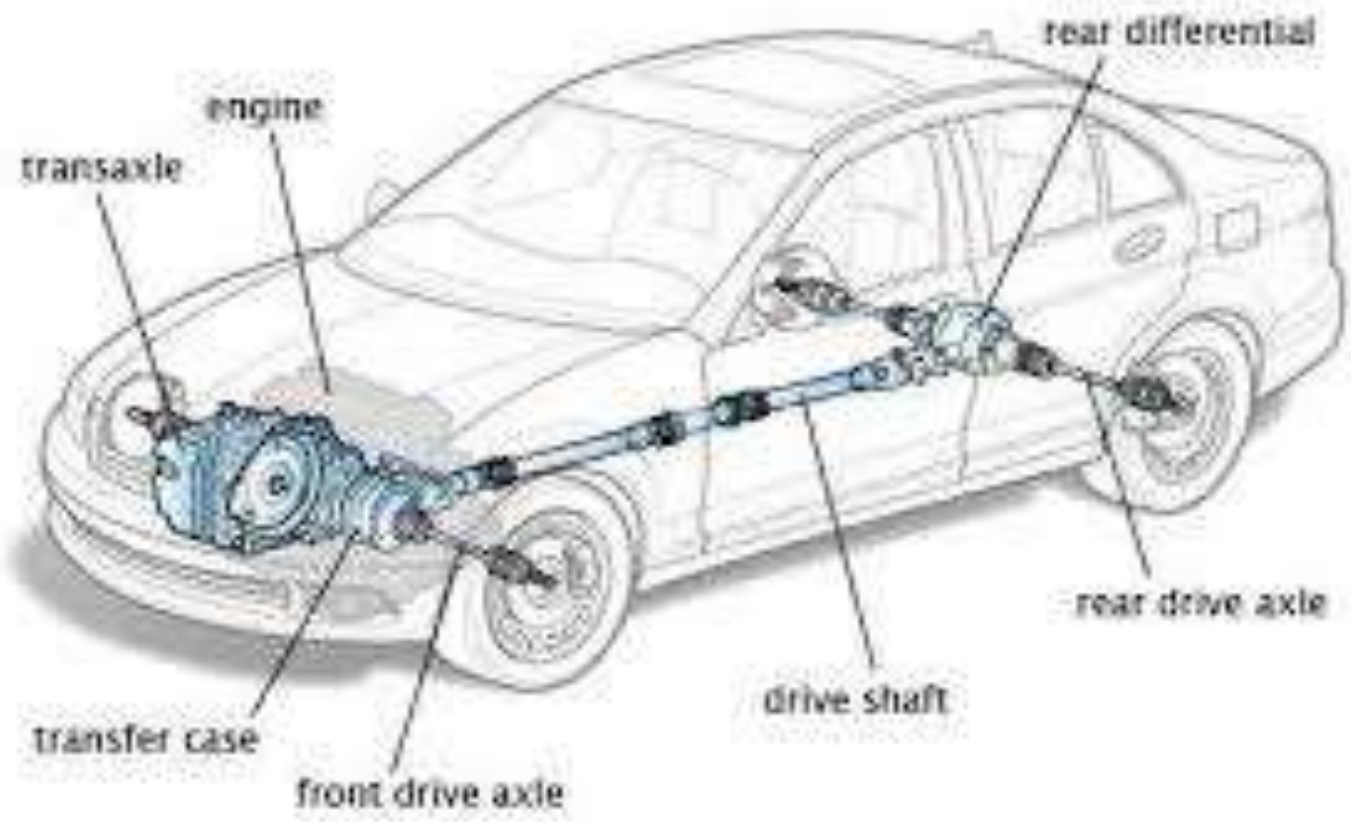
Automotive drivetrain

Automotive Clutch Systems: Principles, Actuation, and Performance



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- Introduction to automotive clutch
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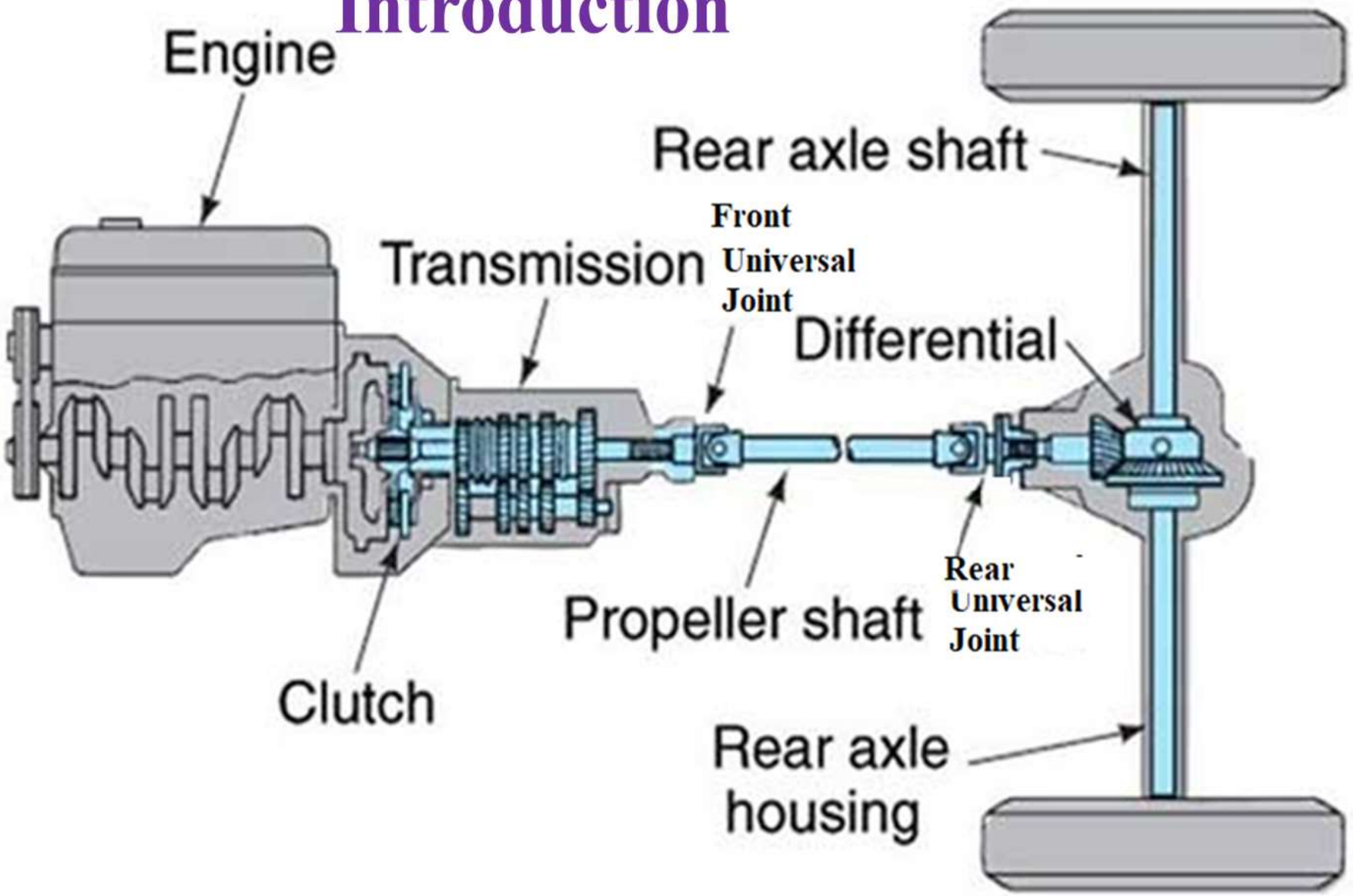
- Types of clutches based on friction disc arrangement
- Clutch theories and calculations

- **Powertrain:** includes everything that generates and transmits power to the wheels. This consists of the engine, transmission, driveshaft, differential, and axles.

- **The drivetrain (driveline):** power transmitting parts of a car between the flywheel and the wheels. It excludes the engine. The torque of the engine is transmitted via:
  - ✓Clutch,
  - ✓Transmission (manual or automatic),
  - ✓Drive shaft and
  - ✓Differential to the wheels.

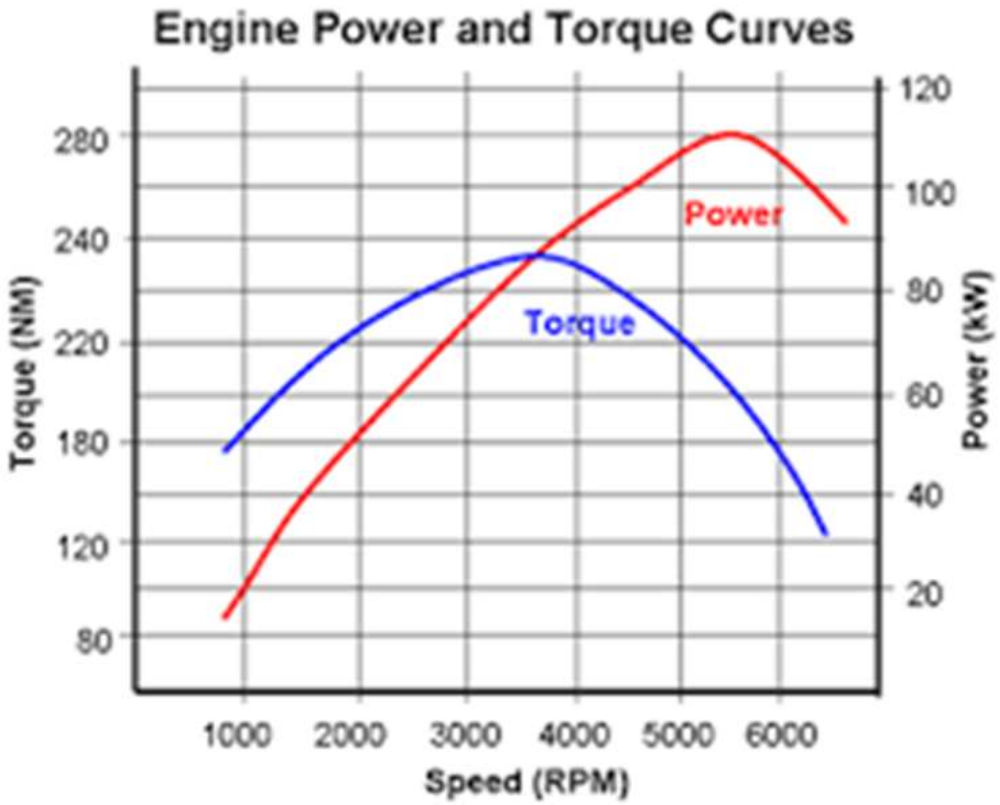
Automotive Powertrain

Introduction



Requirements of a transmission system

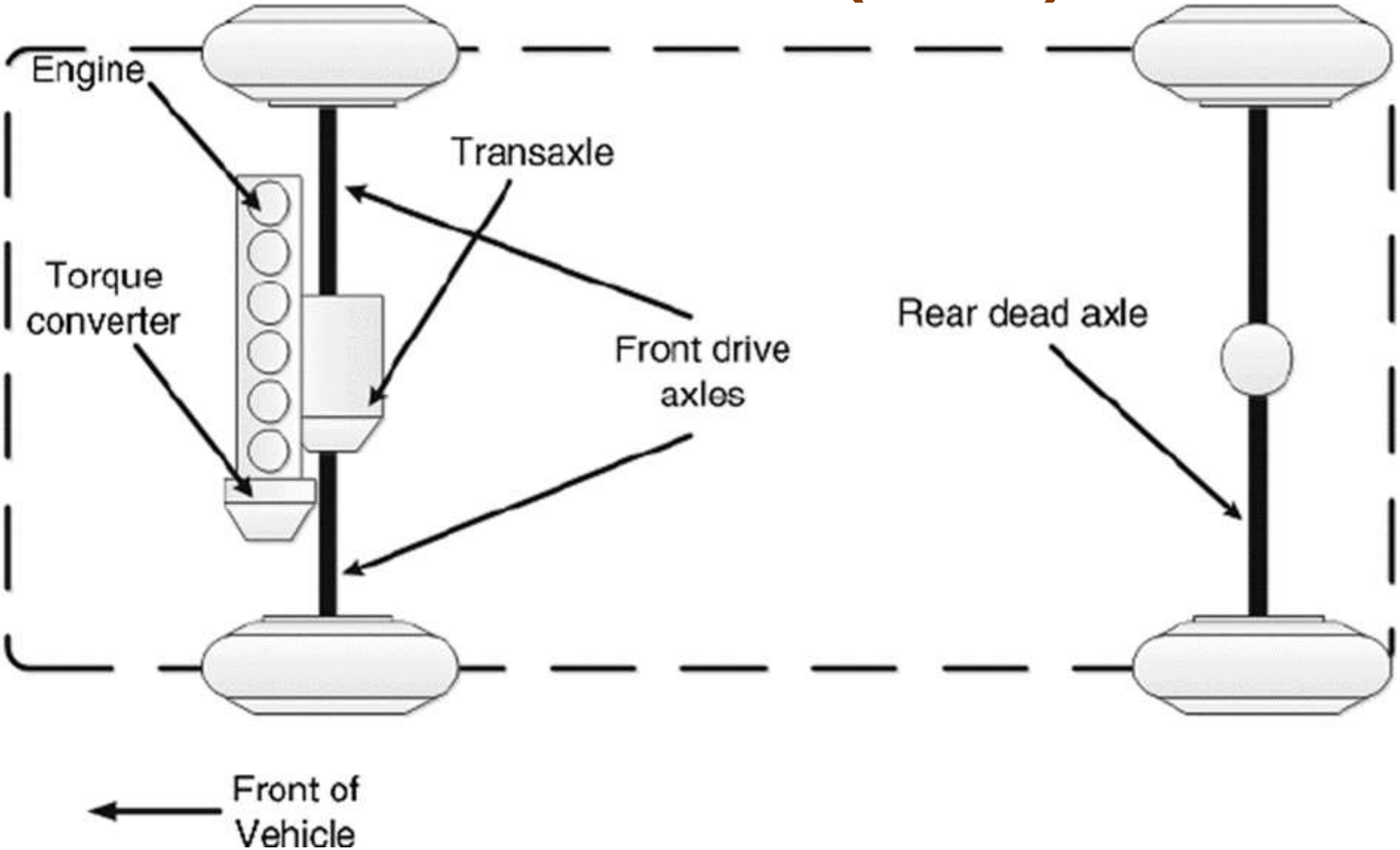
- The engine produces maximum power and torque **within a specific RPM ran**ge. That is it lacks sufficient torque at very low speeds to get a vehicle moving from a standstill.
- Therefore, the transmission must multiply the engine's torque at low speeds to provide enough force to start the vehicle moving (especially on hills or with heavy loads).
- Torque multiplication allows the vehicle to overcome inertia and acceleration resistance.



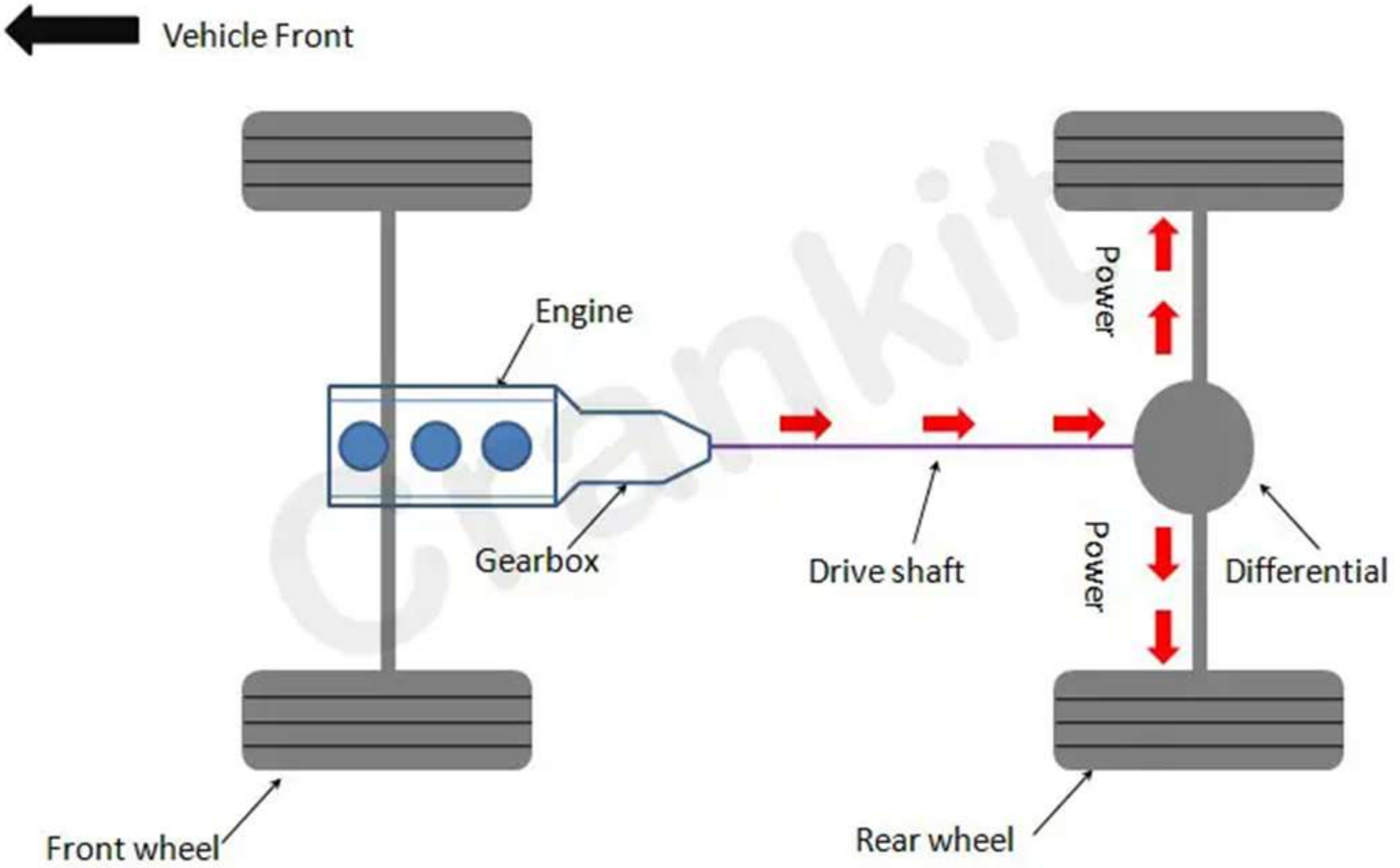
Types of drivetrain configurations

1. Front-wheel drive (FWD)
2. Rear-wheel drive (RWD)
3. Four-wheel drive (4WD)
4. All-wheel drive (AWD)

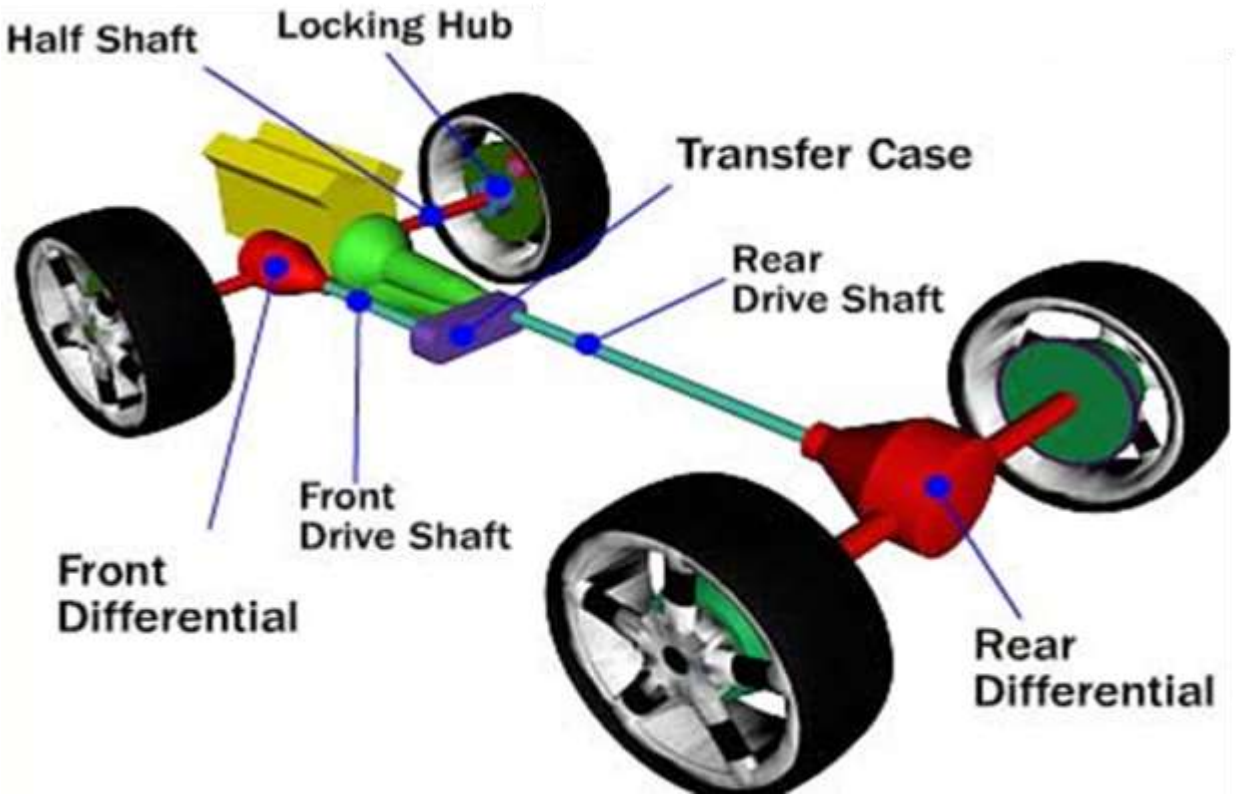
Front wheel drive (FWD)



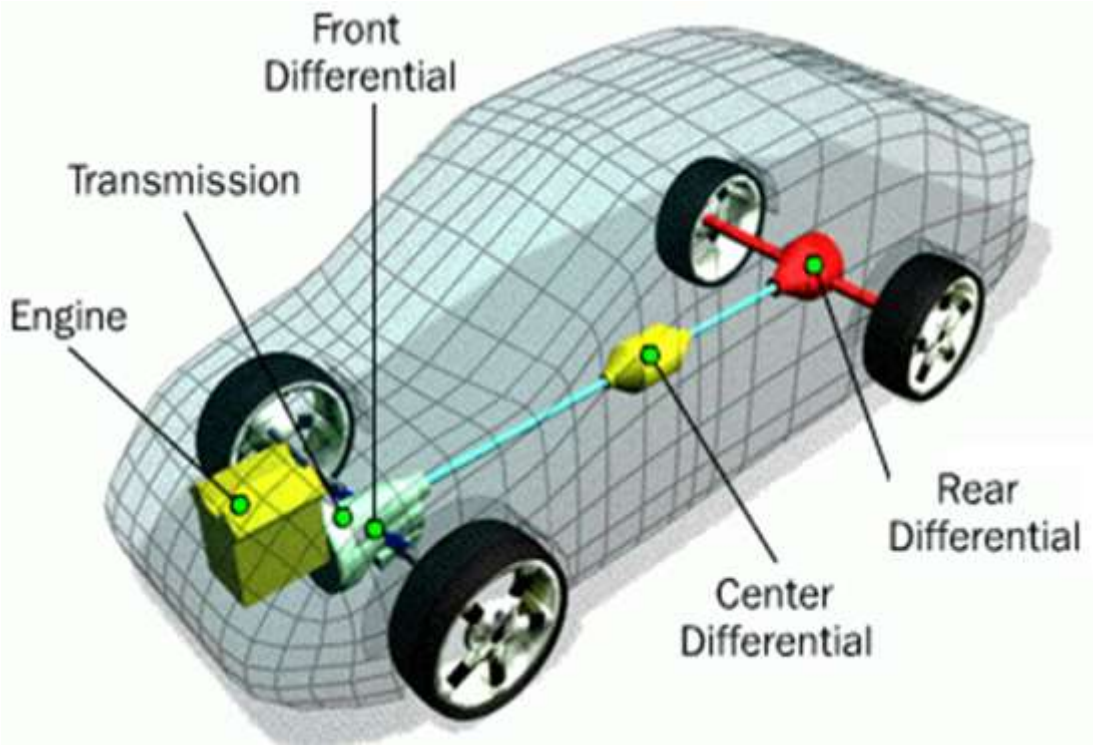
Rear wheel drive (RWD)



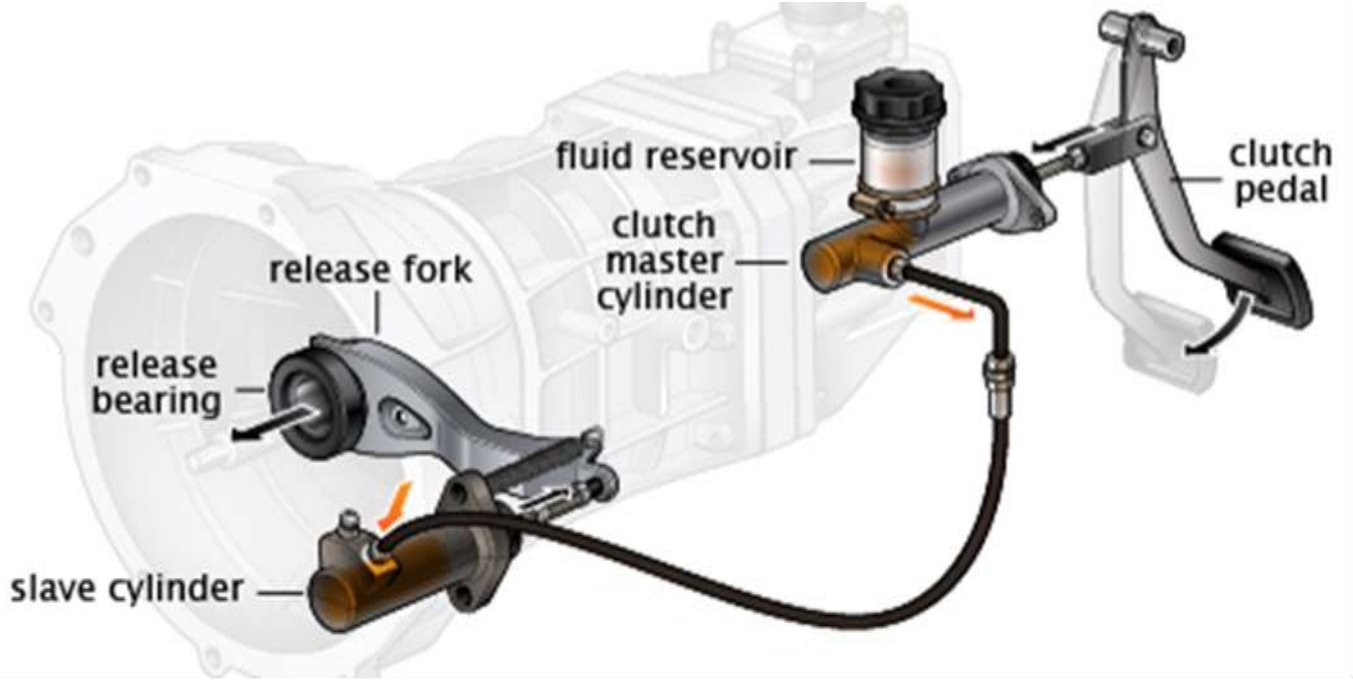
4 wheel drive
(4WD)



All wheel drive
(AWD)



Automotive clutch



Slave Cylinder

Release Bearing

Release Fork

Master Cylinder

Fluid Reservoir

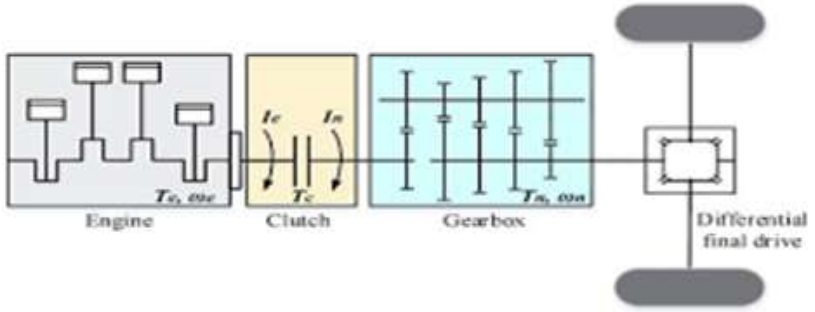
Clutch Pedal

Functions of automotive clutch

- Used to **connect and disconnect** the engine and manual transmission or transaxle. In a manual transmission vehicle, the clutch is essential for changing gears. By temporarily disconnecting the engine from the transmission, the clutch allows you to select a different gear without damaging the transmission.

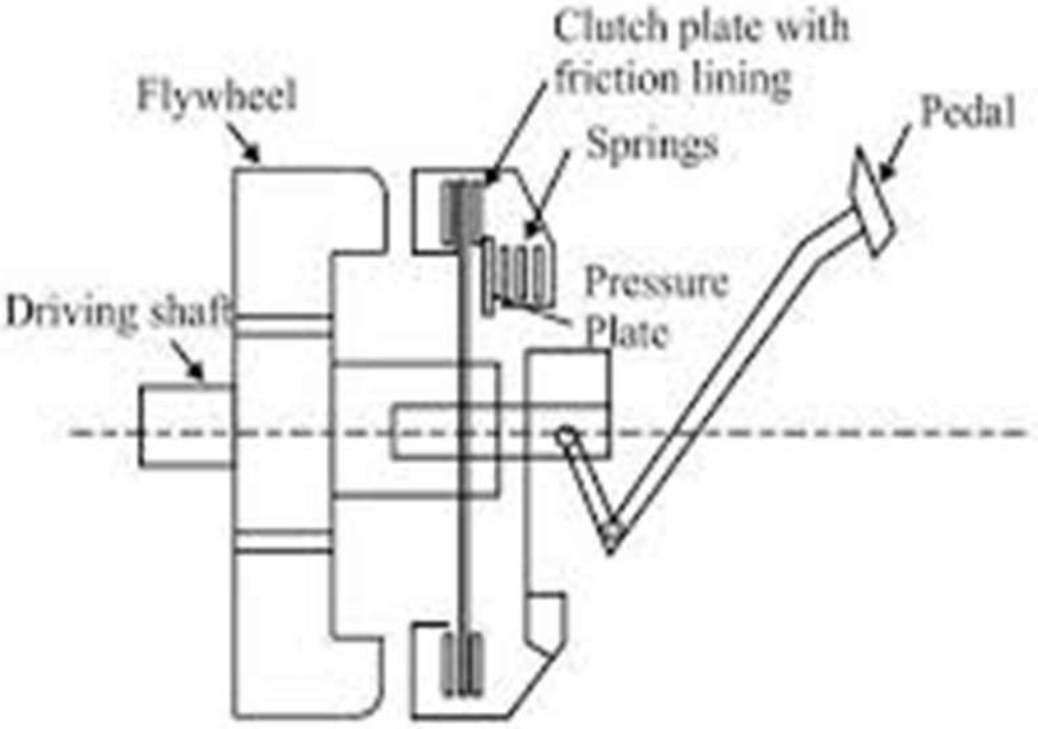
- When starting from a standstill, the clutch allows for a **gradual and controlled transfer of power** from the engine to the wheels.

- **Clutch balancing** (uphill start controlling): prevents vehicle rollback on an incline by coordinating clutch engagement and throttle input for a smooth start.



Types of clutches based on friction disc arrangement

Single- plate

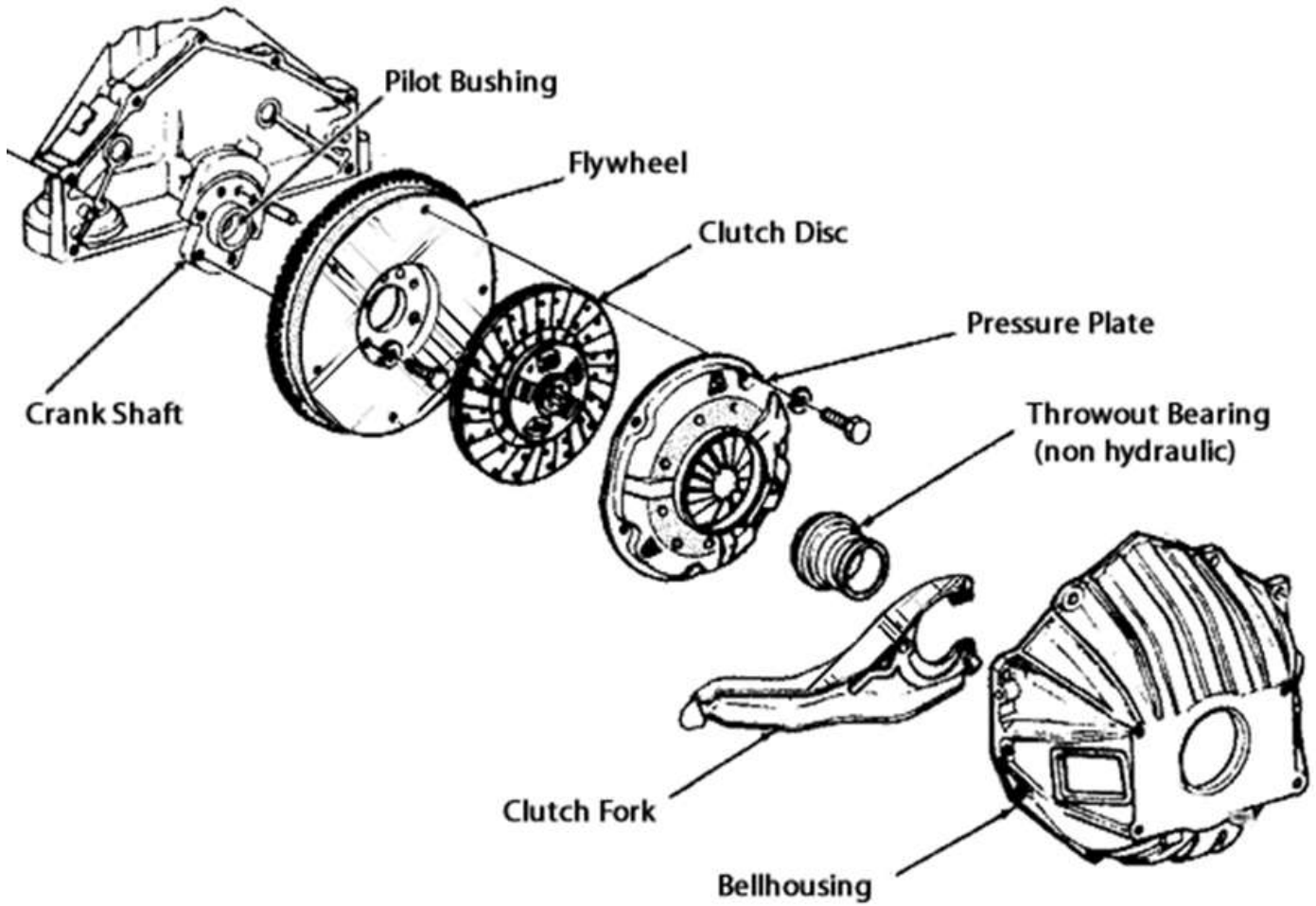


Single plate clutch

Multi-plate

Components of automotive single-clutch

- pilot bearing (bushing)
- flywheel
- clutch disc
- pressure plate
- release bearing
- clutch housing
  (bell housing)
- clutch fork
- clutch start switch



Pilot bearing

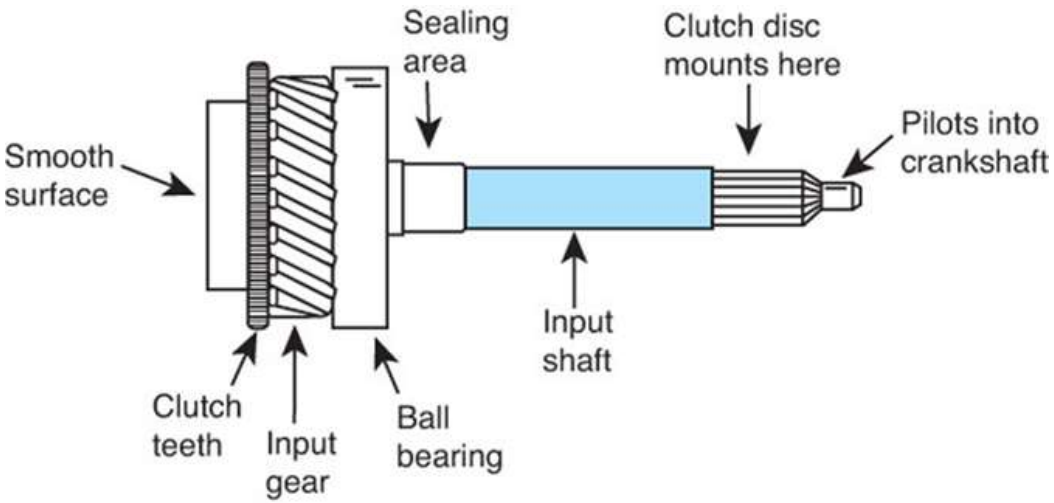
- The pilot bearing in an automotive clutch is located in the center of the crankshaft flange or flywheel. It supports the end of the transmission input shaft, allowing it to rotate independently (freely) from the engine's crankshaft when the clutch is disengaged.

- Supports the end of the transmission input shaft
- The pilot bearing could be a bronze bushing, roller bearing, or **ball bearing** (packed in grease).

- Prevents the transmission input shaft and clutch disc **from wobbling** when the clutch is released

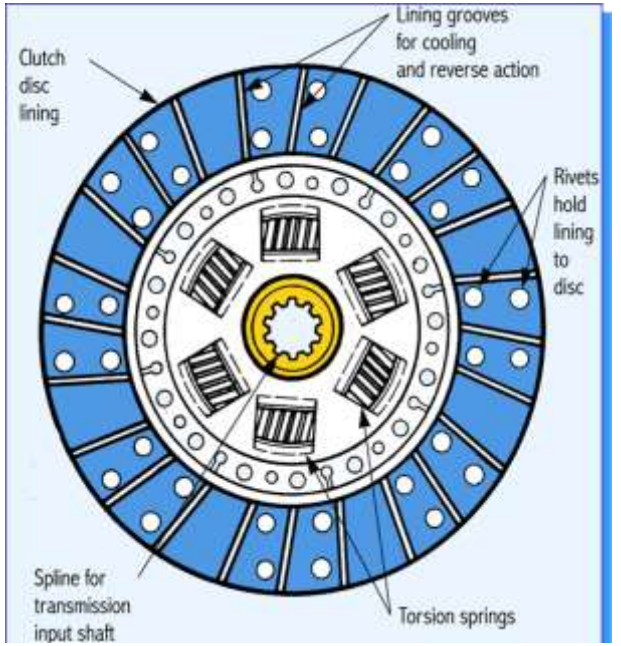
Transmission input shaft

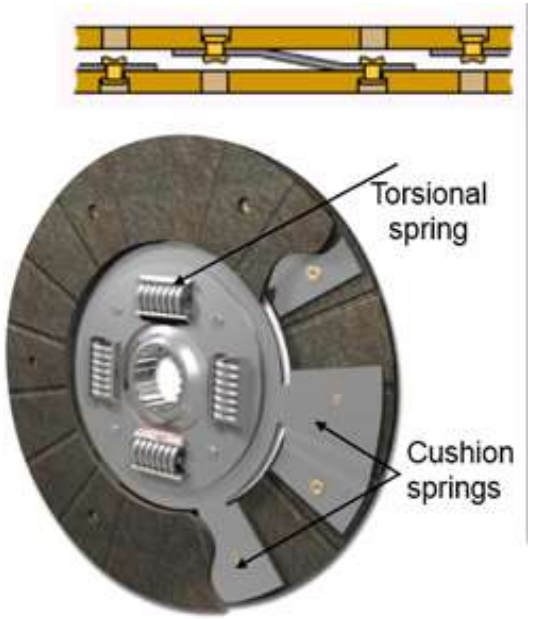
- The clutch input shaft is **supported by a pilot bearing**, which is located in either the crankshaft or the flywheel, depending on the vehicle's design.
- The **splines** in the center of the clutch disc mesh with the splines on the input shaft of the manual transmission.
- This makes the input shaft and disc **turn together**.
- The disc is free to slide **back and forth** on the shaft.
- The input shaft **drives the countershaft's** gear on the transmission.



Friction/Clutch dis

- Located between flywheel and pressure plate.
- Consists of a splined metal hub and a round metal plate covered with friction material (lining)
- Splined to the transmission input shaft.
- Disc is free to slide back and forth on the shaft
- Frictional material riveted to cushion springs on either side of friction ring.
- Grooves are cut into the friction material to aid cooling and release of the clutch disc.
- Rivets are used to bond the friction material





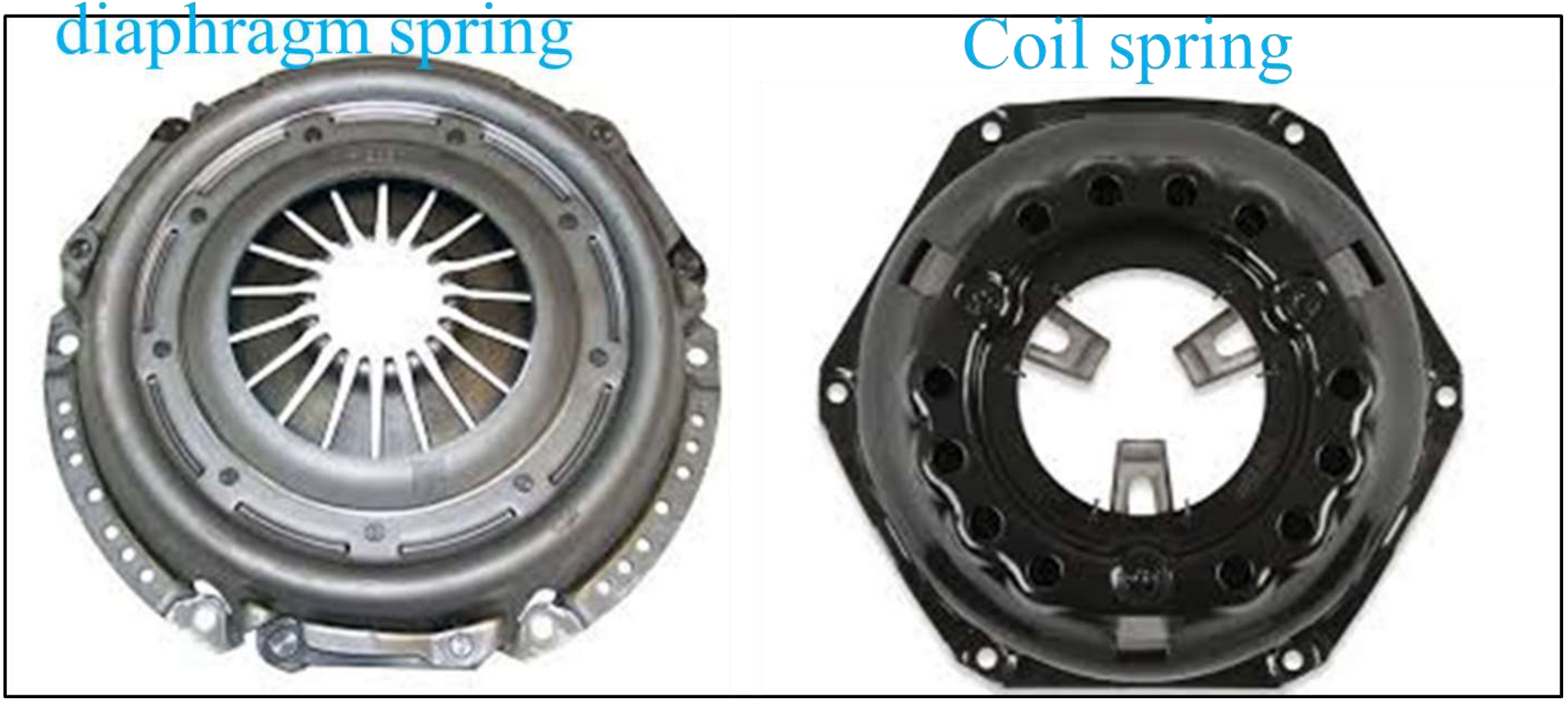
…Clutch disc

- **Torsion springs:**
  - Small coil springs located between the clutch disc hub and the friction disc. absorb some of the vibration and shock produced by clutch engagement. Absorbs fluctuations in engine RPM.

- **Cushion spring**:
  - Flat, metal springs located under the disc's friction materials
  - allow the friction material to flex inward slightly during clutch engagement
    - ✓flexing smooths engagement

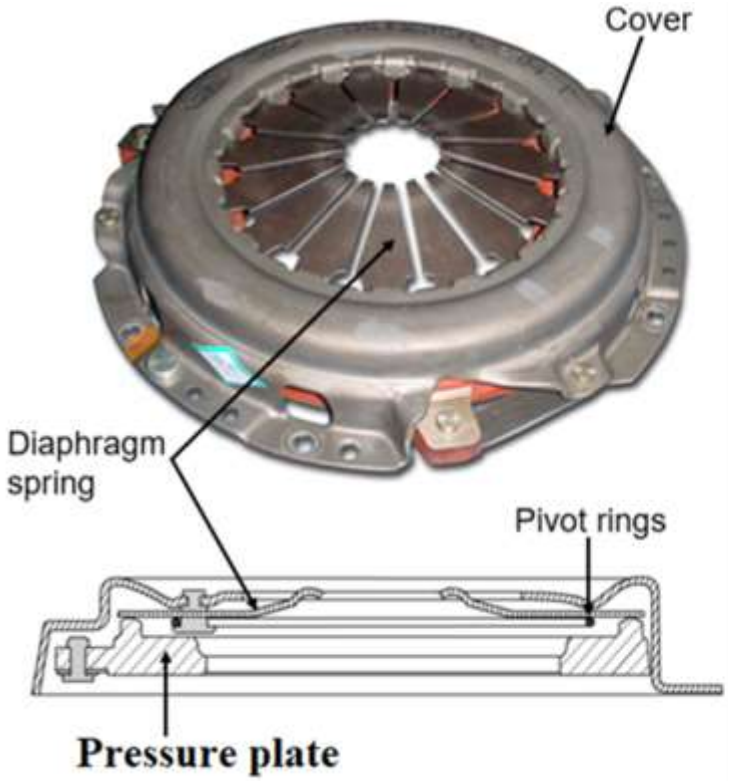
Pressure plate assembly

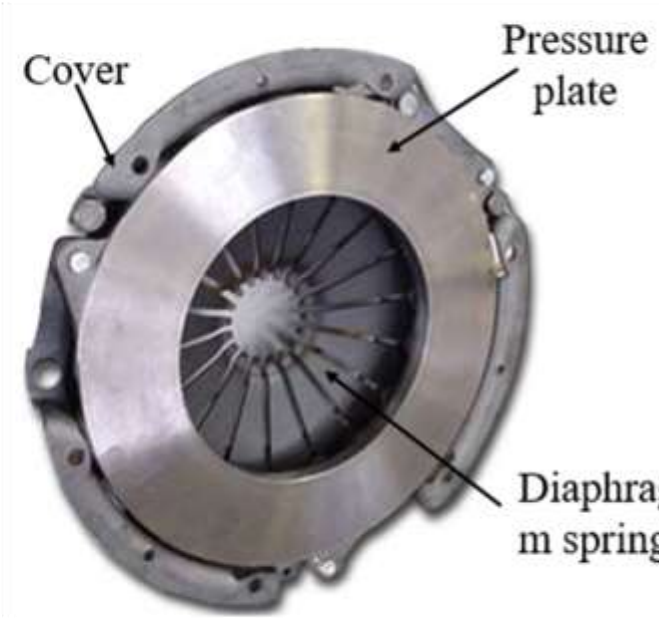
There are two main types of clutch pressure plates: diaphragm spring and coil spring.

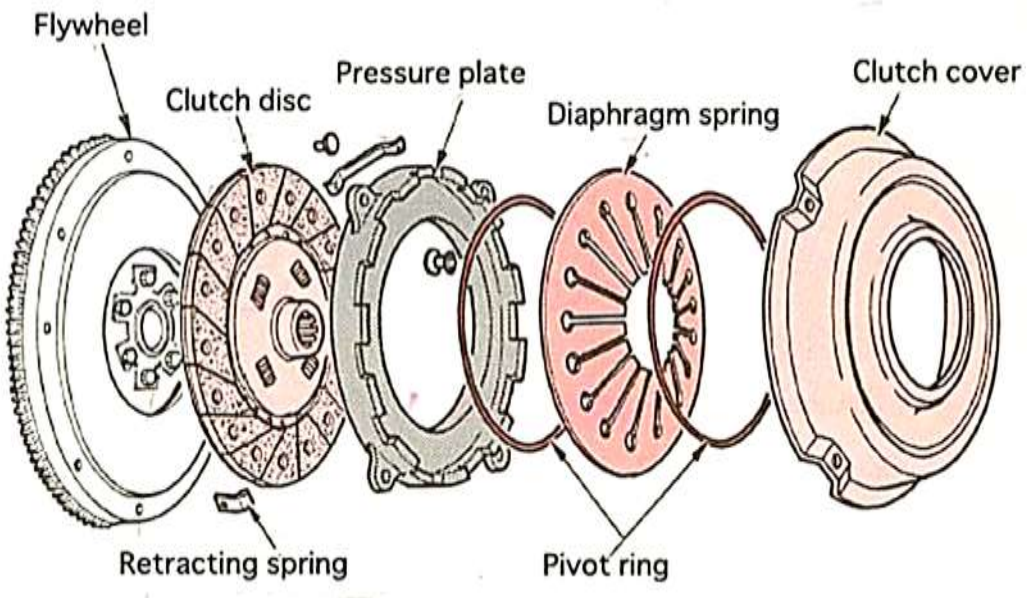


Diaphragm spring type pressure Plate assembly

The diaphragm-spring design consists of a pressure plate, a clutch-cover, diaphragm (Belleville) spring, **fulcrum rings** on which the diaphragm spring pivots, and strap plates that lift the pressure plate away from the flywheel when the clutch is disengaged.

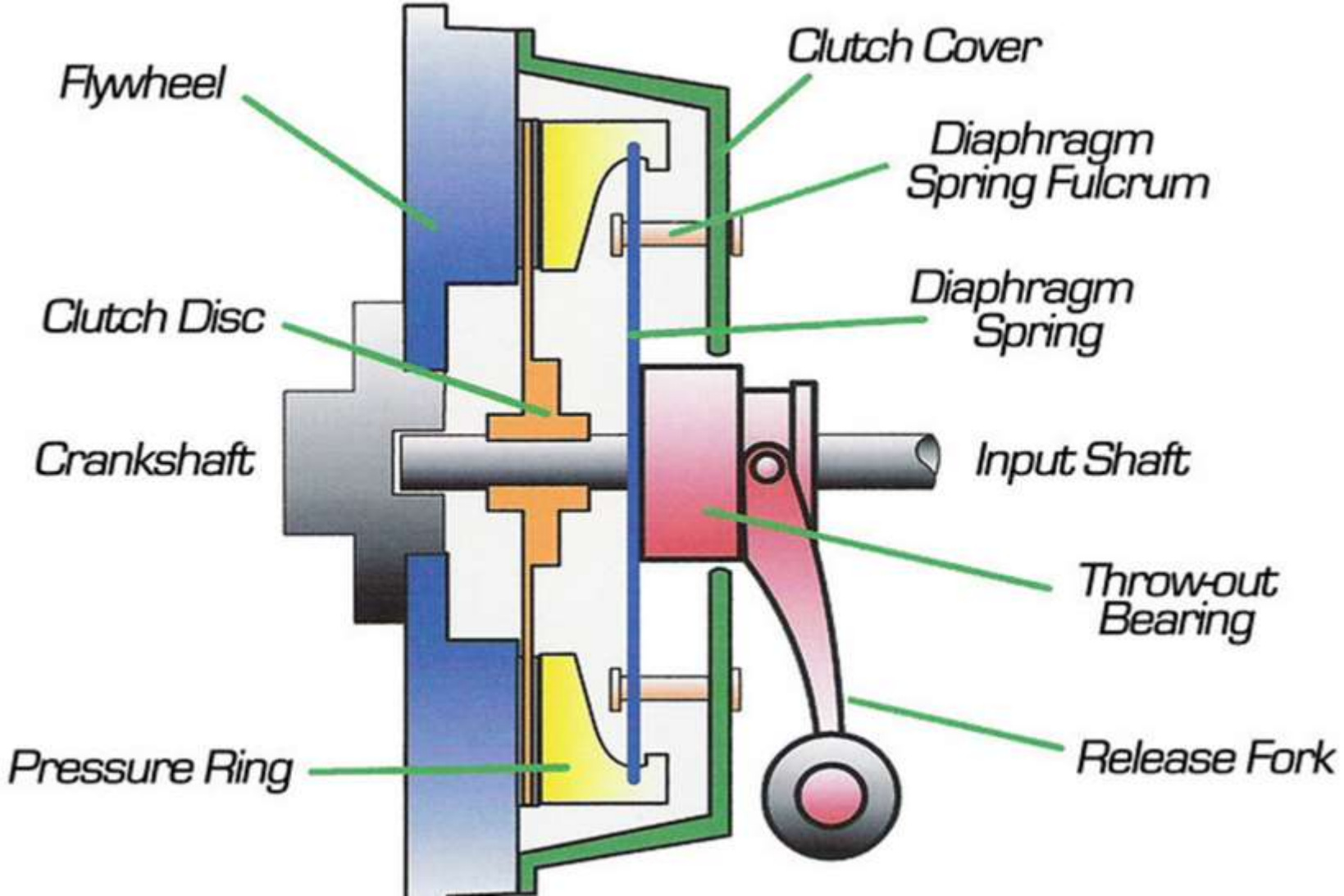






Inside Clutch Housing Components

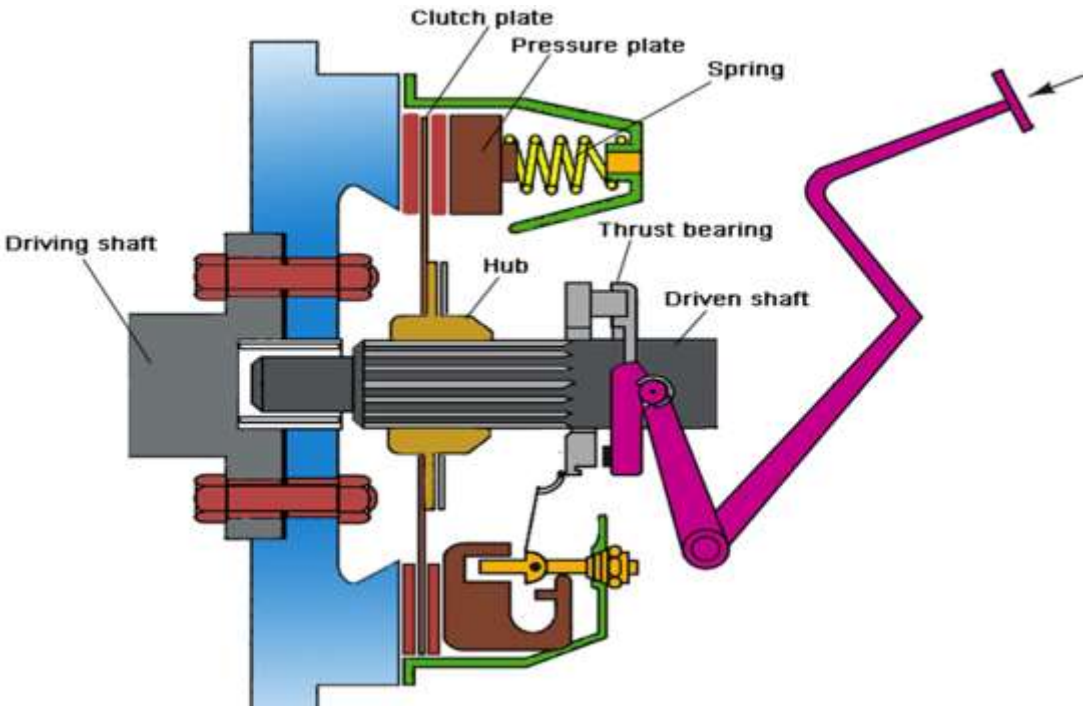
I. Diaphragm spring type



Operation

- As the diaphragm spring pivots on the fulcrum ring, the outer diameter moves toward the transmission and the strap plates lift the pressure plate away from the clutch disc. This amount of travel is very small, and in many instances as little as 0.050 inch (1.27mm) air gap between the pressure plate and the clutch disc is sufficient to disengage the engine power flow from the transmission.

ii. Coil spring type

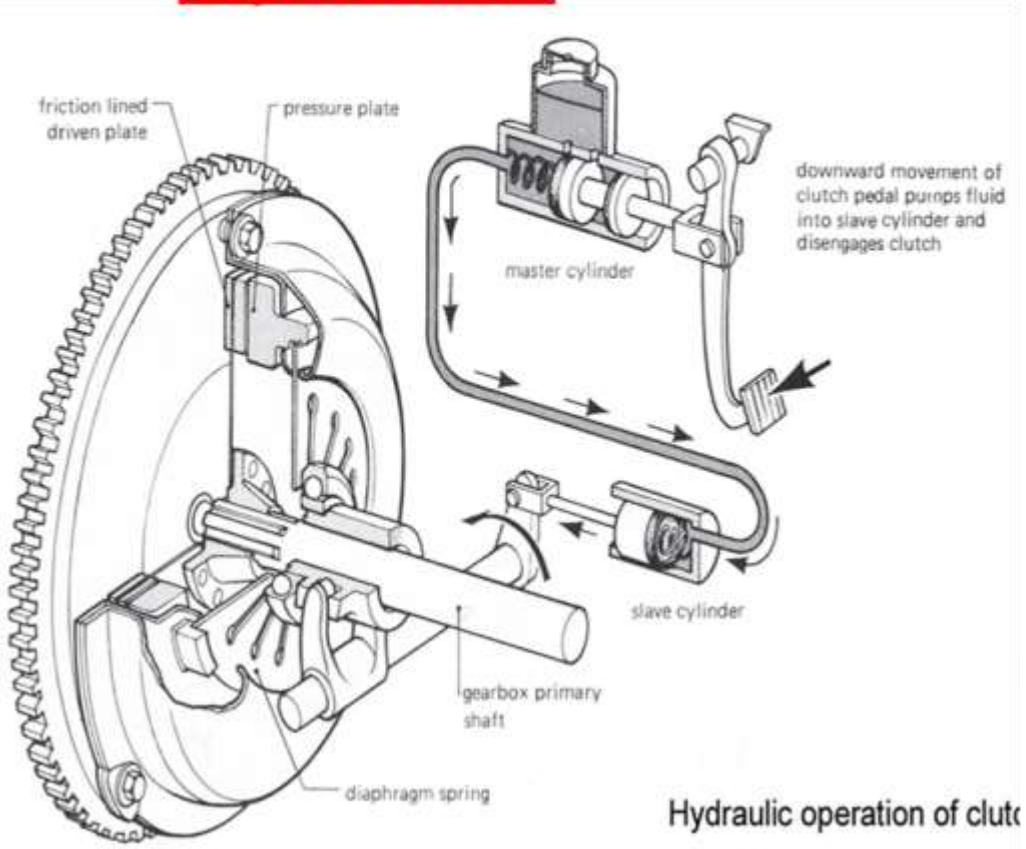


The coil-spring design uses three levers to actuate a series of coil springs that provide the clamp load to hold the clutch disc to the flywheel.

Clutch actuating mechanism

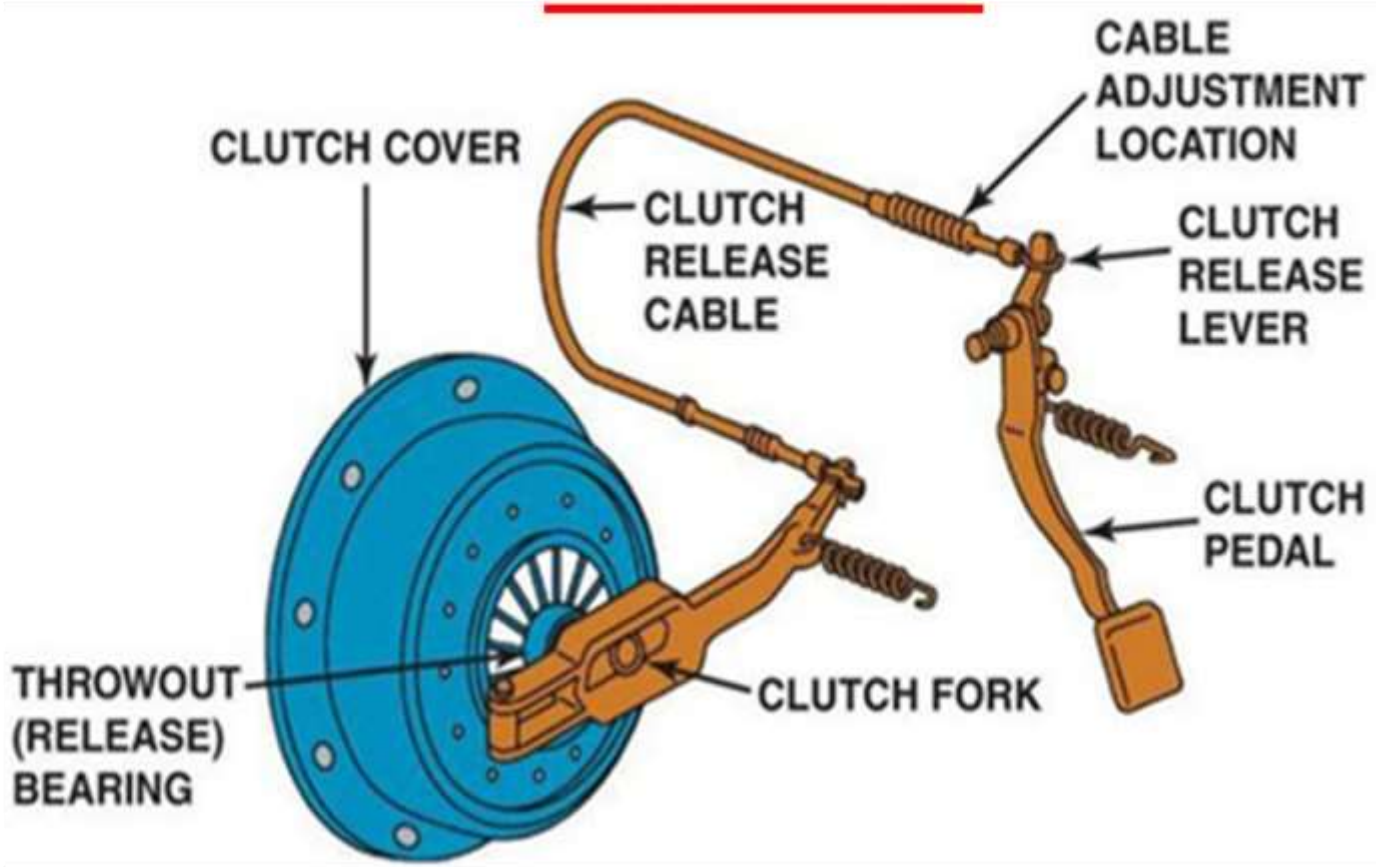
- There are two main types of clutch actuation mechanisms: mechanical and hydraulic. This discussion focuses on hydraulic clutch systems, the most common type in use today.

Hydraulic



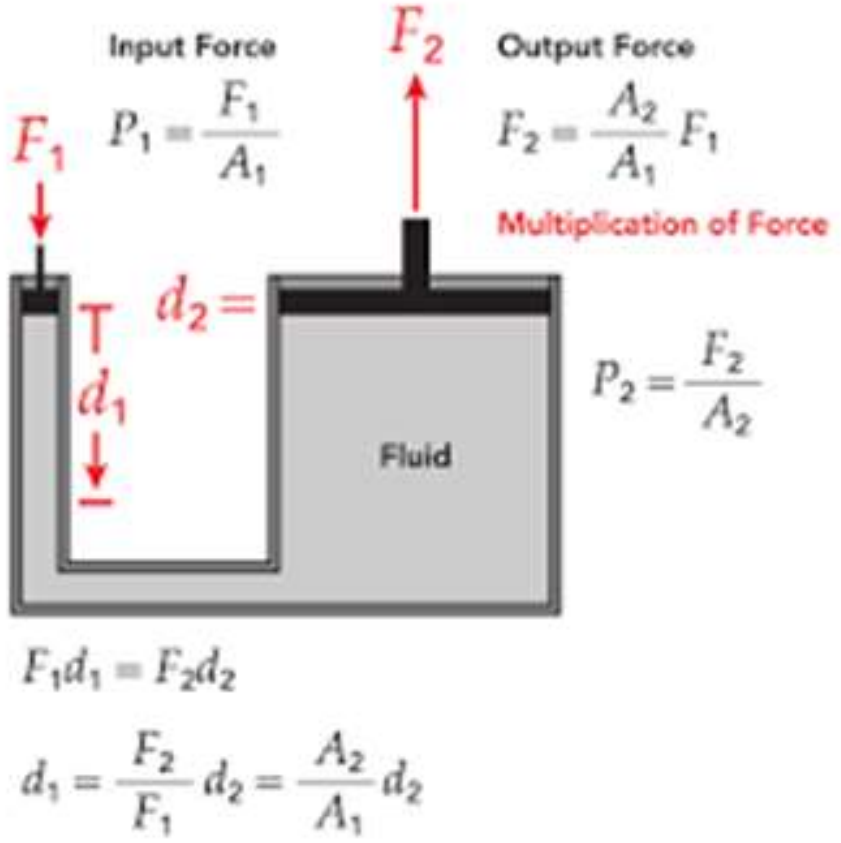
Hydraulic operation of clut

Mechanical



Hydraulic linkage

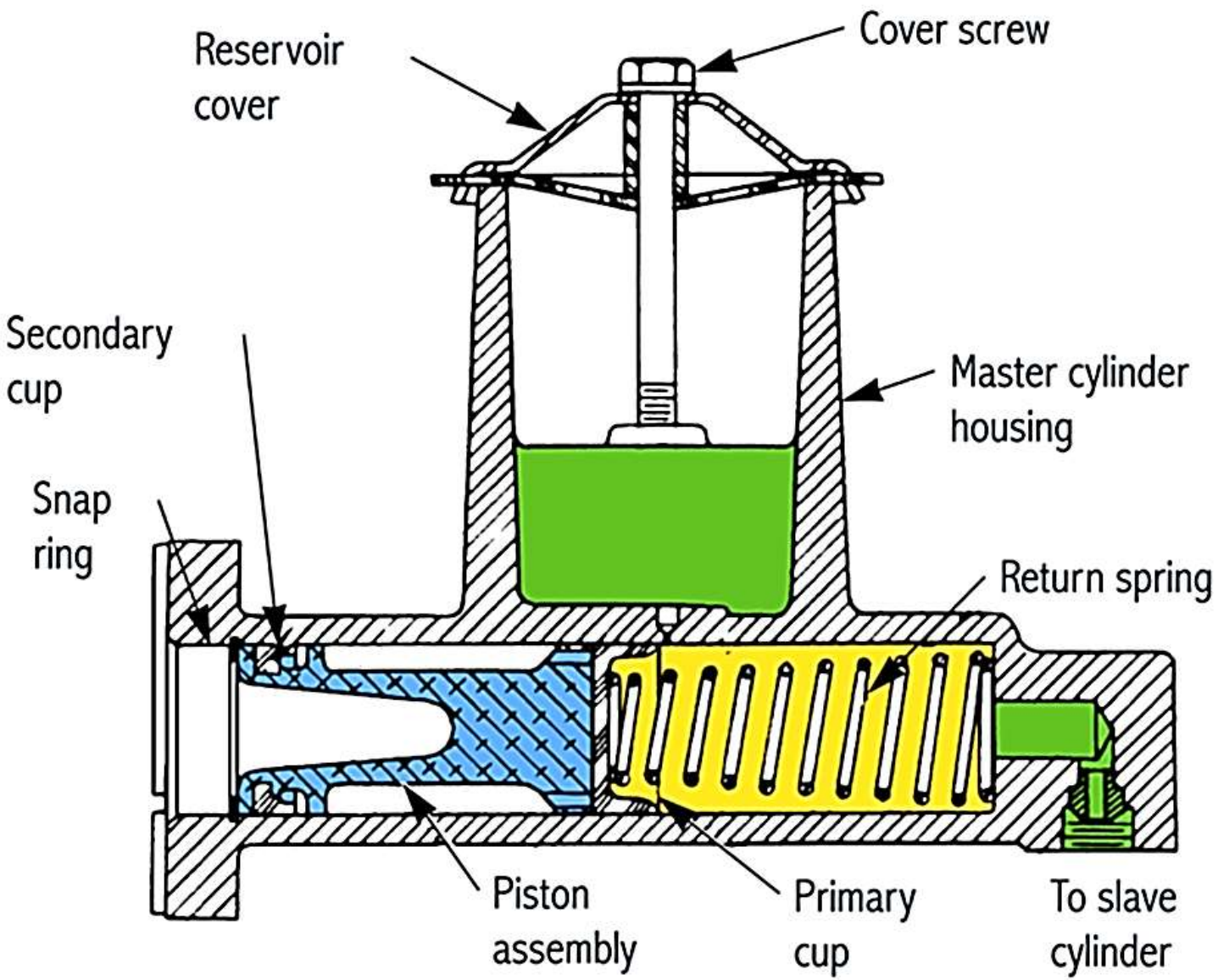
- The principle behind a hydraulic clutch linkage system is based on Pascal's Law, which states that pressure applied to an enclosed fluid is transmitted equally and undiminished to all parts of the fluid and the walls of its container.
- It is often the same as brake fluid. The type of fluid used either DOT 3 or DOT 4 which are glycol based. Both are hygroscopic (absorb moisture over time). This is why brake fluid needs to be changed periodically, as absorbed water lowers the boiling point and can lead to brake fade.
- DOT 3 and DOT 4 clutch fluids are corrosive and can cause significant damage to car body paint.



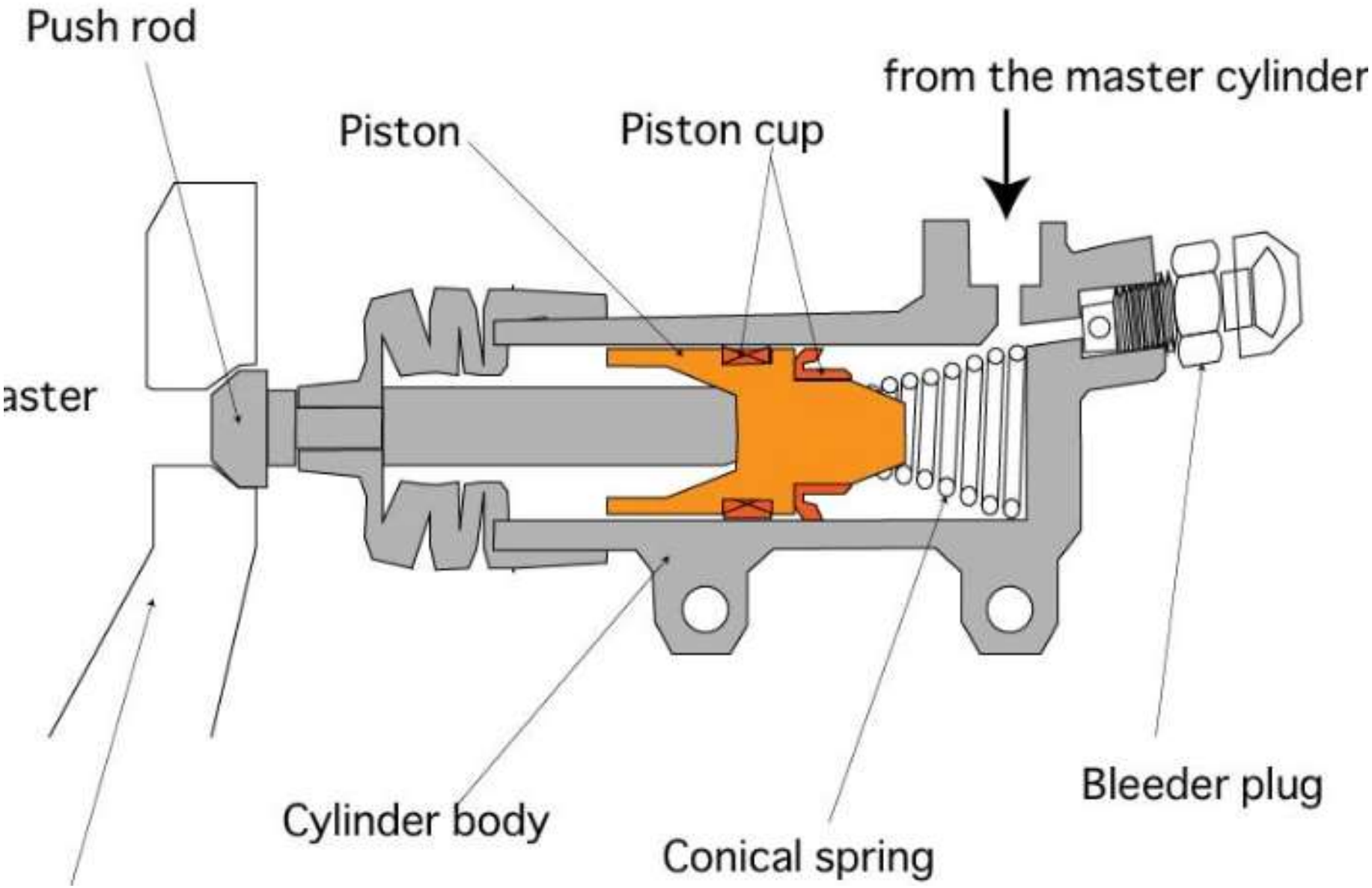
Operation

- When you press the clutch pedal, it pushes a piston in the master cylinder. This creates pressure in the hydraulic fluid. The pressurized fluid travels through a hydraulic line to the slave cylinder. The pressure in the slave cylinder pushes its piston, which in turn moves a rod. This rod moves the clutch fork, which disengages the clutch, separating the engine from the transmission.

Clutch master cylinder

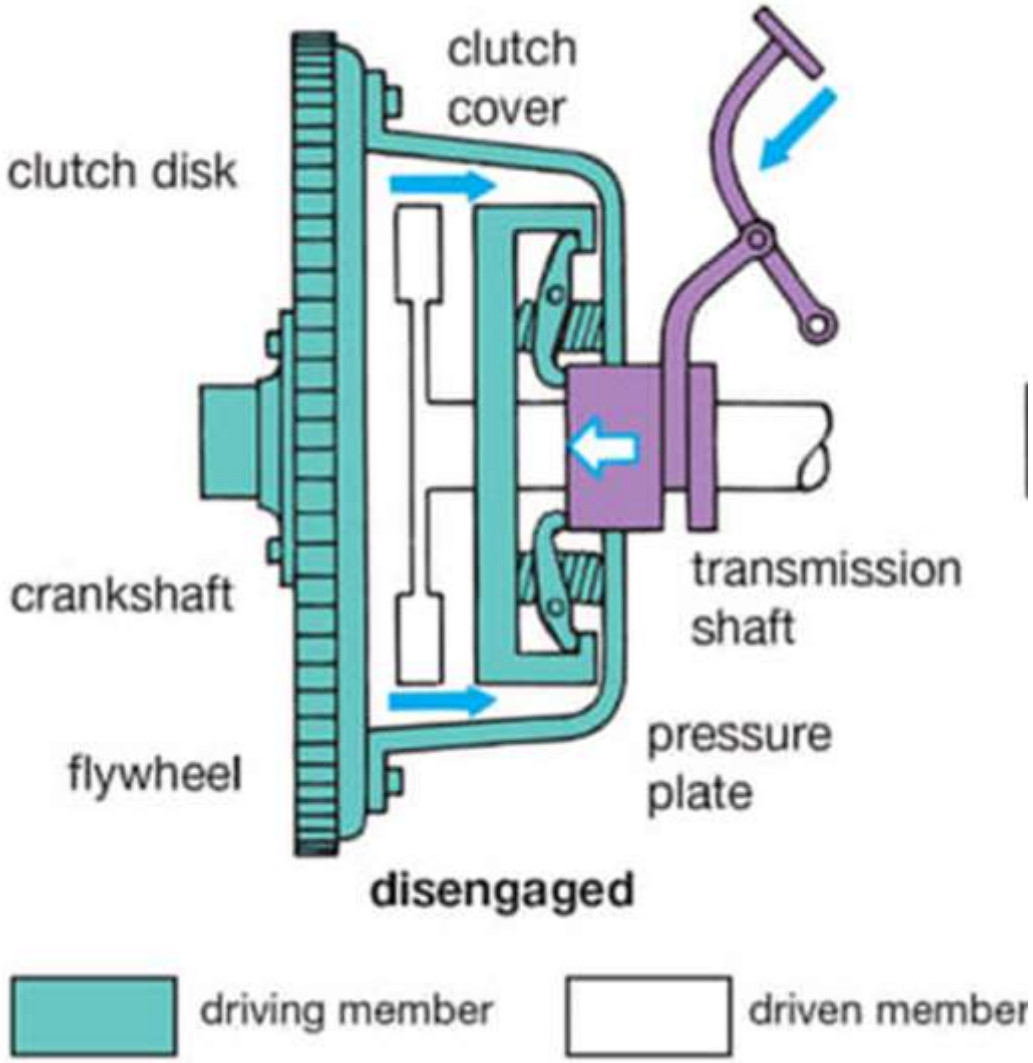


Clutch slave cylinder



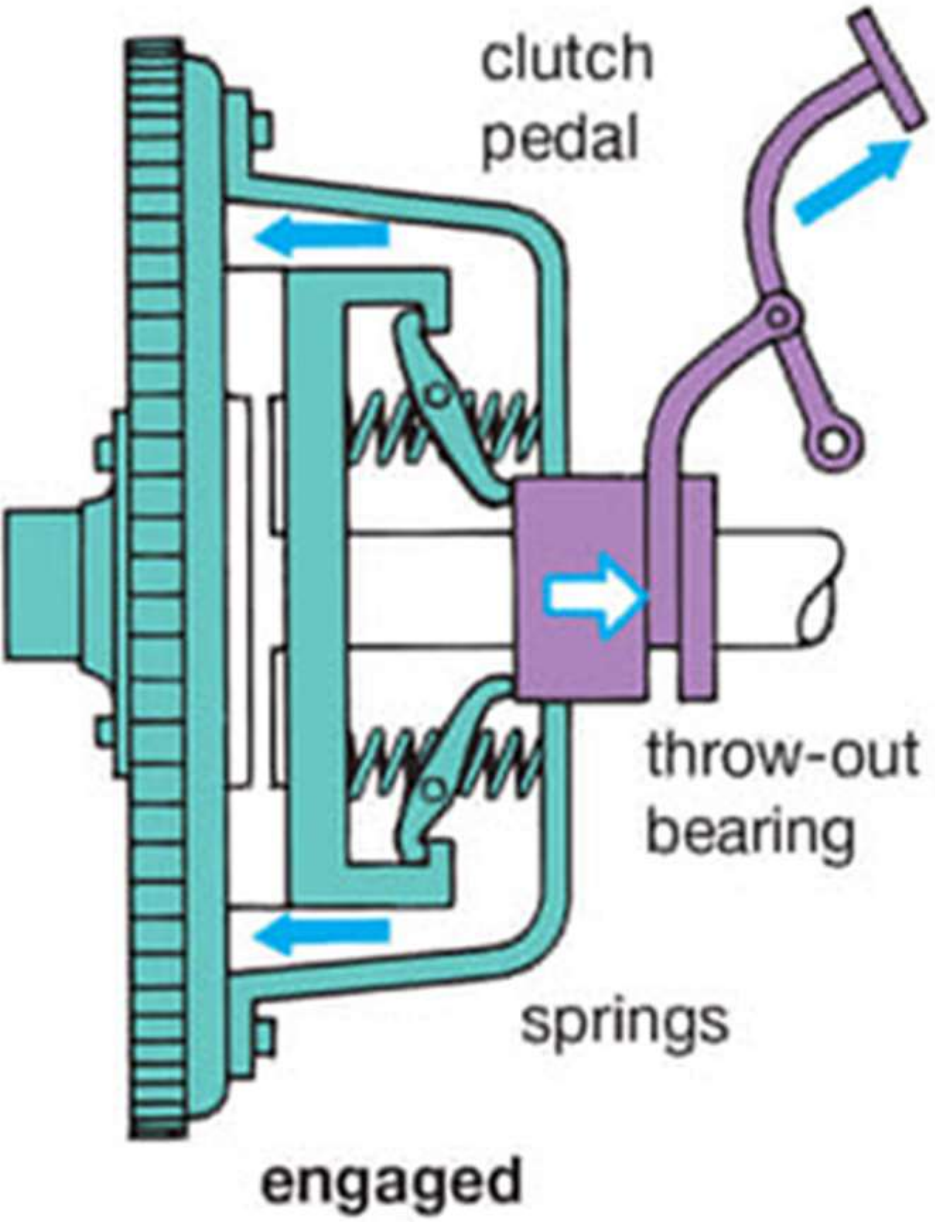
Clutch Action

Disengaged



- When the driver presses the clutch pedal, the clutch release mechanism pulls or pushes on the clutch fork
- The fork moves the release bearing into the center of the pressure plate
- The pressure plate face pulls away from the clutch disc
- The clutch disc and transmission input shaft do not turn

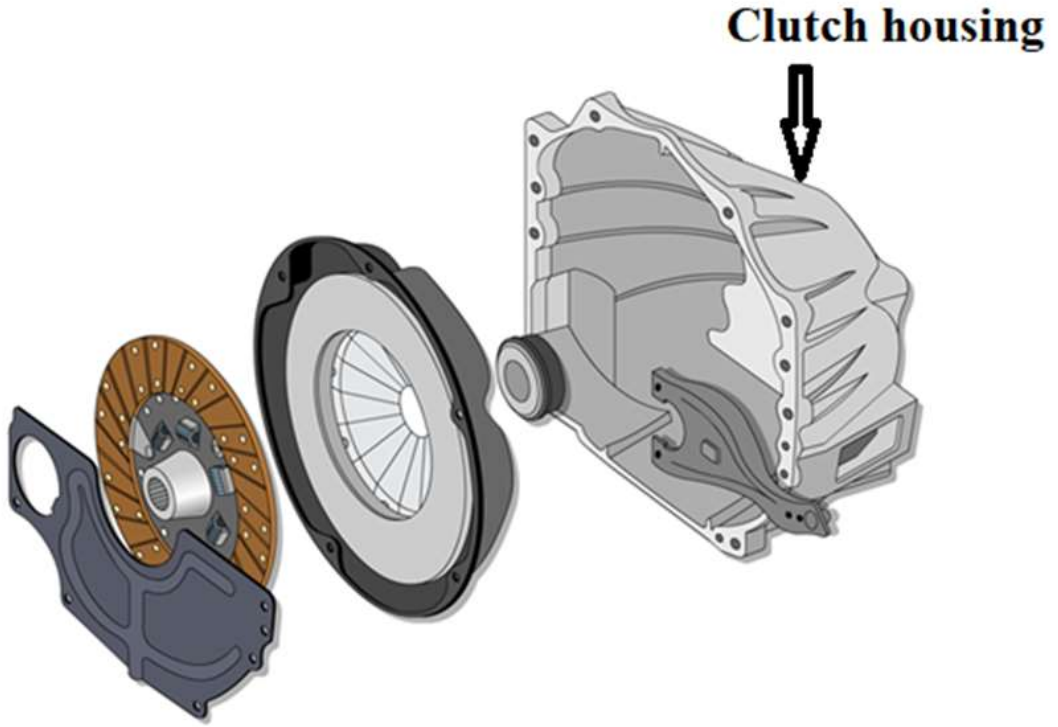
Engaged



- When the driver releases the clutch pedal, the spring pressure inside the pressure plate pushes the pressure plate forward on the clutch disc
- This locks the flywheel, disc, pressure plate, and transmission input together
- The engine rotates the transmission input

Clutch housing

- Bolts to the rear of the engine
- Encloses the clutch assembly
- Mostly made of aluminum,
- The transmission bolts to the back of the clutch housing



Power, and torque transmitted by the clutch

- The **Uniform Wear** Theory assumes that the rate of wear remains constant across the entire friction surface. The theory suggests that pressure decrease as radius increases to maintain uniform wear. This theory is particularly relevant for older, worn clutches.

$$P \cdot r = C$$

where:

P: the pressure at a specific radius.

r: the radius from the center of the clutch.

C: Is a constant value.

- This means the pressure p is inversely proportional to the radius r, unlike the Uniform Pressure

Axial thrust (force)

- Axial Thrust (W): The total normal force exerted on the friction surface. It is primarily comes from the spring force and is given by:

$$W = 2\pi C(r_o - r_i)$$

- Where:

  W = Axial thrust (total normal force applied on the friction surface)

  C = Constant related to pressure and wear characteristics

  r_o = Outer radius of the friction surface (m)

  r_i = Inner radius of the friction surface (m)

- The mean radius (r_m) for uniform wear is given by:

$$r_m = \frac{(r_o + r_i)}{2}$$

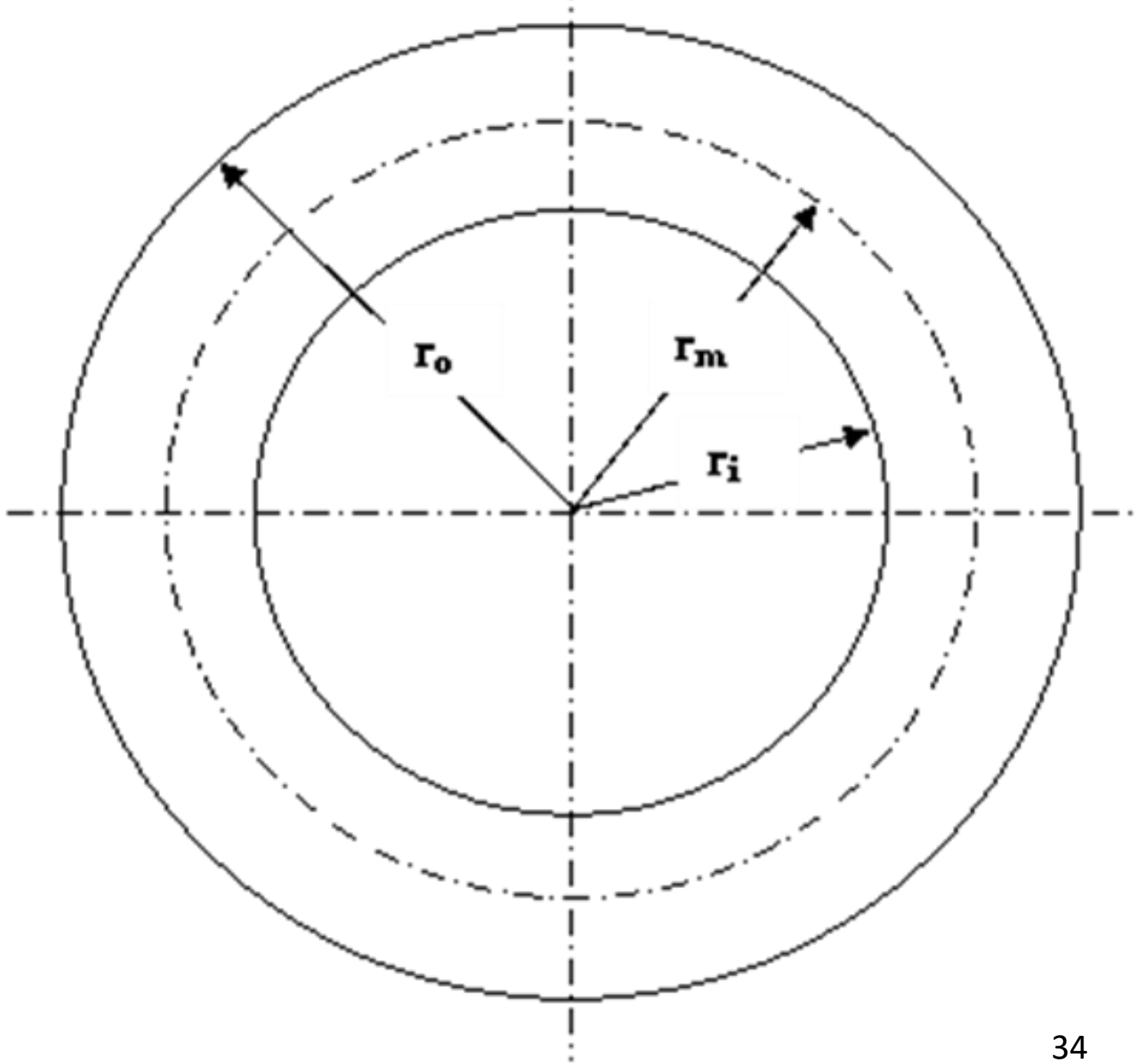
- The power (P) transmitted by the clutch at an angular speed ω i

$$P = \frac{2\pi NT}{60}$$

- The torque (T) is transmitted by the clutch at an angular speed ω is:

$$T = n \cdot \mu \cdot W \cdot \left(\frac{r_i + r_o}{2}\right)$$

- n = number of friction surfaces
- μ = coefficient of friction
- W = axial thrust or normal force
- r_i = inner radius of friction surface
- r_o = outer radius of friction surface
- $\frac{r_i+r_o}{2}$ = mean radius for **uniform wear**

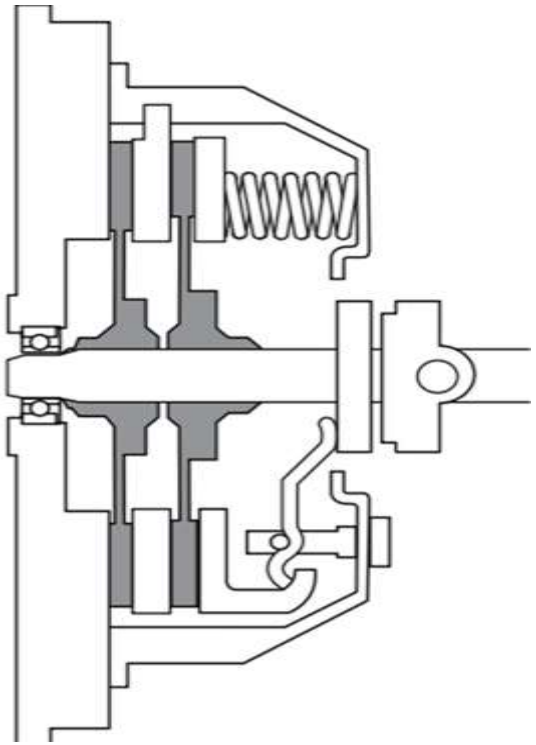

r_o
r_m
r_i

Example 1

- A single-plate clutch, effective on both sides, has outer and inner diameters of 300 mm and 200 mm, respectively. The maximum pressure intensity at any point on the contact surface is limited to 0.1 N/mm². Given a coefficient of friction of 0.3, determine the power transmitted by the clutch (in kW) at a speed of 2500 rpm using the uniform wear theory.(61.7kW)

Example 2

- A twin plate clutch with both sides effective is shown in the figure below. The clutch linings have an inner radius of 250mm and an outer radius of 320mm. The total spring force is 4kN and the coefficient of friction between the linings and the pressure plate and flywheel is 0.35. Calculate the maximum torque in Nm that this clutch can transmit. (1596 Nm)



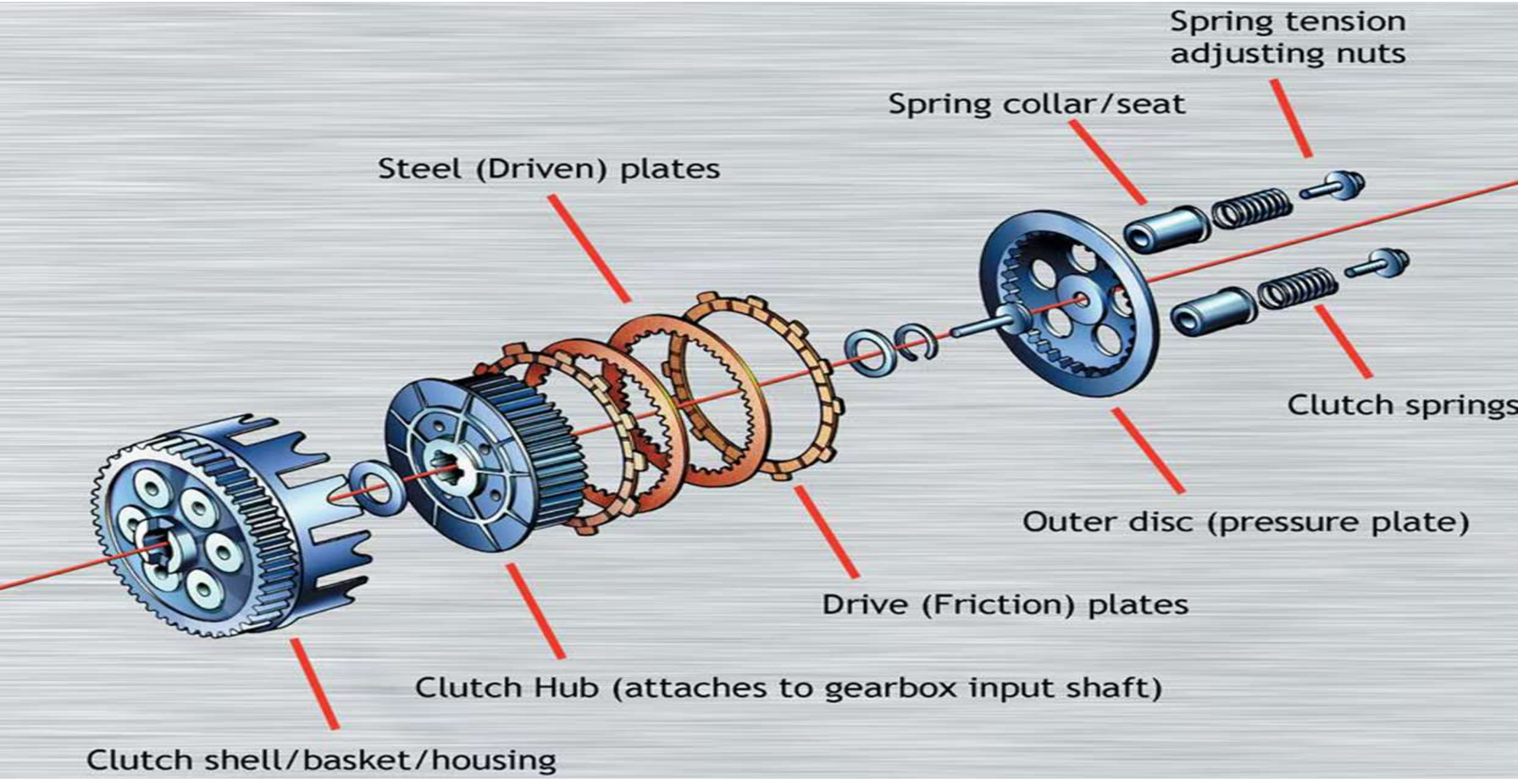
Example 3

- A single-plate clutch operates at 3600 RPM. The clutch linings have inner and outer radii of 160 mm and 190 mm, respectively. Given a coefficient of friction of 0.4 and a total spring force of 2.5 kN, determine the maximum power (in kW) the clutch can transmit.(132kw)

Example 4

- An automobile's single-plate clutch transmits 22.4 kW of power at a speed of 2100 RPM. The total axial load acting on the clutch plate is 1450N. The outer diameter of the friction surface is 250mm. If both sides of the clutch plates are effective and the coefficient of friction (μ) is 0.35, determine the inner diameter of the friction face, assuming uniform wear.(151.42mm)

Multiplate clutch



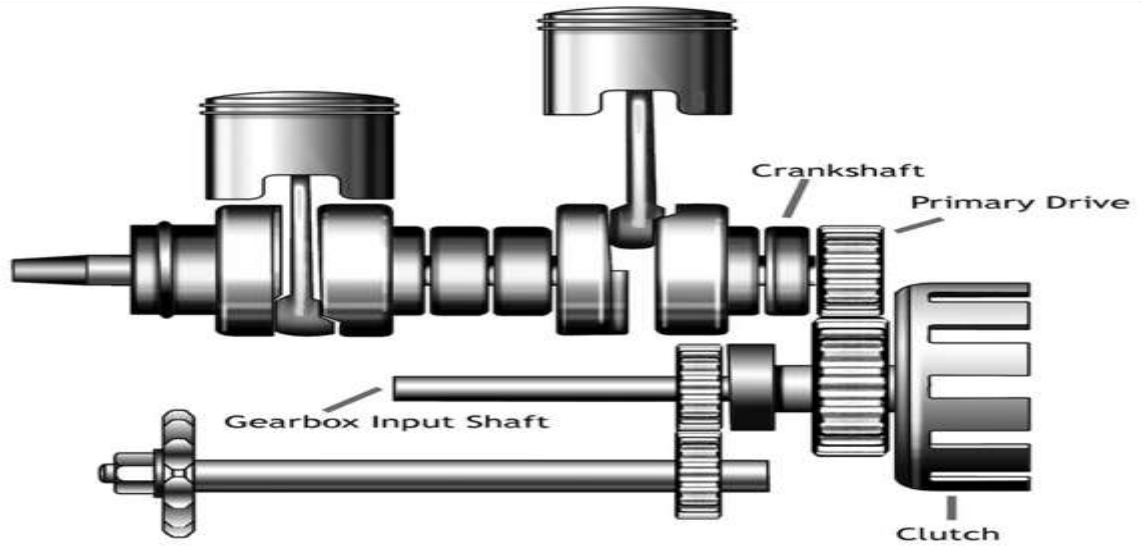
Multidisc clutch…

- Has the ability to transmit more torque within a compact size.
- $T = n*\mu * W * rm$
- For example, if a single plate clutch has two friction surfaces (N=2) and a multiplate clutch has six friction surfaces (N=6), the torque transmission increases three times for the same applied force and friction conditions

- Multi-plate clutches are wet clutches, because they operate submerged in engine oil for cooling and lubricating.

Multiplate clutch…

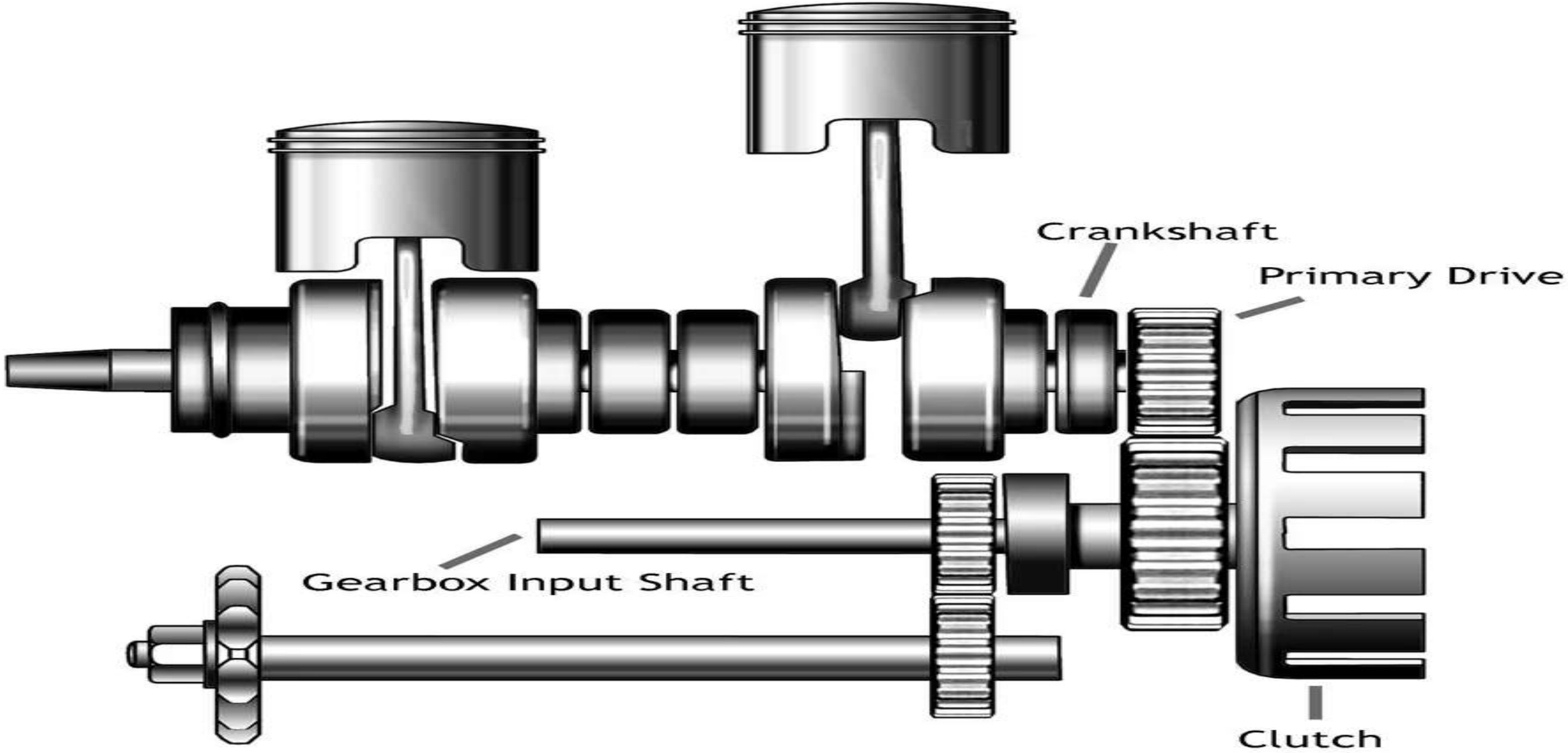
- **Clutch Basket:** A rotating, often aluminum, basket that is driven directly by the engine's crankshaft. A motorcycle clutch basket has teeth (or fingers) that engage the outer tabs of the friction plates.
- **Primary Drive:** The crankshaft is connected to the clutch basket via the primary drive, which often consists of gears or a chain. This connection ensures that the clutch basket rotates whenever the engine is running.



- **Clutch Plates (Friction Plates):** These plates have friction material bonded to them on either side. The outer edges of these plates have **tabs** that fit into the slots of the clutch basket. Thus, the friction plates are always being turned by the engine.
- **Steel Plates (Driven Plates):** Smooth steel discs. They are often thinner than the friction plates. The inner edges of these plates have teeth that engage with the clutch hub.
- **Clutch Hub:** The clutch hub has outer splines that engage with the steel plates. It is a a rotating component that is splined to the transmission input shaft. The steel plates drive the clutch hub.

- **Pressure Plate:** A plate that presses against the stack of clutch and steel plates.
- **Clutch Springs:** Strong springs apply pressure to the pressure plate, clamping the clutch plates and steel plates together.
- **Pushrod/Actuation Mechanism:** A lever, cable, hydraulic system, or a combination thereof, which, when the clutch lever is pulled, moves the pressure plate away from the clutch pack, disengaging the clutch.

Principle of operation



Power flow


Engine crankshaft
Primary drive gear
Clutch Basket
Clutch plates (Friction plates, and steel plates)
Clutch hub
Input shaft

Disengaged

- the **clutch lever on the handlebar** is connected to the clutch assembly via a cable or hydraulic system.
- When the rider pulls the lever, this mechanism actuates a pushrod or similar component that moves the pressure plate away from the clutch discs, disengaging the engine from the transmission and allowing for gear changes or idling without stalling.
  - ✓This **releases the pressure** on the friction and steel discs, allowing them to slip against each other.
- With the discs slipping, power from the engine is not transferred to the transmission.

Engaged (Clutch lever released):

- The clutch springs push the pressure plate against the pack of friction and steel discs, squeezing them tightly together.
- The engine's power is initially transferred to the clutch basket via the primary drive. The friction discs are now tightly pressed against the steel discs, they spin along with the basket. As the friction discs rotate, they transfer the engine's power (torque) to the steel discs and, in turn, to the clutch hub. The clutch hub is connected to the transmission's input shaft which drives the transmission.