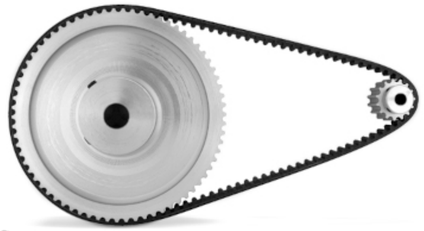
Chain and Belt Drives

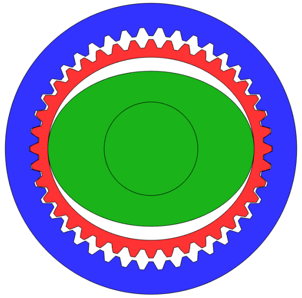
YORK COLLEGE & UNIVERSITY CENTRE

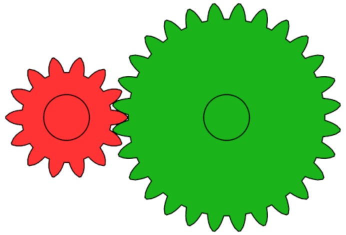
Mechanical power transmission types

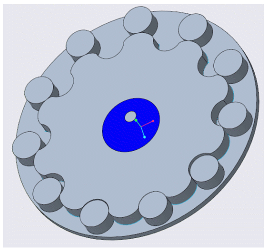
- We can split our power transmission based on how it moves:
  - Rotary: circular motion (e.g. motor shaft, gears)
  - Linear: straight-line motion (e.g. piston, actuator)
  - Oscillating: back-and-forth motion (e.g. cam follower, lever)



- But we can also split them on the properties of the transmitter
  - Flexible drives: belts, chains
  - Rigid drives: gears, cams
  - Special drives: harmonic, cycloidal

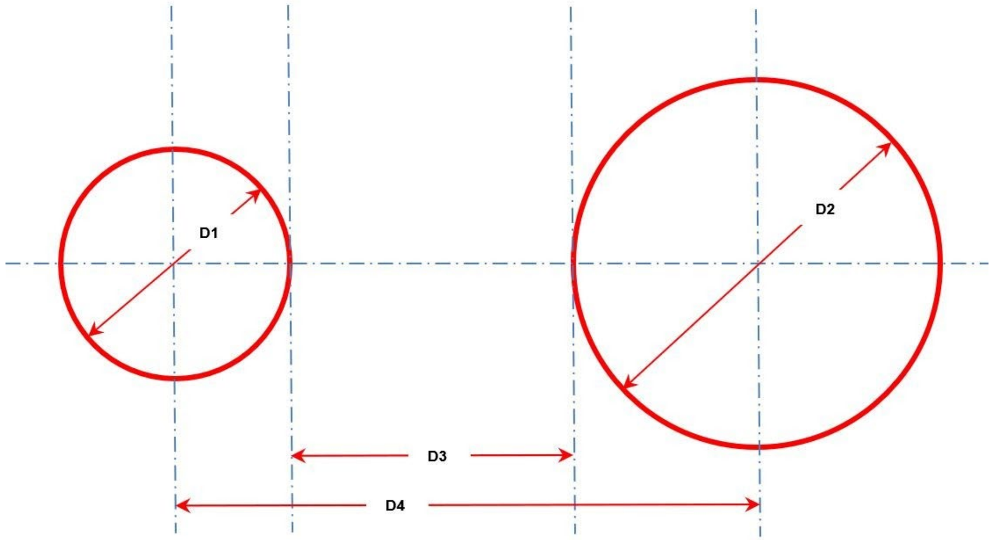






Key Concept – Centre Distances

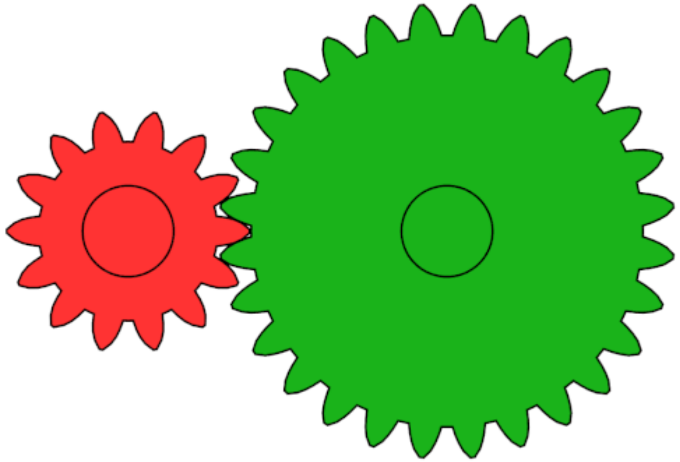
- The centre distance is the distance between the centre of two pulleys/gears
- It affects belt tension, wrap angle, and the overall layout of the drive system.
- Choosing the correct centre distance is important for maintaining grip, reducing wear, and ensuring smooth power transmission.



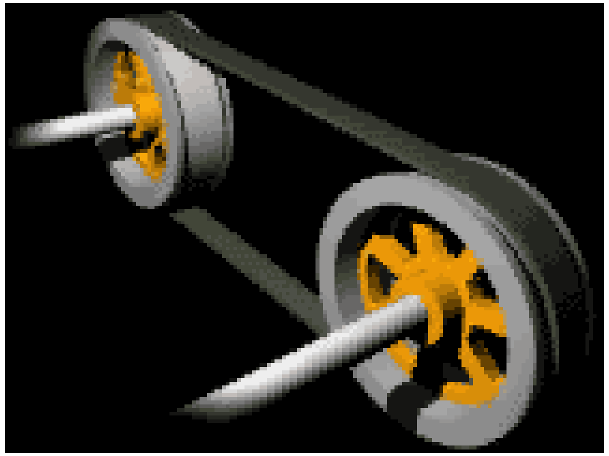
$$D_4 = \frac{D_1}{2} + \frac{D_2}{2} + D3$$

Positive Engagement vs Friction Drive

- **Positive Engagement Drive**
  - Positive engagement means two components transmit motion through interlocking geometry (not friction).
  - Behaves well under high torque scenarios
  - Examples include gears, chains and sprockets, or timing belts, where the teeth physically mesh to prevent slip.

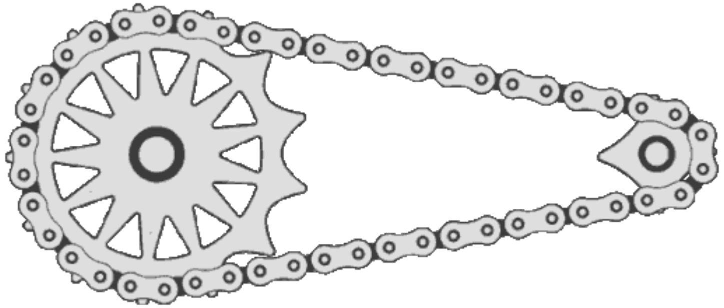


- **Friction Drive**
  - Friction drives transmit motion by surface contact and grip between components.
  - This means they are prone to slipping in high torque scenarios
  - Examples include flat or V-belt pulley systems, where friction between the belt and pulley transfers power.

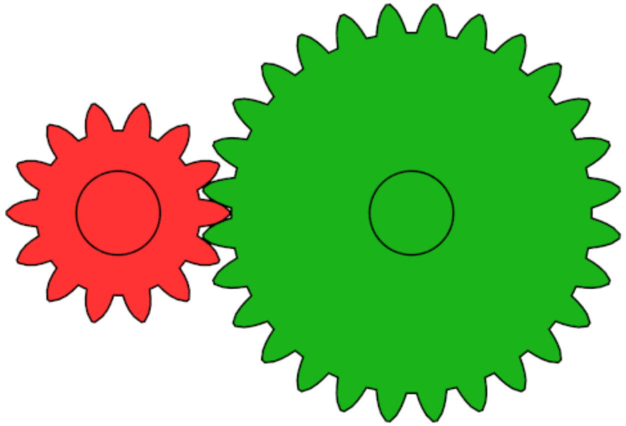


Direction of Rotation

- **Gears:**
  - Gears mesh directly, so they reverse the direction of rotation.
  - If the driver turns clockwise → the driven turns anticlockwise.
  - Each additional gear reverses direction again (odd = reversed, even = same).



- **Belts and Chains:**
  - Belts and chains loop around pulleys or sprockets, so the direction stays the same.
  - If the driver turns clockwise → the driven also turns clockwise.
  - The same applies if both rotate anticlockwise.

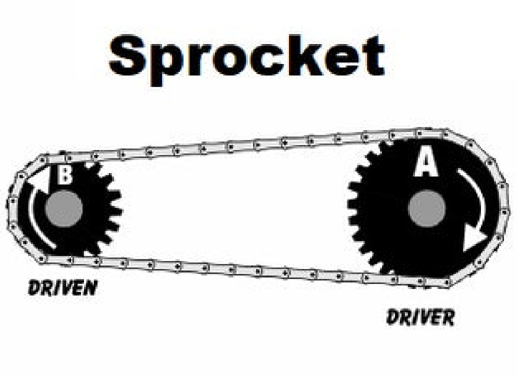


Sprockets

- Sprockets are like gears, but instead of meshing with another gear, they engage with a chain (or occasionally a toothed belt).

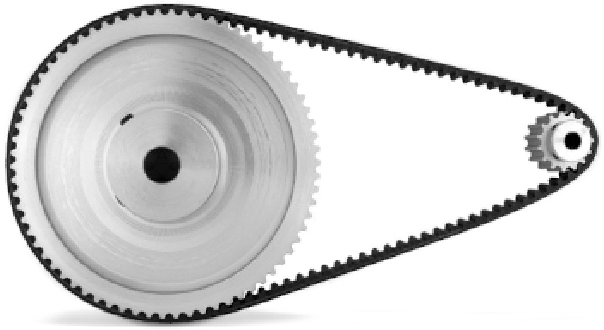
- They transmit motion through positive engagement - the sprocket’s teeth fit precisely into the chain’s rollers or links, ensuring no slip and maintaining a fixed speed ratio.

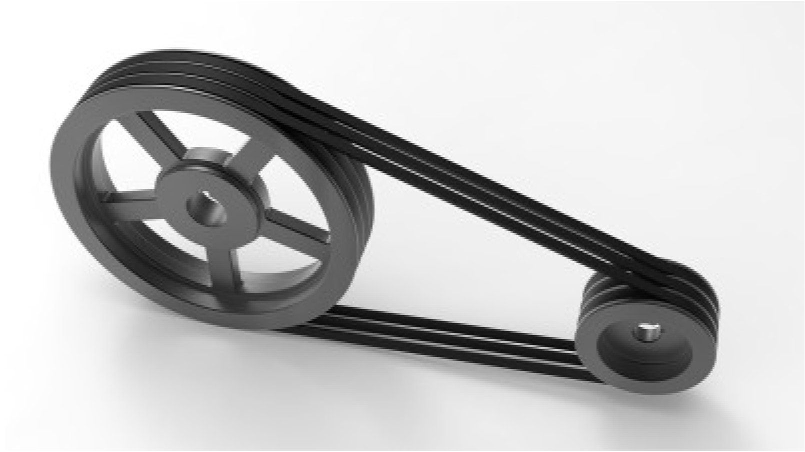
- Sprocket teeth are shaped specifically to match the chain pitch and roller diameter, not the involute profile used in gears.



Belt Drives

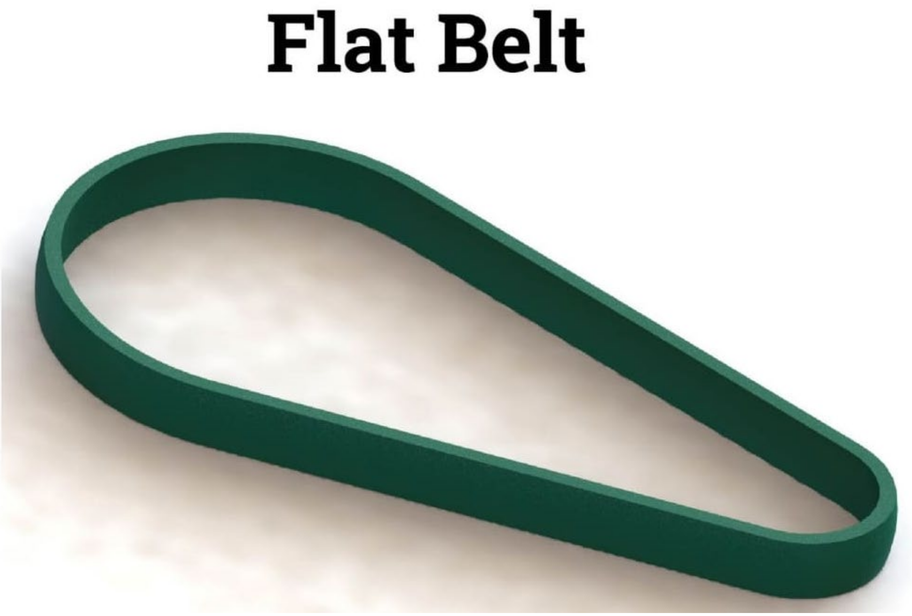
- **Purpose:**
  - Transfer power between rotating shafts using flexible belts and pulleys.
- **How it works:**
  - Power is transmitted by friction between the belt and pulley.
  - The belt wraps around pulleys to change speed, direction, or torque.
- **Types:**
  - Flat Belt
  - V-Belt
  - Timing (synchronous) Belt





Flat Belts

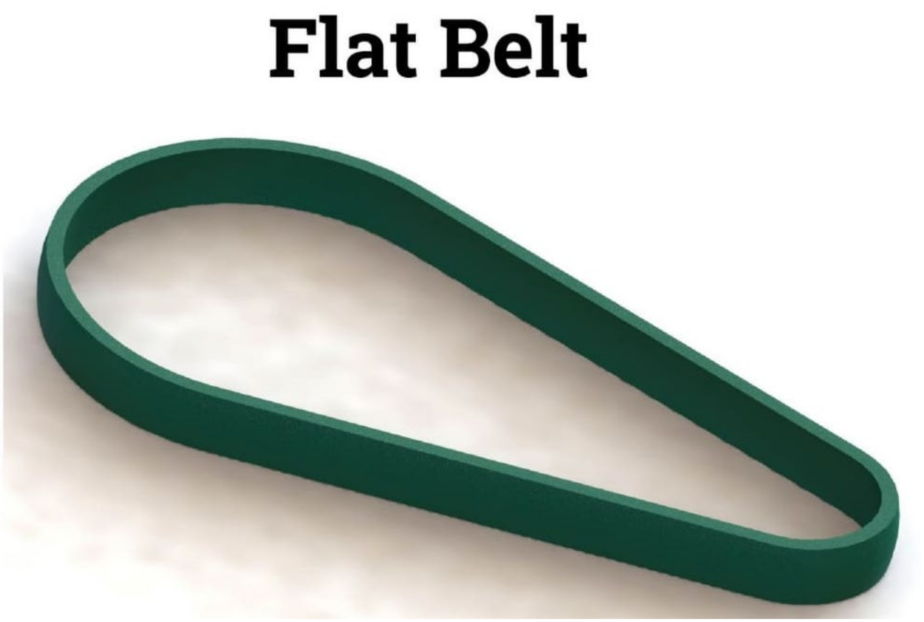
- Description:
  - A flat, flexible strip of rubber, leather, or fabric that wraps around flat pulleys.
- Power Transmission Method:
  - Relies purely on friction between the belt and pulley.
  - The belt slips slightly under load.
- Typical Uses:
  - Older machinery, fans, small conveyors, textile or woodworking equipment.

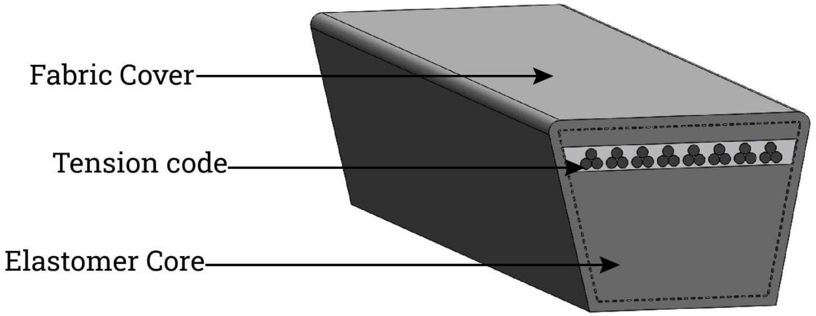


Flat Belts

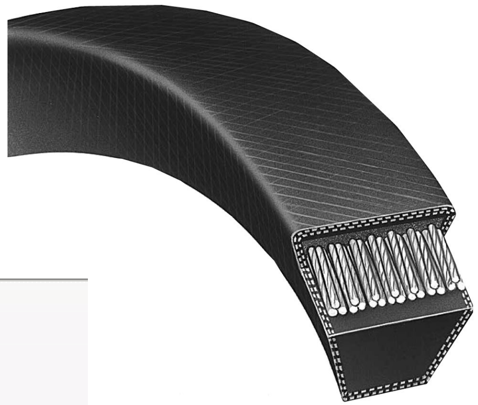
- Advantages:
  - Simple, inexpensive, and easy to align.
  - Can run at high speeds and over long distances.
  - Quiet operation and low maintenance.

- Limitations:
  - Can slip under high torque or sudden loads.
  - Requires good tensioning and alignment.
  - Not suitable for precise motion or high-torque transfer.

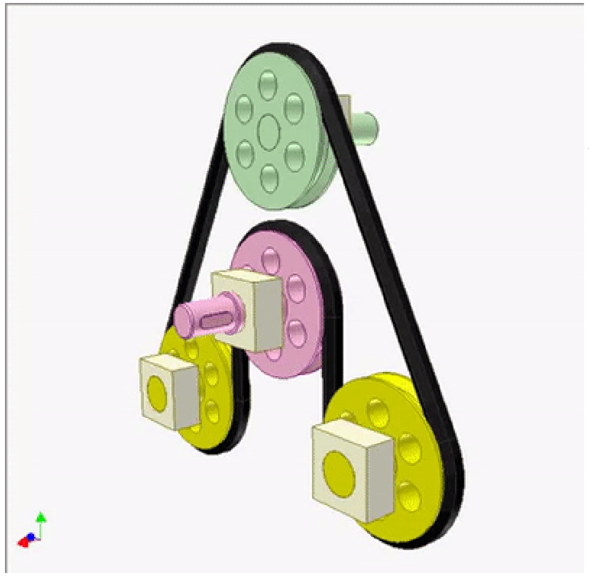




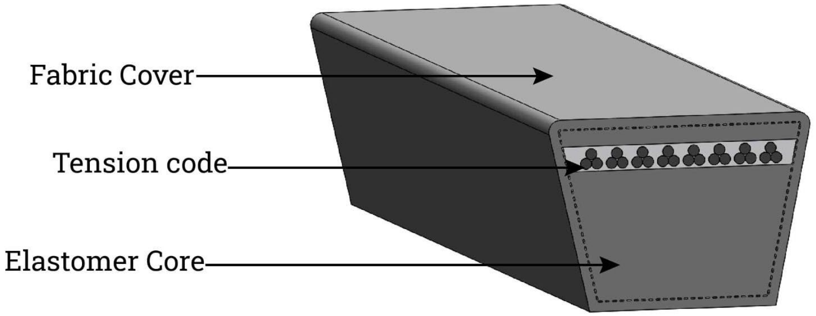
V-Belts



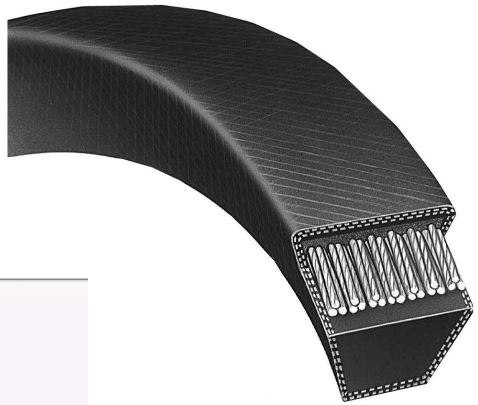
- **Description:**
  - A belt with a trapezoidal cross-section that fits into a matching V-shaped pulley groove.
- **Power Transmission Method:**
  - Uses wedging action for friction.
  - As tension increases, the belt wedges deeper into the pulley groove, increasing grip.
- **Typical Uses:**
  - Automotive alternators and compressors, industrial machines, HVAC blowers, small mechanical drives.

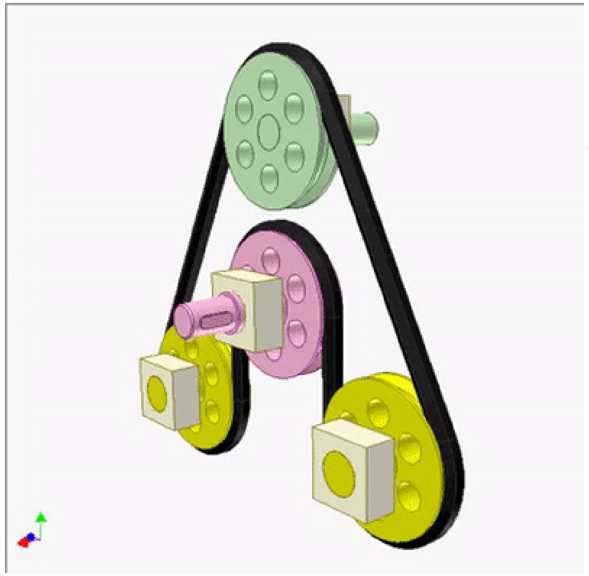


V-Belts



- **Advantages:**
  - Higher torque capacity than flat belts.
  - Less slippage due to wedge effect.
  - Compact and efficient for short-distance drives.





- **Limitations:**
  - Generates more heat at high speeds.
  - Not ideal for very long centre distances.
  - Still subject to some slip, so not suitable for precision timing.

Timing Belts (Toothed Belts or Synchronous Belts)

- **Description:**
  - A rubber or polymer belt with moulded teeth that mesh with matching grooves on the pulley.

- **Power Transmission Method:**
  - The teeth on the belt mesh with the sprocket/pulley making sure there is no slip

- **Typical Uses:**
  - Robotics, 3D printers, CNC machines, automotive camshafts, timing systems where position accuracy matters.

Timing Belts (Toothed Belts or Synchronous Belts)

- **Advantages:**
  - Precise synchronization between shafts (constant speed ratio).
  - High efficiency and quiet operation.
  - No lubrication required.

- **Limitations:**
  - Limited torque capacity compared to chains or gears.
  - Sensitive to debris or wear that can damage teeth.
  - More expensive than friction belts.

Chain Drives

- **Purpose:**
  - Transmit power between rotating shafts using a linked chain and sprockets

- **How It Works:**
  - Power is transmitted by positive engagement between chain links and sprocket teeth — no slip.
  - The centre distance between sprockets determines chain length and tension.
  - Used where consistent speed ratio and higher torque are required.

- **Key Features:**
  - Roller Chain is most common (bushings, rollers, and pins).
  - Chains can connect parallel or offset shafts.
  - Direction and speed depend on sprocket sizes (like gears).

Chain Drives

- **Advantages:**
  - Maintains accurate speed ratio with no slip.
  - Handles high torque and load.
  - Simple to replace or reconfigure for different ratios.

- **Limitations:**
  - Needs proper lubrication and alignment.
  - Chain wear can cause backlash over time.
  - Generates more noise and vibration than belts.

Length of Belt Calculation

$$L = 2C + \frac{\pi(D_1 + D_2)}{2} + \frac{(D_2 - D_1)^2}{4C}$$

where:

- L = **total belt length** (same units as diameters and centre distance)
- C = **centre distance** between pulley shafts
- D_1 = **diameter of the smaller pulley**
- D_2 = **diameter of the larger pulley**

Length of Chain Calculation

$$L = 2C + \frac{\pi(N_1 + N_2)}{2} + \frac{(N_2 - N_1)^2}{4\pi C}$$

where:

- L = chain length **in pitches** (i.e., number of chain links)
- N_1 = number of teeth on the **smaller sprocket**
- N_2 = number of teeth on the **larger sprocket**
- C = **center distance** between sprockets, **in chain pitches**

$$C_{\text{pitches}} = \frac{C_{\text{distance}}}{p}$$

where p = **chain pitch** (distance between adjacent pins, e.g. 12.7 mm for a ½″ chain).