
- However when the driven shaft starts rotating at the higher RPM, it drives the shell faster than the shell and armature
- As a result, rollers roll back to the larger end of the notch allowing collar to spin faster than shell armature
- Thus it prevents driven shaft from driving the drive shaft

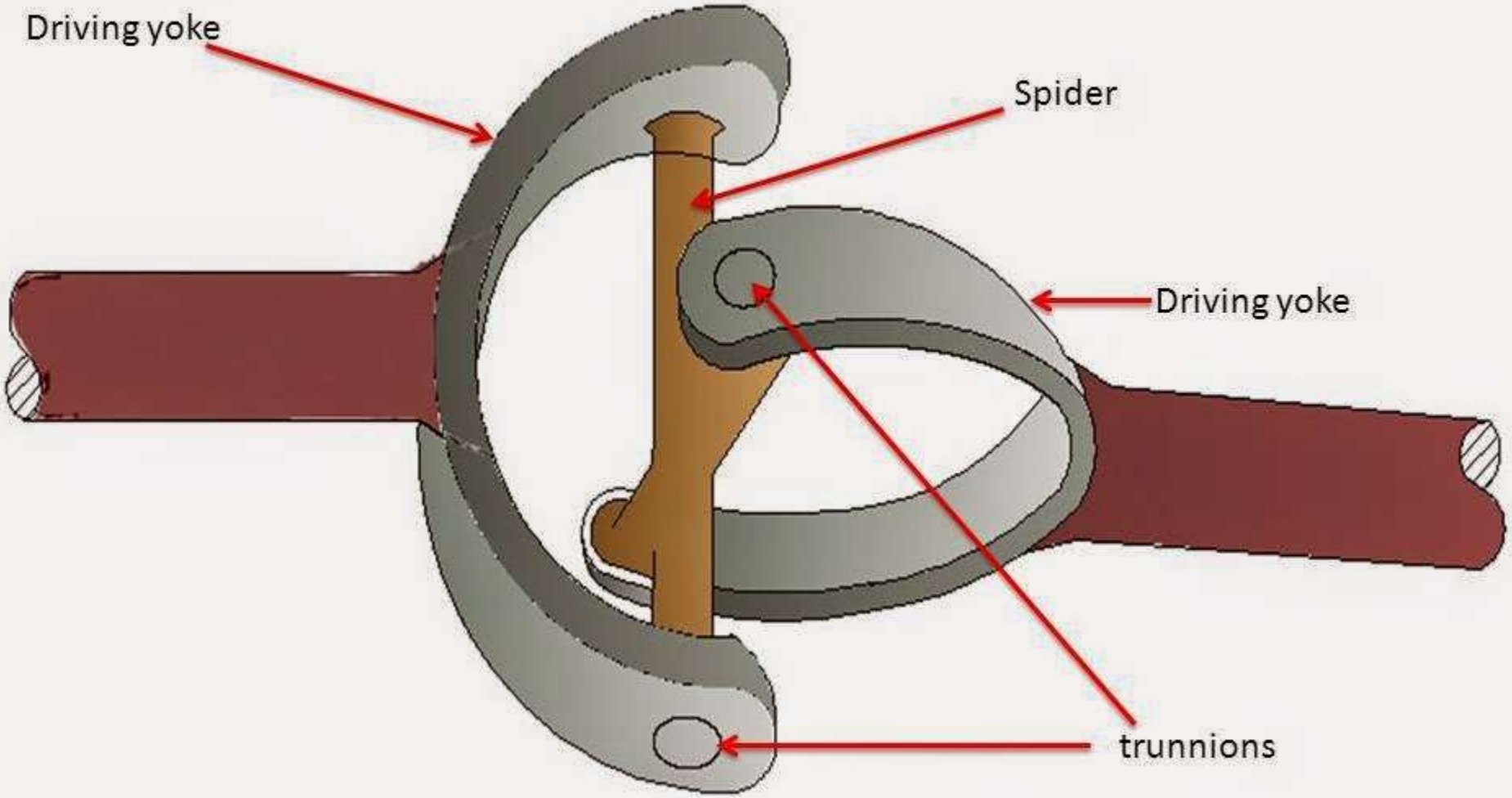
Animation of Freewheel

Universal Joints

- Universal joints are capable of transmitting torque and rotational motion from one shaft to another when their axes are inclined to each other by some angle, which may constantly vary under working conditions



- Due to the severe working conditions, special universal joints known as constant velocity joints are employed
- These joints have been designed to absorb torque and speed fluctuations and to operate reliably with very little noise and wear having long life



Universal joint

TYPES OF UNIVERSAL JOINTS

- Variable velocity joint
  I. Cross or spider type
  II. Ring type
  III. Ball & turnion type

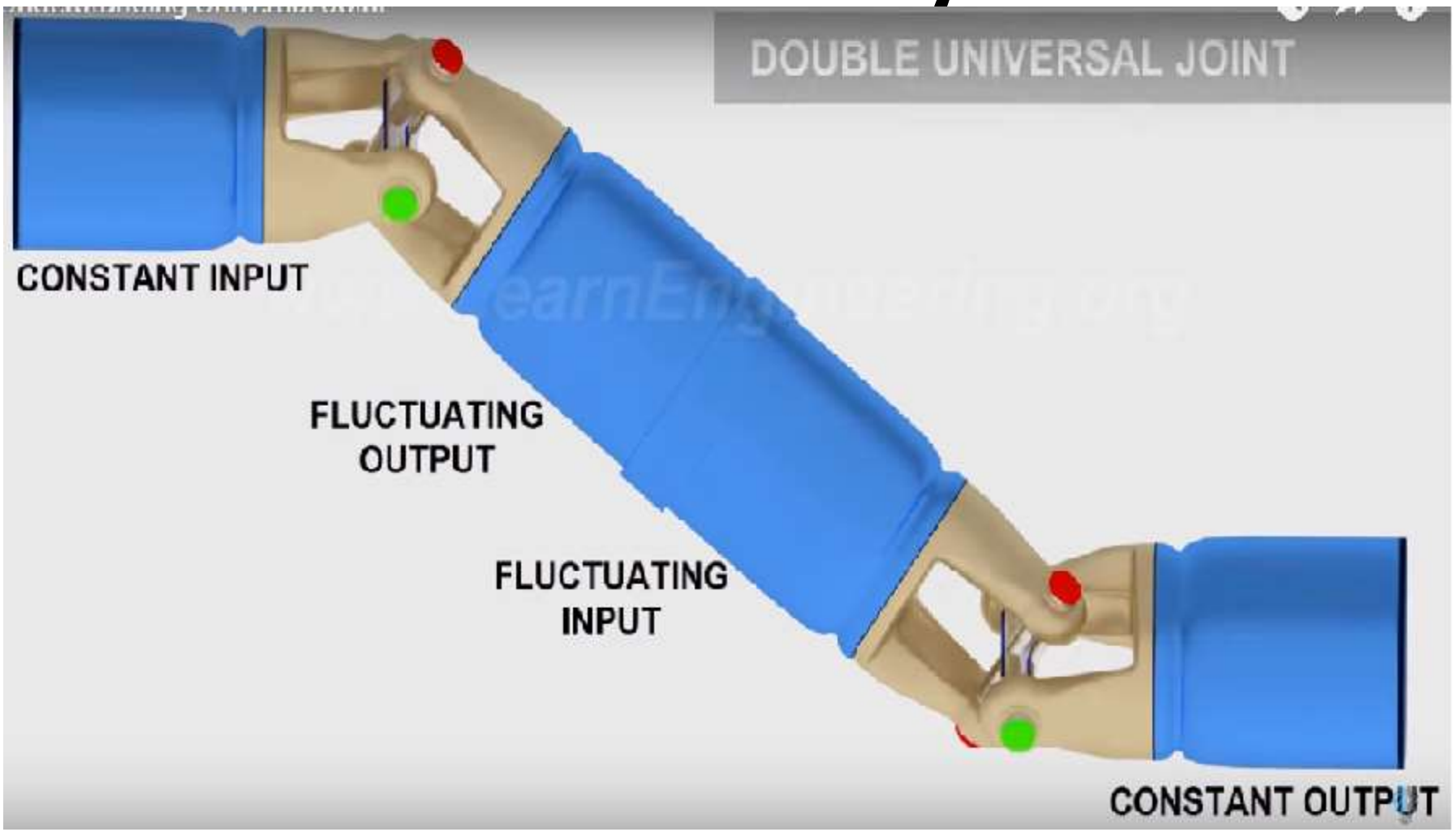
- Constant velocity joint
  I. Rzeppa
  II. Bendix weeiss
  III. Tracta

- **A universal joint,** (universal coupling, U-joint or Hooke's joint) is a joint or coupling in a rigid rod that allows the rod to 'bend' in any direction, and is commonly used in shafts that transmit rotary motion
- To give drive at varying angles (up to 20 degree)

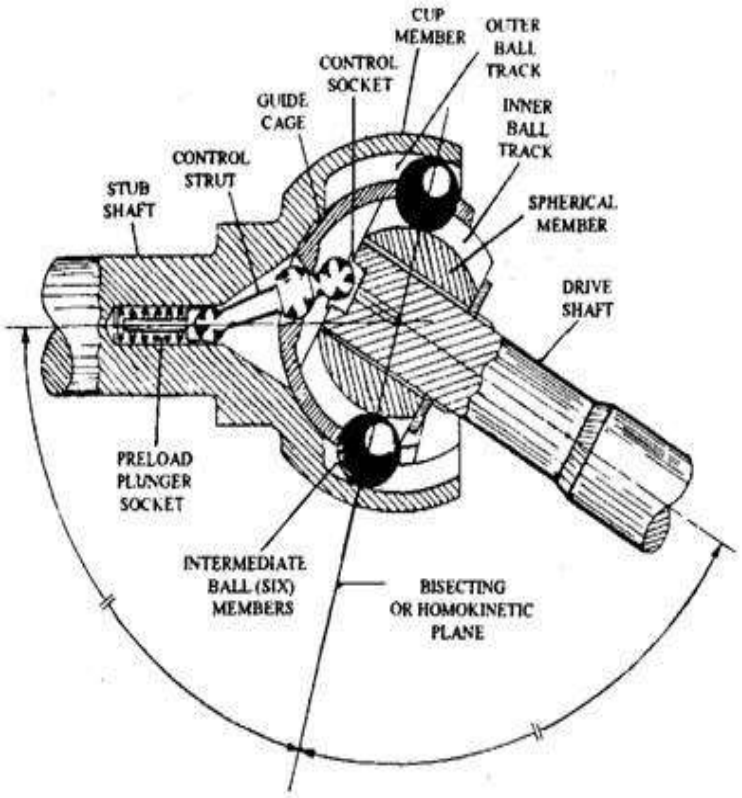
- **Constant-velocity joints** (CV joints) allow a drive shaft to transmit power through a variable angle, at constant rotational speed, without an appreciable increase in friction or play
- They are mainly used in front wheel drive vehicles and 4x4 drive vehicles
- The angle up to 30 degrees

- A **Rzeppa joint** consists of a spherical inner shell with 6 grooves in it and a similar enveloping outer shell
- Each groove guides one ball
- The input shaft fits in the centre of a large, steel, star- shaped "gear" that nests inside a circular cage
- The cage is spherical but with ends open, and it typically has six openings around the perimeter
- This cage and gear fit into a grooved cup that has a splined and threaded shaft attached to it
- Six large steel balls sit inside the cup grooves and fit into the cage openings, nestled in the grooves of the star gear

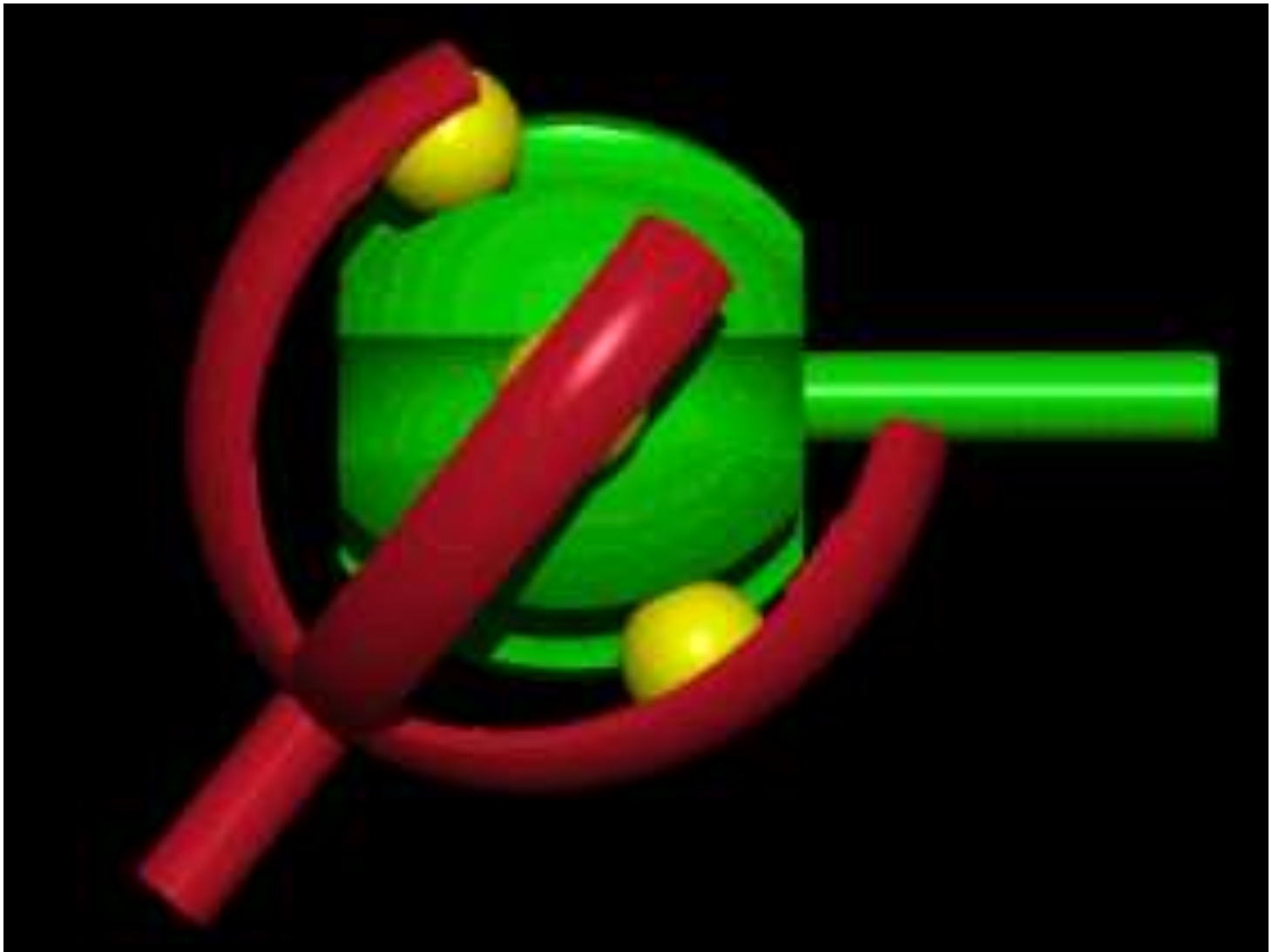
Constant Velocity Joint



Rzeppa Joint



Animation of Rzeppa Joint



Weiss joints

- It consists of two identical ball yokes which are positively located (usually) by four balls
- The two joints are centred by means of a ball with a hole in the middle
- Two balls in circular tracks transmit the torque while the other two preload the joint and ensure there is no backlash when the direction of loading changes

Its construction differs from that of the Rzeppa in that the balls are a tight fit between two halves of the coupling and that no cage is used

AUTOMOBILE ENGINEERING

UNIT-2

Lecture – 05

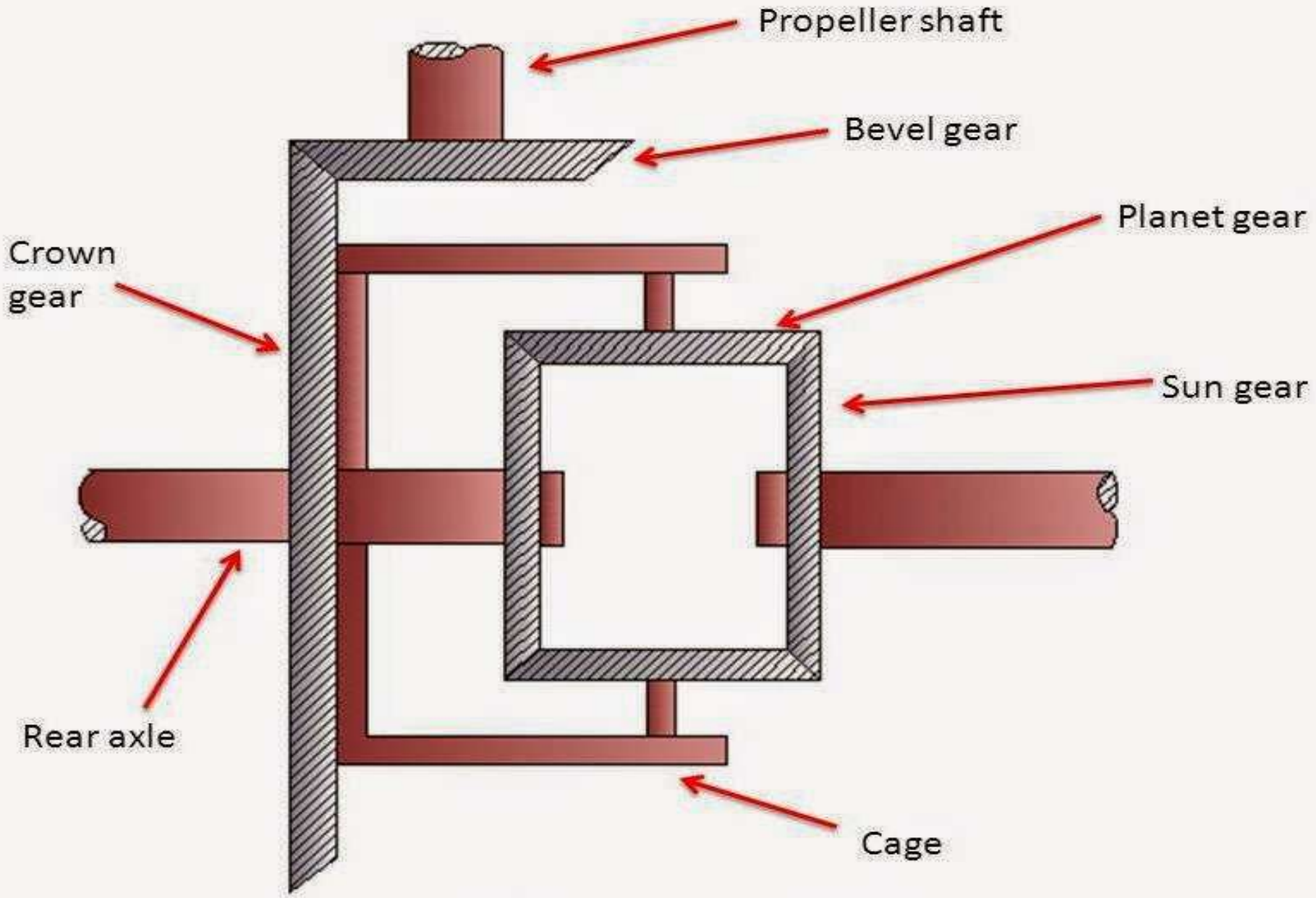
Differential

Differential Gear Mechanism

- Differential is the main component of the power train
- It is bolted on the rear axle and connects the propeller shaft to the rear wheels
- While a vehicle taking a turn, its outer wheel run faster than the inner wheel

Construction of Differential Gear

- In the differential, bevel pinion gear is fixed to the propeller shaft which rotates the crown wheel
- The crown wheel (ring gear) has another unit called the differential unit
  - It consists of two bevel gears (sun gear) and two bevel gears (planet or spider gear)
- The bevel gears are in contact with the half shaft of the rear axle
- When the crown wheel is rotating, it rotates the differential unit
- The bevel (sun) gears of the differential rotate the two shafts

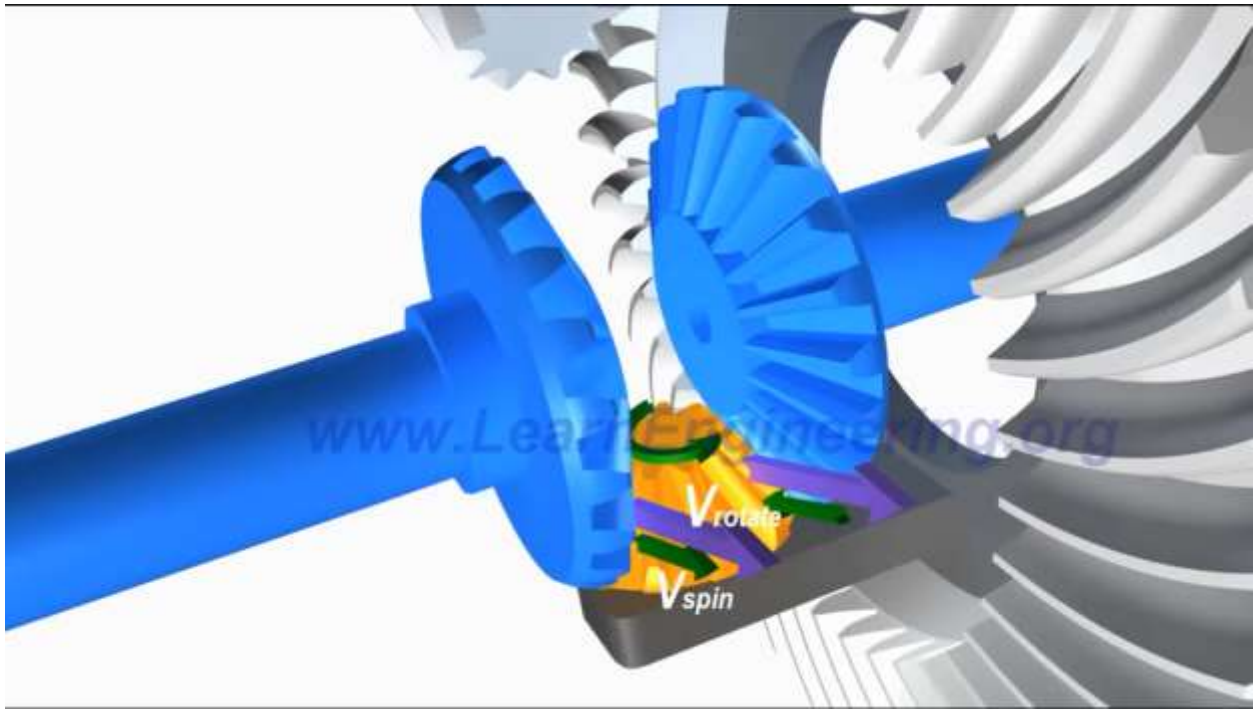


Differential gear

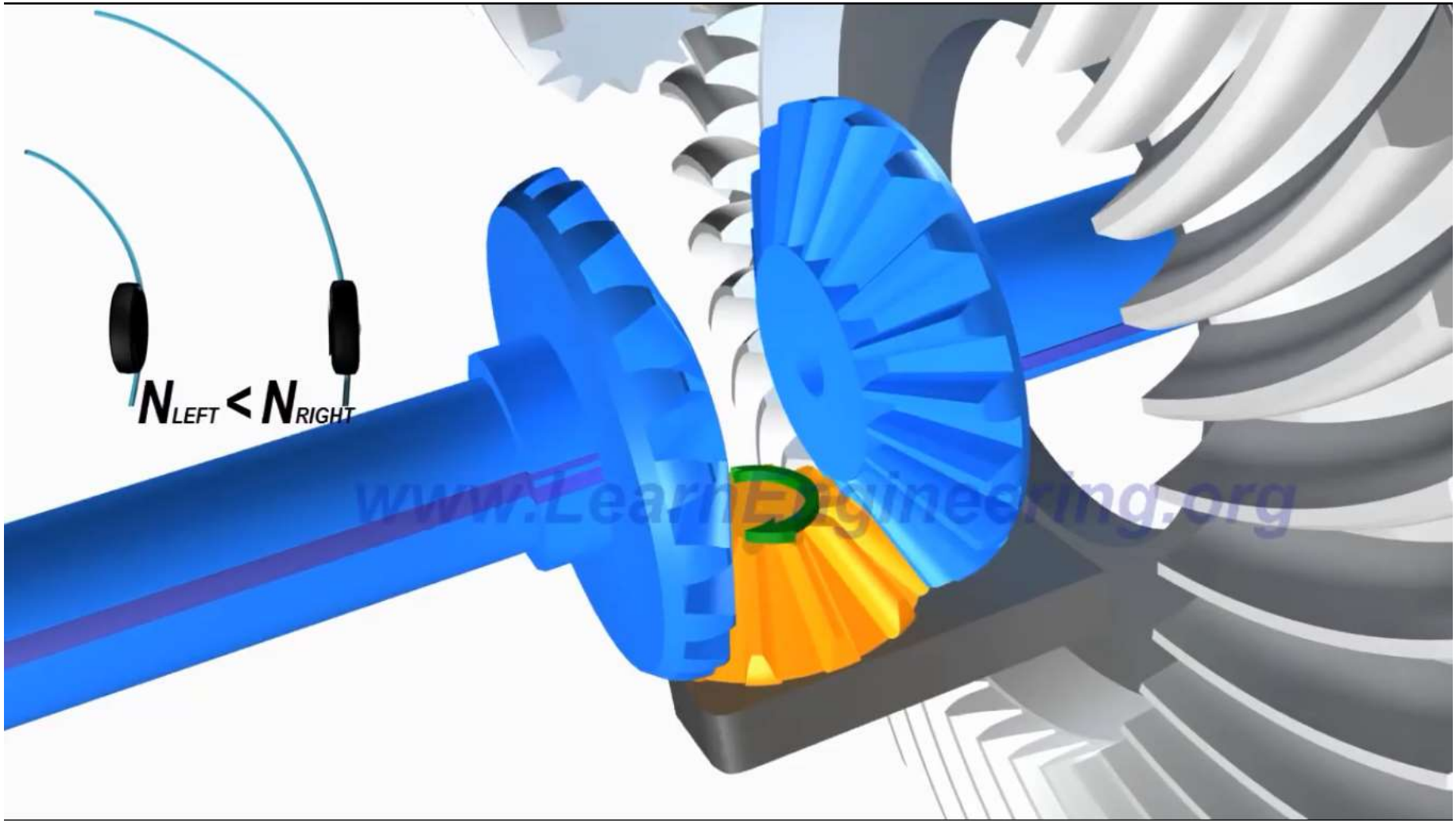
Working of Differential Gear

- When the car is on a straight road, the ring gear, differential case, differential pinion gears (spider gear), and two differential side gears all turn as a unit
- The two differential pinion (spider) gears do not rotate on the pinion shaft (ring gear axis)
- This is because they exert equal force on the two differential side gears
- As a result the side gears turn at the same speed as the ring gear, which causes both drive wheels to turn at the same speed also
- **Note: Spider gears spin in opposite direction**

- When the car begins to round a curve, the differential pinion gears rotate on the pinion shaft. This permits the outer wheel to turn faster than the inner wheel **(Let Ring gear turns anticlockwise)**
- **When vehicle turning right**: Spider gear rotate in anticlockwise direction of **its own axis**



- **When vehicle turning Left**:



Animation of Differential Gear Box

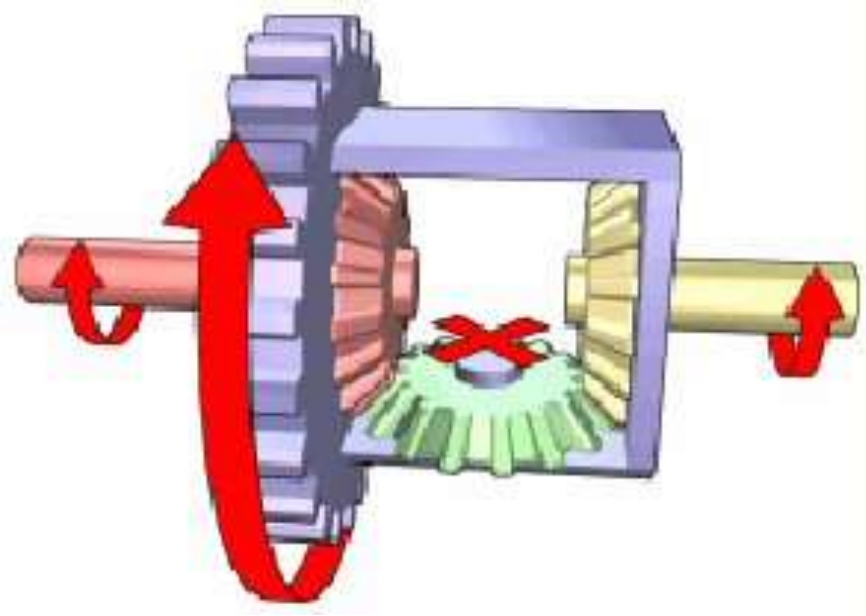
Types of Differential Gears

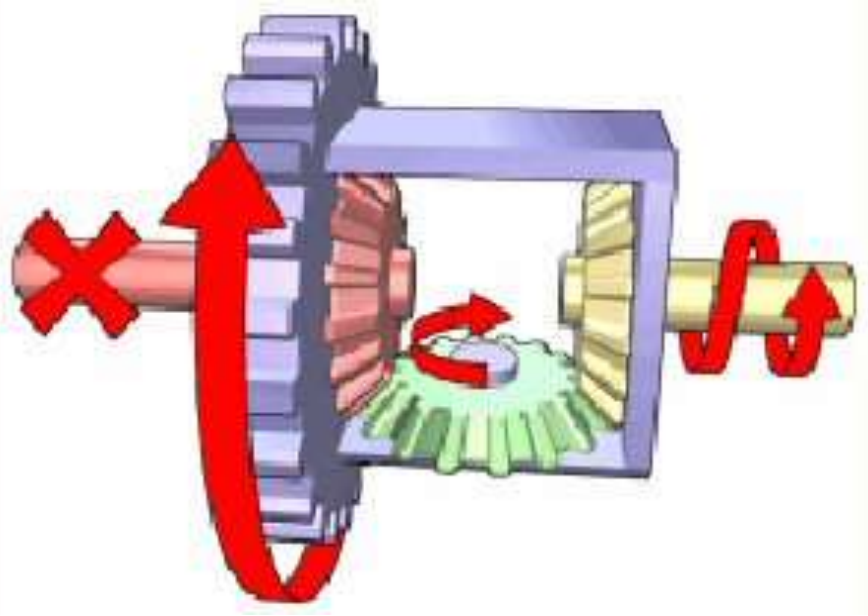
1. **OPEN DIFFERENTIAL** (OD)
   - It is the most common type of differential gear
   - It is also the least expensive
- A differential in its most basic form comprises two halves of an axle with a gear on each end, connected together by a third gear making up three sides of a square
- This is usually supplemented by a fourth gear for added strength, completing the square

- This basic unit is then further augmented by a ring gear being added to the differential case that holds the basic core gears
  - This ring gear allows the wheels to be powered by connecting to the drive shaft via a pinion

- An open differential allows the vehicle to go around corners without dragging the outside wheel
- However, power is transferred to the wheel with the least amount of traction (grip on the road)
- If that wheel is on ice or other slippery surfaces, the vehicle will not move forward and the wheel with the power will simply spin

- The left image shows the differential with both wheels turning at the same speed, while the right image illustrates how the inner gears engage when one wheel turns slower than the other





NOTE:

- In vehicles with **two-wheel drive**, if they have an open differential in effect they have only a single drive wheel
- **In four-wheel drive** vehicles using open differentials (usually standard from the factory), only one wheel on each axle powers the vehicle

Disadvantage of Open Differential

- Because the torque is split evenly between both wheels, the amount of power able to be transmitted through the wheels is limited by the wheel with the lowest amount of grip
- Once the traction limit of both wheels combined is reached, the wheel with the lowest amount of traction will begin to spin – reducing that limit even further as there is even less resistance from the already spinning wheel

2. LOCKED DIFFERENTIAL:

- The locked or locking differential is a variant found on some vehicles, **primarily those that go off road**
- It is essentially an open differential with the ability to be locked in place to create a fixed axle instead of an independent one
- This can happen manually or electronically depending on technology in the vehicle
- **The advantage is that both wheels have power at all times**

- The benefit of a locked differential is it is able to gain a considerably greater amount of traction than an open differential
- Because the torque is not equally split 50/50 it can channel more torque to the wheel that has the better traction - and is not limited by the lower traction of the other wheel at any given moment
- The **disadvantage** is that turning is much more difficult since both wheels must turn at the same rpms
- So most lockers must be **disengaged** when making sharp turns

Locking Differential

3. WELDED/SPOOL DIFFERENTIAL

- A spool is an open differential in which the axles have been **mechanically fastened together**
- This **does not allow** either wheel to go faster or slower around corners
  - It is cheap and adds little or no weight to the vehicle, but is usually **limited to off-road competitions and trail driving**
- They are **not desirable for driving on the street** as they will "chirp" the tires when going around corners

4. LIMITED SLIP DIFFERENTIAL

- Under normal driving conditions, straight roads and typical corners, the limited-slip differential acts like an open diff, allowing for wheel speed differences
- However, under heavy acceleration and hard cornering, clutches or plates in the limited-slip differential prevent the differential from sending all torque to the wheel with the least resistance
- This enables the race car to power through high-speed, high-power corners
- Found on many performance vehicles and some off-road vehicles

Limited-Slip Differential

Summary

OPEN DIFFERENTIAL

- Splits the engine torque into two outputs
- Allows the wheels to rotate at different speeds
- **When one tire loses traction, the opposing tire will also lose power**
- Found in family sedans and economy cars

Summary

LOCKING DIFFERENTIAL

- Connected wheels always spin at the same speed
- Turning the vehicle can be very difficult
- Found in Jeep Wranglers and most full-size trucks
- Found on many off-road vehicles and some performance cars
- Locking differentials use clutches and springs to activate a lock which sends an equal amount of power to each wheel no matter the traction situation

Summary

LIMITED-SLIP DIFFERENTIAL

- Combination of open and locking differentials
- Usually acts as an open differential
- Automatically locks when slipping occurs
- Found in sports vehicles like Nissan 370Z and the Mazda MX-5 Miata

AUTOMOBILE ENGINEERING

UNIT-2

Lecture – 06

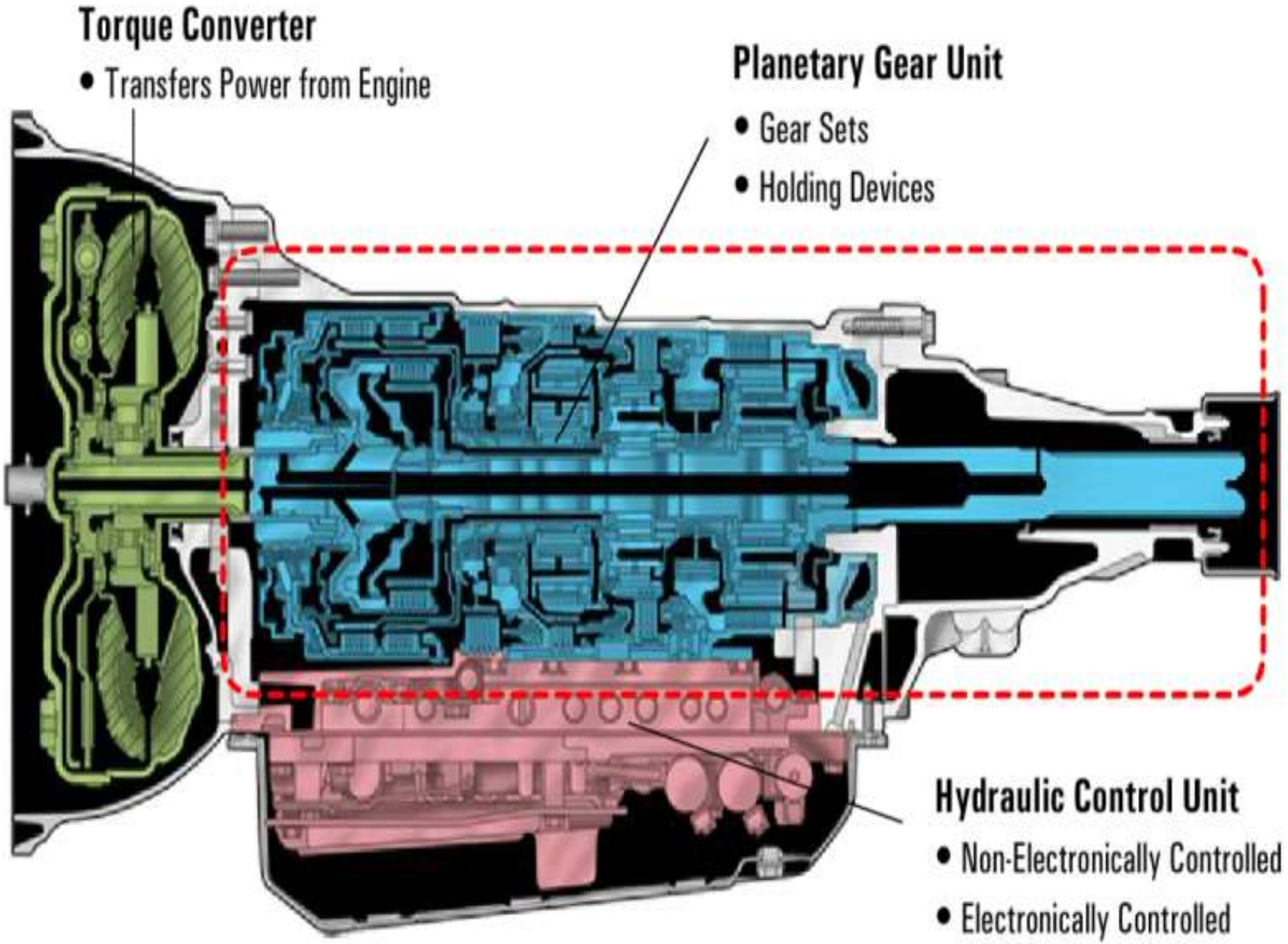
Automatic Transmission

Automatic Transmission

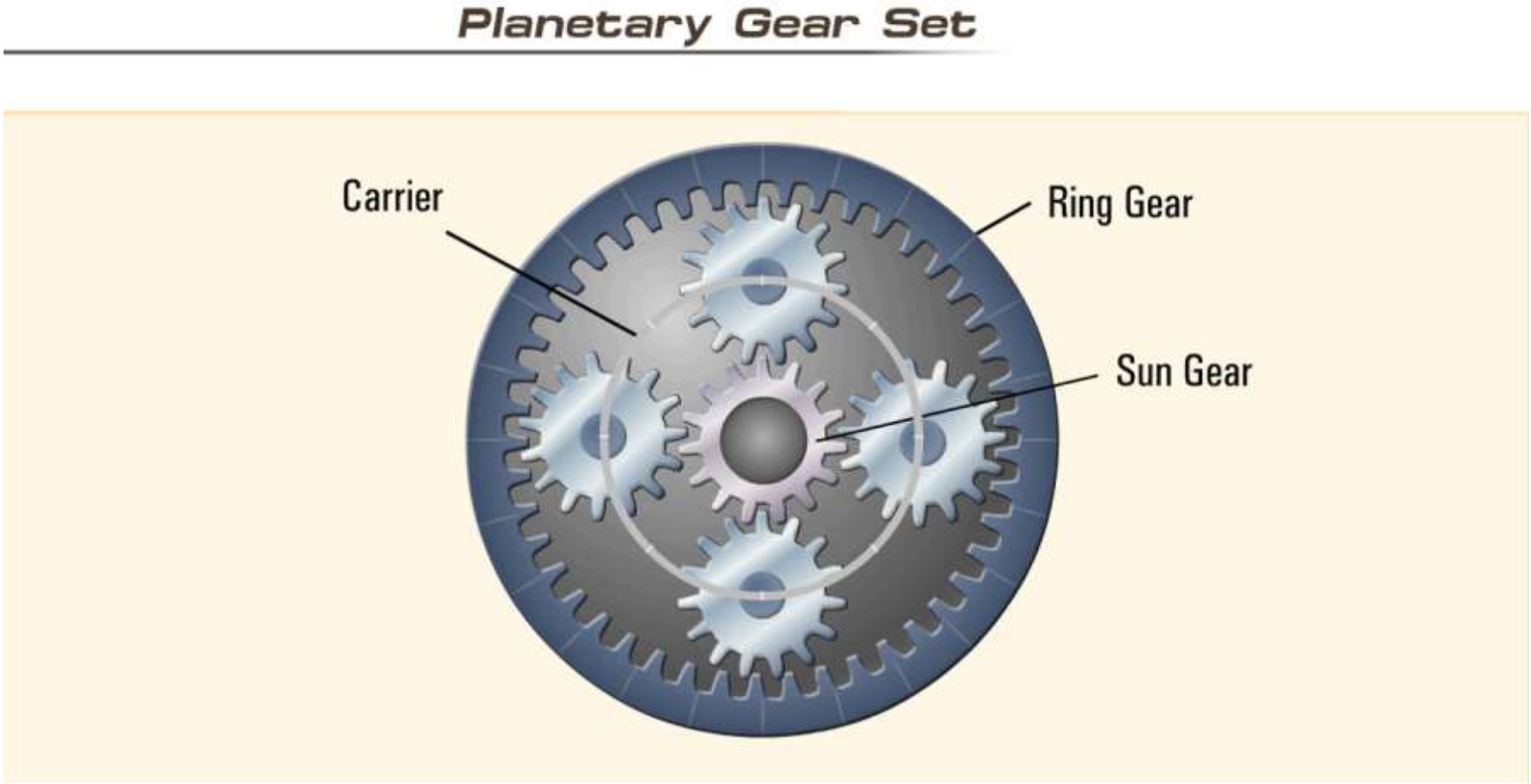
- Automatic transmission system is the most advanced system in which driver's mechanical efforts are reduced very much and different speeds are obtained automatically
- It contain epicyclic gear arrangement, fluid coupling and torque converter
- In this planetary gears sets are placed in series to provide transmission
- This type of transmission are used by Skoda, Toyota , Lexus , etc

- Automatic transmissions are found on many rear wheel drive and four-wheel drive wheel drive vehicles
  - Recent ATs also feature lock-up torque converters
  - Earlier, ATs were controlled by hydro-mechanical systems
  - Modern ATs are controlled by electronic controllers and hydraulics
- An automatic transmission selects gear ratios according to:
  - engine speed
  - power train load
  - vehicle speed
  - other operating factors

Major Components



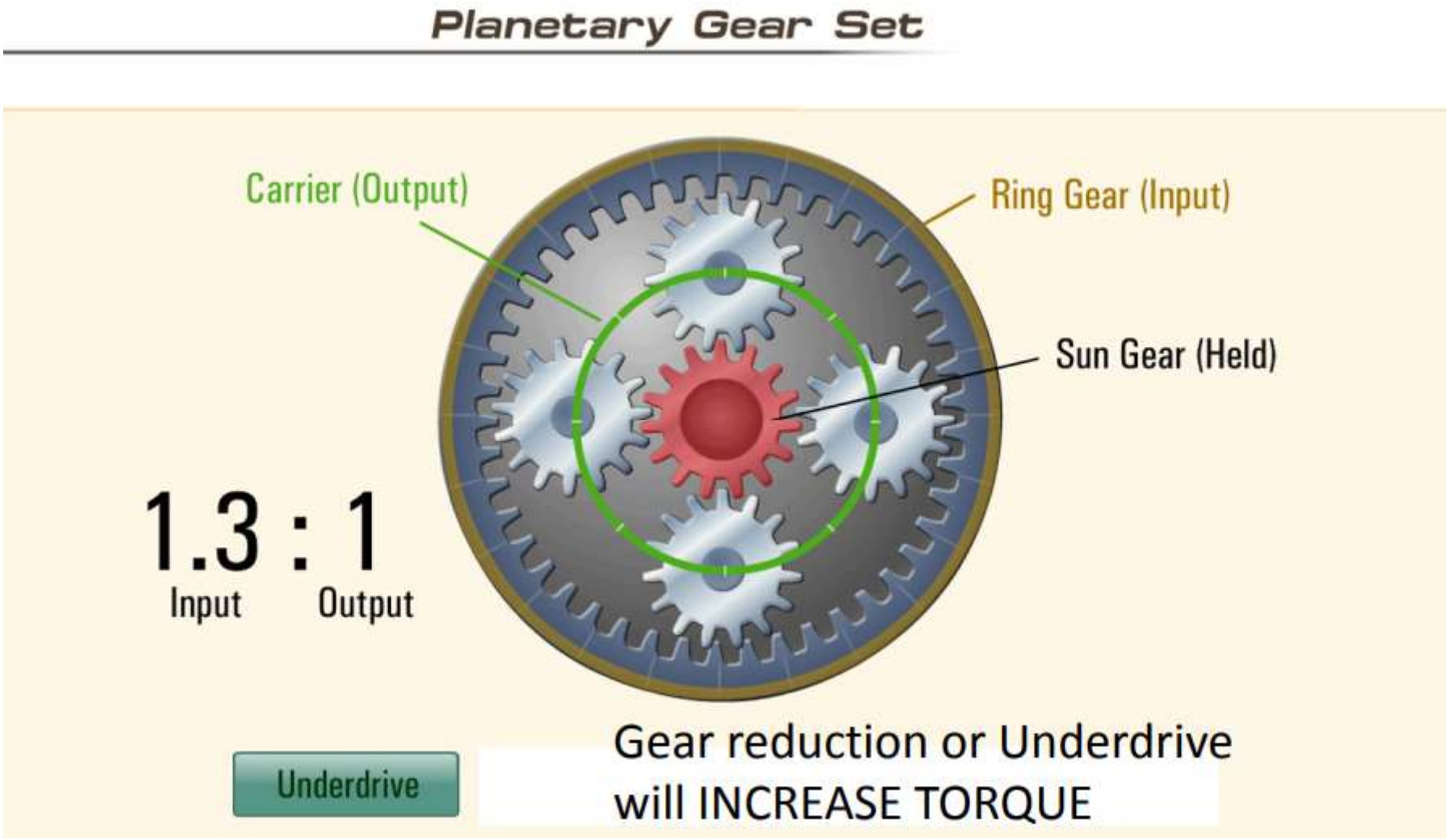
A Planetary gear can provide gear reduction (Underdrive) Direct Drive, Overdrive, or Reverse when you hold one part stationary, or lock two parts together



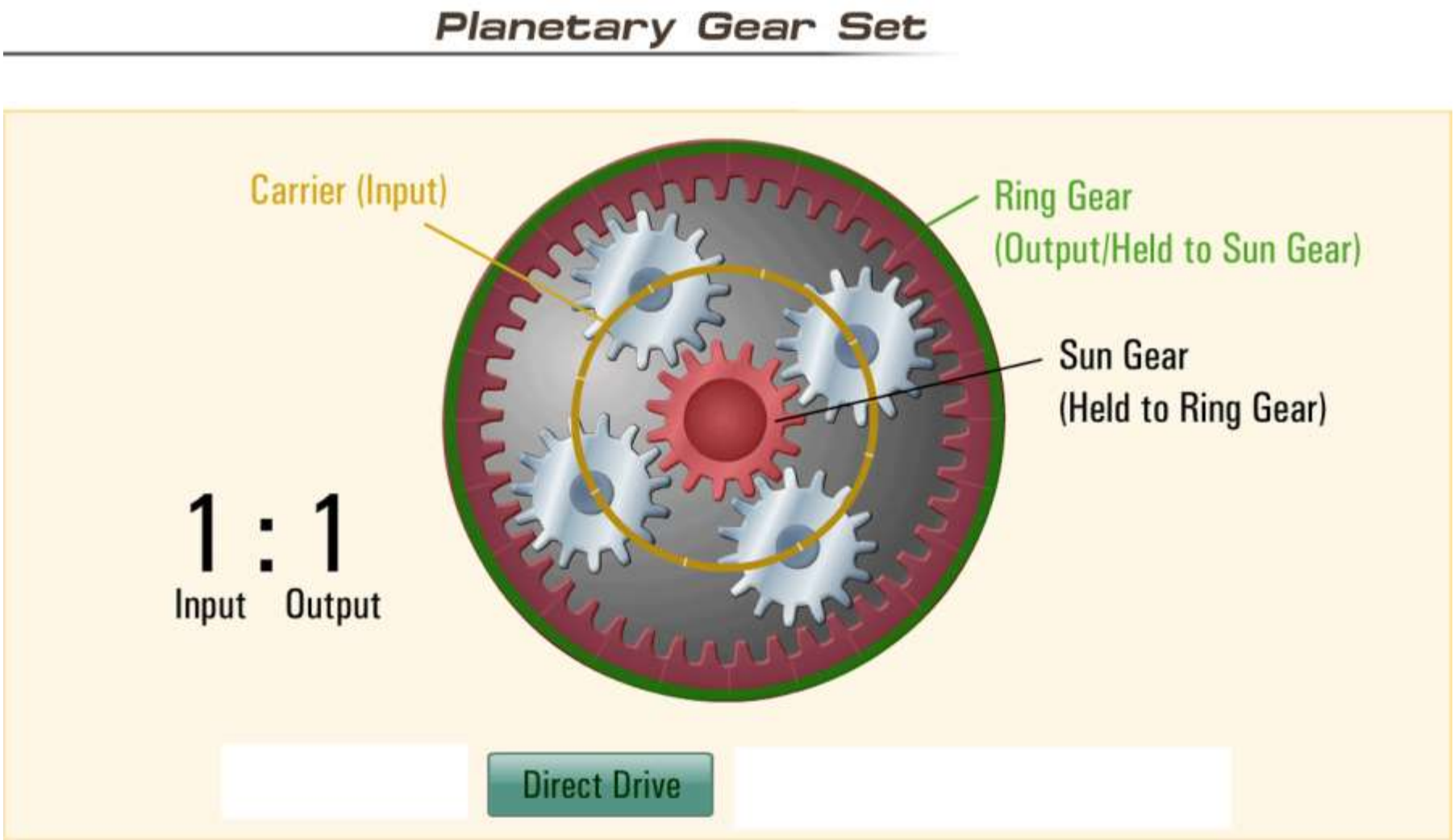
Power flow through the Planetary Gear Set

- Mathematically, the **Carrier is the largest gear** in the planetary gear set
- Small gear driving large gear (Under Drive)
  - Under Drive happens when Carrier is the Output
  - Under drive increases Torque – decreases Speed
- Large Gear driving Smaller gear (Overdrive)
  - Overdrive happens when the Carrier is the Input
- If the Carrier is **fixed**, the Gear set goes to **REVERSE**

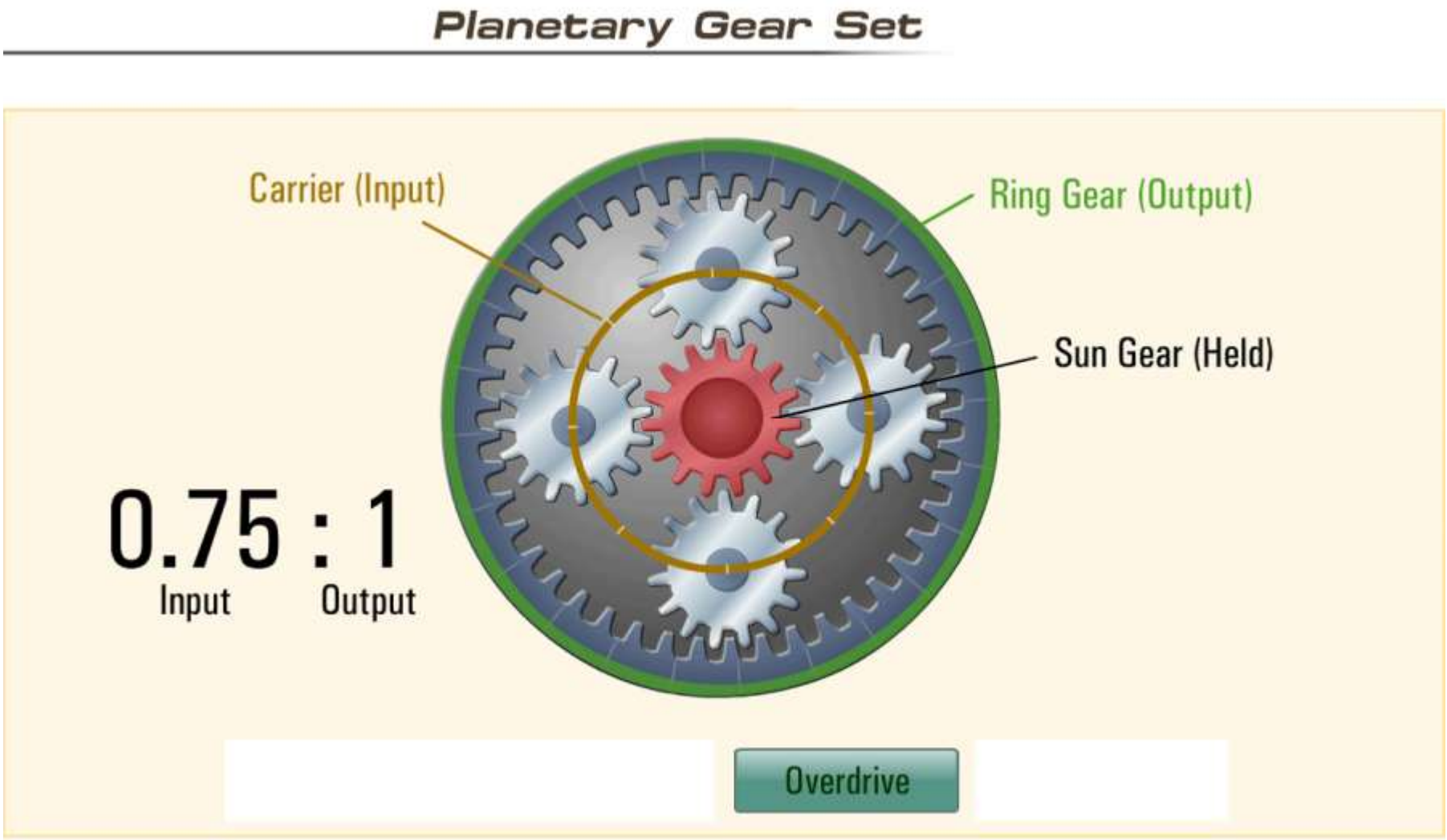
- If you do not hold or lock any part, all gears will “Freewheel” and no power is transferred (neutral)



Direct Drive happens when **ANY TWO** components are locked together



Overdrive is when Carrier is the Input
Hold Ring for **maximum** overdrive
Hold Sun for **minimum** overdrive

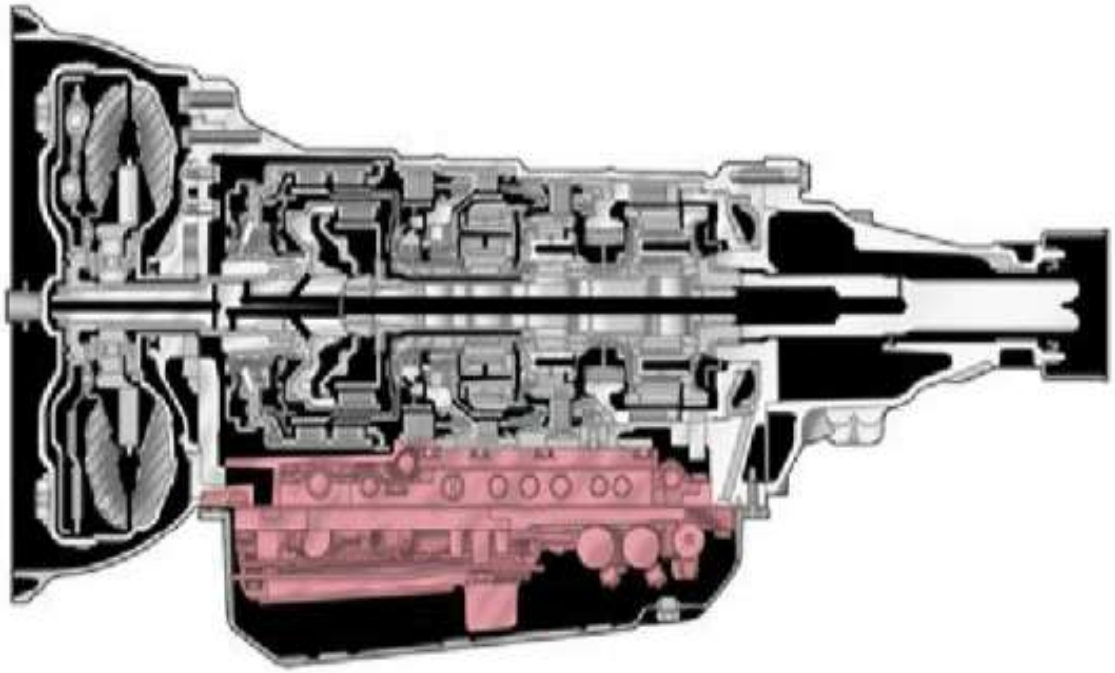


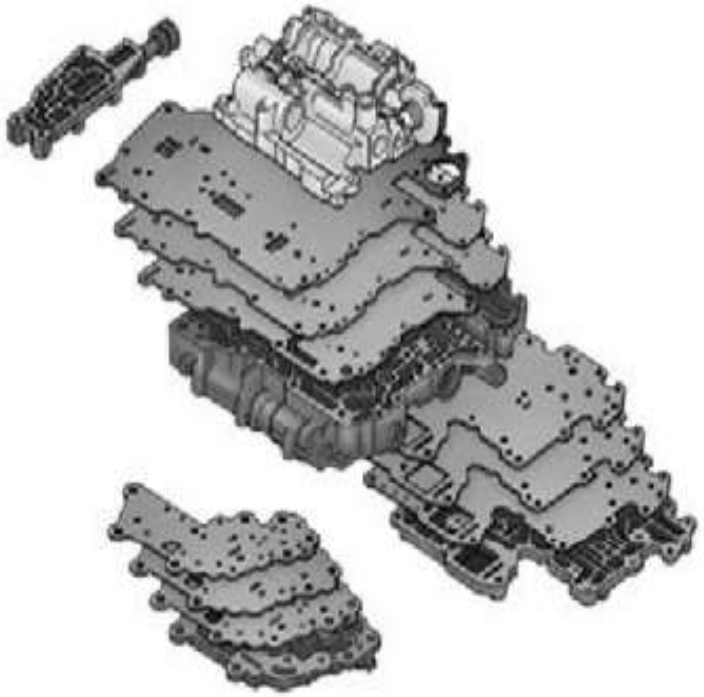
Reverse is when Carrier is Held
Input Ring for reverse overdrive
Input Sun for reverse under-drive

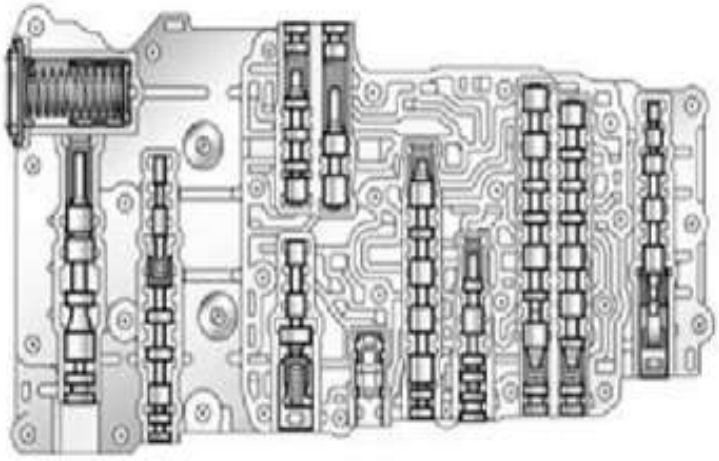
- There are three types of holding devices used to hold gears & carriers in planetary gear sets
  - **Multi-plate clutches**- Used to connect rotating components together
  - **Brakes**- also used to stop or hold
  - **One-way clutches-** Used to connect rotating components together in one direction and freewheel in the other

Each design has specific advantages

Hydraulic Valve Body



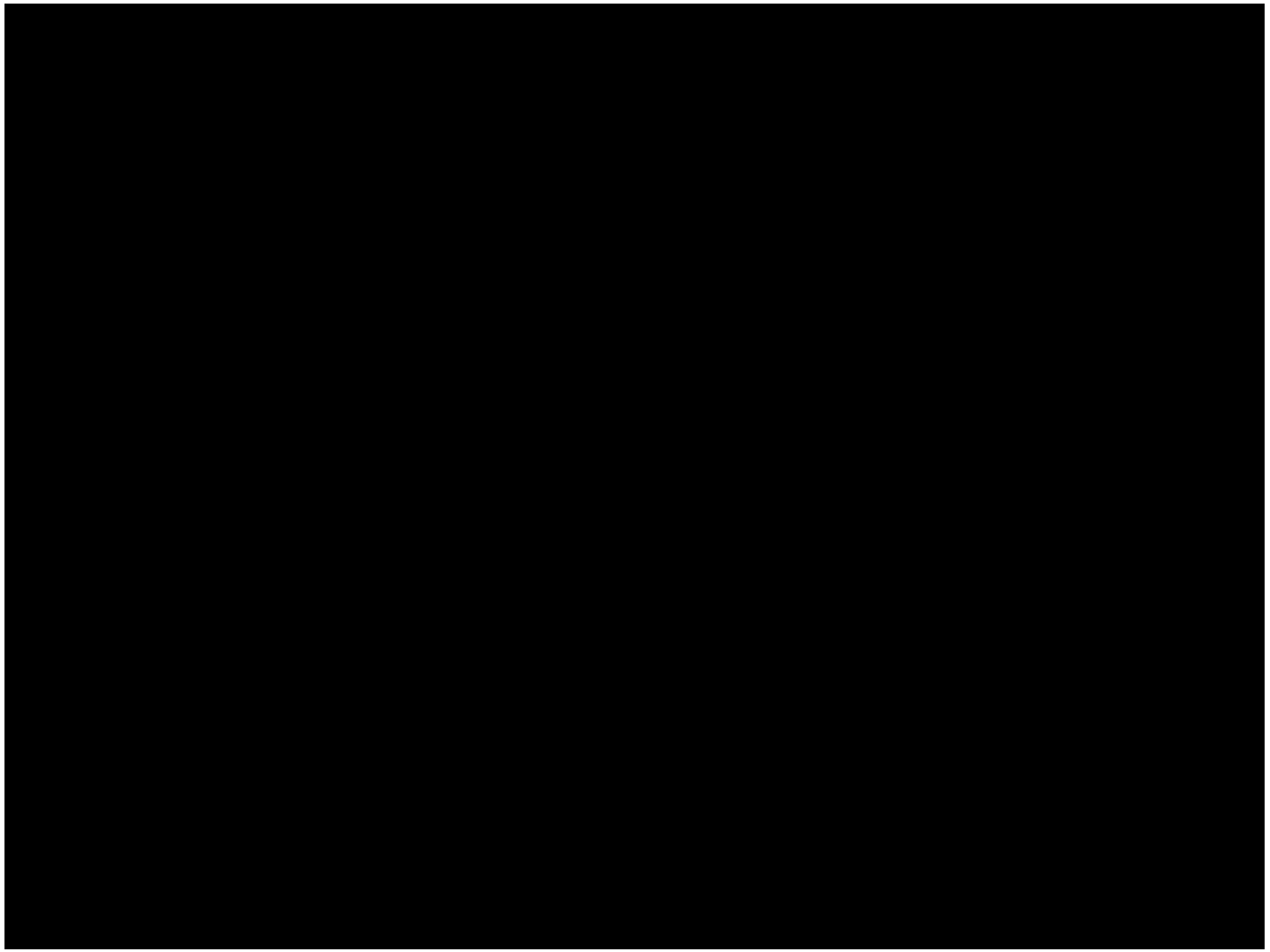




The **hydraulic control unit** has passages and valves that direct fluid flow to control:

- ATF pressure
- Gear selection (application of holding devices)
- Shift timing
- Shift quality

Animation of Automatic Transmission



Difference between Manual and Automatic transmission

- The main difference is that automatic cars don’t have a clutch pedal
- Manual transmission cars have five or six gears, plus reverse, giving you full control over how the car performs
- Automatic cars tend to have four modes:
  - Park - P
  - Reverse - R
  - Neutral - N
  - Drive - D

Stages of automatic transmission

- **Park(P)** :- will lock the transmission, thus restricting the vehicle from moving
- **Reverse(R)** :- puts the car into reverse gear, allowing the vehicle to move backward
- **Neutral (N)** :- disconnects the transmission from the wheel
- **Drive (D)** :- allows the vehicle to move and accelerate through a range of gears

- The car itself selects the right gear for the speed and road conditions
  - This means you only need to think about whether you're going forwards, backwards, or stopping
- There are a number of alternative types of automatic transmission
  - Continuously Variable Transaxle (CVT) gearboxes
  - Single automated clutches and twin clutches

- Automatic car might be better suited to those who are used to urban driving
- If you travel longer distances or are used to driving on faster roads, a manual car could be a better option
- The main plus point to driving a manual car is that you have more control over the car itself
  - Want to shift from second straight to fourth? Go for it!
  - Manual cars are less expensive than automatics
- Driving in slow-moving or stop-start traffic is made **easier with an automatic**
  - There's less chance of accidentally grinding the gears

AUTOMOBILE ENGINEERING

UNIT-2

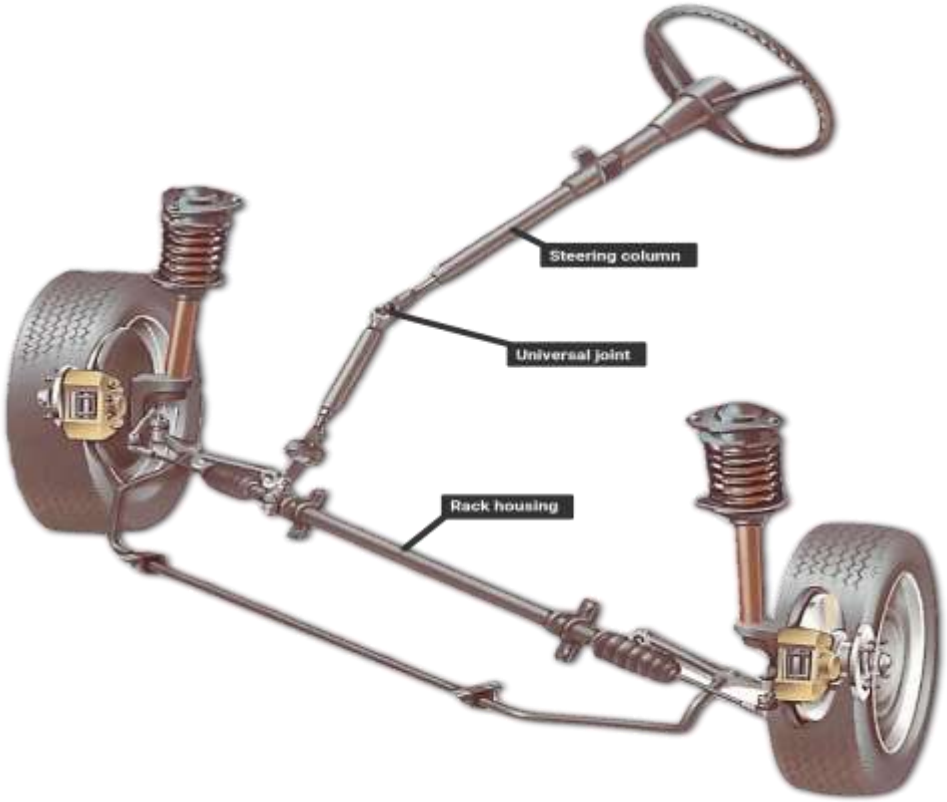
Lecture – 07

Steering-1

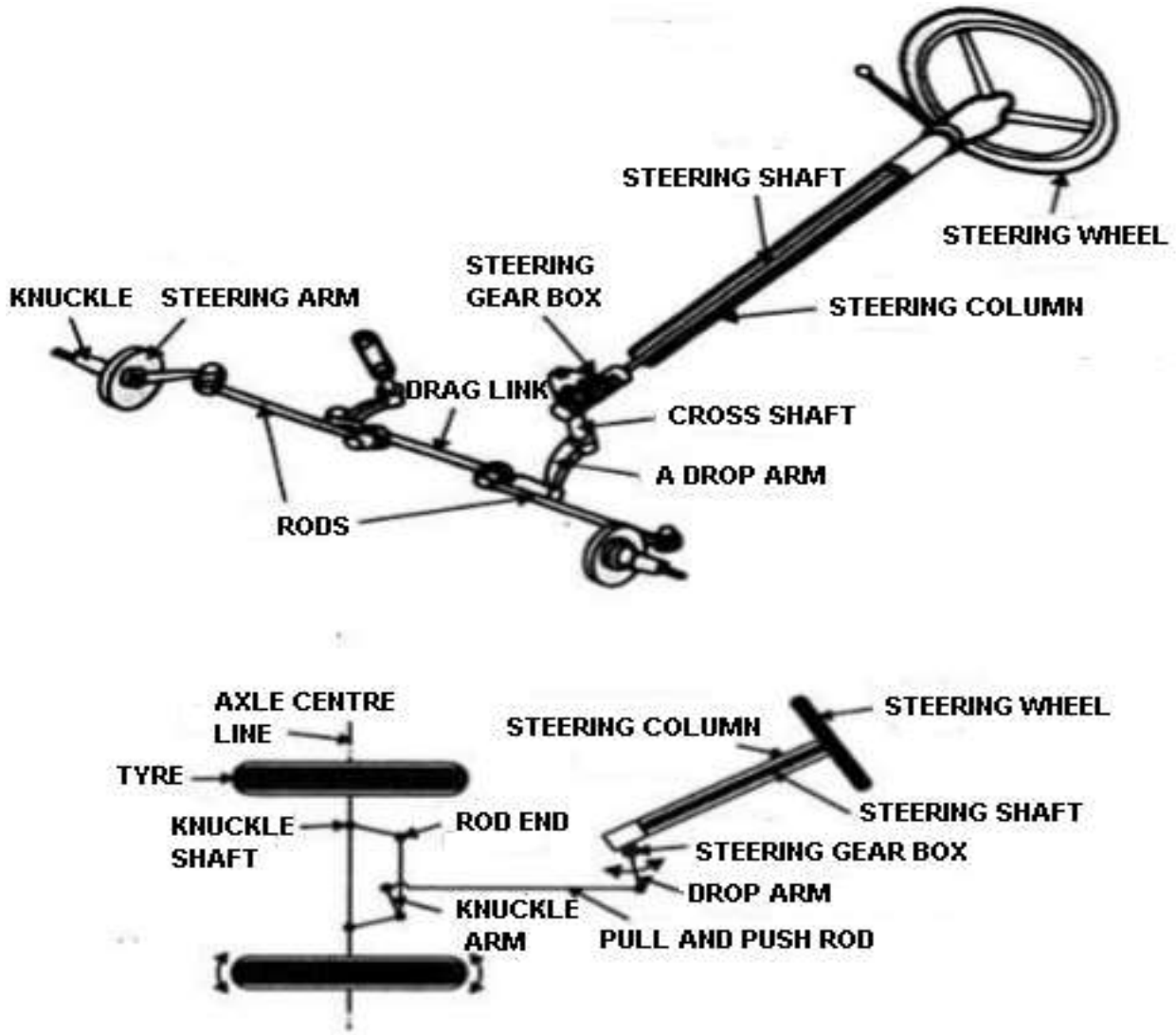
Steering System

- The steering system converts the rotation of the steering wheel into a swivelling movement of the road wheels in such a way that the steering-wheel rim turns a long way to move the road wheels a short way
- The system allows a driver to use only light forces to steer a heavy car
- Car steering system in the automobile, is the process of running the vehicle in the desired direction by turning, usually the front wheels

- Steering is also possible by the **turning of the rear wheels**, which is used generally in low-speed slow floor vehicles, **for lifting and transporting the heavy parts to a short distance** for example forklift



Automobiles are always equipped with front wheel steering.



LAYOUT OF STEERING SYSTEM

The basic system of the steering system

- The steering effort passes to the wheels through a system of pivoted joints
- These are designed to allow the wheels to move up and down with the suspension without changing the steering angle
- The rim of a 15 in. (380 mm) diameter steering wheel moving four turns from full left lock to full right lock travels nearly 16 ft (5 m), while the edge of a road wheel moves a distance of only slightly more than 12 in. (300 mm)

The Purpose of a Steering system

- For effective control of the vehicle throughout its speed range with safety and without much effort to the driver on different types of road surface, proper steering is necessary
- For proper performance and useful service of the automobile, it is necessary that the moving vehicle should be under the perfect control of the driver

The function of the Steering system

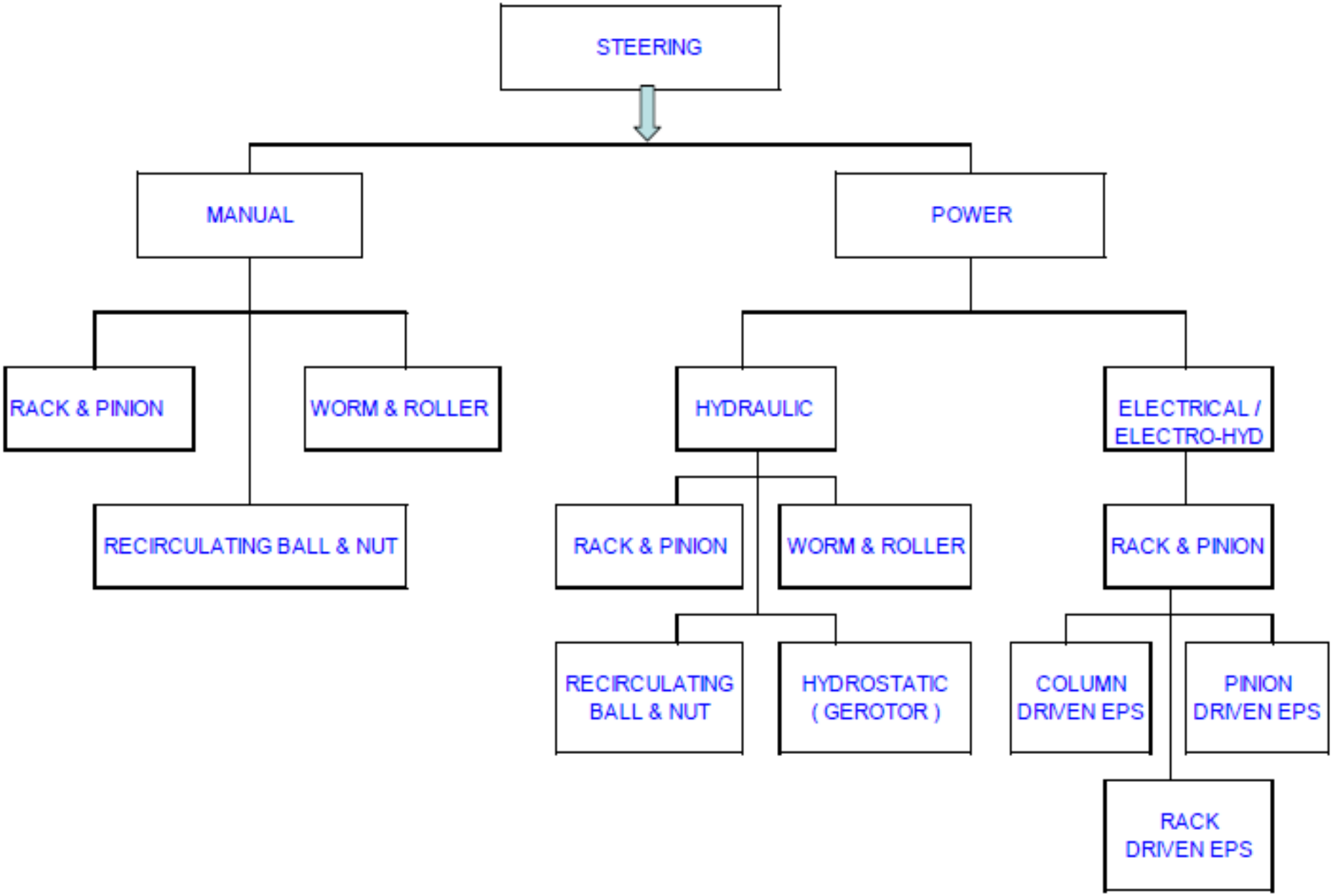
- With the help of steering system, the driver can control the vehicle however he wants
- The steering provides stability to the vehicle on road
- It minimizes tyre wear and tear
- It prevents road shocks reaching to the driver
- The steering provides self-rightening effect after taking a turn

How a car steering system works

- Steering wheel rotates the steering column
- The steering gearbox is fitted to the end of this column
  - Therefore, when the wheel is rotated, the cross shaft in the gearbox oscillates
- The cross shaft is connected to the drop arm
  - This arm is linked by means of a drag link to the steering arms
- Steering arms on both wheels are connected by the tie rods to the drag link

- When the steering wheel is operated the knuckle moves to and fro, moving the steering knuckle are connected to each other
- One end of the drag link is connected to the tie rod
- The other end is connected to the end of the drop arm

Steering systems/mechanisms in use



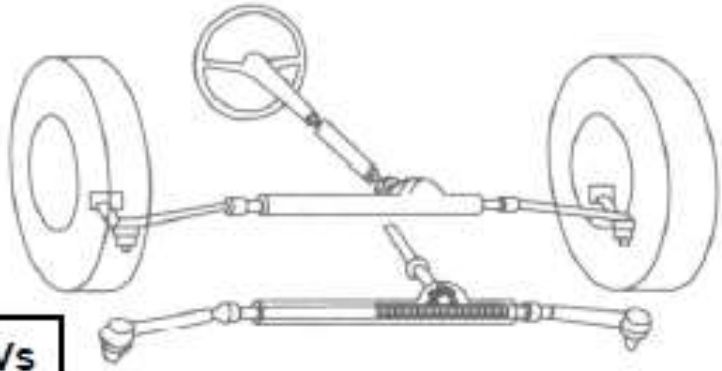
Types of the steering arrangement in an automobile

- Two traditional mechanisms that are used till date are **Rack & Pinion and Re-circulating Ball Steering**
- Fundamentally there are two types of steering arrangements,
  - Turntable steering or centre pivot steering
  - Ackerman steering or side pivot steering

Typical Mechanical Steering Systems

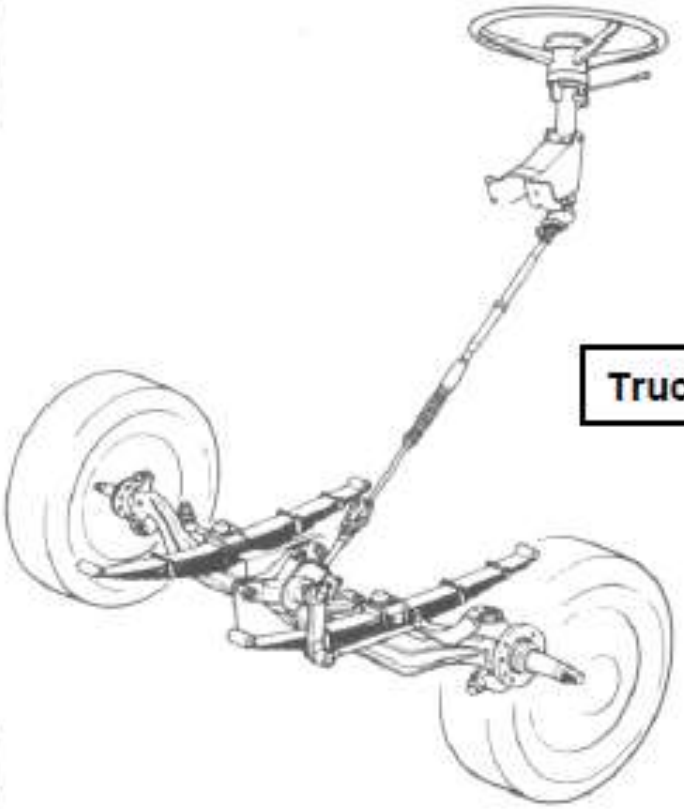
(for "on-road vehicles)

Cars / UVs



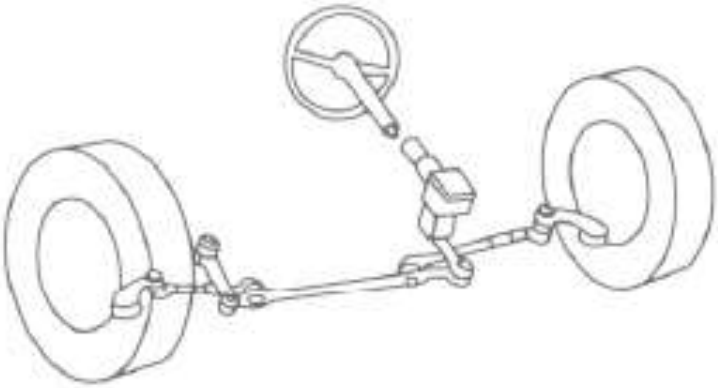
Rack-and-pinion linkage

Trucks / Bus



Truck steering system

UVs/LCVs



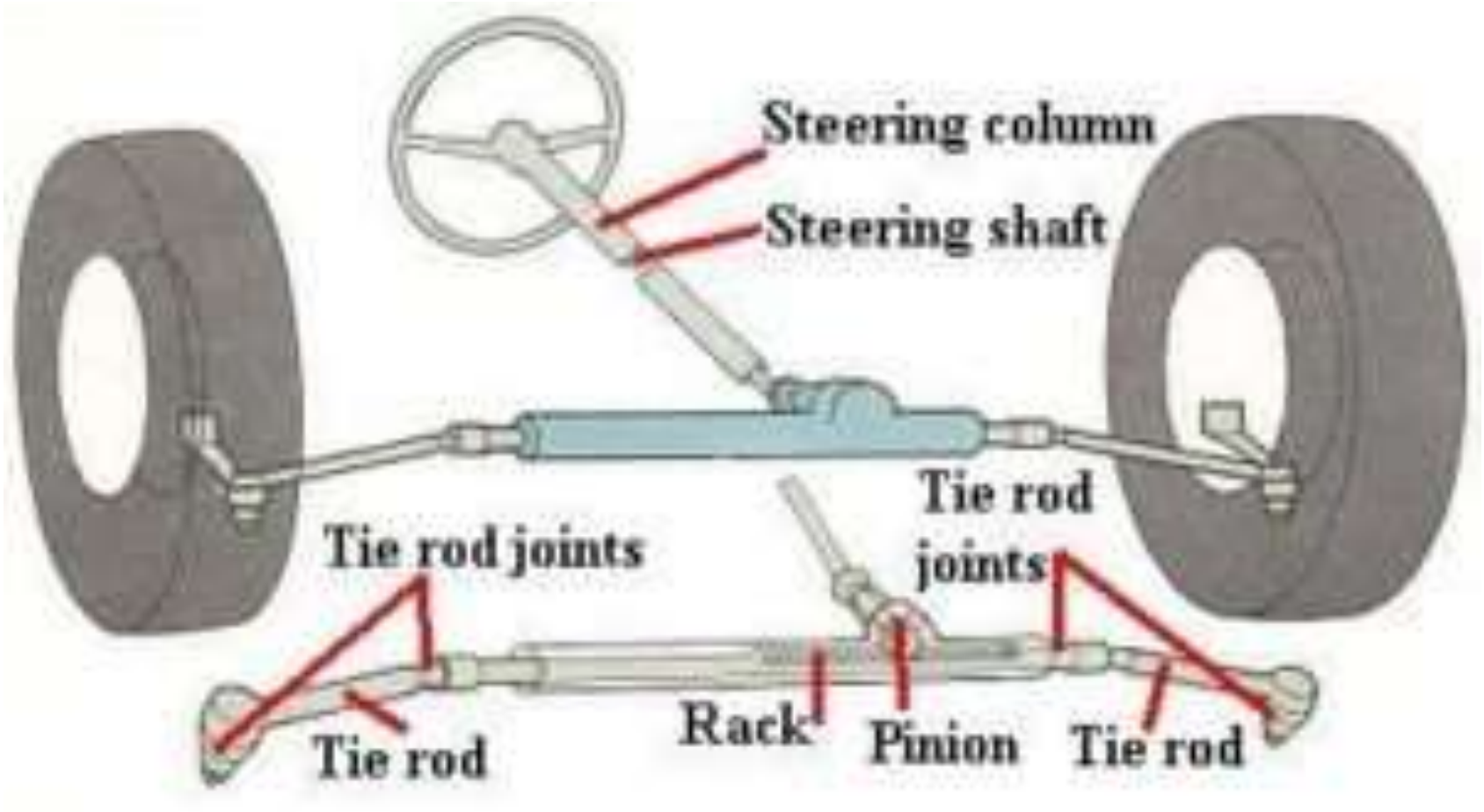
Steering gearbox

- **Rack & Pinion**
  - Rack-and-pinion steering is the most common type of motion control mechanism in cars, small trucks and SUVs
- **Construction**
  - A Rack & Pinion gear set is enclosed in a metal tube with each end of the rack pointing out from the tube
  - A rod – tie rod or axial rod – connects to each end of the rack
  - The pinion gear is attached to the steering shaft

Mechanism

- When you turn the steering wheel the gear will spin, moving the rack
  - The tie rod connects to the steering arm, which is attached to a spindle
- The purpose of a Rack & Pinion gear is to convert circular motion of the steering wheel into the linear motion
  - It allows gear reduction, making it easier to turn the wheels
- The two types of rack-and-pinion steering systems:
  - End take-off
  - Centre take-off

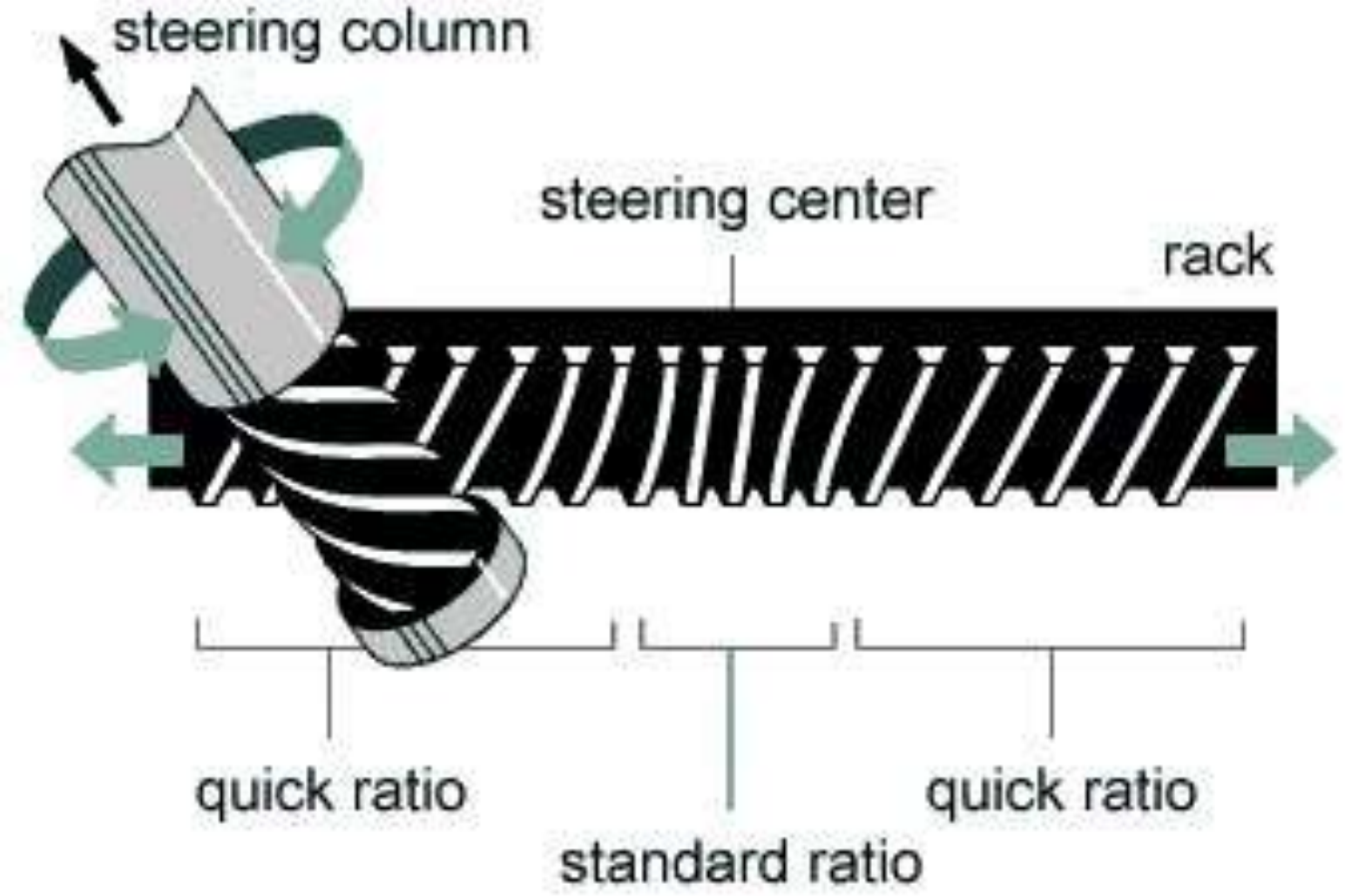
Rack & Pinion


Steering column
Steering shaft
Tie rod joints
Tie rod joints
Tie rod
Rack
Pinion
Tie rod

Rack & Pinion Animation

- **Variable Ratio Steering**
  - A **subtype** of Rack & Pinion gear steering
  - This steering system has different number of tooth pitch at the centre than it has at the ends
  - This makes the steering less sensitive when the steering wheel is close to its centre position
  - And when it is turned towards lock, the wheels become more sensitive to circular motion of the steering wheel

Variable Ratio Steering



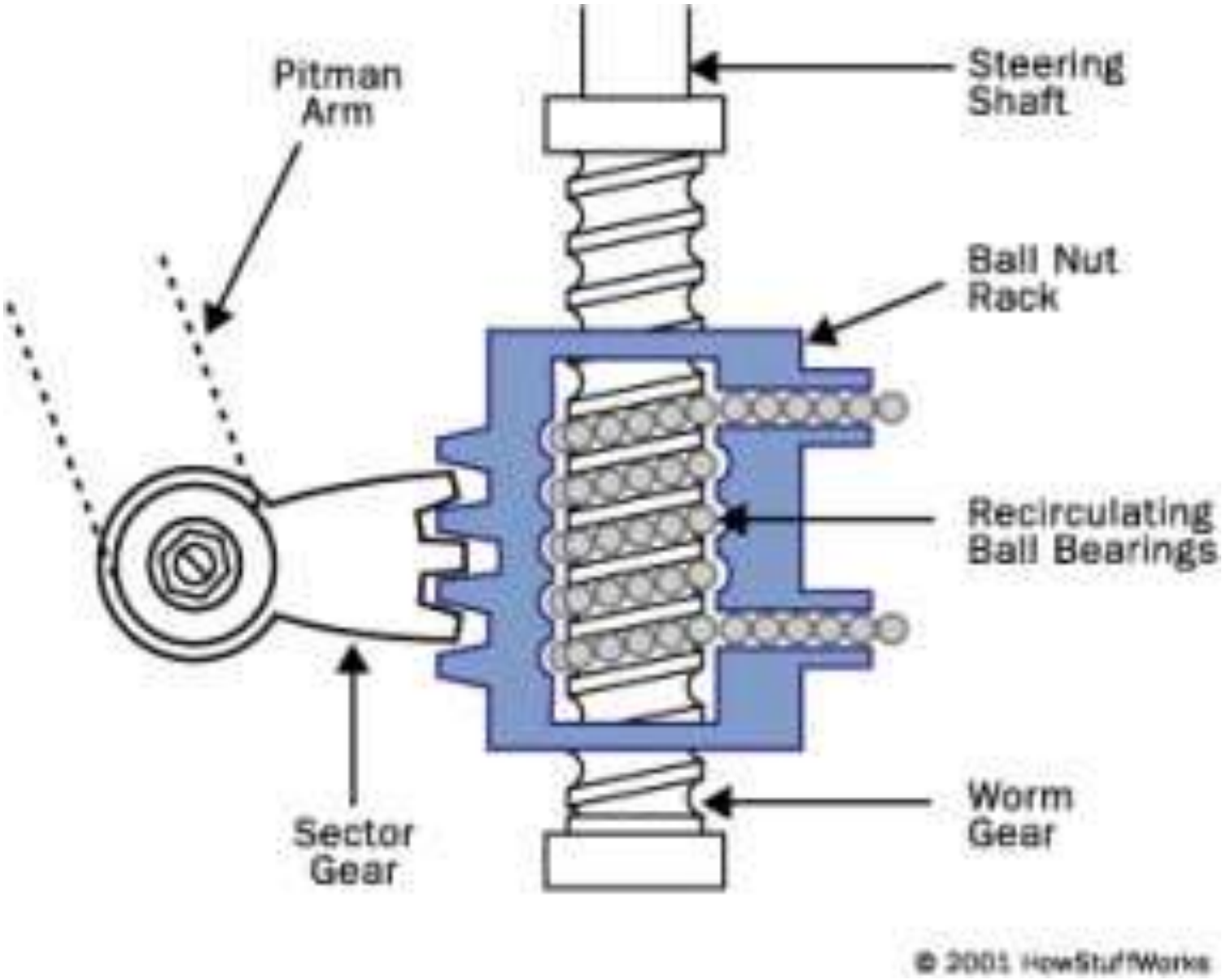
Re-circulating Ball / Steering Box

- Re-circulating Ball Steering is the most commonly used steering system in heavy automobiles
- It runs on Parallelogram linkage, in which:
  - The Pitman & Idler arm remain parallel
- The mechanism absorbs heavy shock loads and vibrations

Construction

- The steering wheel is fixed to the steering shaft, which has a threaded rod at the end
  - The threaded rod is fixed, unlike in the Rack & Pinion type
- The block has gear teeth machined on its surface
- The threads in the rod are filled with ball bearings
- These ball bearings have two functions:
  - To reduce friction and wear in the gear
  - Fixing the teeth of the gear to prevent the former from breaking contact with each other when the steering wheel changes direction

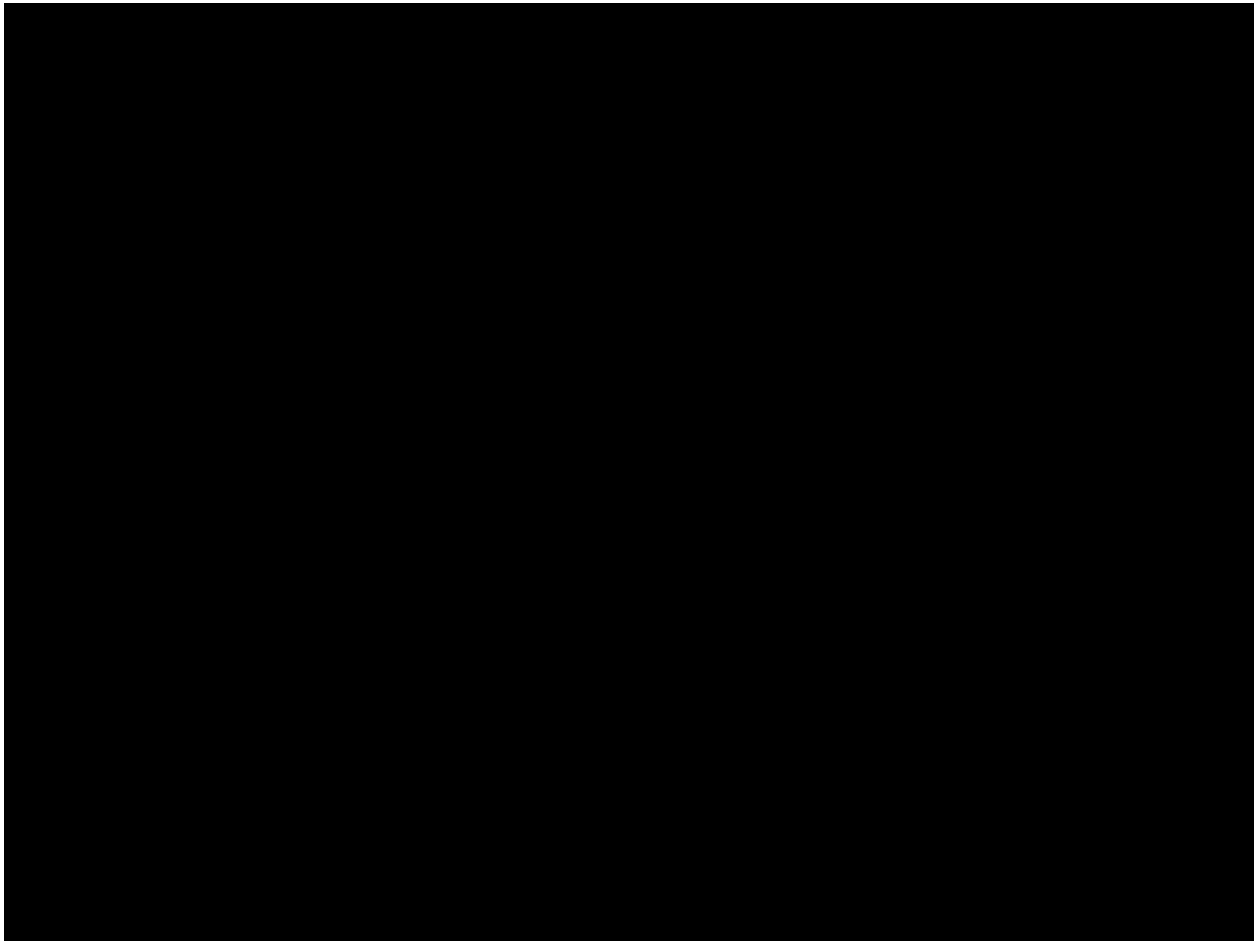
Re-circulating Ball / Steering Box



Mechanism

- When the steering wheel is rotated, the rod turns
- When the wheel spins, the block moves
- The block moves another gear that in turn moves the Pitman arm
- The ball bearings in the threads re-circulate through the gear as it turns

Re-circulating Ball / Steering Box



AUTOMOBILE ENGINEERING

UNIT-2

Lecture – 08

Steering-2

Wheel Alignment

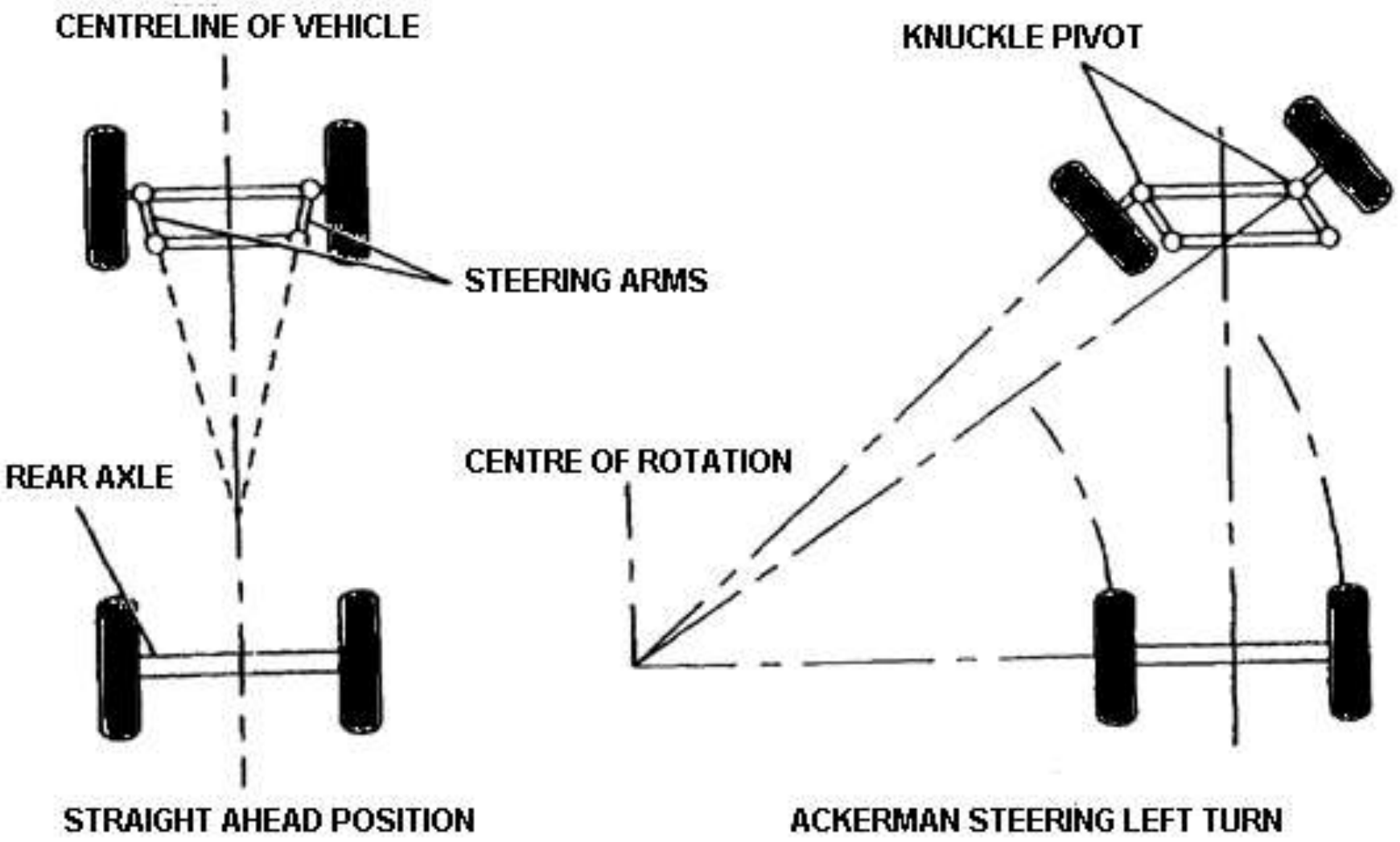
- Wheel alignment is defined as the correct adjustment of the pivot axes controlling the movement of the wheels
- Proper aligned front wheels result in
  - Steering comfort
  - Uniform wear of tyres
  - Minimum energy consumption
  - Minimum vibrations
  - No wheel wobbling
  - Reduce the driver effort to turn the vehicle
  - To achieve self-centring of the wheel after turning
  - To achieve directional stability of the vehicle while running

- **To obtain a good alignment it is necessary to understand the following factors,**
  - Camber (Wheel rake or Camber angle)
  - Caster
  - King Pin inclination
  - Toe-in
  - Toe-out

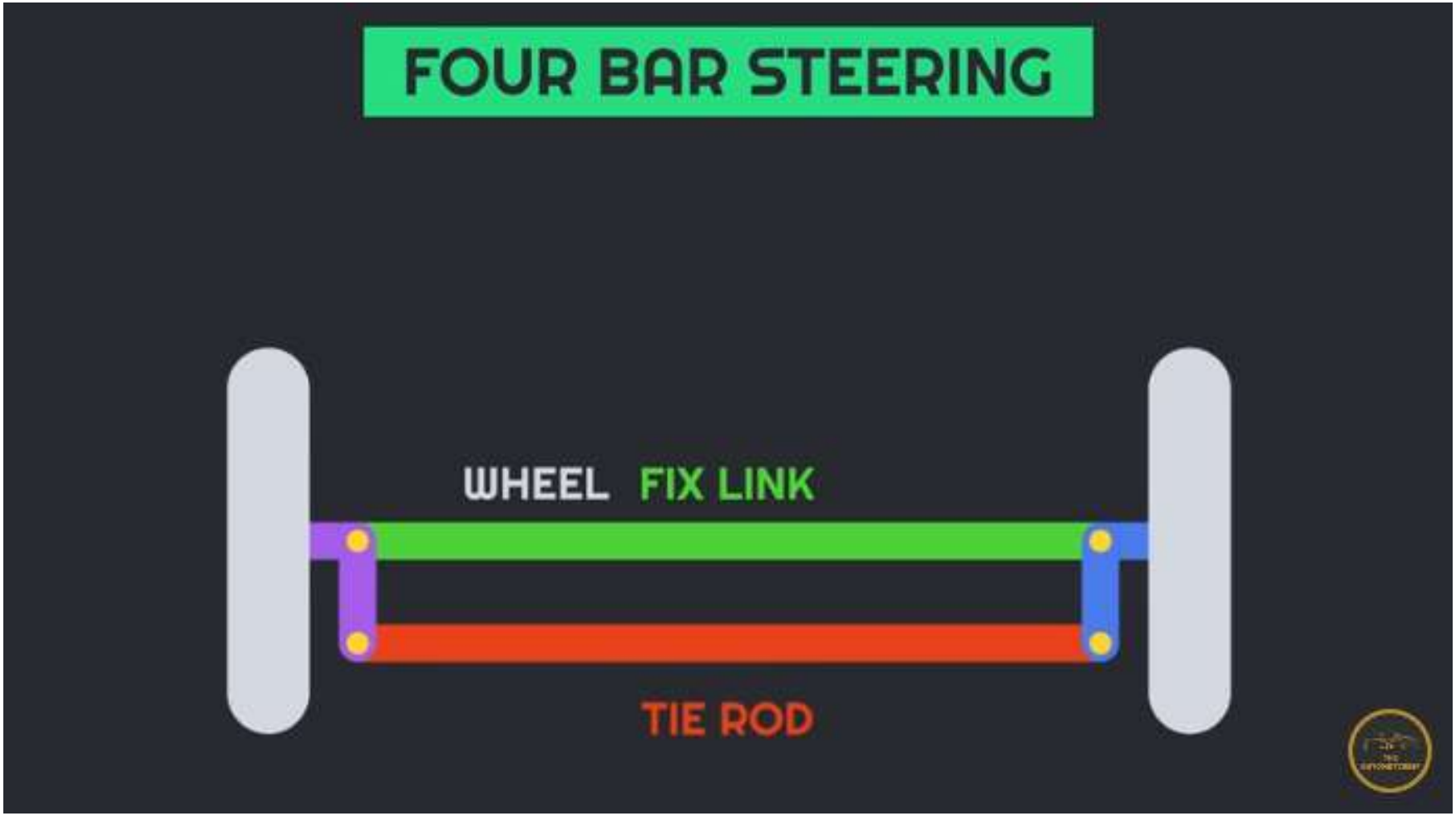
Turntable or Centre Pivot Steering

- In a four-wheel vehicle, the front two wheels are mounted on the axle **and the axle, in turn, is fixed** to a turntable having a single pivot
- When the front wheels are turned, the whole front axle is turned about the central pivot
  - In this case, the perpendiculars of all the wheels meet at a point during any turn, so that the turning is safe and wheels roll freely

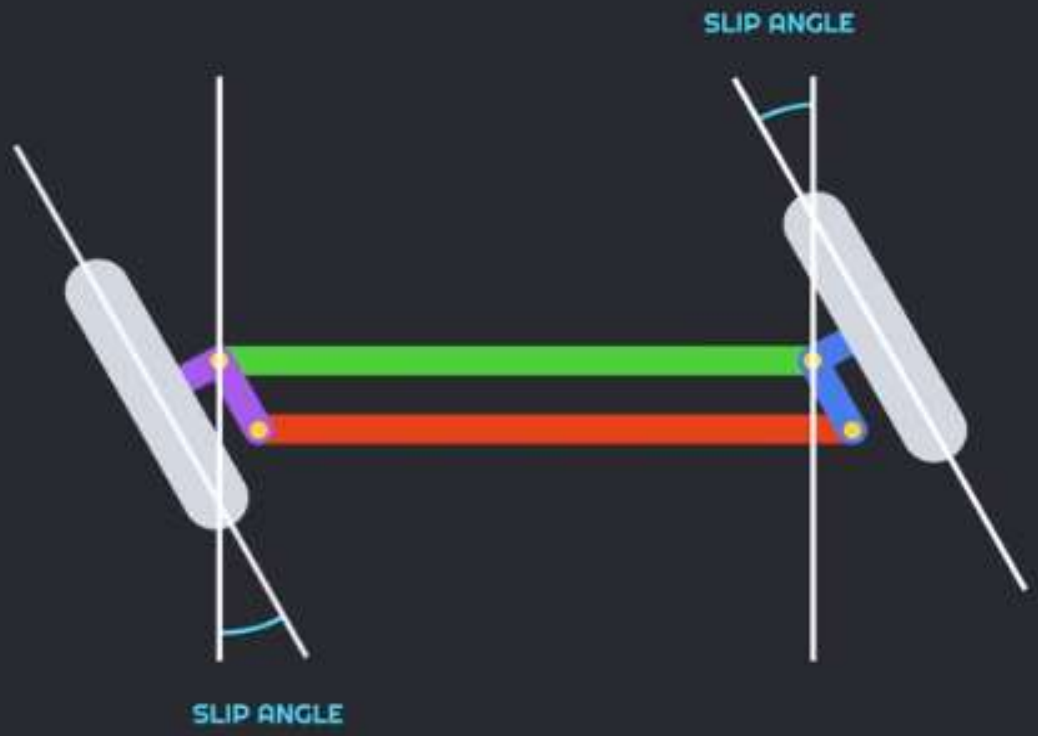
- This type of arrangement is commonly used in horse-drawn coaches and trails
  - This is unsuitable for automobile vehicle because it is unstable at high speeds
- Moreover, a centre pivot steering arrangement requires a lot of space and because for the whole axle to turn



TURNTABLE OR CENTRE PIVOT STEERING


FOUR BAR STEERING
WHEEL
FIX LINK
TIE ROD

FOUR BAR STEERING



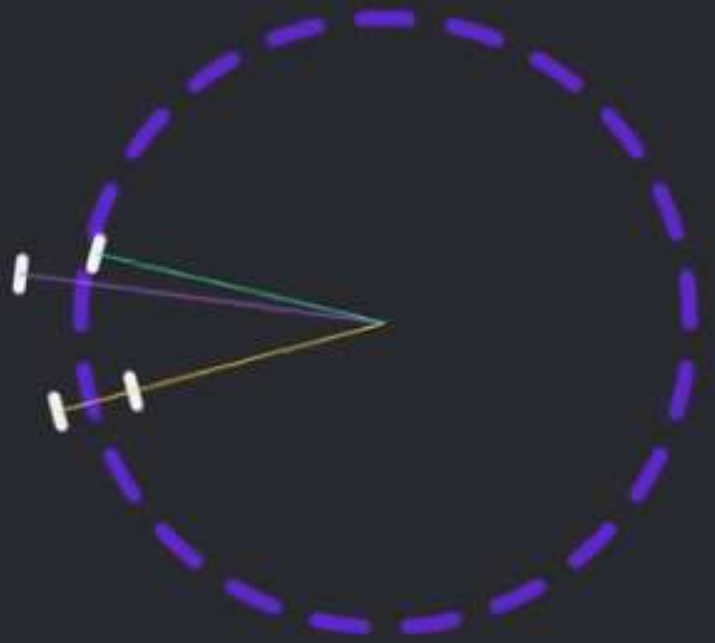
FOUR BAR STEERING

RADIUS OF OUTER WHEEL

NEEDS TO TRAVEL
MORE DISTANCE

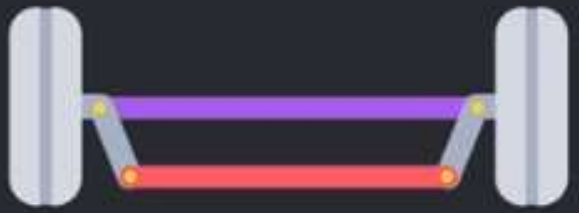
RADIUS OF INNER WHEEL

NEEDS TO TRAVEL
LESS DISTANCE



ACKERMANN STEERING

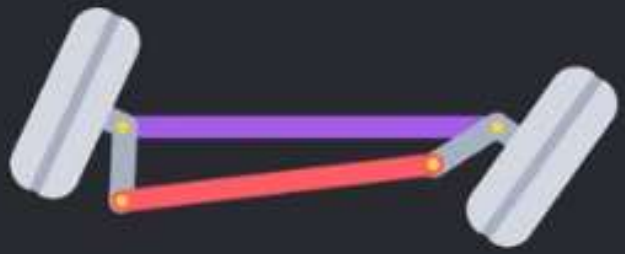
4-BAR STEERING



ACKERMANN STEERING

ACKERMANN STEERING

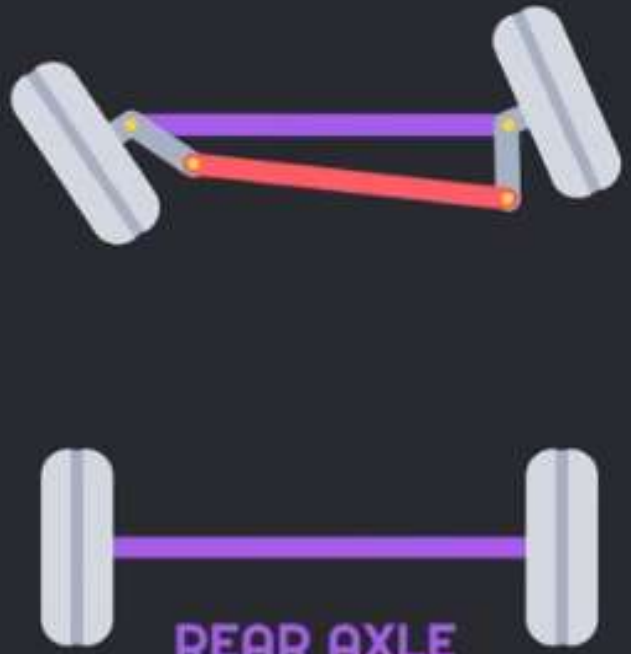
ACKERMANN STEERING



REAR AXLE

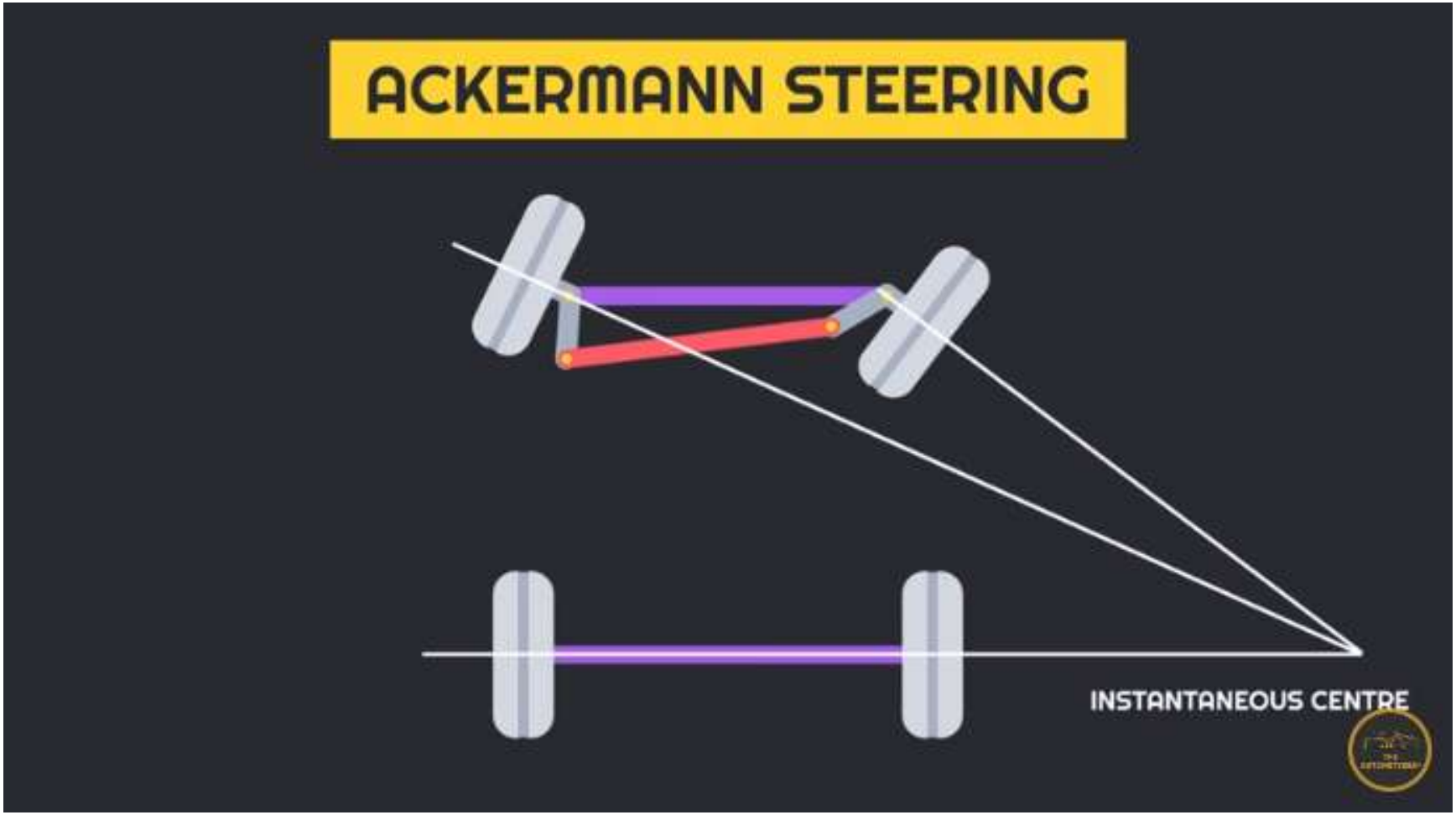
ACKERMANN STEERING

DIFFERENCE IN SLIP ANGLES MINIMISE WHEEL SKIDDING ON TURNING.

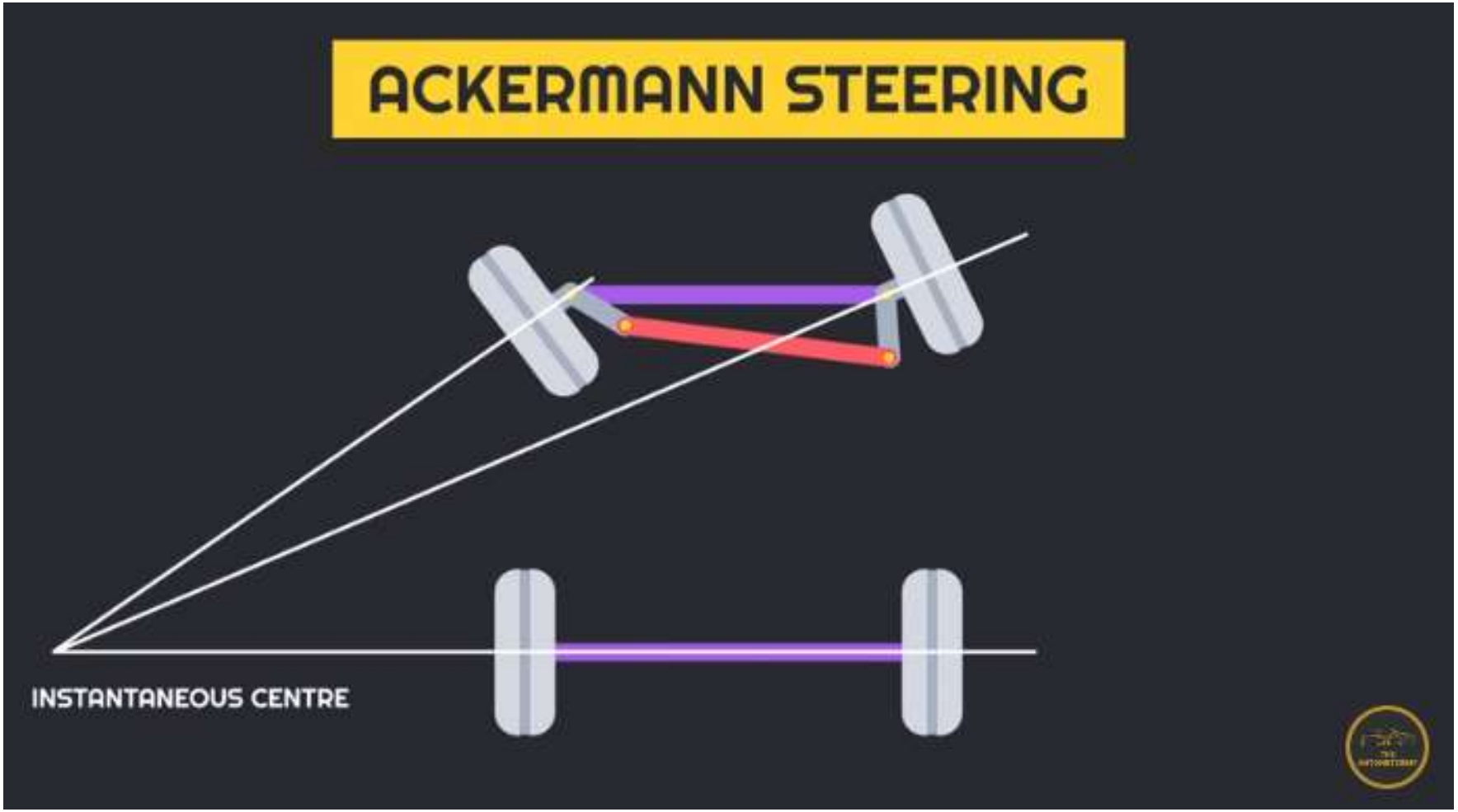


DUE TO INCLINATION STEERING WILL AUTOMATICALLY REUTURN TO INITIAL STATE AFTER TURNING.

ACKERMANN STEERING



ACKERMANN STEERING



DAVIS STEERING

SLIDE JOINT

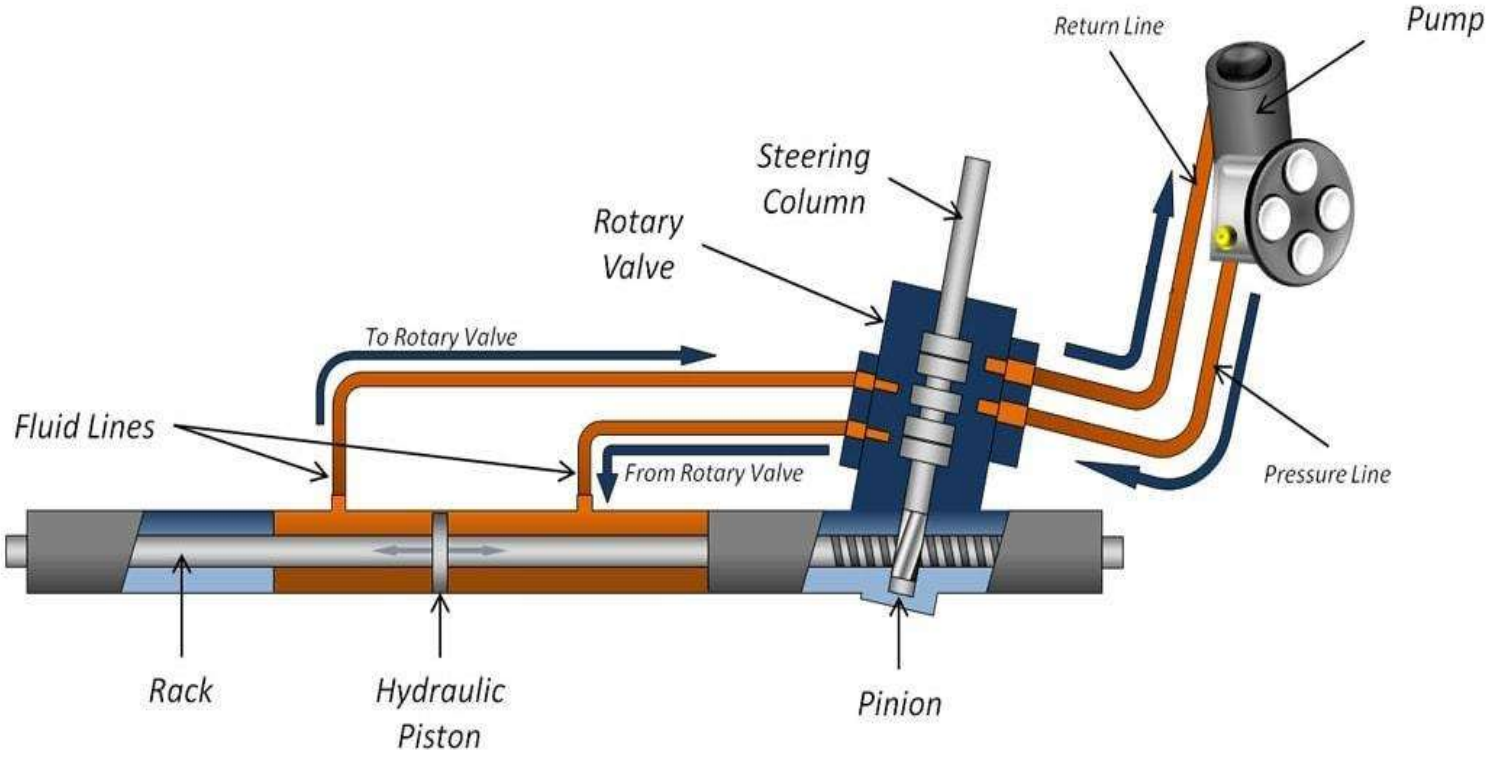
Power Steering System

- The engine drives a pump that supplies oil under high pressure to the rack or the steering box
- Valves in the steering rack or box open whenever the driver turns the wheel, allowing oil into the cylinder
- The oil works a piston that helps to push the steering in the appropriate direction
- As soon as the driver stops turning the wheel, the valve shuts and the pushing action of the piston stops

- **The power only assists the steering** - the steering wheel is still linked to the road wheels in the usual way.
- So if the power fails, the driver can still steer but the steering becomes much heavier.

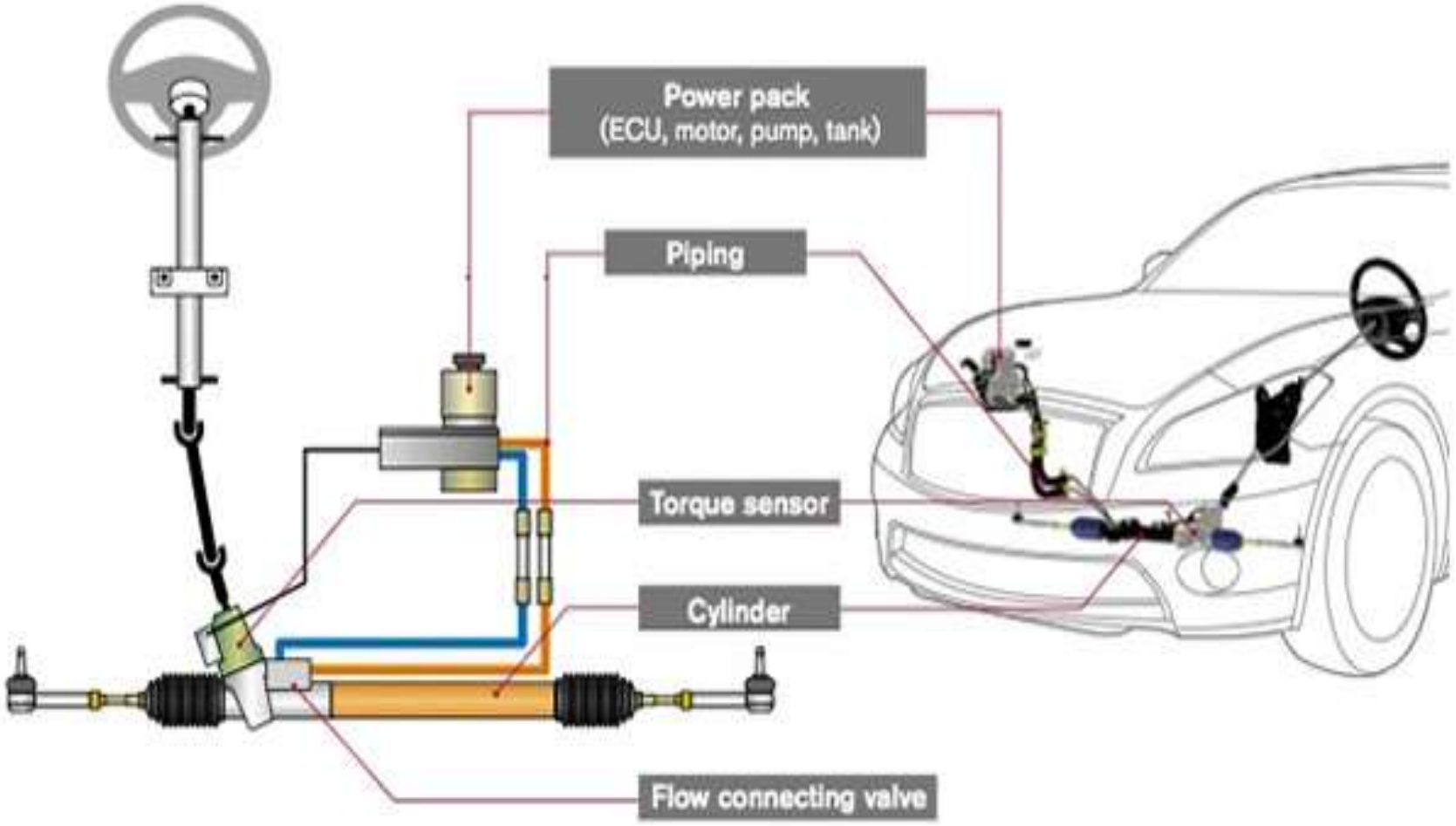
Types of Power Steering

- **Hydraulic power steering**
  - Use hydraulic fluid

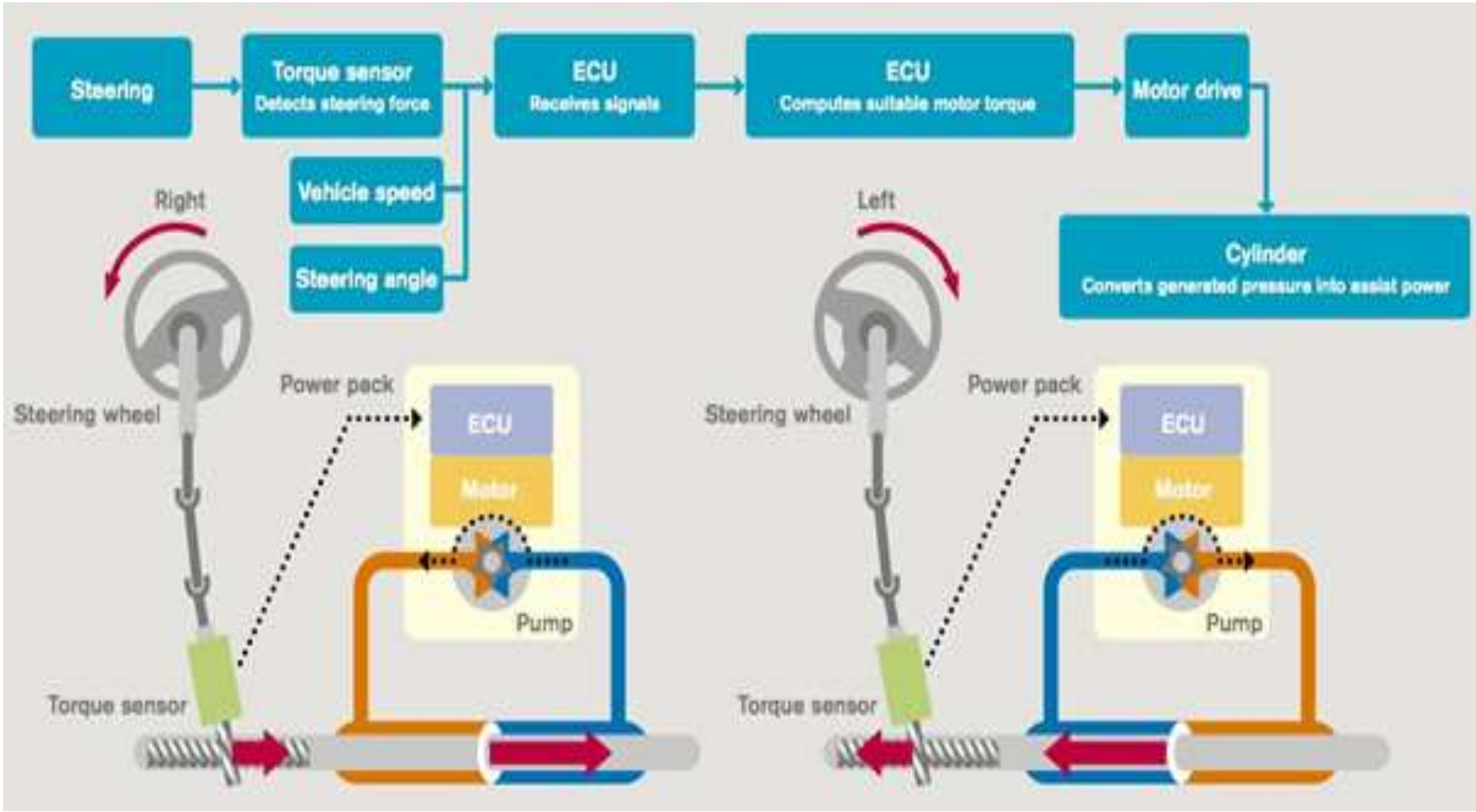


- **Electric power hydraulic steering (EPHS)**
  - Drive belts and pulleys that drive a power steering pump, are replaced by a brushless motor
  - It is driven by an electric motor and thus also reduces the amount of power taken from engine

Electric power hydraulic steering (EPHS)



Electric power hydraulic steering (EPHS)-Overview



- **Fully electric power steering(EPS)**
  - In these systems, the steering movement is assisted by an electric motor
  - The electric motor is either attached to the steering rack or to the steering column
  - The very important component is the electronic control unit **(ECU)** that controls the steering dynamics
  - ➢ EPS are often preferred for the **fuel economy and lower emission**

Next-Generation Electric Power Steering

- Ford, Audi, Mercedes-Benz, Honda and GM are introducing steering systems with variable ratios on some platforms
- Some automakers are also calling this adaptive steering

➢ **The ratio continually changes with vehicle speed, optimizing the steering response in all conditions**

AUTOMOBILE ENGINEERING

UNIT-2

Lecture – 09

Wheel Alignment

Wheel Alignment

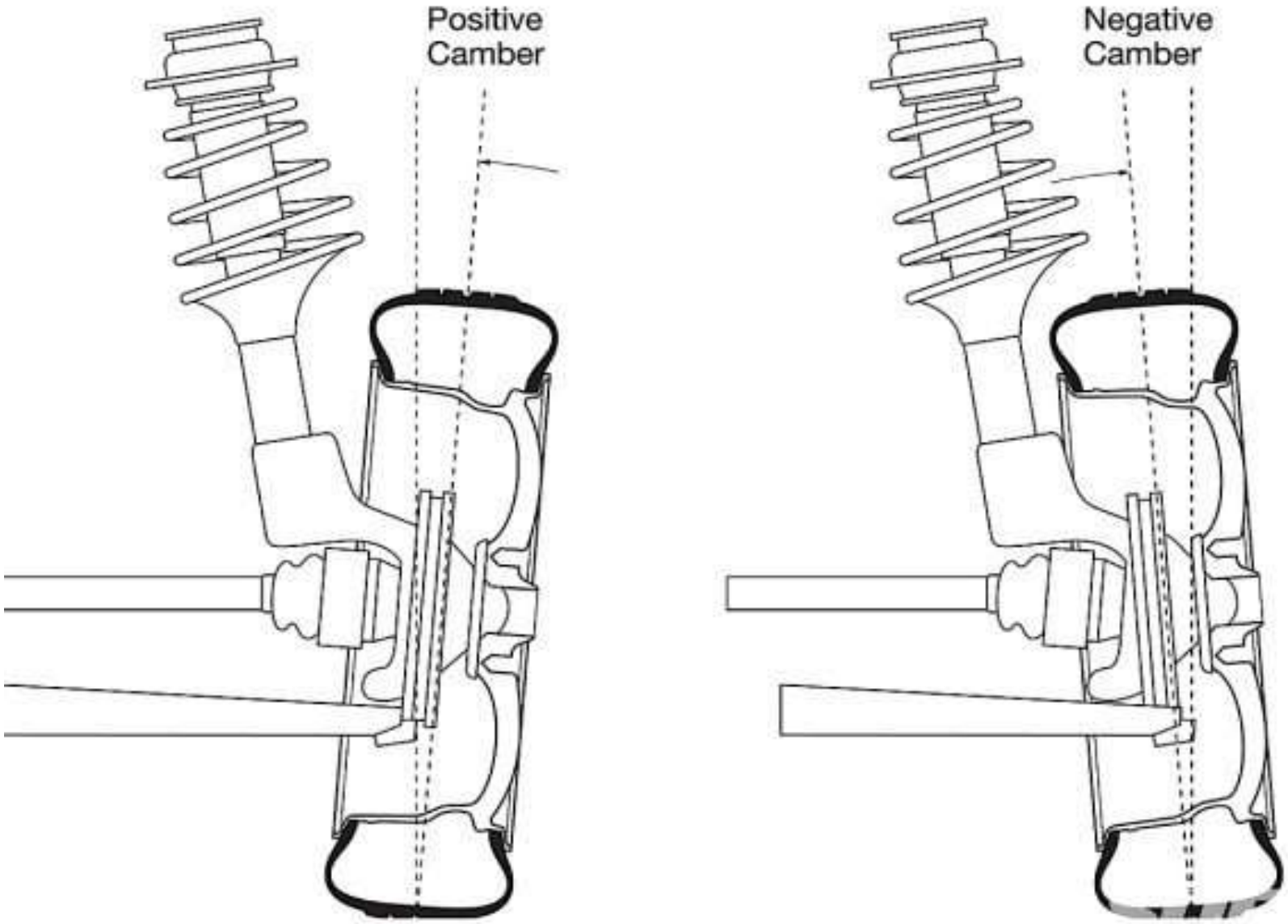
- It is the position of the front and rear wheels in relation to the suspension
- Proper alignment of both the front & rear wheels ensures easy steering, long tyre life, comfortable ride and reduced road vibration
- The term alignment means that while moving straight ahead, the wheels should be parallel

To obtain a good alignment it is necessary to understand the following factors:

- Camber (Wheel rake or Camber angle)
- Caster
- King Pin inclination
- Toe-in
- Toe-out

Camber Angle

- It is the angle made by the wheels of a vehicle
  - Specifically, it is the angle between the vertical axis of the wheels used for steering and the vertical axis of the vehicle when viewed from the front or rear
- It is used in the design of steering and suspension
- If the top of the wheel is farther out than the bottom (that is, away from the axle), it is called positive camber
- If the bottom of the wheel is farther out than the top, it is called negative camber


Positive
Camber
Negative
Camber

Why Camber is required?

- When stationary, the tire maintains a static camber angle, whereas when the car is cornering, due to body roll, the contact patch is reduced
- In order to counteract this effect and have the greatest amount of tire on the road while cornering, camber settings must be taken into consideration and adjusted accordingly

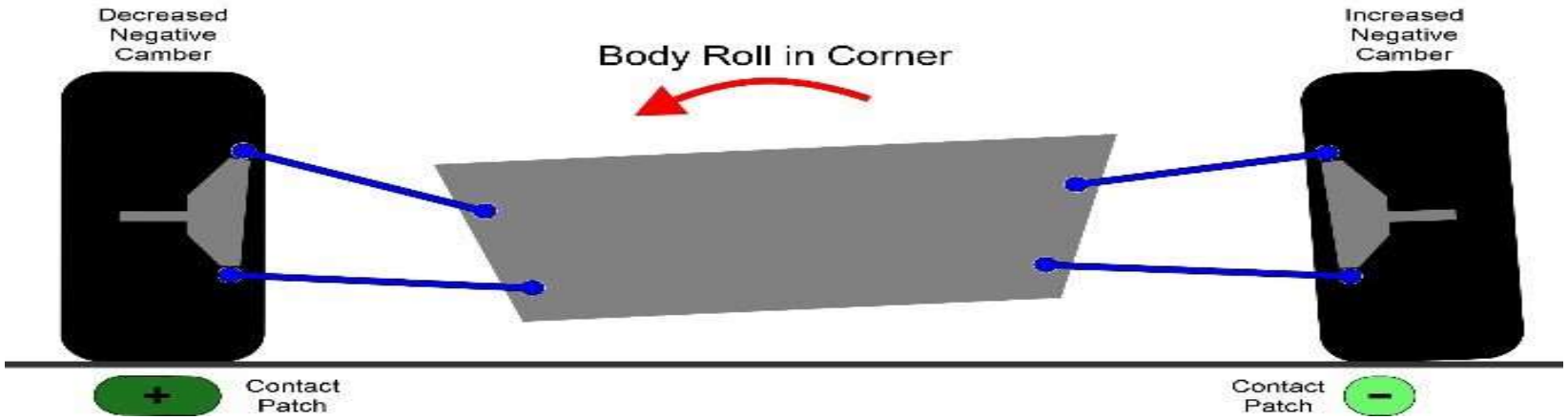
- Camber angle alters the handling qualities of a particular suspension design:
  - In particular, negative camber improves grip when cornering
- This is because it places the tire at a better angle to the road, transmitting the forces through the vertical plane of the tire rather than through a shear force across it

How Does It Work?

- The objective is to adjust camber so the wheels will lineup straight when the automobile is moving ie, with zero camber
- This puts full width of the tyre tread on the road surface
- However, average running camber of zero seldom occurs
- The camber goes negative when the tyre hits a bump and moves up
- It goes positive when tyres drops in a hole in a road

- Camber is a tyre wear angle
- Any camber, positive or negative, can cause uneven and rapid tyre wear
- Off-road vehicles such as agricultural tractors generally use positive camber
  - In such vehicles, the positive camber angle helps achieve a lower steering effort
- Negative camber is the characteristic generally desired in performance driving

- When the wheels and tires are pushed outwards and the car's body rolls, the contact patch, or the area of the tire which comes into contact with the surface of the road, diminishes significantly as it rolls over onto its outer shoulder



- Negative camber helps counteract the natural tendency for a tire to roll onto its outer shoulder while cornering, keeping the contact patch squarely on the road while cornering allow for more grip and higher cornering speeds
- Too much negative camber causes the car to follow cracks or imperfections in the road, and also have an excessive sensitivity to the road's crown (an engineered curve that promotes water drainage on roads)
- It also isn't very friendly to tires, causing them to wear at a significantly higher rate

Determining Optimum –ve Camber Setting

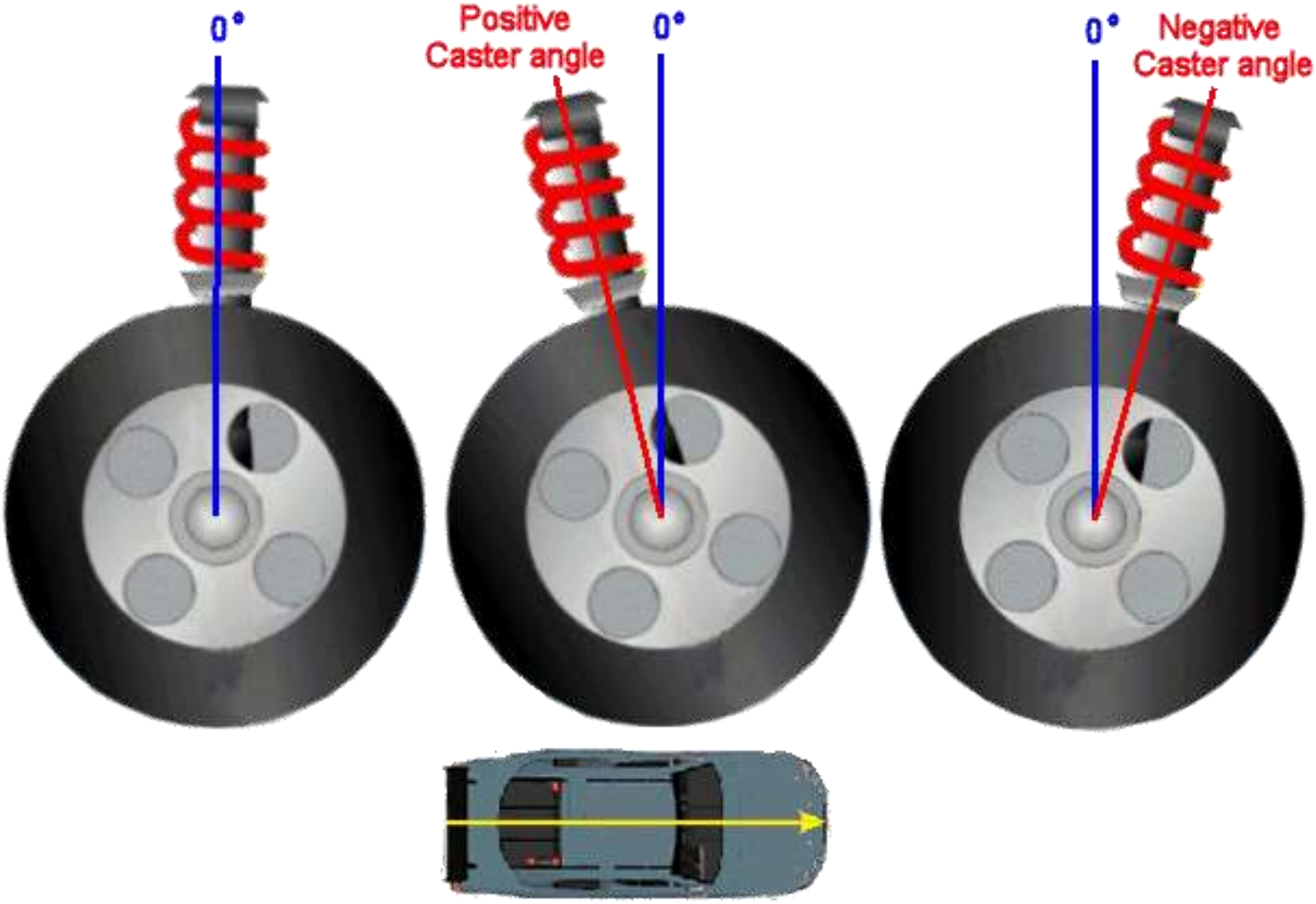
- If the inside is exceedingly hot and wearing faster than the outside, there is too much negative camber
- When this is present with the **front wheels**, the effect is **diminished braking capability, poor turn-in and pronounced mid-corner under-steer**
- When the **rear tires** exhibit too much negative camber, the effect is **over-steer and a reduced ability to accelerate cleanly out of corners**

- The opposite, excessive positive camber, shows up as a reversal of the aforementioned temperature spread
  - The outside is excessively hot and wears much faster than the inside of the tire
- This leads to under-steer after the car has made its initial turn, and is usually the result of too much roll
- **NOTE:** Tire temperature alone is not a sufficient data source to determine all suspension settings

- Incorrect camber at both wheels can cause hard and unstable steering
- Unequal camber can contribute to low-speed wobble
- Most manufacturers specify a very small camber, usually 2^o to 3^o from straight up and down
- However, the exact amount of camber is specified taking into account the king pin inclination

Caster Angle

- It is the tilt of the steering axis towards the front or rear of the vehicle
  - If the tilt is toward the front, the wheel has negative caster
  - A rearward tilt provides positive caster
- **Effect:** Directional stability and steering wheel return ability is aided by positive caster
  - Incorrect caster angle causes excessive steering effort and tyre wear
- It causes the steering axis to pass through the road surface ahead of the centre of tyre contact with the road


0°
Positive
Caster angle
0°
0°
Negative
Caster angle

- The purpose of this is to provide a degree of self-centering for the steering
  - This makes a vehicle easier to control and improves its directional stability
- Excessive caster angle will make the steering heavier and less responsive, **although in racing large caster angles are used for improving camber gain in cornering**
- While greater caster angles serve to improve straight-line stability, they also cause an increase in steering effort

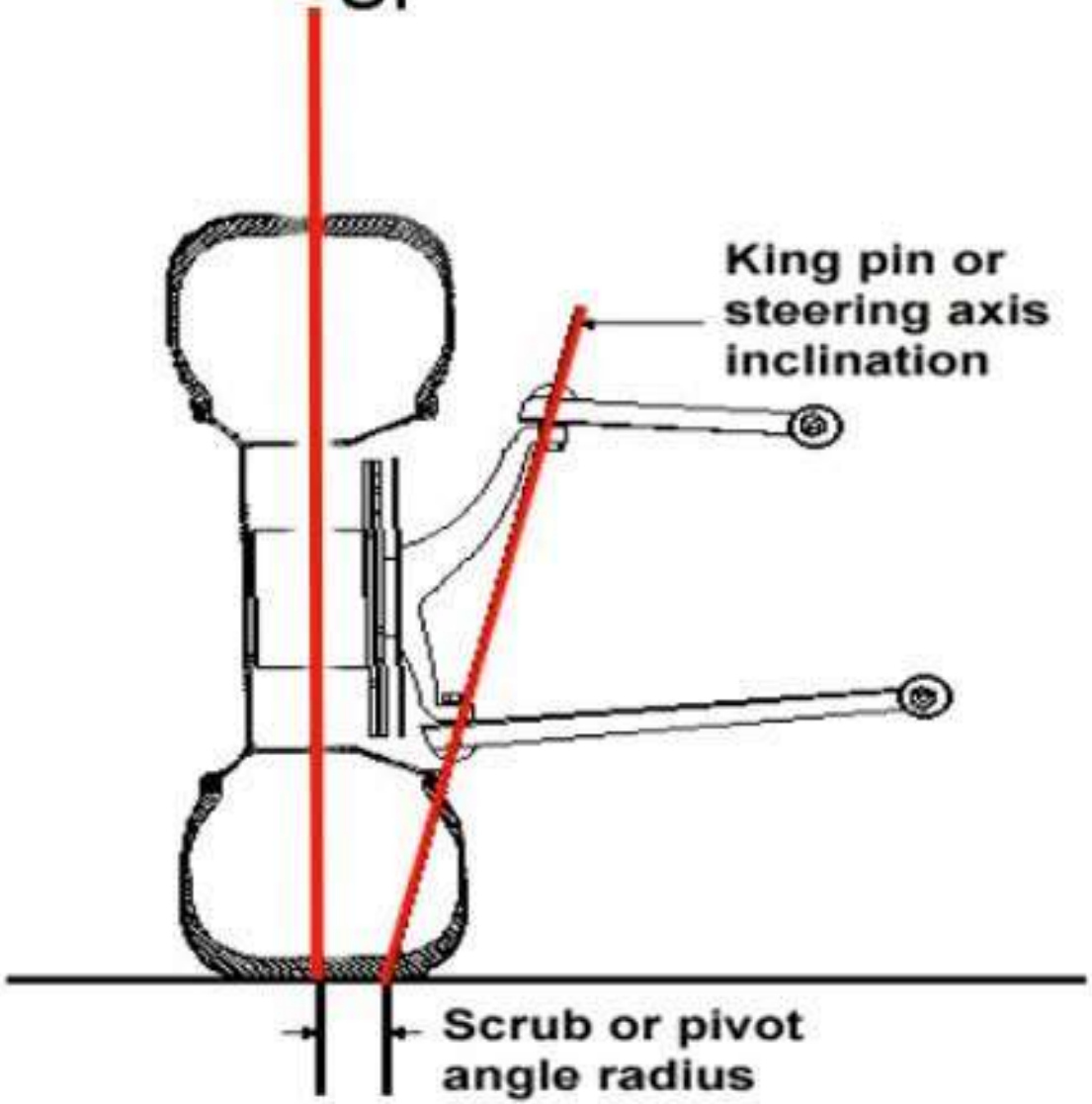
- Three to five degrees of positive caster is the typical range of settings, with lower angles being used on heavier vehicles to keep the steering effort reasonable
- Caster angles over 7 degrees with radial tires are common
- Power steering is usually necessary to overcome the jacking effect from the high caster angle

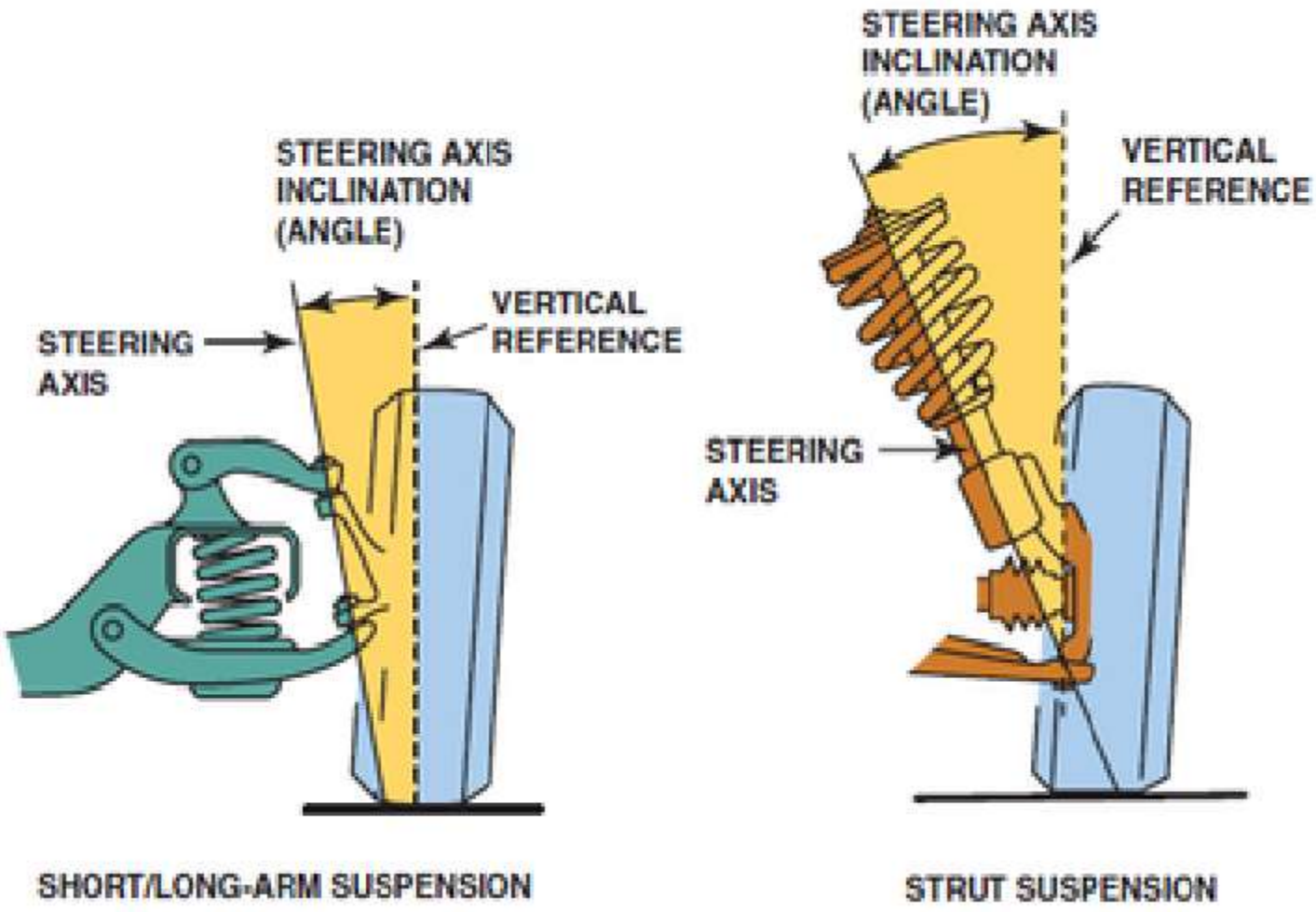
Steering Axis Inclination (SAI)
(King Pin Inclination-KPI)

- Angle to the vertical plane when viewed from the front or rear of the vehicle
- With any kingpin angle, steering will tend to raise and lower the vehicle
  - Therefore to steer away from the straight ahead position, work must be done by the driver
- This contributes to steering wheel **return-ability** as this work is recovered when the steering wheel is released
- Return-ability increases with increased kingpin angle

- The purpose of the KPI is to produce vertical displacement of the vehicle in during steering in an upward direction
- The larger the KPI, the larger the effect
- This lifting effect produces a self centering torque similar to that of caster

Kingpin inclination





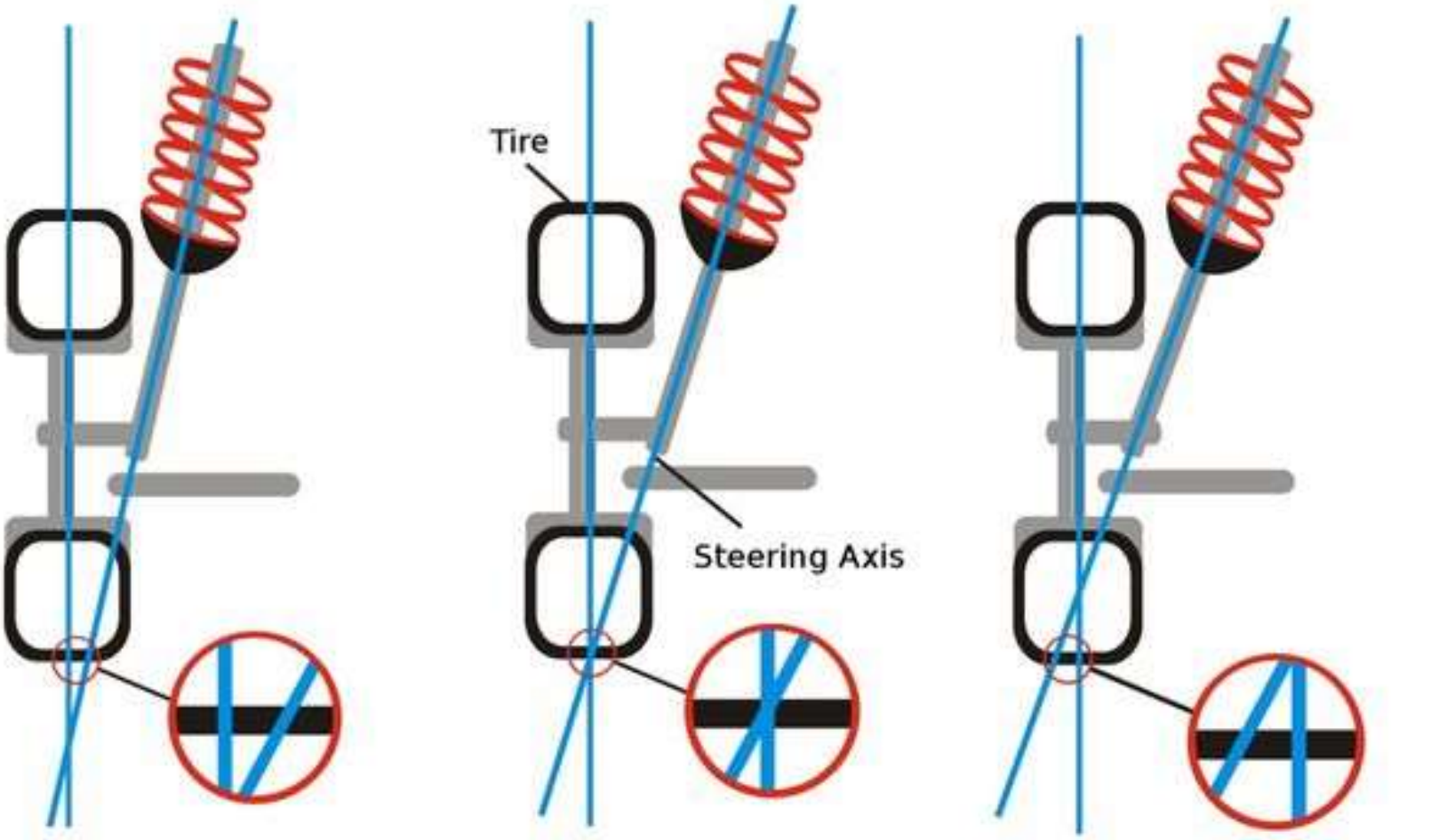
SHORT/LONG-ARM SUSPENSION

STRUT SUSPENSION

- With a positive kingpin angle, the outside wheel in a corner will gain positive camber and the inside wheel will loose positive camber
- As the outside wheel is the heavily loaded wheel during cornering, this increase in positive camber acts against bump camber and will reduce the cornering capacity of the outside tyre
- In general kingpin angles **between 6-14 degrees** are seen on production vehicles

Scrub Radius

- The **scrub radius** is the distance in the front view between the point at which the kingpin would intersect with the ground and the centre of the contact patch of the wheel where it intersects with the ground
- Older cars tended to have very close to zero scrub radius but often on the positive side
- Cars with ABS tend to have a negative scrub radius



Positive Scrub Radius Zero Scrub Radius Negative Scrub Radius

- At **zero scrub** radius, the car feel a **little unstable** at the front end through corners and under hard braking
- On the other hand, when stationary the steering has to turn the contact patch where it lies, which takes more effort and wears the tyre more
- It’s rare these days for a car to have truly zero scrub radius; a little of something is better

- Positive scrub radius does **no favours for braking** if for any reason there's a different amount of force between sides of the vehicle
  - Say, if the left-hand wheels have less grip and the ABS backs the system off on that side
- This kind of setup will see the car want to fight its way in the direction of the wheels with more grip
- Extreme positive scrub radius can make the steering very heavy, too, and it was only really viable on old cars with very thin tyres

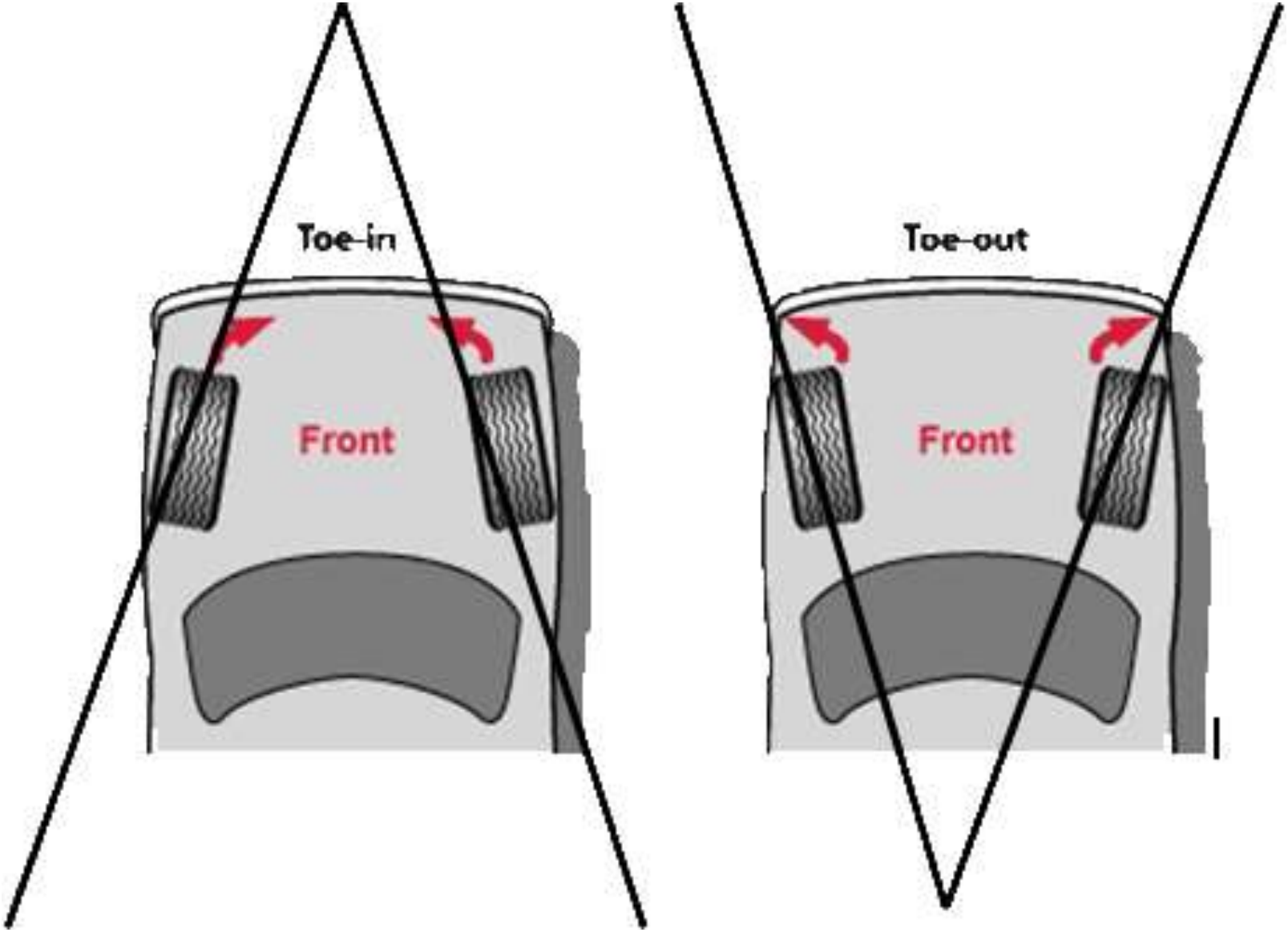
- Most of us have negative scrub radius on our cars
  - Because it tends to go hand in hand with MacPherson strut suspension
- It helps driven front wheels find the straight-ahead, which is good for corner exits or if you have a sudden tyre deflation
- Another **handy side-effect** is that if you hit standing water with the wheels on one side of the car, the negative scrub radius works against the car's natural inclination to pull with a jerk into the water, (making serious/abrupt change in direction)

- Tuning suspension for negative scrub is the safer way to do it
- It generates a slight **toe-in force** that reduces any tendency to change direction in the way that positive scrub radius can allow
  - As a result, in cars with diagonally-split braking systems, if one circuit fails then the remaining braking force on one front and one rear wheel will still pull the car up in a straight line
- For the road, **slightly negative** is the way to go

Toe-in & Toe-out

- **Toe** is the measurement of how much the wheels point in or out from the straight ahead position
- The wheels of an automobile at rest are a fraction of an inch closer at their front edges than at their rear edges, they are said to be **Toe-In**
- **Effect:** When the vehicle is moving, the wheels should roll perfectly parallel to each other to keep tyre wear to a minimum
- As vehicle starts out, the wheels tend to take up slack in the steering system and turn outward (or toe-out)
  - Because of toe-in, this outward turn positions the wheels in a straight position

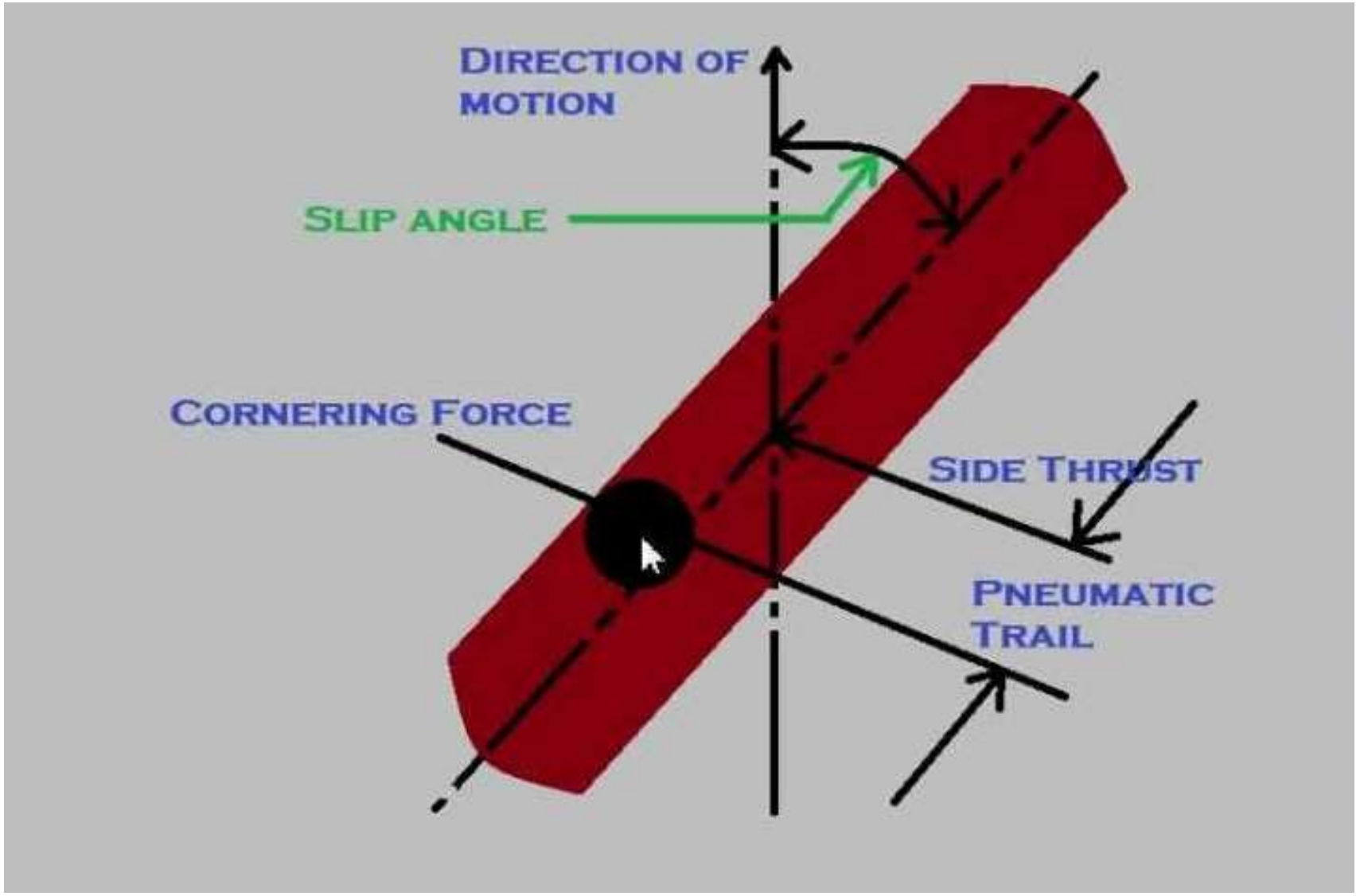
- Any toe-in or toe-out drags the tyre sideways as it rolls in the direction of vehicle
- **The greater the toe-angle, the faster the tyre wear**
- Zero toe allows the tyre to roll straight ahead
- Toe-in is measured during wheel alignment and adjusted by making the steering tie rods longer or shorter
- **Amount of toe-in is about 3 mm**
- **Toe-out:** Increases turn-in steering a lot. But can make the car wandery on the straights. Never use more than 2 degrees of front toe-out


Toe-in
Front
Toe-out
Front

Understeer & Oversteer

- These are the conditions when a moving vehicle gets steered either “less than” or “more than” the normal desired steering
- Both these conditions are undesirable and cause instability to the vehicle
- These occurs due to:
  - Slip Angle
  - Cornering force
  - Tyre inflation pressure
  - Load on the vehicle

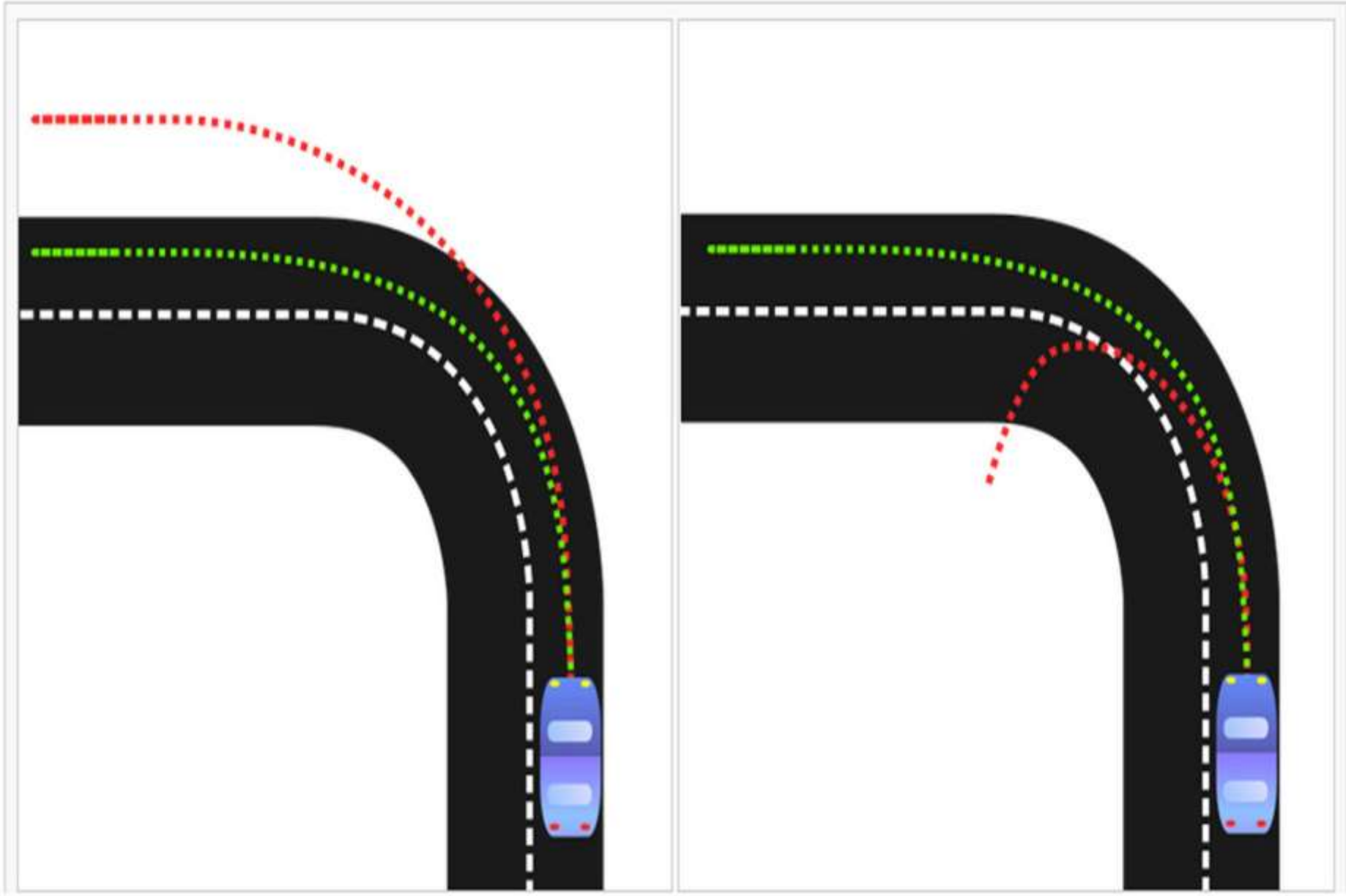
- **Cornering force:** When a vehicle takes a turn, the centrifugal force acts on the wheel which produces a side thrust
- The side thrust produces distortion of the tyre thereby causing the wheel to follow a path which is at angle to its vertical plane of rotation-**This angle is called Slip Angle**
- **Slip angle depends upon:**
  - Amount of side force
  - Load carried by wheel
  - Tyre flexibility
  - Camber angle & road condition

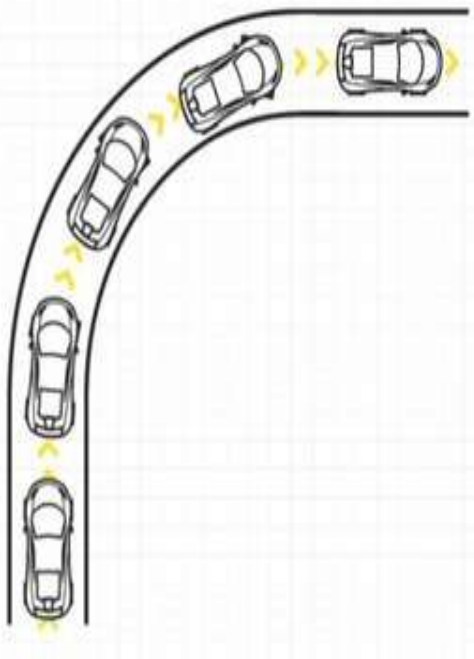

DIRECTION OF MOTION
SLIP ANGLE
CORNERING FORCE
SIDE THRUST
PNEUMATIC TRAIL

Effect of slip angle:

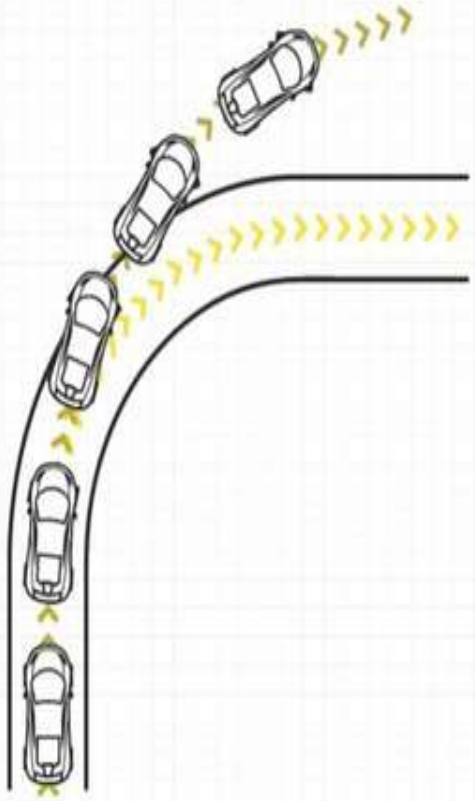
- When slip angle of front wheel is greater than the rear wheel, the vehicle turns less than intended by driver-**Understeer**
- When the slip angle of real wheel is greater than front wheel, the vehicle tends to take more sharp turn than intended by the driver**-Oversteer**
- When both front and rear slip angles are same, normal steer occurs
- Normally, the vehicles are designed to provide understeer conditions at normal speeds
- For higher speeds, the situation changes first to normal steer and then to oversteer
- Oversteering is generally preferred in racing cars


UNDERSTEER
OVERSTEER

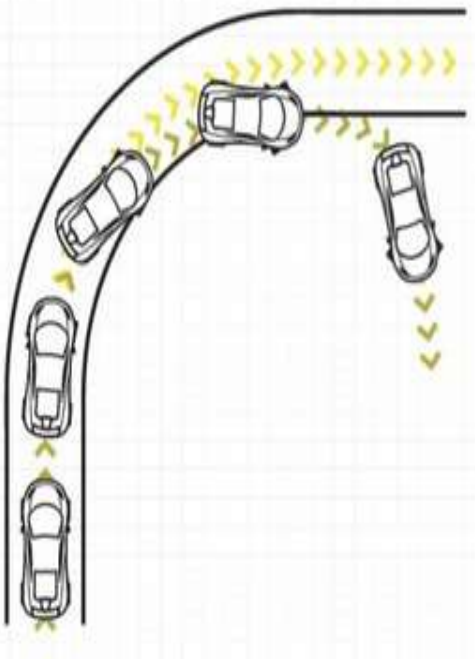

UNDERSTEER
OVERSTEER



Intended Path



Understeer



Oversteer


Thank you