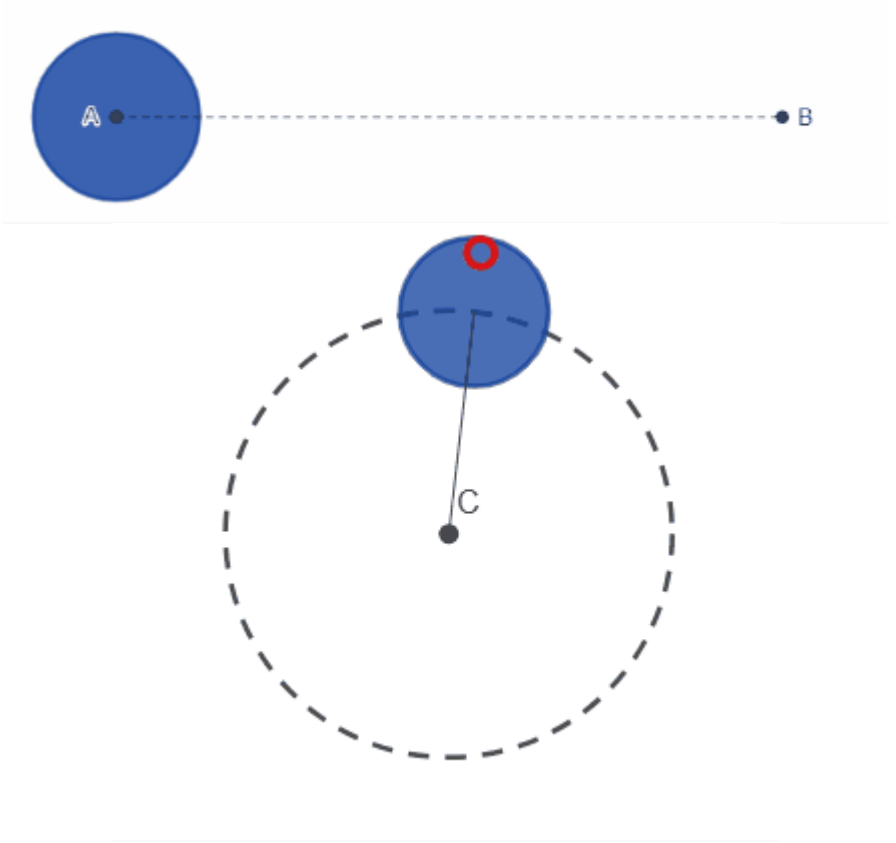
Gears and Cams

Mechanical Power Transmission

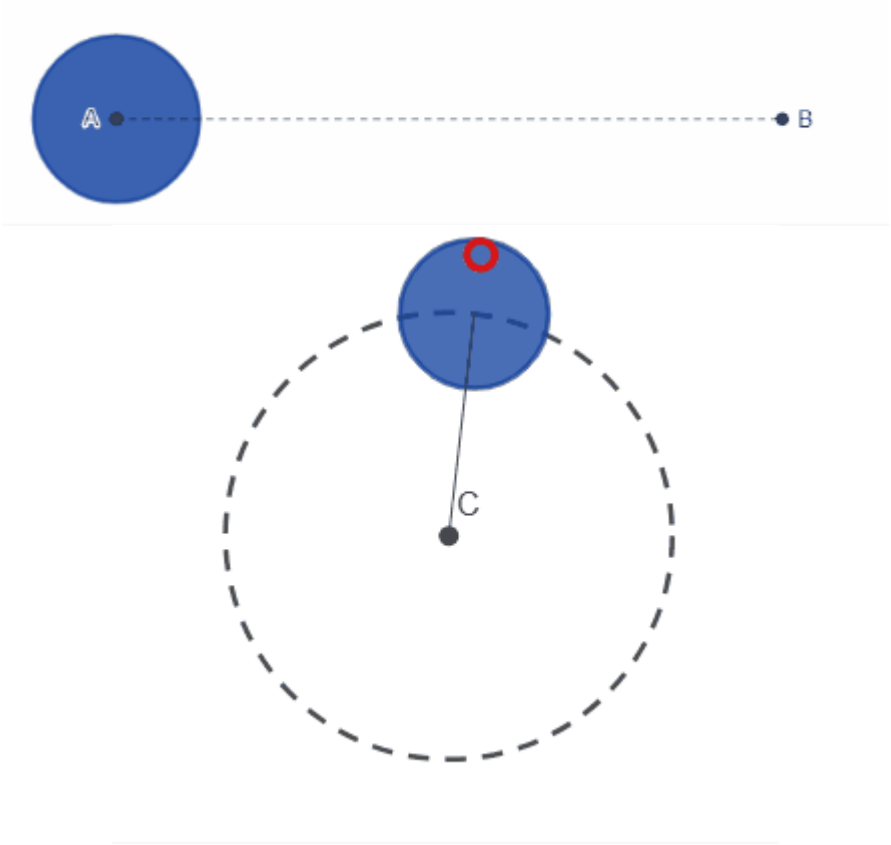
- **What it means:**
  - Mechanical power transmission is how energy and motion are transferred between parts in a system.
  - It allows movement from motors or actuators to be used to drive mechanisms.

- **Main motion types:**
  - 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)



Mechanical Power Transmission

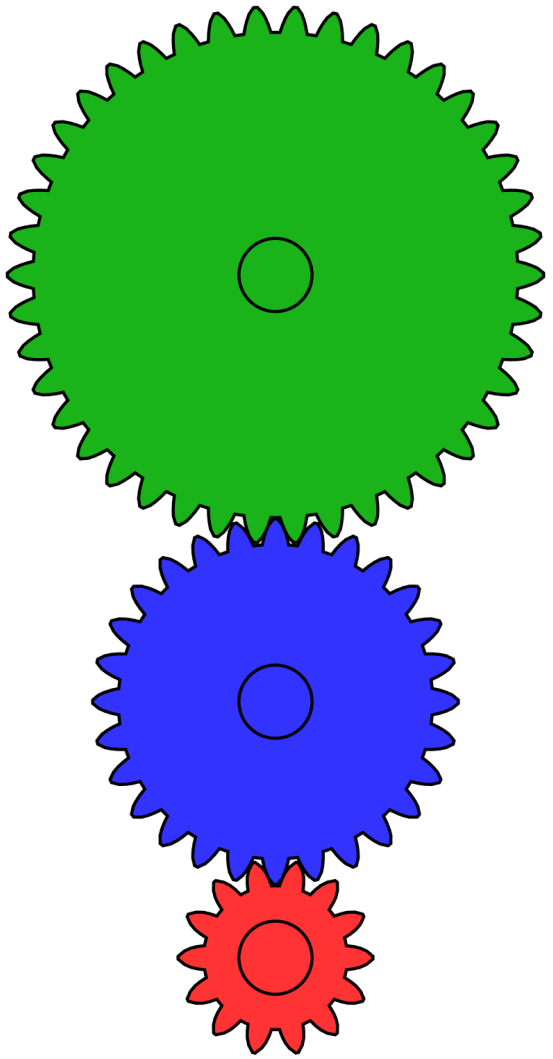
- Why it matters in mechatronics:
  - Converts motor output into useful motion for tasks
  - Allows control of speed, torque, and direction
  - Ensures efficient interaction between mechanical and electronic systems



Gears

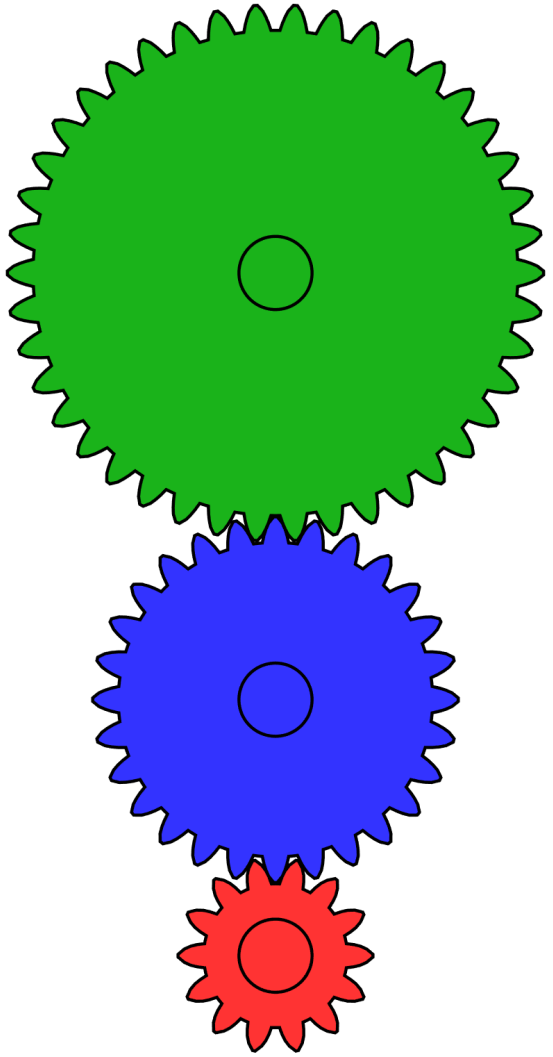
- **What are gears?**
  - Gears are toothed wheels that mesh together to transmit rotary motion between shafts.
  - They can change speed, torque, or direction of rotation depending on their size and arrangement.

- **Why they're important:**
  - Allow precise control of movement in mechatronic systems
  - Enable speed reduction or increase to match motor output with load needs
  - Provide mechanical advantage for lifting or driving heavier loads



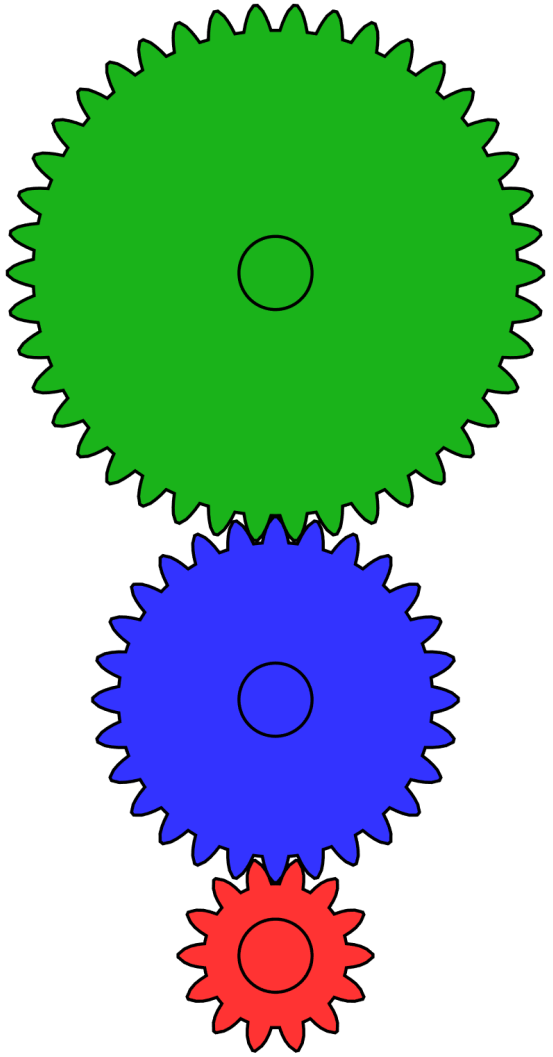
Gears

- **How they work:**
  - When two gears mesh, the driver gear turns the driven gear
  - The gear ratio determines how much speed or torque is altered
- **Gear Ratio =** $\frac{\textbf{Teeth on Driven Gear}}{\textbf{Teeth on Driver Gear}}$
- **Where you'll find them:**
  - Robotic joints, servo gearboxes, conveyor systems, CNC machinery



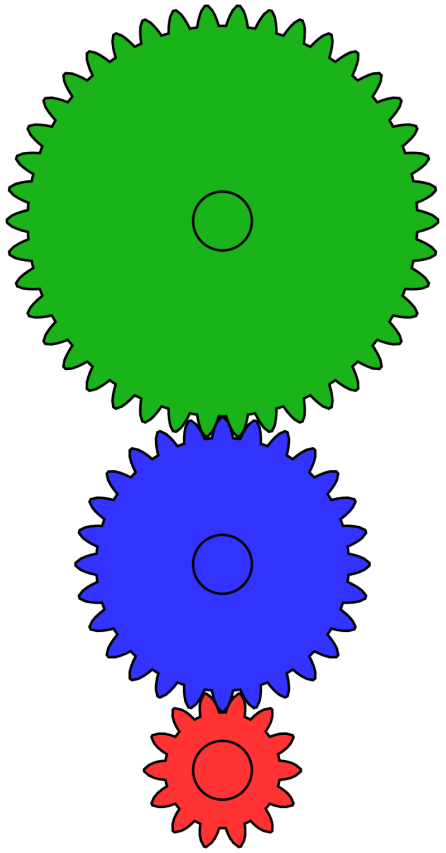
Gear Size and Teeth

- **Larger gears = more teeth**
- This is because all teeth must be the same size for the gears to “mesh” (fit together)
- So, you need more teeth to fit the same circumference



Gear Ratio Effect on Speed/Torque

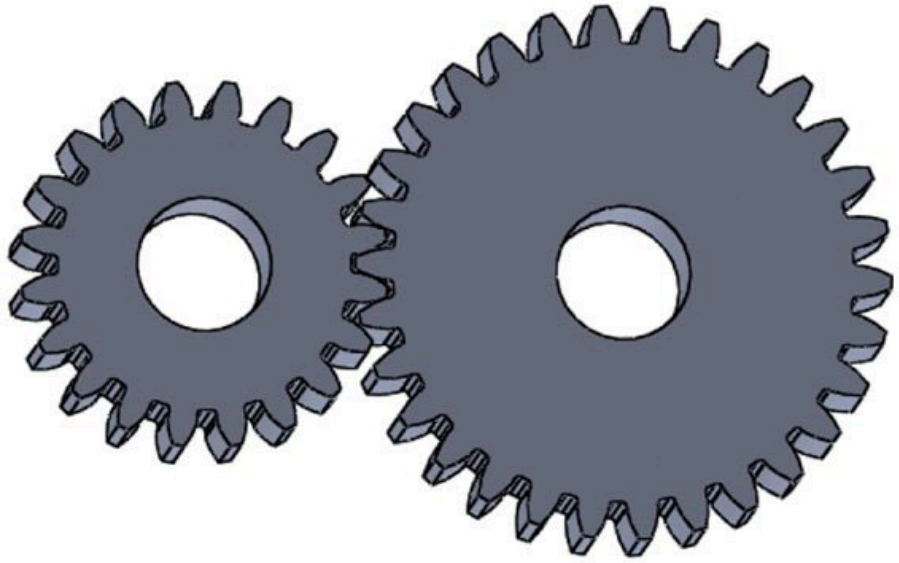
- **If the ratio > 1: torque increases, speed decreases**
- **If the ratio < 1: speed increases, torque decreases**
- **Output Speed = $\frac{\text{Input Speed}}{\text{Gear Ratio}}$**
- **Output Torque = Input Torque * Gear Ratio**



Spur Gears

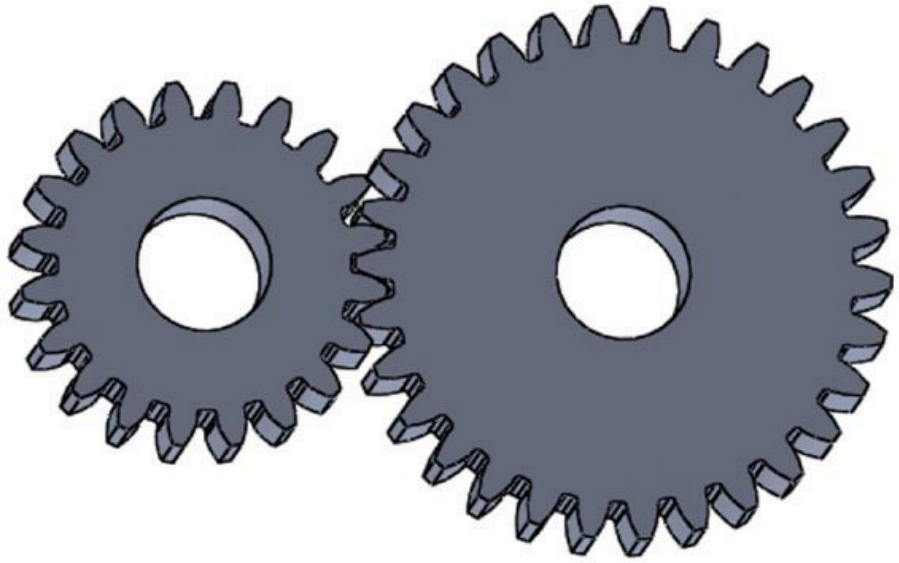
- **Definition:**
  - Spur gears are the simplest and most common type of gear.
  - They have straight teeth cut parallel to the axis of rotation.
  - Used to transmit motion and power between parallel shafts.

- **Key features:**
  - Smooth and efficient for moderate speeds
  - Easy to design and manufacture
  - Produce axial thrust–free motion (no sideways forces on the shafts)



Spur Gears

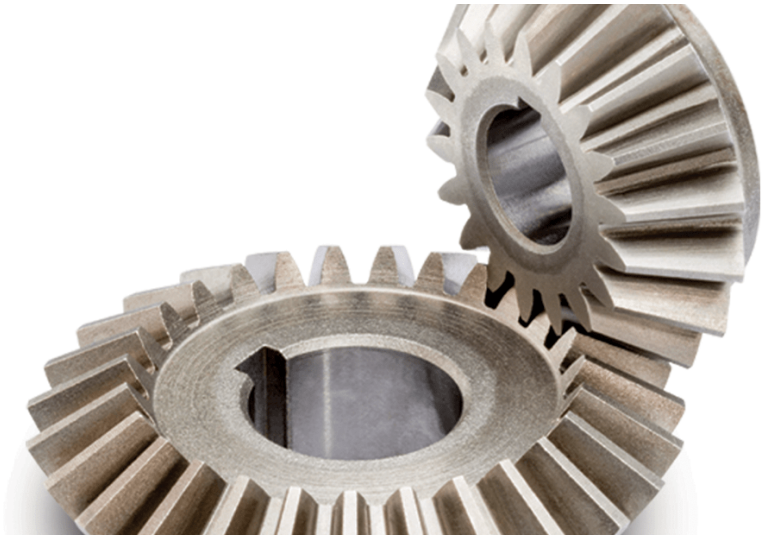
- **Advantages:**
  - High efficiency and reliability
  - Simple to align and maintain
  - Ideal for speed reduction or increase in small gear trains
- **Limitations:**
  - Can be noisy at high speeds
  - Only suitable for parallel shafts



Bevel Gears

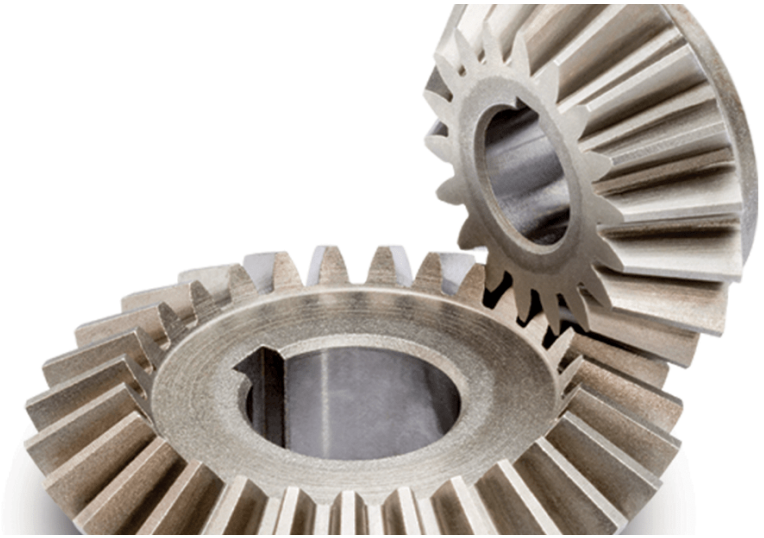
- **Definition:**
  - Bevel gears are conical gears used to transmit motion between intersecting shafts, usually at right angles.
  - The teeth are cut on a cone-shaped surface instead of a cylinder.

- **Key features:**
  - Commonly used for 90° power transfer
  - Available as straight, spiral, or hypoid bevel gears
  - Allow smooth direction changes in compact systems



Bevel Gears

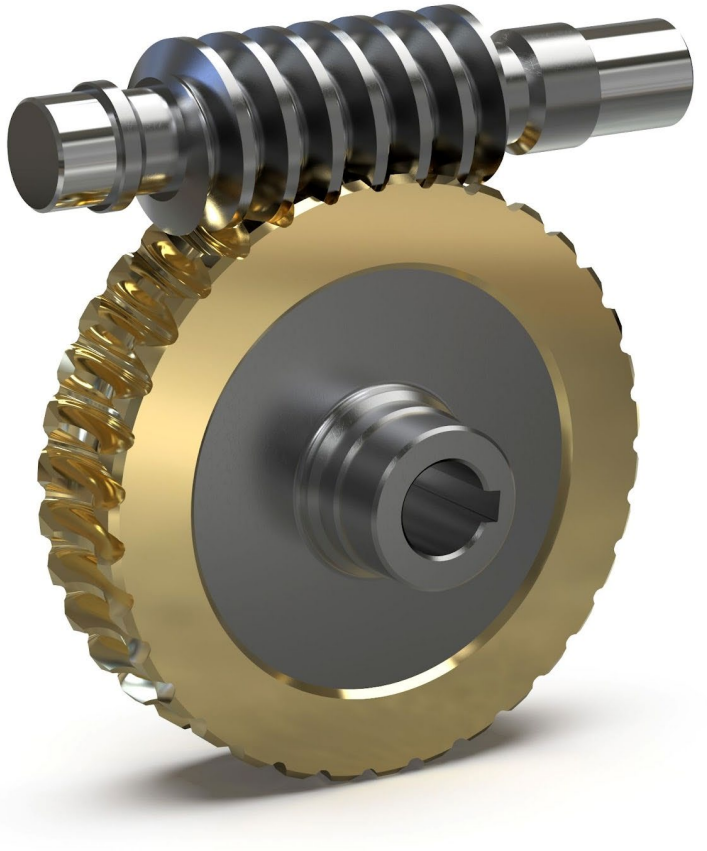
- **Advantages:**
  - Efficient torque transfer at angled shafts
  - Compact and reliable mechanical design
  - Can increase or decrease speed and torque
- **Limitations:**
  - More complex to manufacture than spur gears
  - Require accurate alignment to avoid wear and noise



Worm Gears

- **Definition:**
  - A worm gear system consists of a screw-like worm that meshes with a toothed wheel (worm wheel).
  - It’s used to achieve high torque reduction and large speed decreases in a compact space.

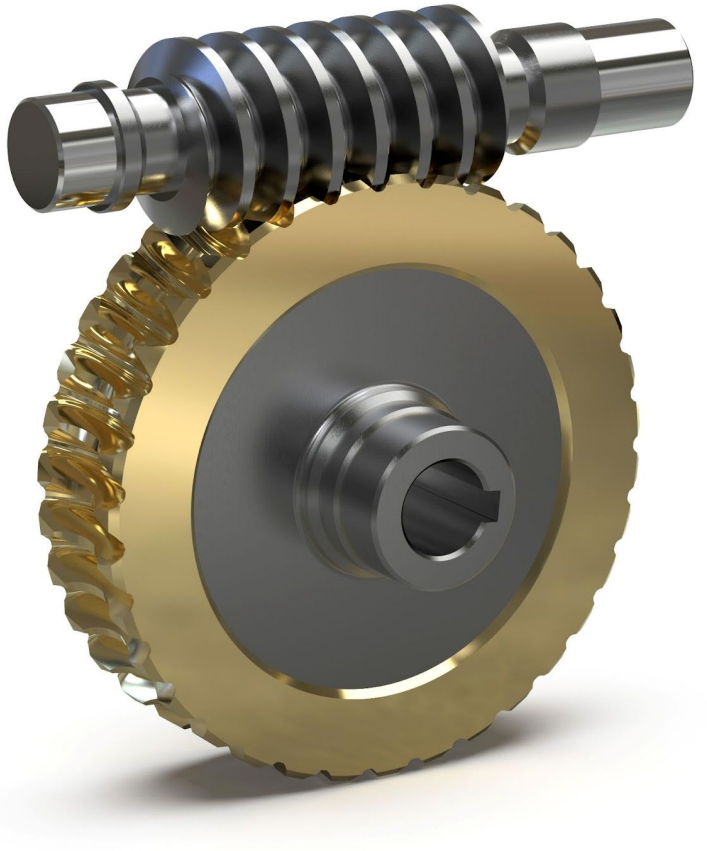
- **Key features:**
  - Transmits motion between non-parallel, non-intersecting shafts (usually at 90°)
  - Provides very high gear ratios in a single stage
  - Motion is non-reversible — the worm can drive the wheel, but the wheel can’t drive the worm



Worm Gears

- **Advantages:**
  - Excellent for torque multiplication
  - Compact and quiet operation
  - Built-in self-locking feature (improves safety)

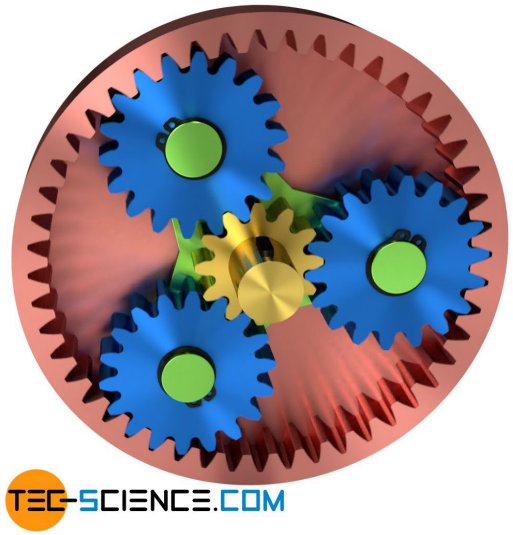
- **Limitations:**
  - Lower efficiency due to friction and heat
  - Requires good lubrication to prevent wear

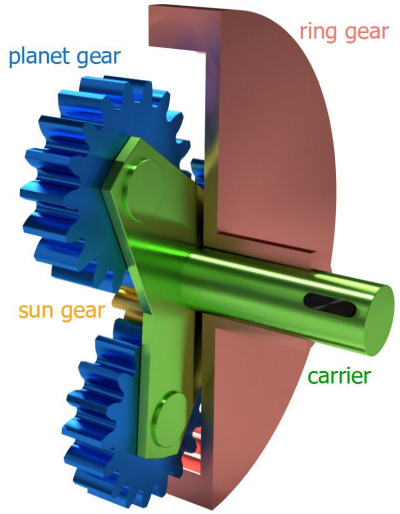


Planetary Gears

- **Definition:**
  - A planetary gear system (also called an epicyclic gear train) consists of a central sun gear, orbiting planet gears, and an outer ring gear.
  - Used to achieve compact, high-torque transmission with multiple gear ratios in one assembly.

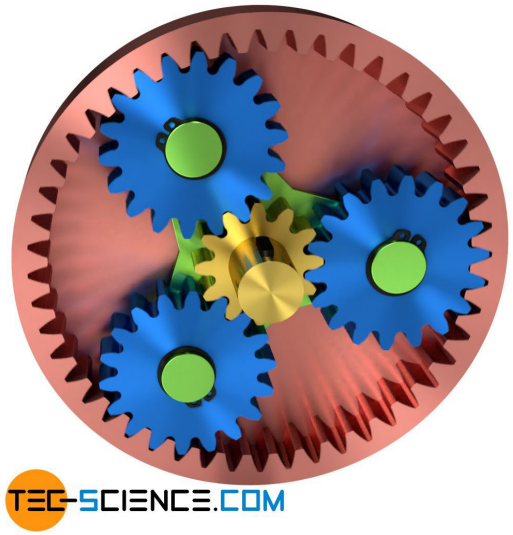
- **Key features:**
  - Sun gear drives multiple planet gears that rotate around it
  - Ring gear provides an outer stationary or driven surface
  - Can produce very high torque density in a small size
  - Different combinations (locking or driving various parts) give multiple speed ratios

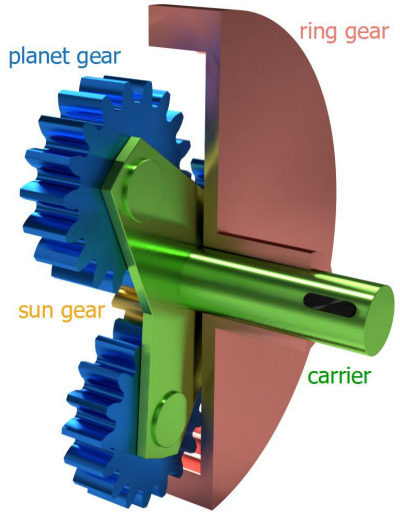




Planetary Gears

- **Advantages:**
  - Compact and efficient
  - High torque output for its size
  - Smooth and balanced operation
  - Ideal for servo motors and robotic joints
- **Limitations:**
  - More complex and expensive than simple gear pairs
  - Difficult to repair or service individually

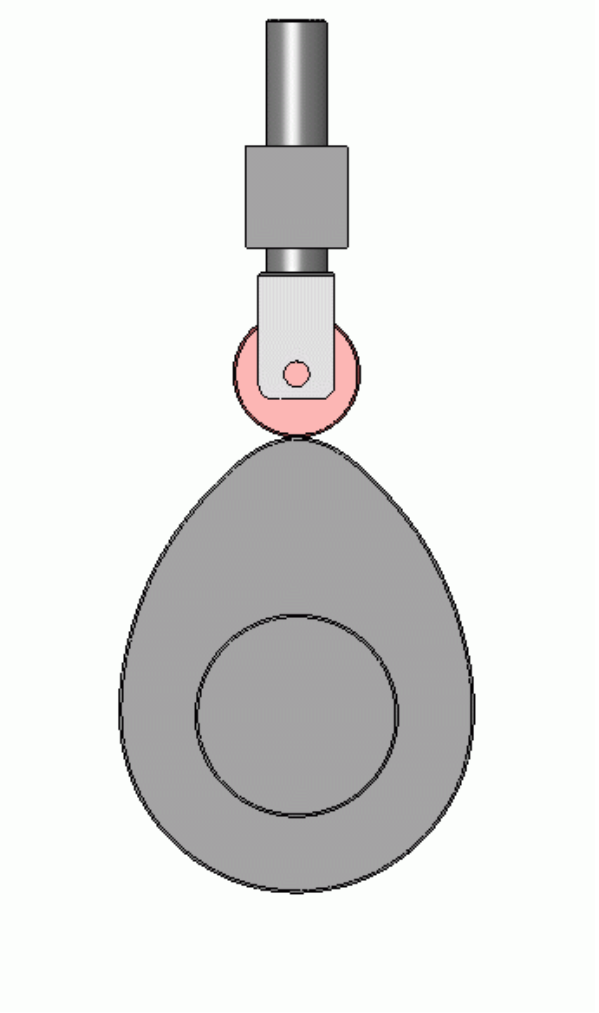




Cams

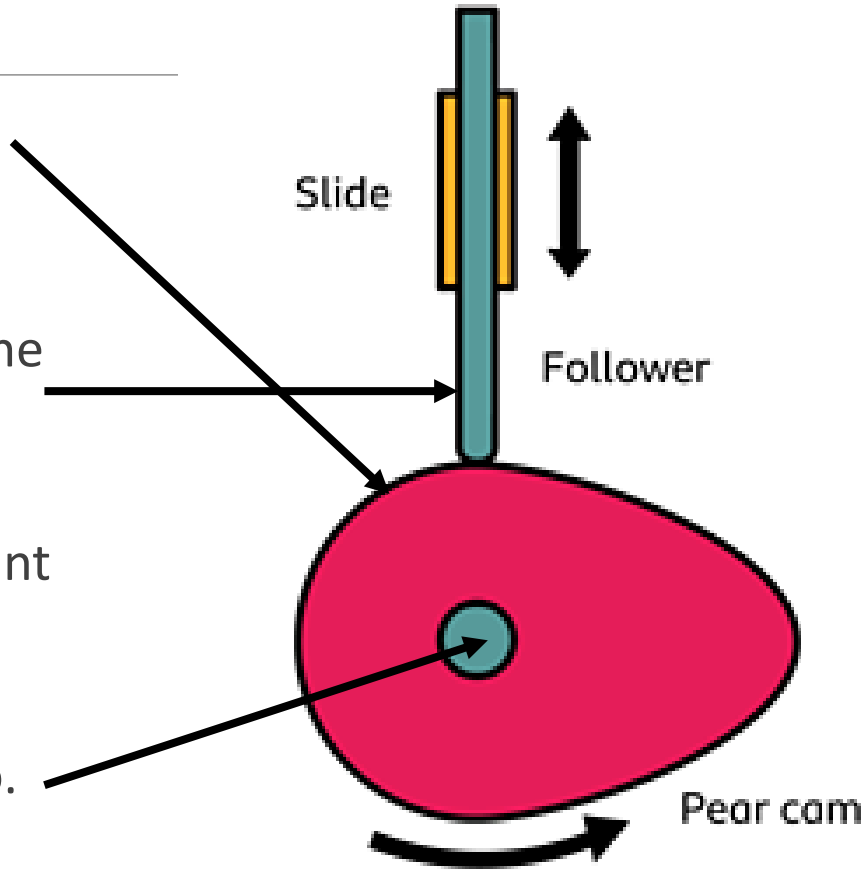
- **Definition:**
  - A cam is a specially shaped rotating or sliding component used to convert rotary motion into reciprocating or oscillating motion.
  - Works with a follower that moves according to the cam's profile.

- **Key features:**
  - Common cam shapes: pear, heart, circular, and eccentric
  - The cam profile controls the rise, dwell, and return of the follower
  - Often combined with a spring or gravity to keep the follower in contact



Parts of a Cam

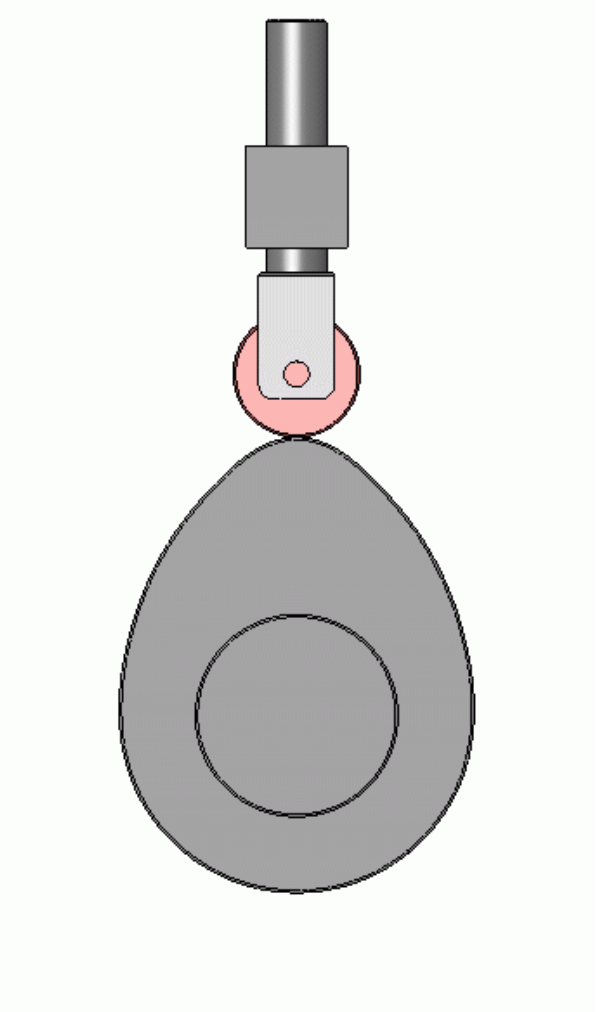
- **Cam -** The driving part that rotates or moves to create motion.
- **Follower -** The driven part that moves in response to the cam's surface.
- **Spring or Gravity Return -** Keeps the follower in constant contact with the cam surface.
- **Camshaft -** The shaft or spindle that the cam is fixed to.
- **Frame or Support -** Holds the components in alignment and allows smooth motion.



Cams

- **Advantages:**
  - Provides precise control of follower movement
  - Can generate complex motion patterns from simple rotation
  - Reliable and compact mechanism

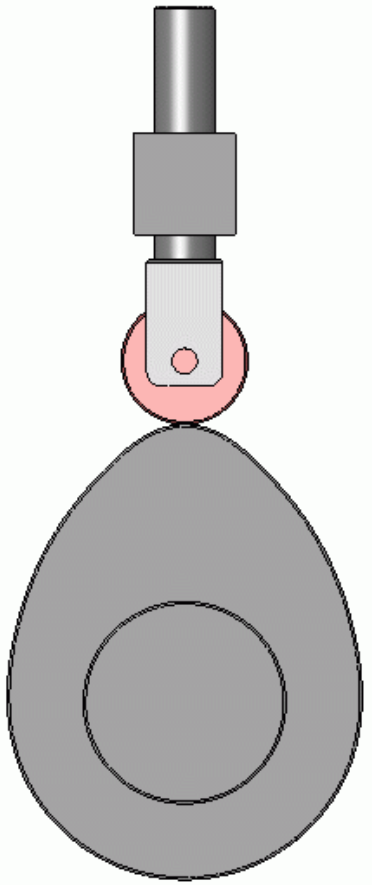
- **Limitations:**
  - Generates friction and wear at contact points
  - Usually limited to low or moderate speeds
  - Difficult to adjust motion without changing cam shape



Cam profiles and motion types

- **Cam profile basics:**
  - The shape of the cam determines how the follower moves.
  - One full cam rotation produces a cycle made up of:
    - Rise – follower moves upward/outward
    - Dwell – follower stays still
    - Return – follower moves downward/back

- Motion types produced:
  - Uniform motion – constant speed of follower
  - Accelerating and decelerating motion – smoother movement, reduces shock
  - Intermittent motion – follower stops and starts during rotation



Common Cam Profiles

- **Common cam profiles:**
  - Pear cam: smooth rise and fall with a long dwell – used for consistent timing
  - Heart cam: ensures uniform motion and returns to start smoothly
  - Eccentric cam: produces simple harmonic (smooth sinusoidal) motion
  - Cylindrical cam: follower moves parallel to cam axis – used in automatic machinery
  - Drop (Snail) cam: provides a gradual rise followed by a sudden drop, used where a quick return motion is needed