



## Mechanics and Machines, Lecture 3

Types of drives: kinematics, where to find other info

Drives: friction, belts, chains, gears, universal, geneva, ballscrew



## Goal of the lecture

Make an overview of typical drives.

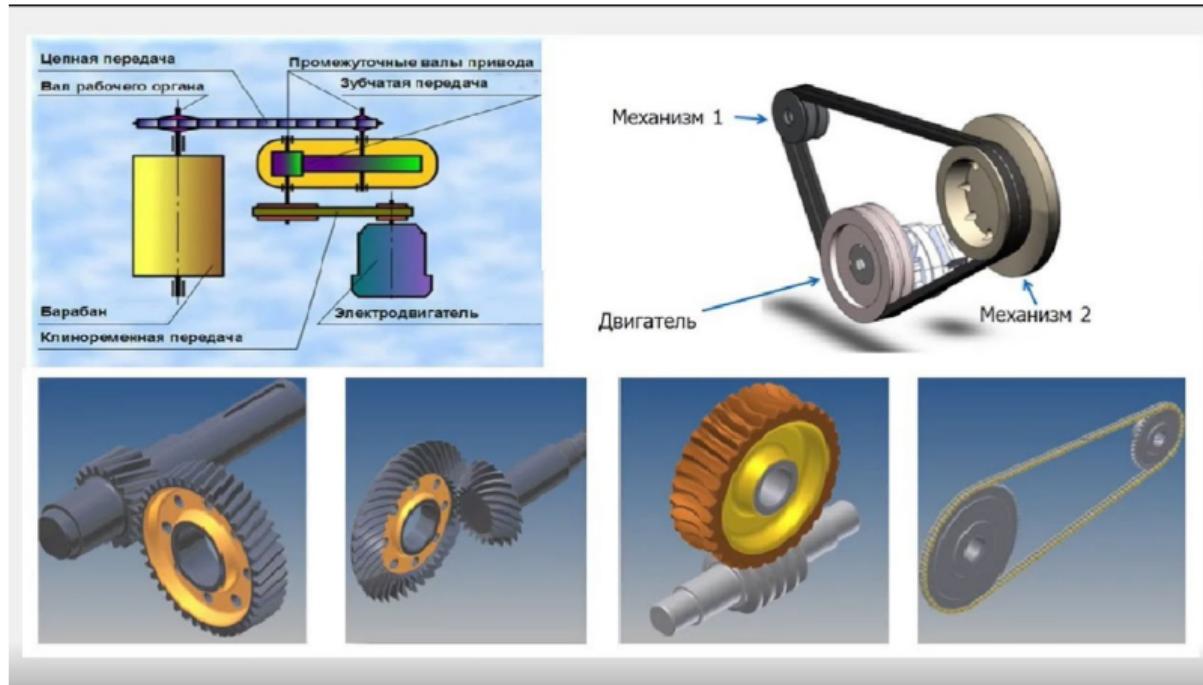
Give a hint how to work with it.

Explain how to find information about particular drive.



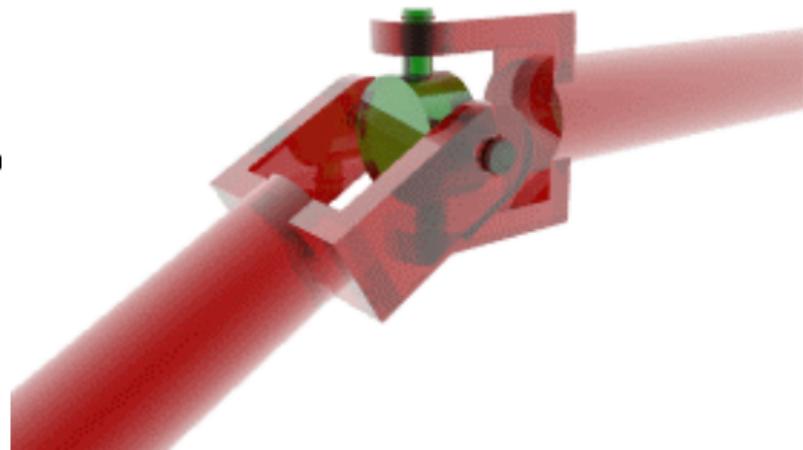
# General info about drives

Video



# Universal Joint

*Visualisation*



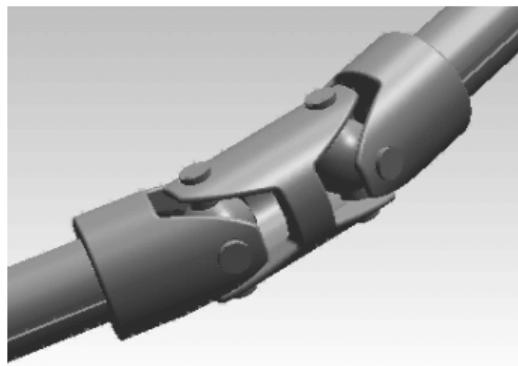


# Universal Joint

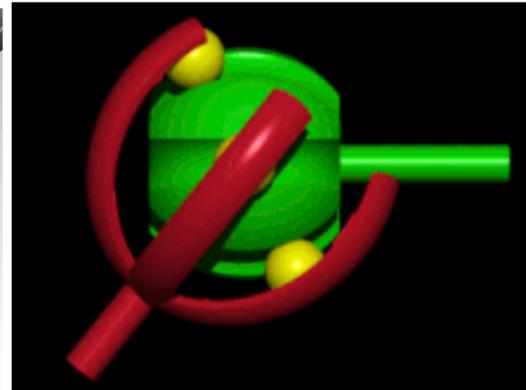
*Types of universal joint*



Cardan



Double cardan joint



Constant-velocity universal ball joint

# Universal Joint

*Drive kinematics*

Angle relationship —  $\tan(\psi) = \tan(\psi') \cos(\beta)$

Angular velocities relationship —

$$\omega \cos(\beta) = \omega' (\sin^2(\psi) + \cos^2(\psi) \cos^2(\beta))$$





# Universal Joint

*Features and facts*

- It's effective tool for transferring a torque for max 30 degrees.
- Constant-velocity universal ball joint (шпyc) is not a small device and it's not easy to find it (it can be found as a car detail).



# Universal Joint

*What can be interesting to find (queries)*

1. Correlation between velocities and angle between links in Universal joint
2. Cardan dynamics



# Universal Joint

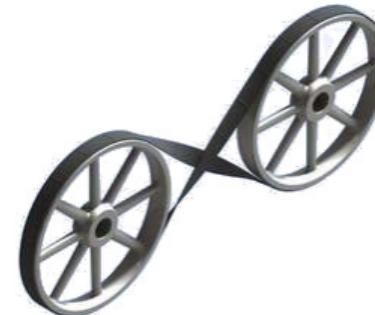
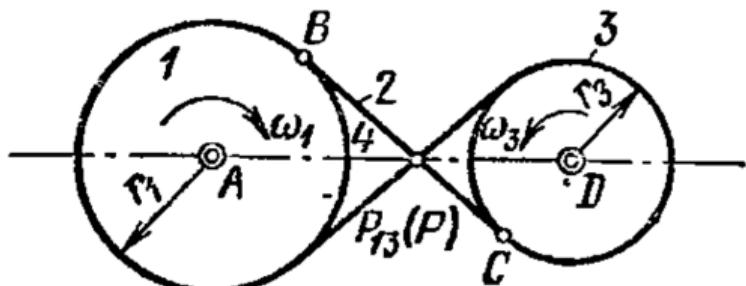
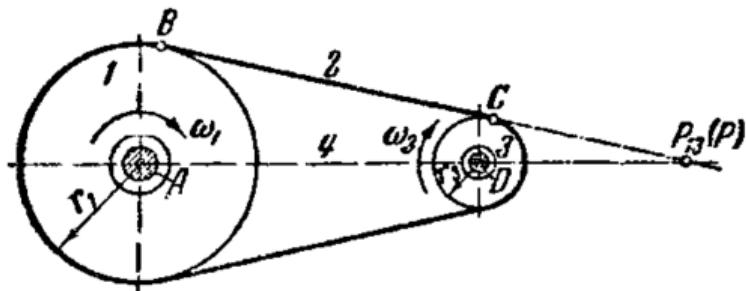
Reference material

1. **Other names:** cardan joint, Hooke's joint, кардан, универсальный шарнир
2. [Universal joint \(wiki\)](#)
3. "Теория механизмов и машин" Артоболевский И. И. 1988, pdf pages 168-172
4. Find U-joint parameters using quaternions
5. Dynamics of universal joints



# Belt

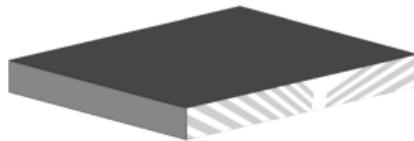
Visualisation



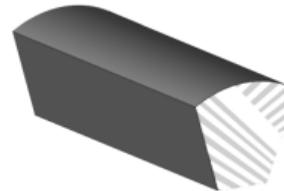


# Belt

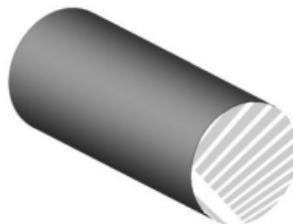
*Types of belts*



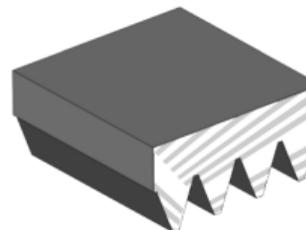
*a*



*б*



*в*



*г*

*а) flat (плоская), б) vee belt (клиновидная), в) round (круглая), г) timing (toothed, зубчатый)*



# Belt

## Drive kinematics

- Linear velocity of a pulley —  $v_1 = \omega_1 \frac{d_1}{2}$ ,  $d$  — diameter of a pulley (шкив)
- Length of a belt —  $I = 2a + \frac{\pi}{2}(d_1 + d_2) + \frac{(d_2 - d_1)^2}{4a}$ , where  $a$  — distance between center of pulleys.



# Belt

*What can be interesting to find (queries)*

- How to find the appropriate diameter of a pulley
- Min and max distance between pulleys
- Appropriate angle of covering the pulley



# Belt

## *Features and facts*

- Simple design and operation, relatively low cost.
- Smooth and quiet operation due to elasticity belt.
- Possibility to transfer power over long distances (with V-belts up to 15 m) at speed up to 100 m/s.
- Softening of vibrations and shocks due to elasticity of the belt.
- Possibility to protect machines from overloading due to elastic belt tension and slippage
- Reduced requirements for axle alignment shafts.



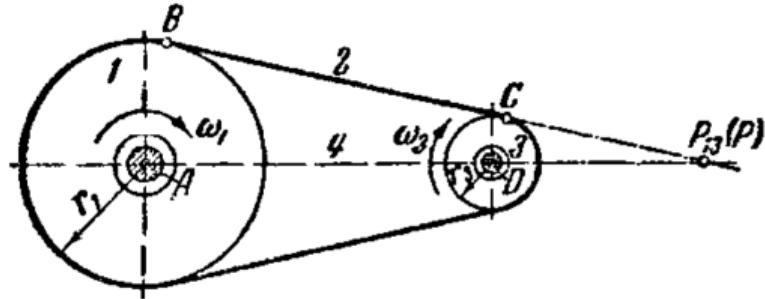
# Belt

Reference material

1. Other names: ременная передача
2. Belt drive (wiki)
3. "Теория механизмов и машин" Артоболевский И. И. 1988, pdf pages 166–168
4. Детали машин. 9 лекция
5. Belt formulas
6. Ременная передача (видео)

# Chain

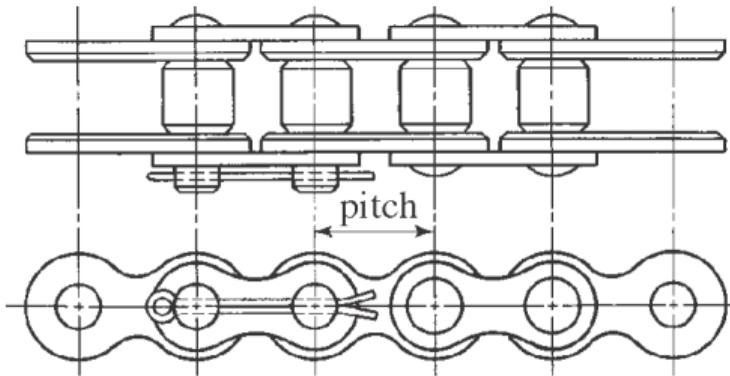
Visualisation



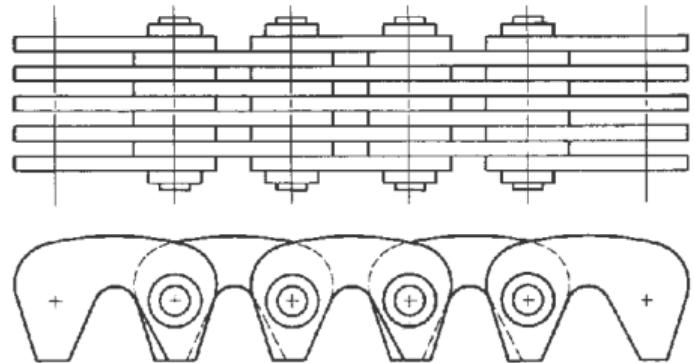


# Chain

*Types of chain transmissions*



(a) Roller chain



(b) Inverted-tooth or silent chain



# Chain

## *Drive kinematics*

Almost the same as in belt. The main difference, that max angle of sprocket covering by chain is  $120^\circ$ .

Distance between centers can be found  $a = (30 - 50)P$ , where  $P$  — chain pitch.



# Chain

*What can be interesting to find (queries)*

- Amount of tooth in sprockets.
- How to find a length of the chain



# Chain

## *Features and facts*

- Compared to gears, chain transmissions can transmit motion between shafts at large center distance (up to 5 m)
- Compared to belt drives, chain transmissions are more compact, transmit more power, can be used within a considerable range of axle spacing, ensure constant transmission ratio (no slipping);
- can transmit motion with one chain to several sprockets.
- Irregularity of sprocket rotation.
- The necessity of a high accuracy of the transmission assembly.



# Chain

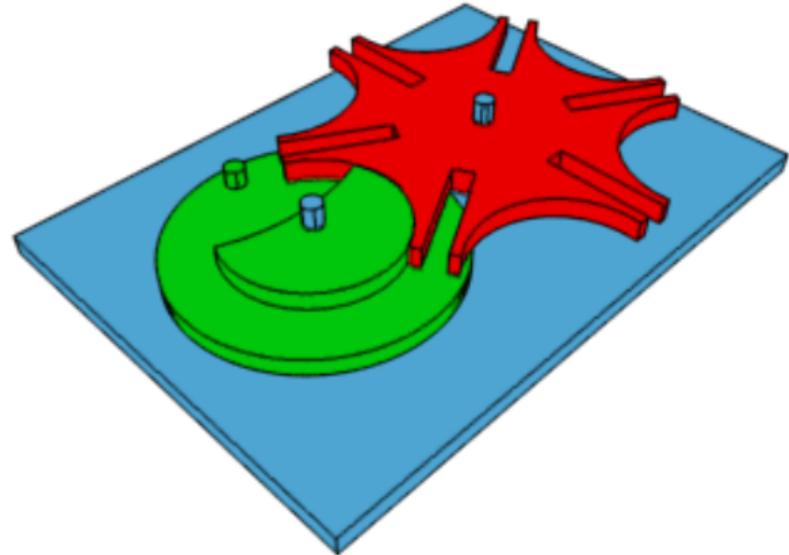
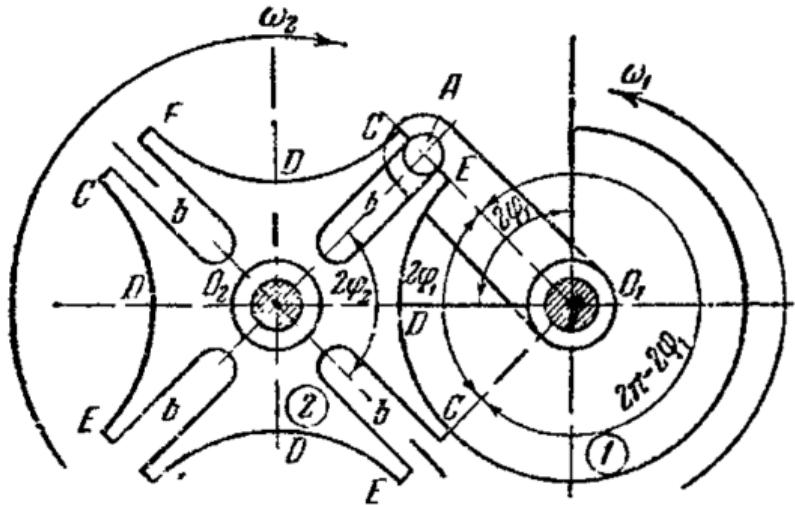
Reference material

1. **Other names:** цепная передача
2. [Roller chain \(wiki\)](#)
3. "Теория механизмов и машин" Артоболевский И. И. 1988, pdf pages 166–168
4. [Детали машин. 10 лекция](#)
5. [Sprockets & Chains For Engineers](#)
6. [Расчет цепной передачи](#)
7. [Цепная передача \(видео\)](#)



# Geneva drive

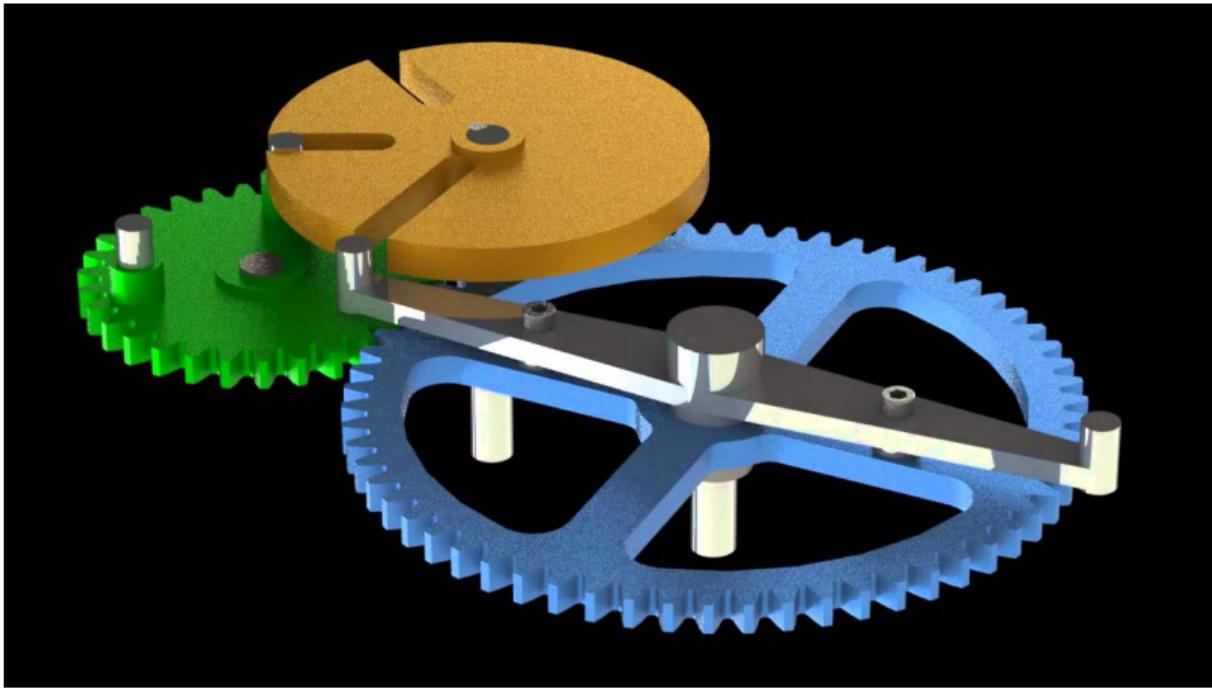
Visualisation





# Geneva drive

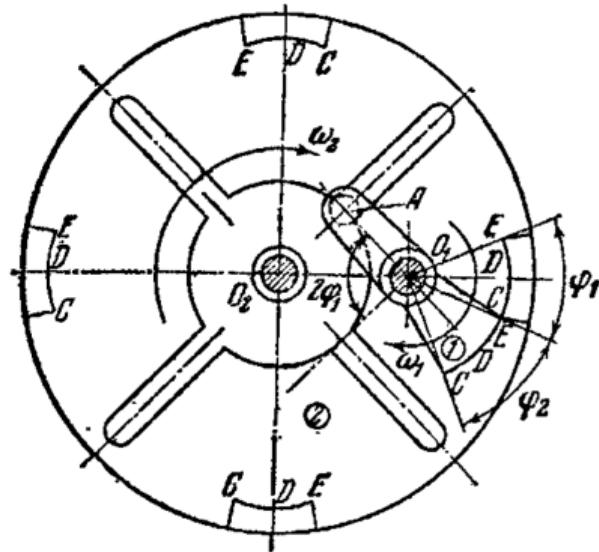
*Example of geneva drive*



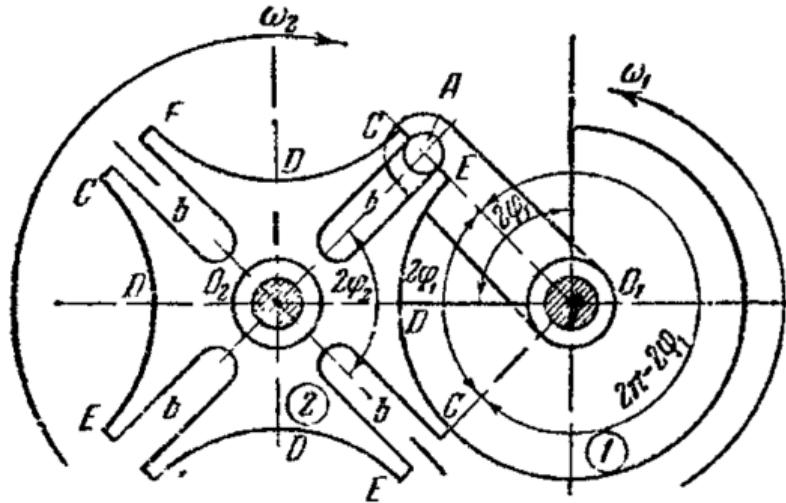


# Geneva drive

Types of geneva drive



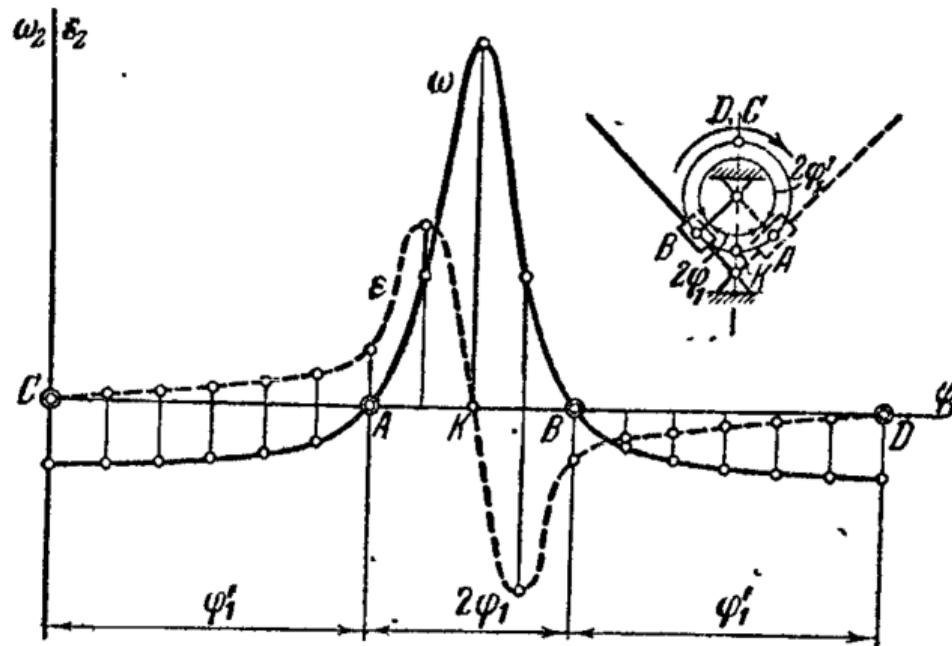
Inner connection



Outer connection



# Geneva drive



Angular velocity and acc diagram of output link



# Geneva drive

## *Features and facts*

- The best application — when you want to have a constant velocity in input link and some fancy behavior with stopping — on output link.



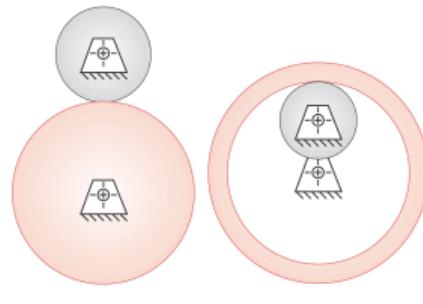
# Geneva drive

Reference material

1. **Other names:** мальтийский крест
2. [Geneva drive \(wiki\)](#)
3. "Теория механизмов и машин" Артоболевский И. И. 1988, pdf pages 172-174
4. [How to draw a geneva drive](#)
5. [Make a geneva wheels of any size](#)
6. [Structural synthesis of geneva wheels \(rus\)](#)

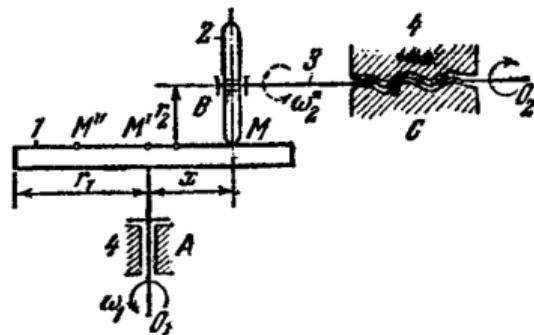
# Friction drive

## Visualisation



(a) External set

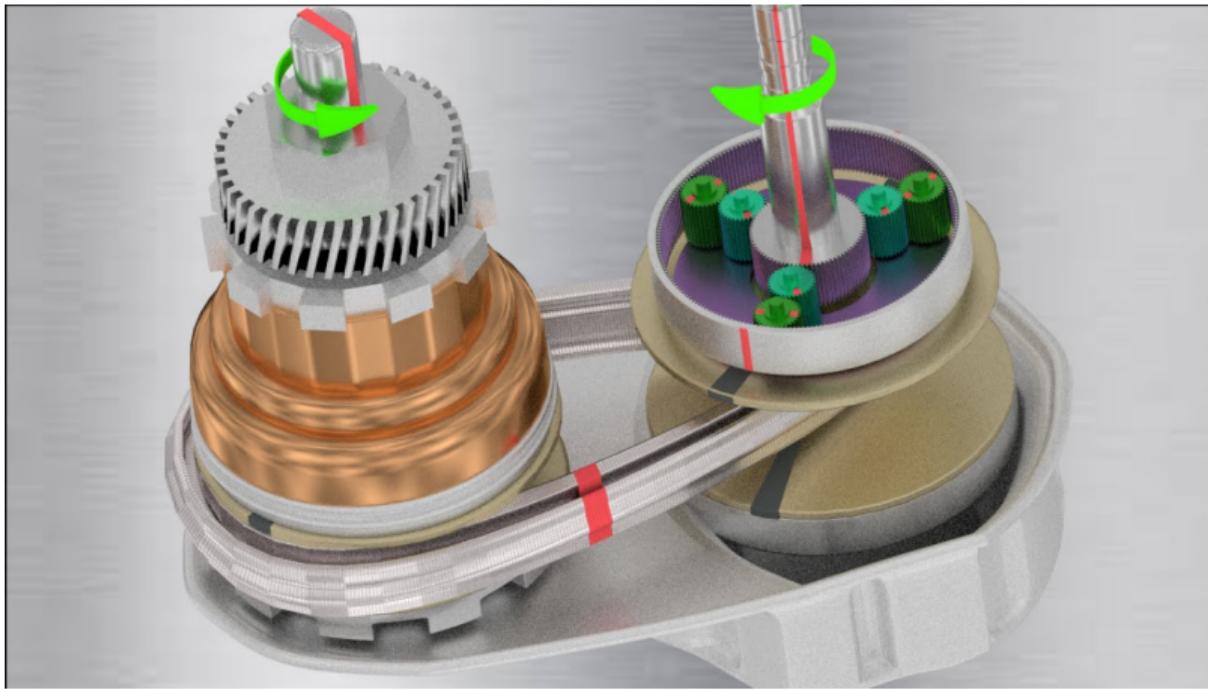
(b) Internal set





# Friction drive

*Continuously Variable Transmission (CVT) Video*





# Friction drive

## *Features and facts*

- Simple design and maintenance.
- Smooth motion transmission and noiseless operation.
- Large kinematic capabilities (conversion of rotary motion into translational motion, stepless speed change, reversing on the fly, gear engagement and disengagement on the fly without stopping)
- Gear ratio varies due to slippage.
- Necessity of using specially designed shaft supports with clamping devices.



# Friction drive

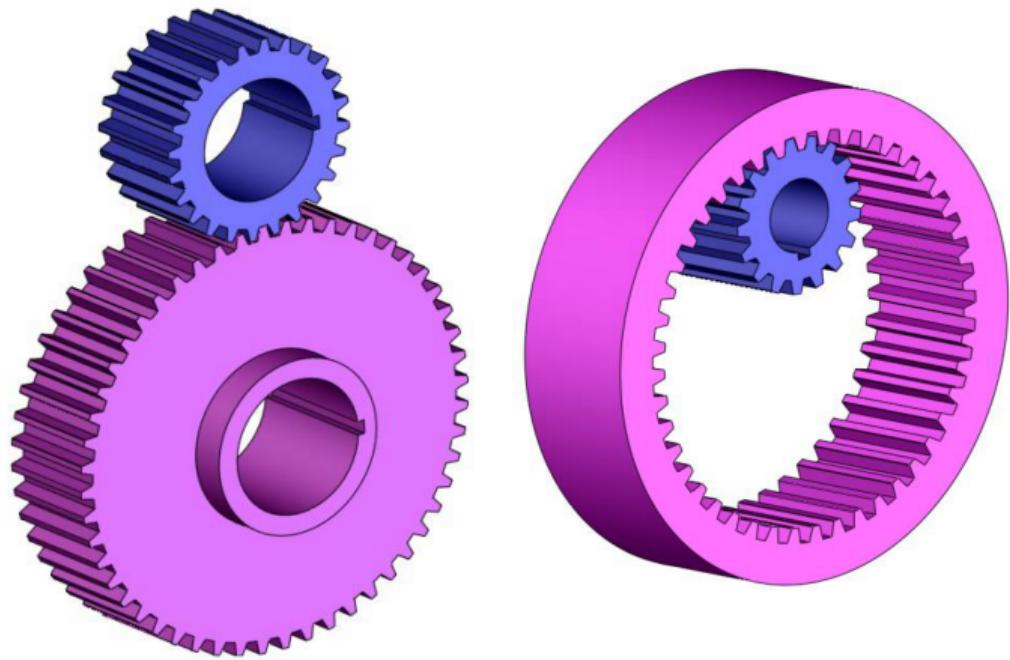
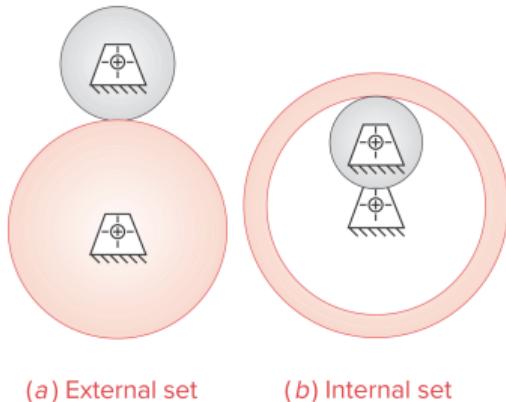
Reference material

1. **Other names:** фрикционная передача
2. [Friction drive \(wiki\)](#)
3. "Теория механизмов и машин" Артоболевский И. И. 1988, pdf pages 141-146
4. [Детали машин. 22 лекция, 2 страница](#)
5. [CVT — how it works](#)
6. [Фрикционная передача](#)



# Gears

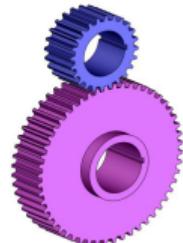
Visualisation



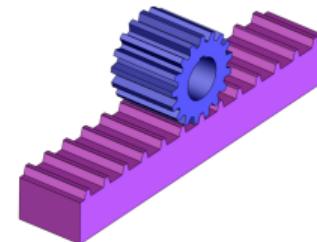


# Gears

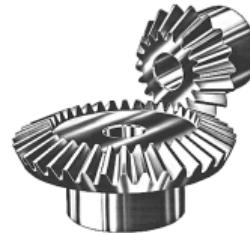
## Types of Gears



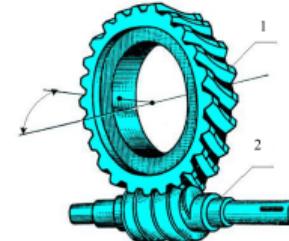
(a) Spur and helical gears



(b) Rack and pinion



(c) bevel gear

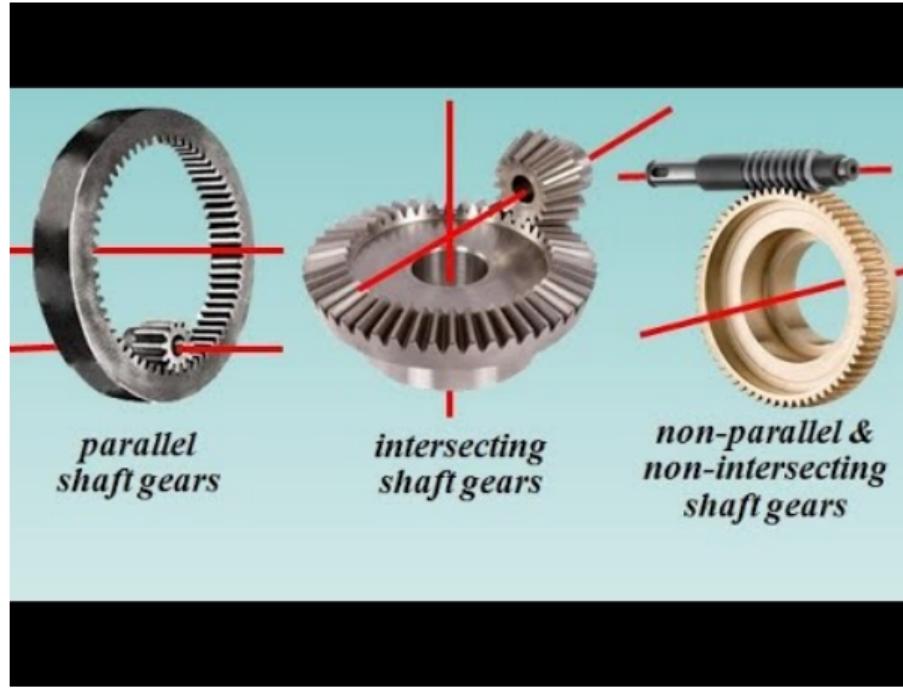


(d) worm gear



# Gears

*Gear classification (Video)*





# Gears

## *Gear ratio calculation methods*

1. Common one, when you have a simple gear train. (Artobolevskii, pdf page 150)
2. When you have a planetary gearset, fundamental formula of the planetary gear train (Формула Виллиса для дифференциалов). (Artobolevskii, pdf page 154 – 166)
3. When you have a planetary gearset, tabular method (Norton R., pdf page 550 – 551)



# Gears

## *Features and facts*

- Consistency of transmission ratio.
- Reliability and durability of operation.
- Large range of transferable speeds.
- High efficiency.
- The need for high accuracy of fabrication and assembly



# Gears

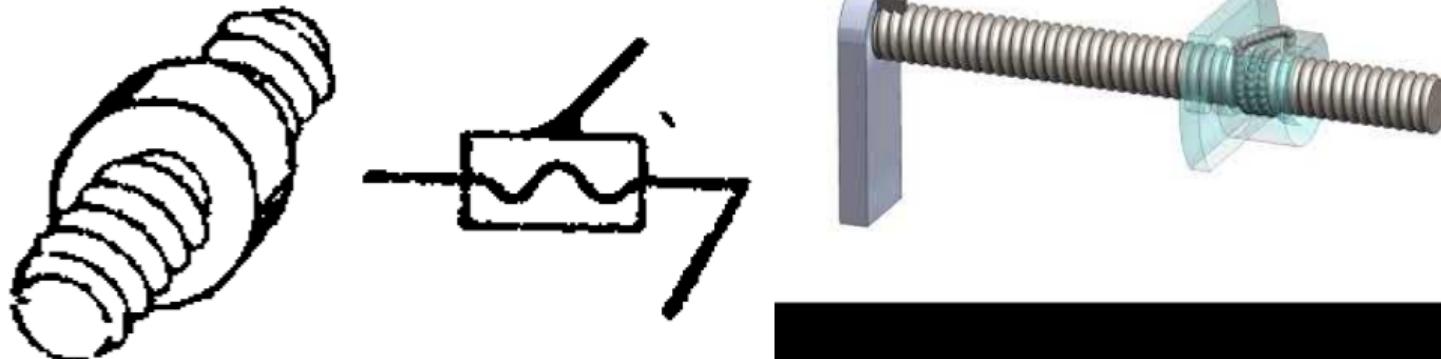
Reference material

1. **Other names:** зубчатая передача
2. [Gears \(wiki\)](#)
3. "Теория механизмов и машин" Артоболевский И. И. 1988, pdf pages 145–166
4. [Детали машин. 5-8 лекции](#)
5. "Design of machinery" Robert L. Norton, pdf pages 517–557 2.0 — 2.11
6. [Зубчатая передача \(видео\)](#)



# Ballscrew

*Visualisation*





# Ballscrew

Types of ballscrew (Video)





# Ballscrew

*Drive kinematics (1)*

[Helical gear kinematics \(rus\)](#)

Artobolevskii, pdf page 27



# Ballscrew

## *Features and facts*

- Conversion of fast rotational motion of the master element into slow rectilinear motion of the slave element.
- Conversion of a small torque at the leading element into a significant force at the moving linear element.
- Realization of the self-locking phenomenon.
- Simplicity of design, compactness, reliability.



# Ballscrew

Reference material

1. **Other names:** шарико-винтовая передача, передача винт-гайка
2. [Ball screw \(wiki\)](#)
3. "Теория механизмов и машин" Артоболевский И. И. 1988, pdf pages 166–168
4. [Детали машин. 10 лекция](#)
5. [Передача винт-гайка \(видео\)](#)



# How to use provided materials

*Guideline*

## Live Demo

# Deserve “A” grade!

– Oleg Bulichev

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↗ @Lupasic

🚪 Room 105 (Underground robotics lab)