Lecture 17

Cams

ME 370 - Mechanical Design 1

Module 6 topics: Motors, Cams and Motion Control

- **Motors**
  - DC motor principle
  - DC motor model
  - Linear Motor Model
    - Constraints
    - Behavior in time
    - Gearboxes
  - Motor Parameters
  - Power and Efficiency

- **Cam and Follower**
  - Types of Motion
  - Types of Follower
  - Practical Considerations

- **Motion control**
  - Simple Motion Control Dwell-Rise-Dwell motions:
    - Fundamental Law of Cam (Motion) Design
    - Simple Harmonic Motion
    - Sinusoidal Acceleration (i.e., Cycloidal Displacement)
  - Advanced Motion Control
    - Additional Dwell-Rise-Dwell motions:
      - Trapezoidal acceleration
      - Modified Trapezoidal acceleration
      - Modified Sine acceleration
      - 3-4-5 Polynomial Rise Displacement
      - 4-5-6-7 Polynomial Rise Displacement
    - Rise-Fall-Dwell motions:
      - Cycloidal Motion
      - Double Harmonic
      - 3-4-5-6 Polynomial

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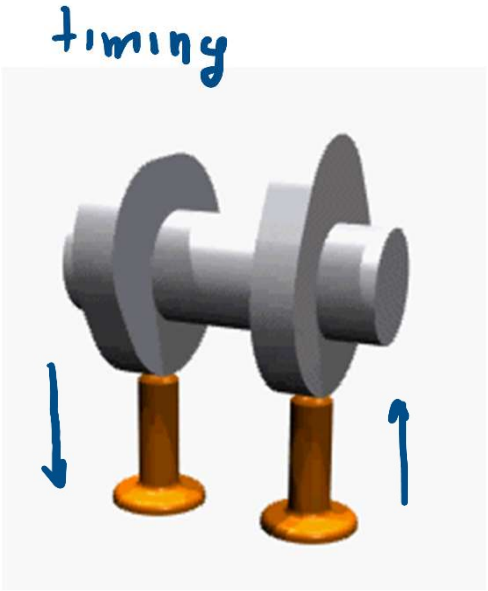
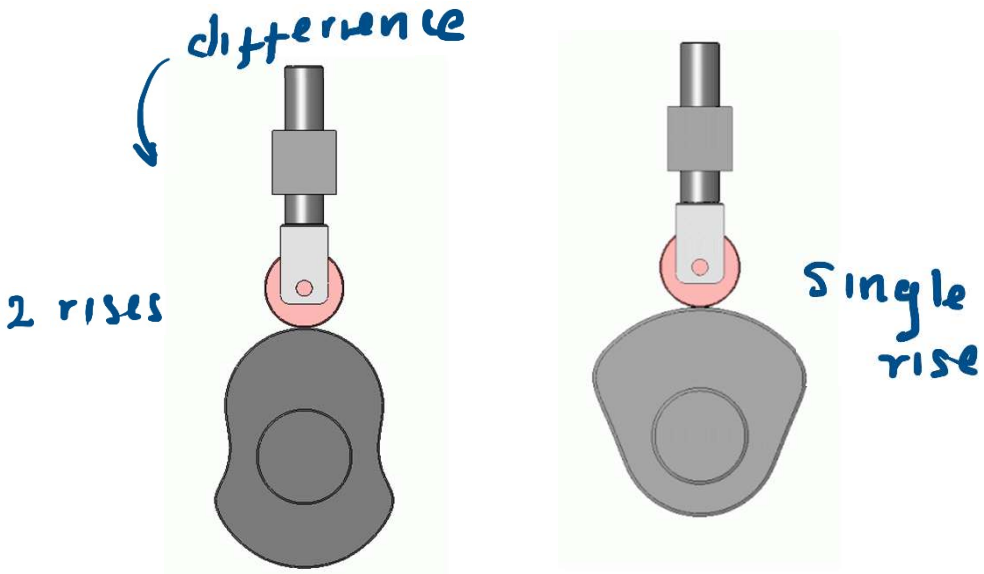
Cam usage:

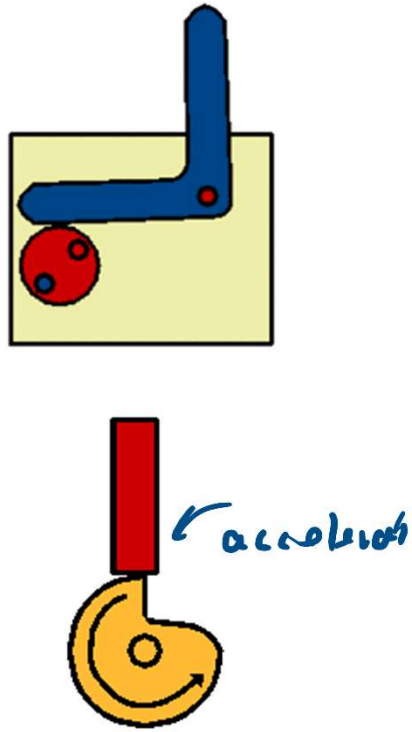
- To transform *rotational* motion to *translational* motion
- For *repetitive output* motion, or displacement(s)
- Competition: pneumatic or electro-mechanical actuators



https://en.wikipedia.org/wiki/Cam
https://i.imgur.com/hfvwPCQ.gif



https://www.creativemechanisms.com/blog/common-mechanisms-explained-with-animation.-part-1



http://wiki.dtonline.org/index.php/Radial_Cam

Categorization of cams and followers

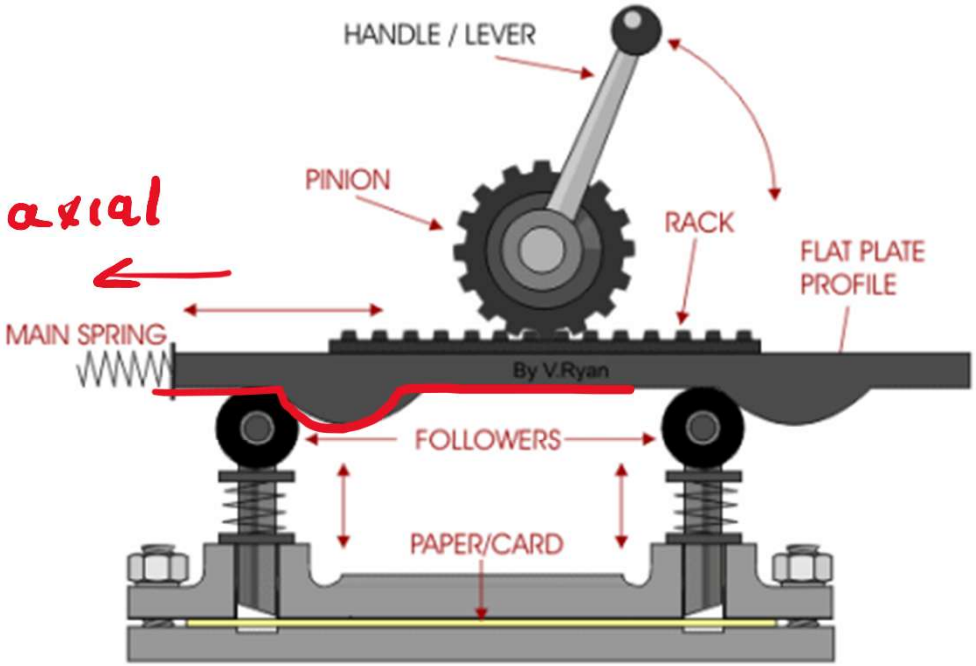
1. Types of cams
   - Radial
   - Axial
2. Follower motion & contact
   - Rotating or translating
   - Roller / mushroom / flat
3. Types of joint closure
   - Force-closure
   - Form-closure

1. Types of cams (radial or axial)

Radial:

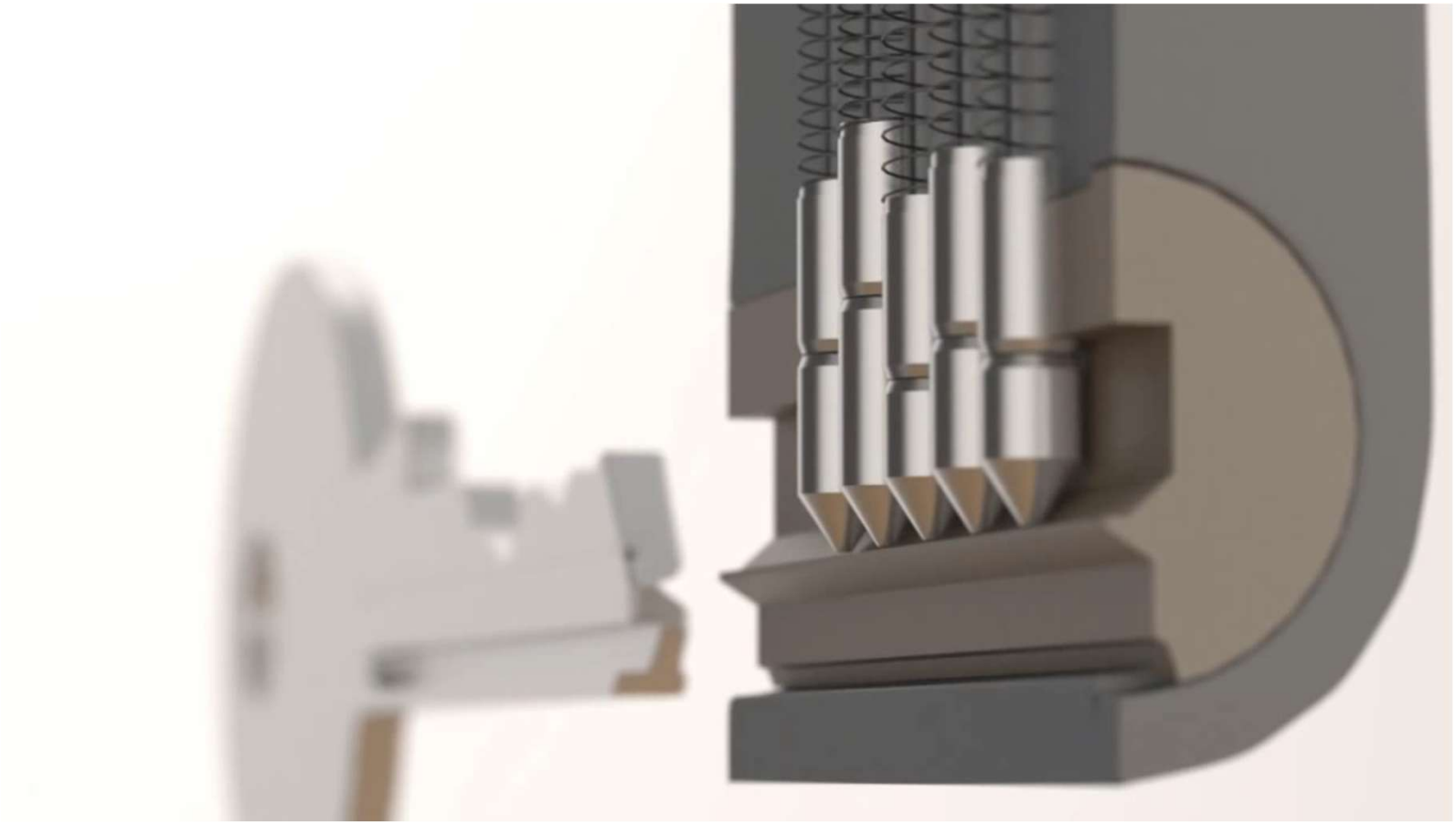
https://www.creativemechanisms.com/blog/common-mechanisms-explained-with-animation.-part-1

Axial:



https://technologystudent.com/cams/flat1.htm

How a pin tumbler lock works:



https://www.youtube.com/watch?v=OIqFStAbDfU

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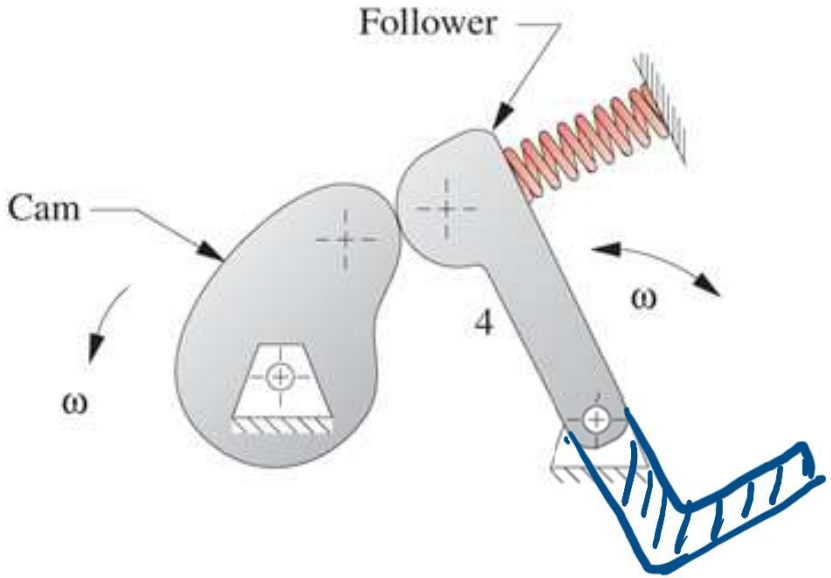
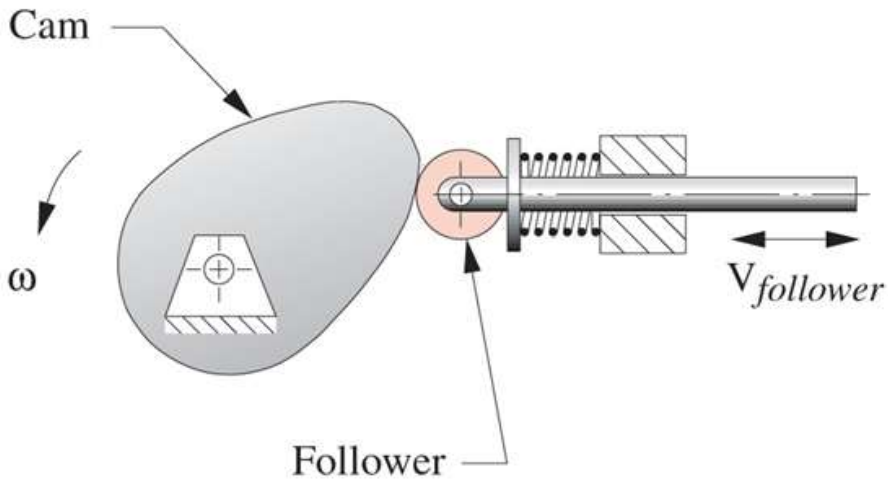
2. Types of follower (rotating or translating)

Rotating:



Translating:



Images from Norton textbook

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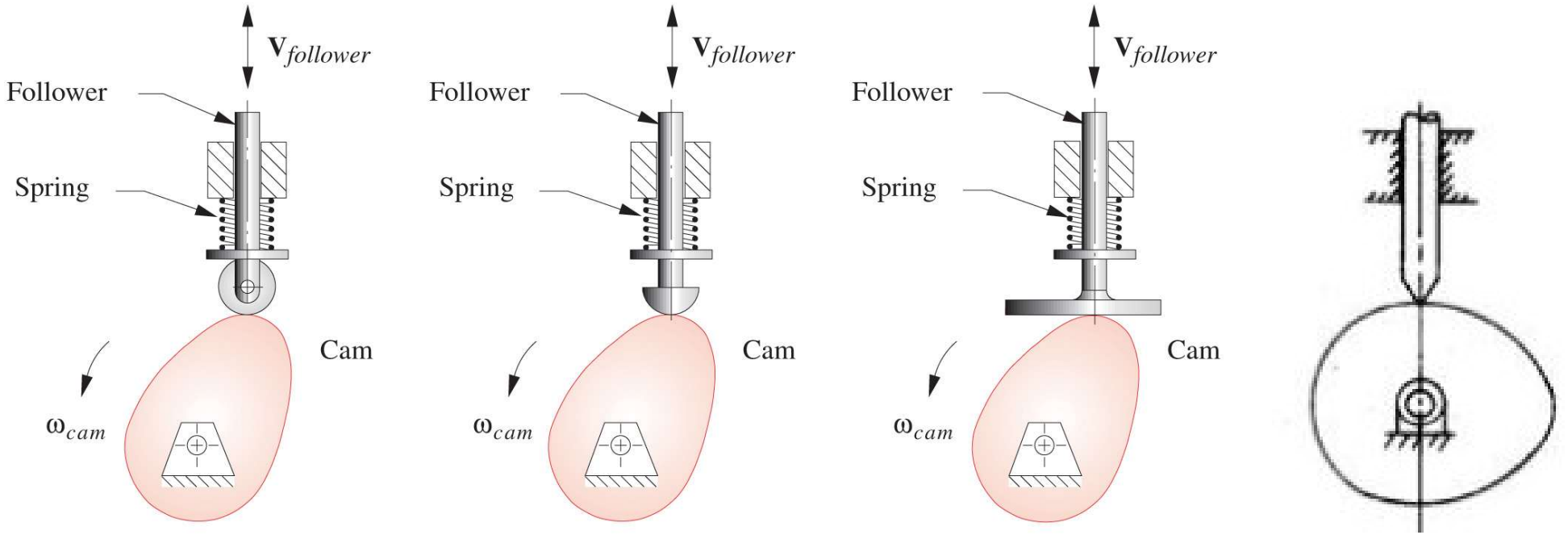
3. Types of follower shape



(a) Roller follower (b) Mushroom follower (c) Flat-faced follower (d) Knife-edge Follower

cost

friction, wear

Images from Norton textbook

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4. Types of joint closure (forced or form)

- *Force*-closure: external force (e.g. spring) used to keep the cam in contact with the follower.
- *Form*-closure: closed by joint geometry, using a slot in the cam.

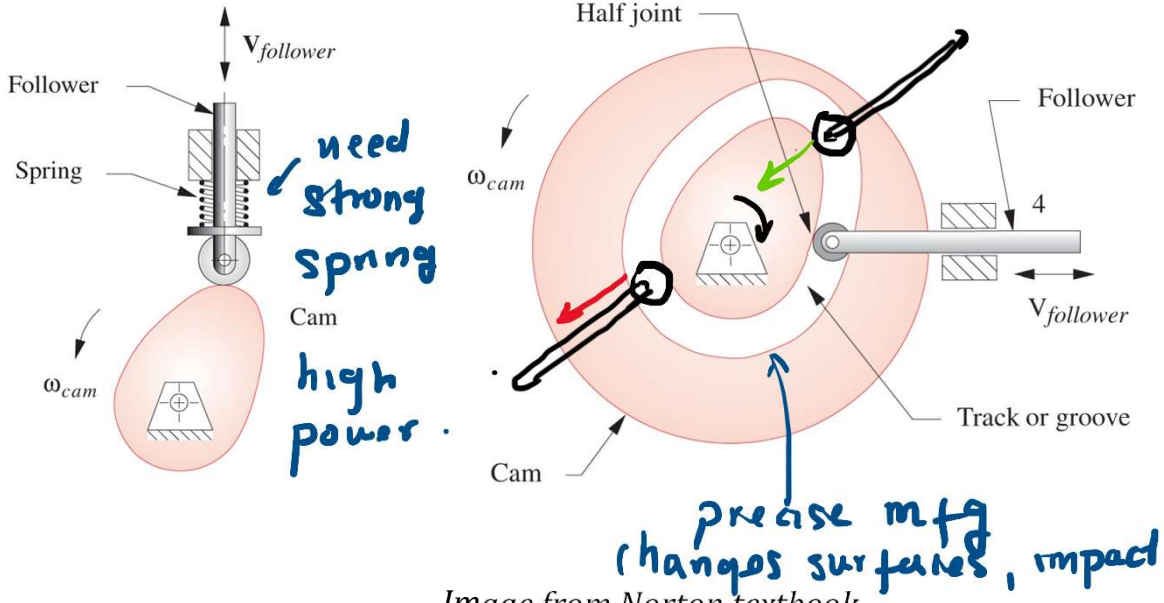
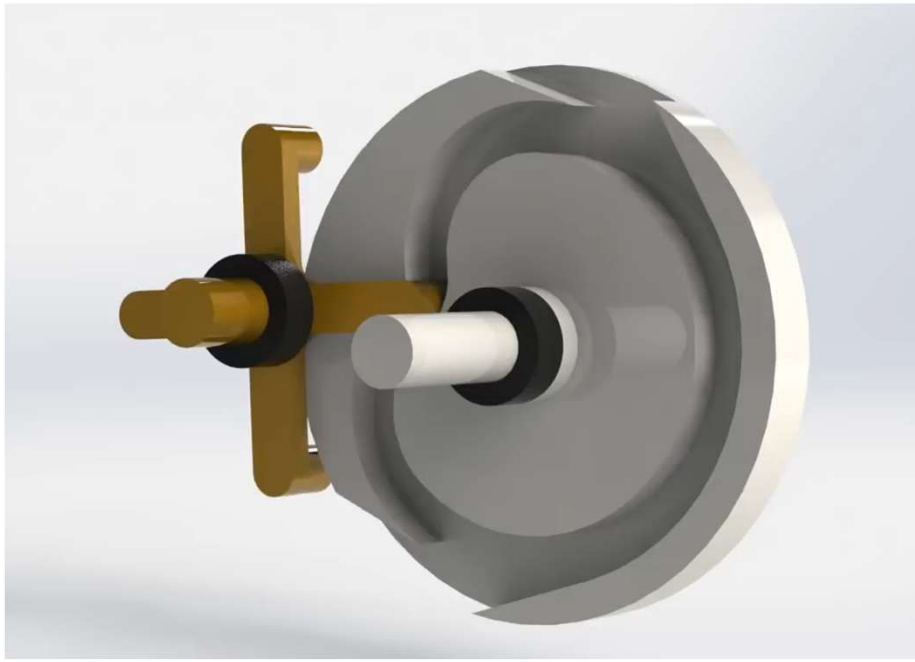


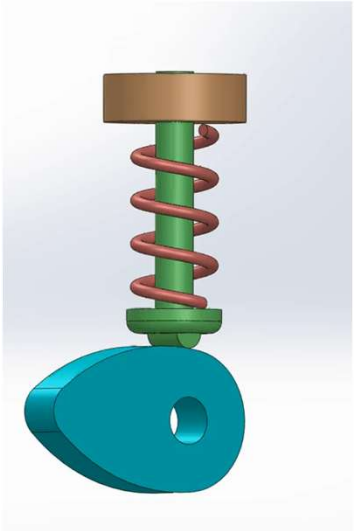
Image from Norton textbook



https://www.youtube.com/watch?v=09n9U4nZMZY

Review of classification

1. Cam motion: radial axial
2. Follower motion: rotate translate
3. Follower contact: roller mushroom flat
4. Closure: force form



https://www.youtube.com/watch?v=H903HIwxN7g

Select correct:
A: radial, rotate, roller, force
B: radial, translate, roller, form
C: radial, translate, mushroom, force
D: axial, translate, flat, form
E: axial, translate, flat, force

Join Code: **370**

Review of classification

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https://i.imgur.com/XT5QhCC.gif

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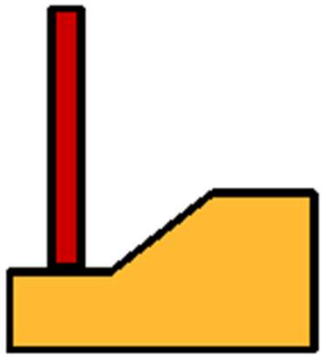
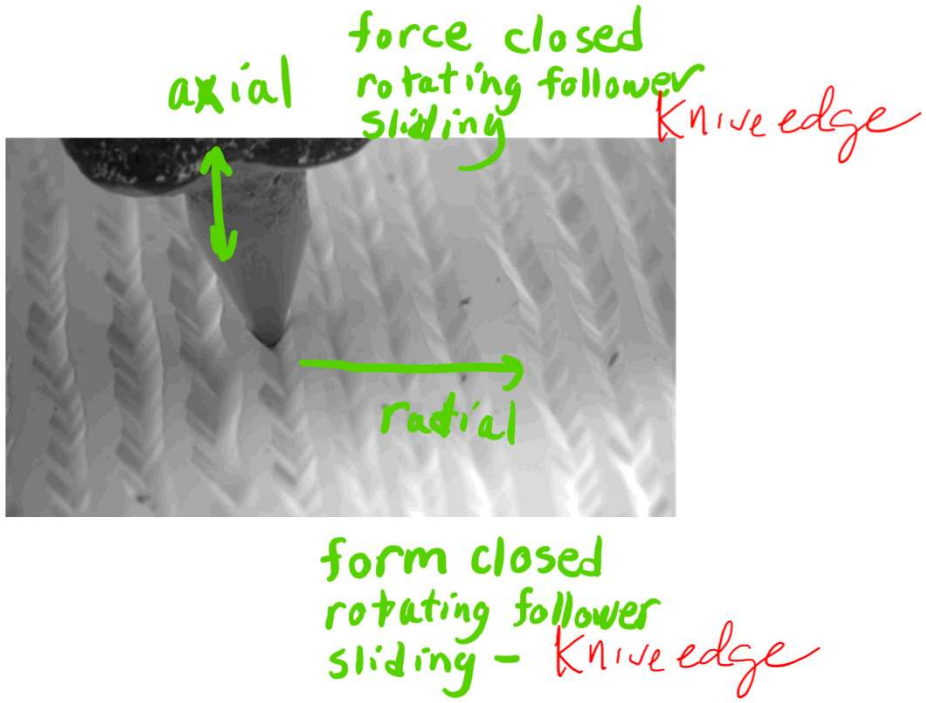


http://wiki.dtonline.org/index.php/Linear_Cam

Record player/turntable



How would we classify this 3D cam-follower along each axis (Radial/Axial)

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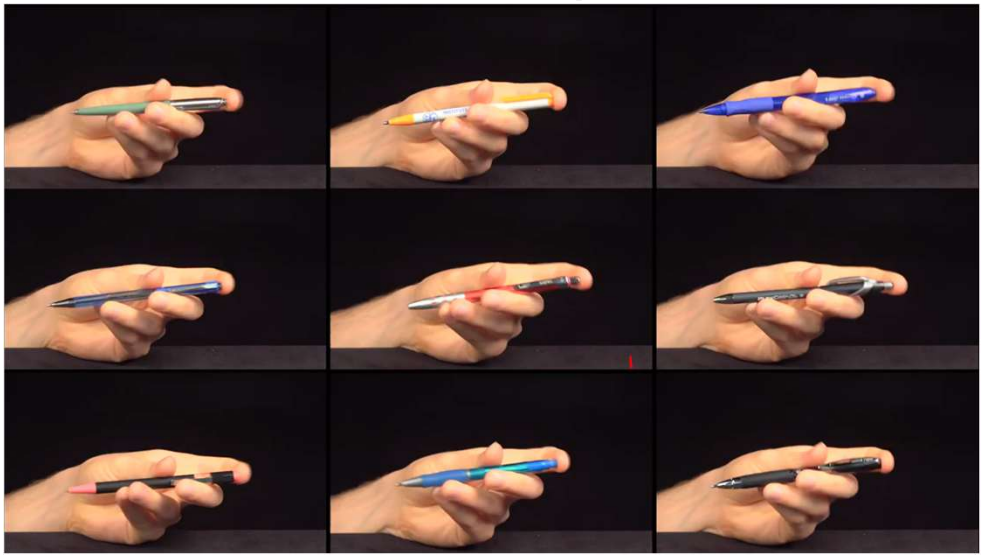
Cam Applications

How a Retractable Ballpoint Pen Works



https://youtu.be/MhVw-MHGv4s?si=Qwc44m0Ksf5fSvGW

https://youtu.be/0dDiXJsmDOQ?si=P3t2_6s8PxSHOenv

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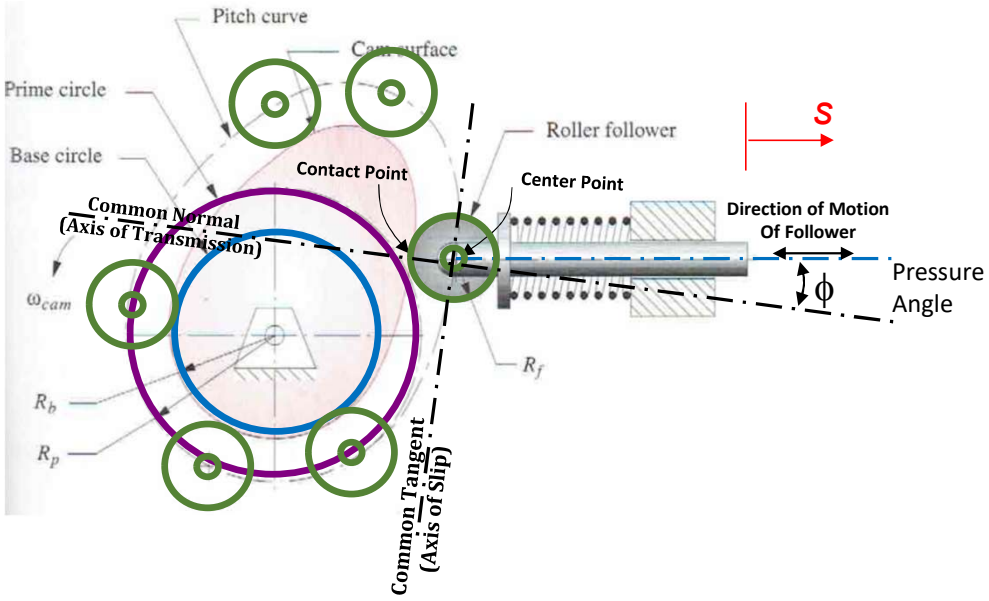
Practical consideration: Cam sizing

While motion design is fundamentally important to cam design, once completed, concerns shift to efficient transmission of the motion from cam to follower. This is fundamentally related to '**sizing**' the cam relative to the 'lift', ***s***, it is supposed to generate in the follower.



Besides lift, size of a cam is related to:

1. **Base circle radius (R_b)**: The radius of smallest circle, with center at center of rotation, that touches the surface of the cam.
2. **Prime circle radius (R_p)**: The radius of the smallest circle, centered at the cam's center of rotation, that is tangential to the locus of the center point of the follower (which is called the **pitch curve**)

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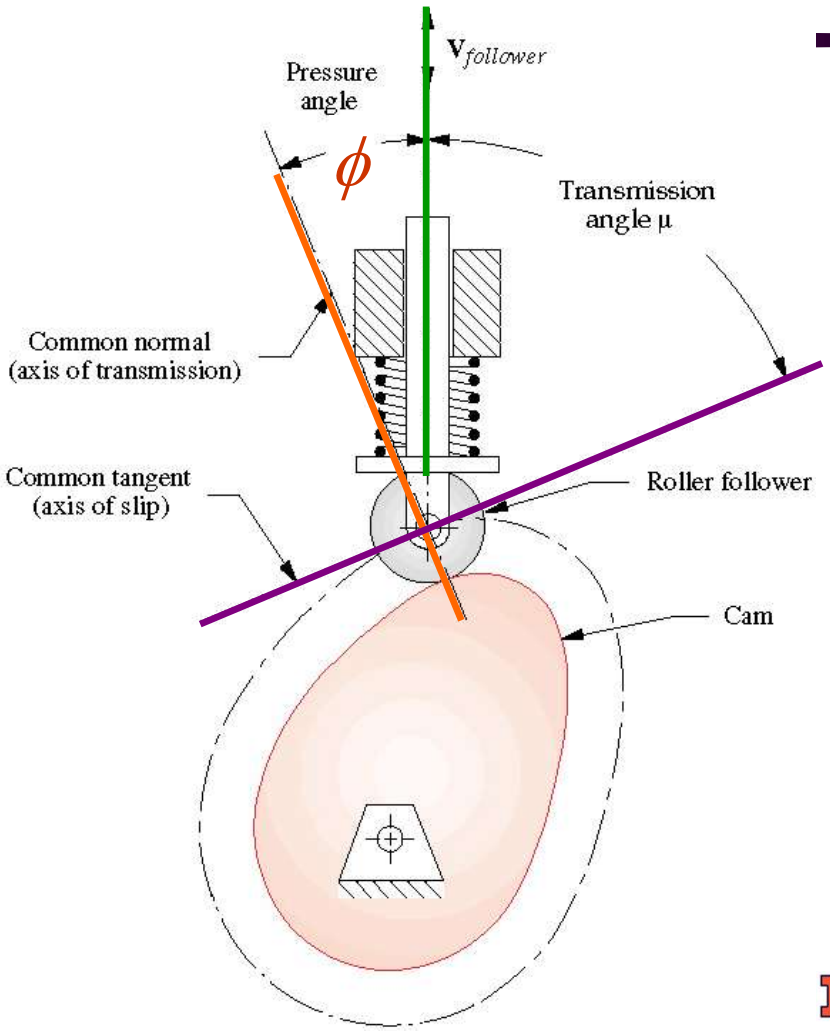
Practical consideration: Cam Pressure Angle (much like in gears)

- Pressure Angle (ϕ)
  - the angle between the direction of motion (velocity) of the follower and the direction of the axis of transmission

- Want ϕ <30 for translating and ϕ <35 for oscillating followers



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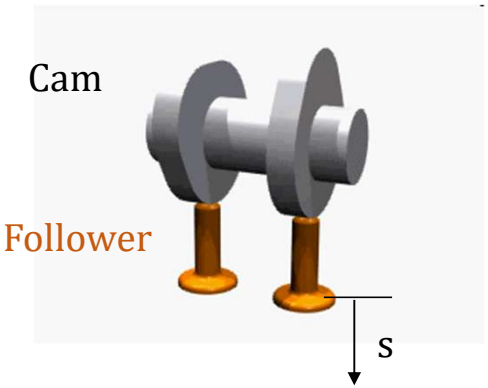
Cam Motion

Purpose:

- Transform rotational motion to translational (typically) motion
- Produce desired repetitive output motion, or displacement (*s*)
  - Function generator
  - Intermittent motion
- More expensive than gears
- Wears more easily, needs lubricant



https://en.wikipedia.org/wiki/Cam#/media/File:Nockenwelle_ani.gif

See these URLs for examples of motions and how to build own from paper

http://www.robives.com/mechanisms/cams this URL has old Adobe Flash images, but has good explanation of cam design considerations

https://www.robives.com/mechanism/cam/ this newer URL shows multiple types of cam designs

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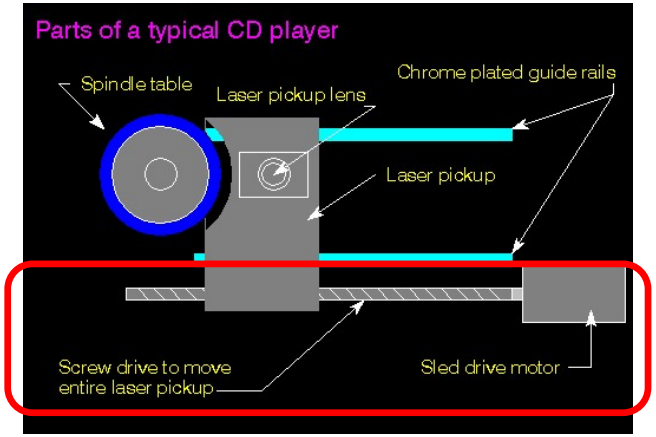
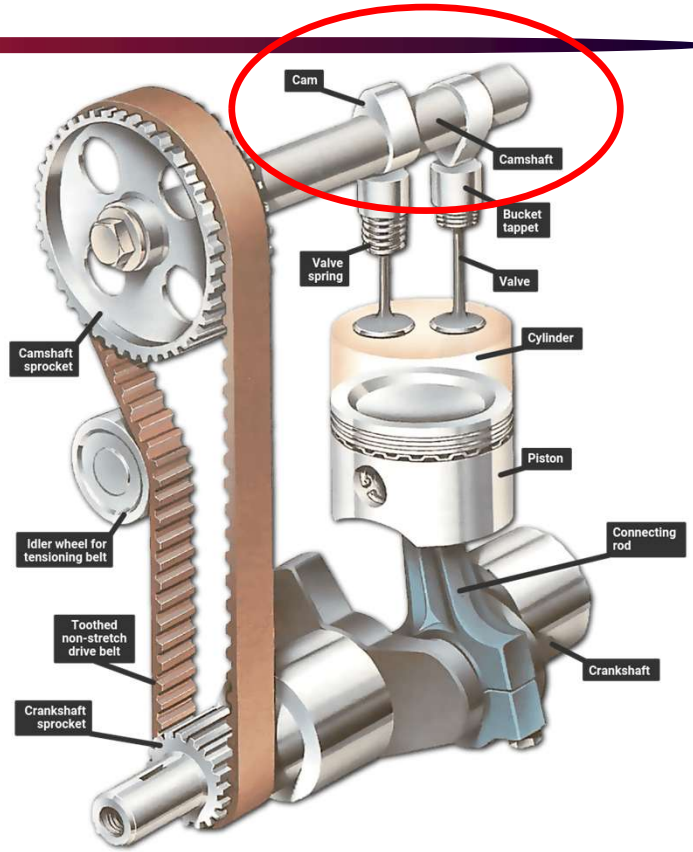
Examples of Cam Usage

- Conventional cam design:
  - sewing machine
  - 4-stroke internal combustion engine
- New designs:
  - Replace cams with actuators
    - Pneumatic, electro-mechanical
  - Example: Laser positioning in CD drive





https://www.howacarworks.com/basics/the-engine-how-the-valves-open-and-close

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